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**LIGHT-DUTY VEHICLE  
ELECTRIFICATION IN CALIFORNIA:**

**POTENTIAL BARRIERS AND OPPORTUNITIES**

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**Staff White Paper**  
Policy and Planning Division  
California Public Utilities Commission  
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**LIGHT-DUTY VEHICLE  
ELECTRIFICATION IN CALIFORNIA:  
POTENTIAL BARRIERS AND OPPORTUNITIES**

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## **ACRONYMS**

<b>American Recovery Reinvestment Act</b>	<b>ARRA</b>
Advanced Meter Initiative	AMI
Advanced Technology Vehicle Manufacturing Loan Program	AVTML
Air Quality Improvement Program	AQIP
Alternative and Renewable Fuel and Vehicle Technology Program	ARFVTP
Alternative Fuel Incentive Program	AFIP
Assembly bill	AB
Battery electric vehicle	BEV
California Air Resources Board	CARB
California Electric Transportation Coalition	CalETC
California Energy Commissions	CEC
California Public Utilities Commission	CPUC
California Solar Initiative	CSI
Carbon Dioxide	CO <sub>2</sub>
Center for Energy Efficiency and Renewable Technologies	CEERT
Compressed Natural Gas	CNG
Conventional vehicle	CV
Cost of Service	COS
Department of Energy	DOE
Electric Drive Transportation Association	EDTA
Electric Power Research Institute	EPRI
Energy and Environmental Economics, Inc.	E3
Energy Policy Act	EPAct
Environmental Protection Agency	EPA
Federal Energy Regulatory Commission	FERC
Fiscal year	FY
General Rate Case	GWC
Gigawatt-hour	GWh
Greenhouse Gas(es)	GHG
Heavy-duty vehicle	HDV
Home Area Network	HAN
Hybrid electric vehicle	HEV
Increasing-block pricing	IBP
Infrastructure Working Council	IWC
Investor-owned utility	IOU
Kilowatt-hour	kWh
Light-duty vehicle	LDV

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Liquefied natural gas	LNG
Load serving entity	LSE
Los Angeles Department of Water and Power	LADWP
Low Carbon Fuel Standard	LCFS
Low Emission Vehicle	LEV
Medium-duty vehicle	MDV
Megawatt	MW
Megawatt-hour	MWh
Methane	CH <sub>4</sub>
Million metric tons of carbon dioxide equivalent	MMtCO <sub>2</sub> e
National Electric Code	NEC
Natural Resources Defense Council	NRDC
Neighborhood electric vehicle	NEV
Nitrous Oxide	NO <sub>2</sub>
Pacific Gas & Electric	PG&E
Particulate matter	PM
Photovoltaic	PV
Plug-in electric vehicle	PEV
Plug-in hybrid electric vehicle	PHEV
Renewable Portfolio Standard	RPS
Sacramento Municipal Utility District	SMUD
San Diego Gas & Electric	SDG&E
San Diego Regional Planning Association	SANDAG
Senate bill	SB
Society of Automotive Engineers	SAE
Southern California Edison	SCE
Southern California Gas Company	SoCalGas
Time of use	TOU
Union of Concerned Scientists	UCS
United States	U.S.
Vehicle miles traveled	VMT
Vehicle to grid	V2G
Volatile organic compounds	VOC
Zero Emissions Vehicle	ZEV

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***Executive Summary:***

This white paper has been developed to identify for California Public Utilities Commission (CPUC) commissioners and staff the opportunities for and barriers to on-road light-duty vehicle (LDV) electrification (electrification).<sup>1</sup> The paper is intended to serve as a preliminary scoping tool to explore and provoke stakeholder input on potential policies that might support LDV electrification. It is not intended to make policy recommendations.

LDV electrification merits CPUC attention in light of volatile petroleum costs, petroleum security concerns, increasing fuel economy standards, and the overarching California Assembly Bill 32 (Nuñez) goal of reducing greenhouse gas (GHG) emissions in all sectors. Additionally, an historic number of automakers have already begun or announced deployment of a range of on-road electric vehicles, including light-duty plug-in hybrid electric vehicles (PHEVs), full-size battery electric vehicles (BEVs), two wheel BEVs, and three or four wheel low-speed neighborhood electric vehicles (NEVs) in 2010.<sup>2</sup> Light-duty hydrogen fuel cell vehicles are also classified as electric drive vehicles that create an energy demand from the production of compressed hydrogen fuel. This paper focuses on plug-in electric vehicles (PEVs), because thus far only one automaker has announced a hydrogen vehicle production model available for lease in limited initial availability,<sup>3</sup> and BEV and PHEV technologies are argued to be more efficient and less costly than hydrogen fuel cell vehicles.<sup>4</sup>

While this paper is focused primarily on light-duty PEVs, the CPUC also regulates gas utilities and has adopted a variety of policies related to compressed natural

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<sup>1</sup> Electrification is used here to mean substitution of some portion of the on-road petroleum-fueled conventional passenger light-duty vehicle fleet with electricity-fueled electric drive vehicles. CPUC staff acknowledges that transportation electrification also involves to medium to heavy duty vehicle electrification, transit electrification, and off-road vehicle electrification, such as at ports or truck stop electrification. The scope of this white paper targets on-road light-duty electric drive passenger vehicles. Emissions from the light-duty passenger vehicle class represents 30% of CO<sub>2</sub> emissions in the California Emissions Inventory, greater than medium, heavy duty or non-road CO<sub>2</sub> emissions. However, medium-duty vehicles, heavy-duty vehicles, and non-road vehicle electrification is an important means of emissions reduction and in some cases an important segment of utility clean transportation programs. Nevertheless, this paper focuses on LDV electrification because it represents a significant emissions reduction opportunity in the largest class of transportation sector emissions in the California Emissions Inventory. See ([http://www.arb.ca.gov/cc/inventory/pubs/reports/appendix\\_a1\\_inventory\\_IPCC\\_Sum\\_1990.pdf](http://www.arb.ca.gov/cc/inventory/pubs/reports/appendix_a1_inventory_IPCC_Sum_1990.pdf)).

<sup>2</sup> Certain automakers have already deployed a limited number of plug-in vehicles. A larger commercial release is expected from automakers in 2010. This white paper uses PEVs to refer to PHEVs and BEVs, unless a distinction is warranted to describe different characteristics associated with each vehicle.

<sup>3</sup> The Honda FCX Clarity was unveiled in 2007. Honda is making available 200 vehicles for lease over the next three years to the Southern California market. <http://automobiles.honda.com/fcx-clarity/>

<sup>4</sup> Wallis, George. "Why batteries not hydrogen fuel cells are the future of private motoring," (Claverton Energy Research Group, 2009). <http://www.claverton-energy.com/why-batteries-not-hydrogen-fuel-cells-are-the-future-of-private-motoring-george-wallis.html> (accessed May 11, 2009).



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gas (CNG) vehicles, and consequently the paper also includes a discussion of policies related to CNG vehicles.<sup>5</sup> The widespread use of PEVs and CNG vehicles presents a major opportunity to cut GHG emissions from the transportation sector. Increased electricity and natural gas usage for transportation also complements state mandates to improve vehicle efficiency and reduce total vehicle miles traveled (VMT).<sup>6</sup>

PEVs are anticipated to impact the electricity system in various ways. System impact research indicates that LDV electrification has the potential to increase total energy demand, substantially increase daily load capacity requirements, alter peak load shapes, increase transmission and distribution system demands, and result in net negative emissions of carbon dioxide (CO<sub>2</sub>), while increasing the electricity sector's emission profile.<sup>7</sup> Research also indicates that managed PEV load, through an appropriate tariff or other command and control mechanism, has the potential to increase off-peak demand. This increase in off-peak demand may flatten the electricity system load shape and improve utility transmission and distribution asset utilization while increasing utilities' load factors. In the long term, the utility has an opportunity to use PEV load to provide "supply-following" demand to support intermittent renewable resources such as off-peak wind. Managed PEV load integration with the electricity system can potentially provide grid support and distributed storage for load capacity using "Vehicle to Grid" (V2G) technology.<sup>8</sup>

California electricity utilities are preparing for and promoting the widespread use of PEVs, and the utilities can play a variety of roles in this regard. A utility may conduct system impact assessments; offer preferential PEV rate options to its PEV-owning customers to encourage off-peak PEV charging; deploy widespread reliable electricity fuel metering (and related residential on-site capital infrastructure, commercial charging infrastructure, public charging infrastructure, upgrade distribution level infrastructure); encourage the use of renewable energy resources for PEV load; and potentially drive down the cost of PEV battery technology through large battery technology purchase orders. Additional roles include PEV customer service to build customer readiness, streamline on-site PEV charging equipment installation, and may include PEV purchase rebate incentives and low-interest bill finance options for infrastructure upgrades on the customer side of the meter.

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<sup>5</sup> Experts note that CNG vehicle market growth may emerge in medium-duty and heavy-duty vehicle markets, whereas this paper focuses primarily on LDVs.

<sup>6</sup> CFEE Roundtable on Transportation Fuels, Current Status of the Alternative Transportation Fuels Debate, Remarks of Commissioner Rachele Chong, May 7, 2009

<sup>7</sup> See Southern California Edison. "Assessment of electrification of transportation and potential impacts" February 27, 2009: 2-8; EPRI & Natural NRDC. "Environmental assessment of plug-in hybrid electric vehicles, Volume 1: Nationwide greenhouse gas emissions." (2007): 2.

<sup>8</sup> See Ibid; Pacific Northwest National Laboratory. "Impact assessment of plug-in hybrid vehicles on electric utilities and regional U.S. power grids, Part 2: economic assessment." *Journal of EUEC*, V. 1 (2007): 2; Kempton and Tomić. "Vehicle-to-grid power fundamentals: calculating capacity and net revenue." *Journal of Power Sciences* V5 (2005): 1.

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While there is much the CPUC and the electricity utilities can do to prepare for and encourage the widespread use of PEVs, market and battery technical barriers may ultimately influence the sustainability of PEV commercialization. Market and technical barriers to sustained PEV commercialization include current battery and PEV cost, the storage to energy ratio of PEV batteries, automaker PEV production capacity, PEV battery production capacity, and the volatile cost of gasoline.<sup>9</sup> CPUC-relevant policy barriers to PEV commercialization include the increasing-block pricing (ICB) rate structure, which penalizes increased electricity usage for PEV battery charging, and any AB 32 cap-and-trade emissions allowance allocation policy that does not address the anticipated transfer of emissions from the transportation to the electricity sector associated with transportation fuel “switching” from petroleum to electricity.

The CPUC can optimize PEV tariffs, consider utility infrastructure investments, and authorize utility programs to support environmental goals and economic benefits of PEV commercialization. One available means to guide CPUC policy action is to open a new CPUC proceeding to evaluate policies and programs to incent PEV commercialization. Proposed topics identified in this paper for a new CPUC rulemaking on policy opportunities to support PEVs include:

- Rate design options, including the potential of a statewide electricity rate for PEVs,
- Vehicle incentives to encourage Californians to buy and operate PEVs, including ratepayer funded incentive programs,
- Options for development of metering and charging infrastructure for PEVs, and
- Options to streamline permitting requirements and contractor installation of residential PEV charging equipment;
- Options to incorporate PEV charging with renewable energy supply, including, but not limited to, photovoltaic (PV) arrays over charging stations or off-peak charging that takes advantage of overnight wind resources expected in the utility resource portfolio.

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<sup>9</sup> The Economist. “The art of the possible,” Nov. 13, 2008  
[http://www.economist.com/specialreports/displaystory.cfm?story\\_id=12544947](http://www.economist.com/specialreports/displaystory.cfm?story_id=12544947) (accessed May 11, 2009).

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## **1. Introduction**

Electric drive light-duty passenger vehicles were prolific in the nascent stages of the automotive industry in the United States (U.S.). Gasoline surpassed electricity as a primary onboard conventional vehicle (CV) fuel due in large part to its portable energy density and low cost. California industry and policy efforts to diversify the transportation fuel and technology portfolio from gasoline and the internal combustion engine (ICE), thereby reducing petroleum consumption, have recurred without substantial success.<sup>10</sup>

In the 1990s and first half of this decade, California consumers faced limited options to lease or purchase a factory model PEV. Due to alleged product unprofitability and battery technology reliability problems, certain automakers closed PEV factory production.<sup>11</sup> Petroleum cost volatility, energy security, rising fuel economy standards, and California air quality regulations have created renewed consumer demand for alternatives to petroleum fuel vehicles in California. As of this paper's release, a number of automakers are ramping up production plans to release PEV technologies for limited commercial availability to different international markets starting in late 2009 and 2010. Automakers that have already deployed or announced PEV deployment plans into California and other markets include, but are not limited to, General Motors, Build Your Dreams, Fisker Automotive, Think Motors, Ford Motors, Mercedes Benz, Daimler-Chrysler, Mitsubishi, Renault-Nissan, BMW, Toyota, and Apetura, and Tesla Motors. A number of NEV manufacturers operate in California markets. Finally, several auto repair shops in California convert CVs and hybrid electric vehicles (HEV)s for plug-in capacity.

PEVs use electricity fuel to power an electric motor, fully or partially replacing a petroleum-fueled ICE for propulsion. PEVs draw power from the electricity grid to charge a large on-board battery, and capture residual braking energy in a flywheel, like many HEVs. PEV types vary by fuel source, drive-train structure, onboard battery

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<sup>10</sup> Sperling, Daniel and Sonia Yeh. "Low Carbon Fuel Standards." *Issues in Science and Technology*: V. 25 (Winter 2009): 57.

<sup>11</sup> Taylor, Alex. "Why GM killed the electric car," (Fortune Magazine, November 25, 2008), <http://money.cnn.com/video/fortune/2008/11/25/fortune.taylor.gm.electric.fortune/>. (accessed May 11, 2009).

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chemistry and battery capacity, vehicle weight, and other characteristics. A BEV operates solely on grid-derived electricity and/or distributed electricity generation directed through the vehicle to an electric motor for propulsion. A PHEV operates on grid-derived electricity and/or distributed electricity generation directed to an electric motor for propulsion, but also includes a gasoline tank and smaller ICE to extend the vehicle range. PHEVs may also have an alternative propulsion system and fuel source other than gasoline to extend vehicle range, such as a blended biofuel tank and smaller ICE or onboard hydrogen fuel cell. The onboard battery capacity (kWh) and vehicle weight influence the electric power range. Battery pack systems are larger for full-size BEVs than PHEVs. All-electric driving range varies for a PHEV, but a common anticipated vehicle range is either 20 or 40 miles in “all-electric” mode. Some PHEVs operate in all-electric mode and switch to gasoline when the vehicle exhausts the stored power. Other potential PHEV designs include a blended design where a gasoline engine and electric motor both provide power to the wheels and are able to achieve higher a fuel economy due to the increased amount of electrical energy obtained from overnight charging.<sup>12</sup> Electric drive motors demonstrate increased energy conversion efficiencies relative to ICEs.

Infrastructure investments at the customer site, commercial site, public charging site, and distribution system level are all required to prepare the electricity system for the widespread use of PEVs. Nevertheless, in broad terms, electricity fuel availability theoretically extends across the entire electricity grid. Consequently, electricity fuel presently enjoys a competitive advantage in terms of existing refueling infrastructure over other alternative fuels (such as hydrogen, CNG, ethanol, propane, and other biofuels).

***A. Demand Assumptions Used in this Paper***

This white paper does not attempt to forecast BEV and PHEV market growth. Instead, it analyzes impacts of electrification on the California electricity system at the generation and distribution level and on net GHG emissions for several plausible vehicle

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<sup>12</sup> Phone communication. Spencer Quong, UCS, 02/27/2009

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market penetration scenarios, with a specific focus on policies the CPUC could pursue to support increased market penetration in a manner that is fair to ratepayers. This subsection describes the assumptions and rationale behind the market penetration scenarios used in this analysis.

The potential PEV market period from 2010-2020 is characterized here as an “early adoption” period. The early adoption period may serve as an indicator of post-2020 PEV adoption rates and may test the assumption that costs decline with technology improvement. Moore’s law assumes every doubling of cumulative production volume typically makes manufactured goods about 10 to 30 percent cheaper, across a wide range of products.<sup>13</sup> Increased demand for a product sends a signal to the market to improve economies of scale and reduce scarcity, resulting in increased production at decreasing costs. Technology quality (e.g., the energy density and weight of a PEV battery) is hypothesized to improve along the learning curve within certain parameters, such as resource cost and availability.

The early adoption period for PEVs faces significant uncertainty. Major factors that influence sustained PEV commercialization include the initial PEV cost premium relative to a comparable CV, electricity rates, gasoline fuel cost trends, competitor vehicle and cost trends, consumer willingness to pay, availability of electricity, forecasts of California demographics (such as population, employment, and personal income, consumer behavior), and PHEV and BEV manufacturer production capacity (these factors are discussed in Section 3).<sup>14</sup>

Some experts concede that PEV market penetration may be slow in the near term. As mentioned above, this white paper is not intended to forecast the PEV market; however, staff’s analysis suggests that any significant level of increased consumer

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<sup>13</sup>Lovins, A., Williams, B. “A Strategy for the Hydrogen Transition.” 10<sup>th</sup> annual U.S. Hydrogen meeting, National Hydrogen Association, April 7-9, 1999. [http://www.rmi.org/images/other/Trans/T99-07\\_StrategyH2Trans.pdf](http://www.rmi.org/images/other/Trans/T99-07_StrategyH2Trans.pdf) (accessed May 11, 2009).

<sup>14</sup> For a more accurate forecast of these factors, see “Transportation fuel price and demand forecasts: inputs and methods for the 2009 integrated energy policy report.” California Energy Commission, January 2009.

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adoption will depend on a sustained increase in gasoline cost and at least a 50% decrease in battery and vehicle cost.<sup>15</sup>

Vehicle population data assumptions accommodate TIAX LLC projections data for achievable and expected market growth scenarios to 2020.<sup>16</sup> In addition, a low to no market growth case incorporates a current CARB ZEV program compliance option whereby automakers may use 58,000 PHEVs to meet ZEV requirements.<sup>17</sup> The low case includes an estimated existing 1,000 full-size BEVs and 10,000 NEVs.<sup>18</sup> A middle case accommodates a TIAX LLC report projection of expected vehicle population of 33,000 full-size, city and neighborhood BEVs (upper bound), and 312,000 PHEVs (upper bound).<sup>19</sup> Achievable vehicle population is projected at 455,000 full-size, city, and neighborhood BEVs and 2,500,000 PHEVs in 2020 for a potential high case.<sup>20</sup> TIAX projections incorporate CARB and industry data for “anticipated natural market growth, expected incentives programs, and the use of electric-drive technologies to comply with existing and expected federal and state regulations.”<sup>21</sup>

***B. Contents and Organization***

This paper is divided into six sections, including this introduction. Section 2 describes the environmental benefits and costs associated with electrification, including a summary of state environmental policy drivers. Section 3 addresses the economic benefits, costs, and barriers associated with the widespread use of PEVs electrification for each societal actor (PEV consumers, utilities/grid operations, and utility ratepayers). Section 4 addresses non-economic and indirect economic barriers to greater adoption of

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<sup>15</sup> Levin, Robert. Presentation to CPUC Division of Ratepayer Advocates, January 7, 2009. “Will plug-in hybrids roll to the rescue?”

<sup>16</sup> TIAX, LLC. Jackson, Fable, Aumann, Moore. (October 2005) “Electric transportation and goods-movement technologies in California: Technical Brief.” Prepared for California Electric Transportation Coalition. This white paper analysis accommodates TIAX population data as an model input assumption. TIAX impact analysis results are different that CPUC analysis results; TIAX models are more complex than the CPUC spreadsheet model developed with the assistance of E3 Consultants, San Francisco, CA.

<sup>17</sup> Future ZEV program iterations are expected to change this regulatory “low-case” data assumption.

<sup>18</sup> NEVs are treated as one/fifth of a full size BEV for capacity calculations. This adds and additional 2,000 BEVs to the existing 1000 BEVs for 2020 low case scenario.

<sup>19</sup> TIAX LLC “Electric transportation and goods-movement technologies in California: Technical Brief.” Report for California Electric Transportation Coalition. (October 2005): Table A-1.A.

<sup>20</sup> Ibid, Table A-2. B.

<sup>21</sup> Ibid, p. 3-1.

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electric vehicles. Section 5 summarizes existing and pending Federal and state policies in support of electrification, as well as a summary of existing investor-owned utility (IOU) programs that support electrification and CNG. Finally, Section 6 focuses on specific barrier reduction opportunities that are within the purview of the state's energy agencies.

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## **2. Environmental Benefits and Costs of LDV Electrification**

This section provides the potential environmental benefits and costs of electrification, as well as the related environmental policy drivers that have been adopted in California.

### ***A. Environmental Benefits***

CARB estimates that transportation sector emissions represent approximately 38% of the total carbon footprint of the California economy, or 182 million metric tonnes of carbon dioxide equivalent (MMtCO<sub>2</sub>e),<sup>22</sup> and emissions from LDV mobile sources alone are estimated to represent up to 30% of the total California carbon footprint.<sup>23</sup> Transportation emissions include CO<sub>2</sub> and other criteria air pollutants, such as particulate matter (PM) .10, PM .25, methane (CH<sub>4</sub>), hydrofluorocarbons, nitrous oxide (NO<sub>2</sub>) and volatile organic compounds (VOC). Aggregate transportation sector emissions are expected to increase with expected population growth, absent LDV market and fuel transformation to lower carbon options.

Research indicates that electrification is an available means to reduce emissions and petroleum consumption in the transportation sector.<sup>24</sup> While CO<sub>2</sub> emissions increase due to additional electricity generation required for electricity fuel, PEV operation avoids petroleum combustion and results in net emissions reductions relative to CV operation, since centralized electricity generation plants demonstrate efficiency levels that exceed dispersed internal combustion engine efficiency.<sup>25</sup> Reduction of petroleum consumption also avoids additional “upstream” emissions, such as those emitted in refining petroleum.

A 2007 EPRI and NRDC nation-wide electricity and transportation sector forecast found significant GHG reductions for PEV fleet penetration, and significant reduction in

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<sup>22</sup> California Air Resources Board Staff. Climate Change Proposed Scoping Plan 2008, Approved December 11, 2008. p.C-55. <http://www.arb.ca.gov/cc/scopingplan/document/psp.pdf> (accessed May 11, 2009).

<sup>23</sup> Meeting communication, Patty Monahan, UCS, 11/5/08

<sup>24</sup> EPRI & NRDC. “Environmental assessment of plug-in hybrid electric vehicles, Volume 1: Nationwide greenhouse gas emissions.” (2007): Executive Summary.

<sup>25</sup> For example, the internal combustion engine in a conventional vehicle is about 37% efficient due primarily to heat loss (EPA Fuel Economy site). The conversion efficiency differs per generation fuel source, but natural gas (the marginal power plant in California is between 40%-50% efficient. An electric drive motor is approximately 95% efficient.



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the consumption of petroleum fuels across a range of vehicle adoption forecasts and electricity generation portfolios.<sup>26</sup> As California moves toward a 33% renewable electricity portfolio, and as the carbon intensity<sup>27</sup> of new central station generating capacity is reduced compared to existing capacity, the emissions reductions associated with electrification will be even more pronounced.

Table 1 below shows a preliminary CPUC staff estimate of the net CO<sub>2</sub> emissions resulting from various levels of electric drive LDVs charging on the grid, based on the following assumptions:

- (1) Full-size BEV battery capacity (66) kWh; PHEV battery capacity (16 kWh) that draws 10 kWh per charge from the grid, and NEV capacity is assumed 1/10 of BEV capacity for the low case,
- (2) BEV vehicle efficiency of 4.5/kWh, PHEV vehicle efficiency of 4 miles/kWh,
- (3) Electricity generation emissions of 408.2 kg CO<sub>2</sub>e/MWh,<sup>28</sup>
- (4) 76% of PEV drivers charge off-peak,
- (5) PEV technology replaces a 30mpg CV,
- (6) The carbon intensity of gasoline is 8.8 kg/gal.

The table assumes no behavioral change (i.e. the PEV is driven no more or less than the CV it replaces). Total VMT are assumed to be 13,322 miles/year for both vehicle technologies.<sup>29</sup> CPUC staff is also aware that assumptions (4) and (5) may not match charging behavior or technology parameters for many PEV drivers/electricity customers.

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<sup>26</sup> EPRI & NRDC. "Environmental assessment of plug-in hybrid electric vehicles, Volume 1: Nationwide greenhouse gas emissions." (2007): 3.

<sup>27</sup> Carbon intensity is used here to mean the amount of carbon dioxide released per unit of delivered energy.

<sup>28</sup> This assumption is lower than the California GHG emission performance standard requirement that all new generation be less than or equal to 1100 lbs CO<sub>2</sub>e/MWh, or 498.95 kg CO<sub>2</sub>e/MWh, but it includes the integration of renewable energy sources into the state's generation portfolio.

<sup>29</sup> Based on hybrid electric vehicle driver polling data from ARB ZEV program biennial review, August 7, 2000, in TIAX LLC "Electric transportation and goods-movement technologies in California: Technical Brief." Report for California Electric Transportation Coalition. (October 2005): 5-9.

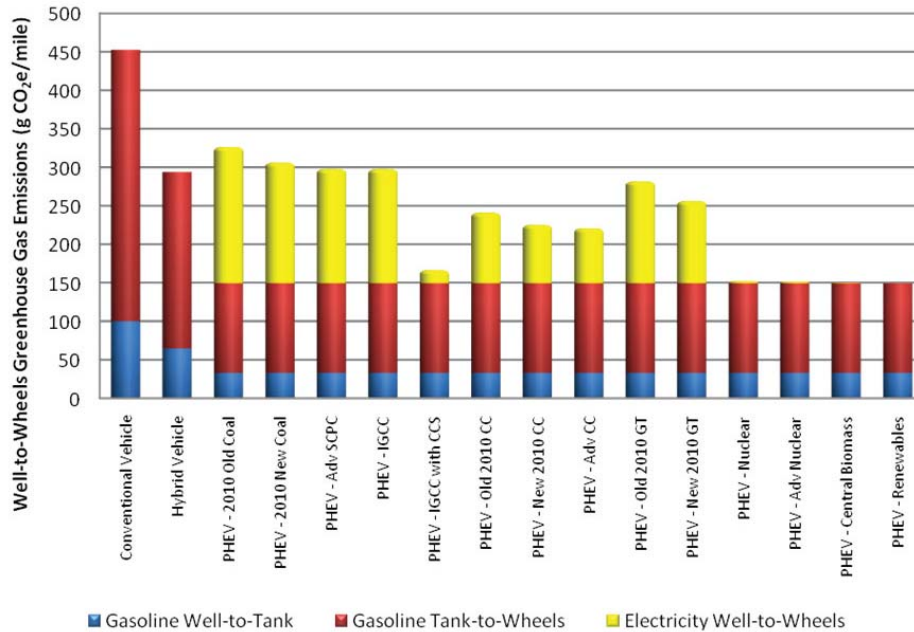
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*Table 1 Draft Impact of PEVs on GHG emissions*

PEVs in 2020	Increased GHG emissions from electricity generation (MMtCO <sub>2</sub> e)	Net MMtCO <sub>2</sub> e Reductions, accounting for avoided emissions from reduced gasoline consumption (MMtCO <sub>2</sub> e)
3,000 BEVs 58,000 PHEVs	0.083	(.158)
33,000 BEVs 312,000 PHEVs	0.46	(0.90)
455,000 BEVs 2,500,000 PHEVs	0.62	(7.73)

A portfolio of PEVs including BEVs, NEVs, converted HEVs, and PHEVs with variable daily capacity (kWh) and range requirements is likely to require charging at different times of the day. The chart below demonstrates relative emissions reduction of HEV technologies and PHEV with a 20-mile range in electric mode, accounting for some gasoline consumption. Each bar provides indirect (well-to-tank, including petroleum extraction, refining, and fuel distribution to the gasoline tank) and direct (gasoline tank to wheels, electricity-well-to-wheels) emissions. The chart demonstrates that while the carbon intensity of the electricity generation resource influences total GHG emissions emitted per mile, there is a net reduction in emissions for all PHEVs relative to CVs, and in most cases relative to HEVs.

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Source: EPRI/NRDC (2007) “Environmental Assessment of Plug-In Hybrid Electric Vehicles.”

The EPRI/NRDC report finds that a CV releases approximately 100 grams of CO<sub>2</sub>e per mile from gasoline well-to-tank emissions, and an additional 350 gCO<sub>2</sub>e/mile of emissions are released when the gasoline is combusted to produce motive force. A “well-to-wheels” GHG calculation accounts for upstream indirect emissions associated with fuel production, in addition to direct emissions from fuel conversion. Emissions reductions from HEV and PHEVs with 20-mile ranges that use fossil fuel based electricity are approximately equal in their emissions reductions. A hybrid releases approximately 300 gCO<sub>2</sub>e/m, as does a PHEV powered by a new coal plant. Total emissions are much lower for combined cycle natural gas, geothermal, nuclear, advanced nuclear, biomass, and renewable energy sources.

The EPRI/NRDC report analyzes emissions associated with fossil fuels, but does not investigate the relative merits of renewable and other alternative, low- or no-carbon energy sources. For this information, a recent Stanford analysis finds that a wind-and concentrated-solar-powered fully BEVs and wind-powered hydrogen fuel cell vehicles ranked as the optimal energy-related transportation solution to global warming, air

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pollution, and energy security, while nuclear- and coal-with-carbon-capture-powered-BEVs and corn-E85 vehicles ranked the lowest.<sup>30</sup>

To the extent that a significant portion of PEV battery charging occurs off-peak, utilities may be able to maximize the benefits of wind resources, which typically operate at highest capacity during the night in California. In addition, vehicle-to-home and V2G technology may enable load firming of renewable energy resources by providing storage and responsive back-up power when energy supply temporarily drops off. Broadly, V2G refers to the bidirectional flow of electricity from the grid to battery storage inherent in PEVs, and vice versa.

V2G technology economic feasibility will require PEV market penetration that is sufficiently scaled to allow stabilization of centralized renewable energy resource plants, as well as a number of technological advances and grid infrastructure upgrades (e.g., the PEV charger bi-directional and distribution system will need to be bi-directional, and the battery technology would permit frequent charging and discharging of the battery by the utility without unacceptable adverse battery life impacts).<sup>31</sup>

In addition, V2G technologies would enable utilities to utilize capacity stored in PEVs to defer or otherwise avoid emissions associated with additions of central peaking generation during peak demand periods.<sup>32</sup> If the stored electricity were generated from off-peak wind energy, the emissions avoided would be even greater.

***B. Potential Environmental Costs***

While the widespread use of PEVs is expected to significantly reduce net emissions, there may be other losses of environmental capital associated with electrification (environmental capital, or natural capital, is used here to mean the economic value of ecosystem services, such as water irrigation for agriculture).<sup>33</sup>

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<sup>30</sup> Jacobson, Mark. "Review of solutions to global warming, air pollution, and energy security." *Energy & Environmental Science* 2009, 2: 148.

<sup>31</sup> Kempton, W. and A. Dhanju, "Electric Vehicles with V2G: Storage for Large-Scale Wind Power." *Windtech International* V. 2 (March 2006): 18-21.

<sup>32</sup> Ibid

<sup>33</sup> Lovins, A., Lovins, A., Hunter. Natural Capitalism: creating the next industrial revolution. 2008 Ed: 15.

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The analysis that indicates that electrification will result in net emissions reductions in California is due in part to the assumption that natural gas or renewable energy generation supplies the additional electricity load. This assumption is based on California's renewable portfolio standard (RPS) and on California's GHG emission performance standard, which requires all new power plant generation to be equal to or less carbon intensive than a combined cycle natural gas turbine. However, two studies conclude that electrification may result in no net change to CV operation or increase emissions in other regions, if an increased percentage of coal and oil generation is used to supply load due to electrification.<sup>34</sup> Also, the amount of avoided emissions due to electrification partly rest on an assumption that approximately 76% of PEV drivers will charge off peak, and 24% will charge on peak. On-peak electricity delivery is associated with marginally increased emissions due to decreasing efficiency levels of the marginal natural gas generation plants.<sup>35</sup> Finally, the amount of avoided emissions due to electrification also assumes no behavioral change from a plug-in vehicle relative to a CV, which may or may not occur under real world conditions.

Electricity generation also requires increasingly strained water resources. In 2001, approximately 48,000 Gigawatt-hours (GWh) or 19% of total electricity use in California was directed for water supply and treatment and wastewater treatment.<sup>36</sup> Experts assert that "any switch from gasoline to electric vehicles or biofuels is a strategic decision to switch our dependence on foreign oil to domestic water."<sup>37</sup> Drought conditions limit the availability of electricity produced by hydroelectricity. California hydroelectric electricity megawatt (MW) supply capacity varies, depending on climate conditions. Thermal power plants that consume uranium, coal, and natural gas depend on available water

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<sup>34</sup> See Hadley, Tsvetkova, "Potential impacts of plug-in hybrid electric vehicles on electric power generation." Oak Ridge National Laboratory. January 2008.

[http://www.ornl.gov/info/ornlreview/v41\\_1\\_08/regional\\_phev\\_analysis.pdf](http://www.ornl.gov/info/ornlreview/v41_1_08/regional_phev_analysis.pdf)

And McKinsey, Co. "China Charges Up." October 30, 2008

[http://www.mckinsey.com/client-service/ccsi/pdf/the\\_electric\\_vehicle\\_opportunity.pdf](http://www.mckinsey.com/client-service/ccsi/pdf/the_electric_vehicle_opportunity.pdf)

<sup>35</sup> Hadley, Tsvetkova, "Potential impacts of plug-in hybrid electric vehicles on electric power generation." Oak Ridge National Laboratory. January 2008

<sup>36</sup> Table 1-1 California's Water-Energy Relationship. Nov. 2005. CEC – 700-2005-011-SF

<sup>37</sup> Webber, M. "Catch 22: Water vs. Energy." *Scientific American*

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supplies for cooling.<sup>38</sup> Some 7,400-20,000 gallons of water are required to generate 1 MWh in a combined cycle natural gas plant; 21,000-50,000 are required for coal and oil, and 25,000-60,000 are required for nuclear power plant cooling.<sup>39</sup> Research indicates that approximately 24 gallons of water are required to drive 100 miles in a PHEV, and between 7 and 14 gallons are required to drive the same distance in a gasoline vehicle.<sup>40</sup> (Note that while electricity fuel increases demand for water relative to a gasoline-fueled vehicle, it is more efficient than other alternative fuels – approximately 130-6,200 gallons of water are depleted to travel 100 miles for an ethanol fueled vehicle.)<sup>41</sup>

Finally, increased production of PEV batteries may result in upstream and downstream environmental costs. For example, a recent study finds that increased lithium carbonate extraction for forecasted lithium-ion battery production results in small indirect land use changes. Lithium carbonate is a non-renewable resource extracted economically from high-altitude lakebeds, although it can be extracted from other domestic sources. Future estimated lithium carbonate demand due to PEV market growth could exceed 2% of the global reserve base per annum, resulting in a projected 3.9% price increase annually starting in 2010.<sup>42</sup>

Further, increased lithium-ion, nickel metal hydride, lead acid, and other battery production may result in additional downstream waste in the long term. Some stakeholders are concerned that toxicity levels associated with such waste streams may pollute soil and groundwater around landfills. Battery toxicity is found to be less problematic for lithium-ion and nickel metal hydride batteries – batteries currently used in HEVs and projected for use in PEVs – than lead acid or nickel cadmium.<sup>43</sup> While many battery designs are improving in longevity, energy storage factors, and are

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<sup>38</sup> Ibid

<sup>39</sup> Ibid

<sup>40</sup> Ibid

<sup>41</sup> Ibid

<sup>42</sup> Heo, J., Padmanabhan, A., Powley, B., Salmon, L., Sathe, A. (2007) “Lithium Carbonate: A Depletable Resource Study.” MS&E 248. Stanford University.

<sup>43</sup> Hybrid Cars. “Hybrid battery toxicity,” (HyridCars.com, April 8, 2006), <http://www.hybridcars.com/battery-toxicity.html> (accessed May 12, 2009).

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recyclable,<sup>44</sup> it may be impossible to divert every battery from a landfill.<sup>45</sup> Nevertheless, the California Air Resources Board (CARB) recently adopted a resolution indicating that the increased disposal of batteries in PEVs “is not expected to have significant adverse environmental impact on landfills because the disposal of such batteries is already subject to extensive regulation in the State, and automotive batteries are among the most highly recycled products today.”<sup>46</sup>

***C. Environmental Policy Drivers in California***

California has adopted multiple policies directing CARB, the California Energy Commission (CEC), and the CPUC to address the problems of growing transportation petroleum fuel use, continued petroleum dependence, and associated GHG emissions in the transportation sector. These policies are described below (note that this survey focuses on state environmental policies that electrification could help achieve, whereas Section 5 provides a summary of state policies that are intended to support the commercialization of PEVs, such as tax credits, manufacturing grants and loan programs, and infrastructure/vehicle deployment funds in the recent federal stimulus bill).

**Assembly Bill 1493 (Pavley).** AB 1493 requires CARB to adopt and enforce regulations that achieve the maximum feasible reduction of GHGs emitted by passenger vehicles and light-duty trucks and any other noncommercial personal vehicles.<sup>47</sup> The CARB rulemaking to implement AB1493 includes a Zero Emissions Vehicle (ZEV) automaker deployment mandate that requires 22 automakers to manufacture and deploy “a declining fleet average standard for ... pollutants, with separate standards for the lighter and heavier portions of the passenger vehicle fleet.”<sup>48</sup>

A March 2008 CARB meeting proposed two additional phased modifications to the ZEV mandate. Under phase II (2012-2014), CARB required that automakers deploy a

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<sup>44</sup> Toyota, Honda, and Tesla Motors have protocols for ensuring that batteries in their electric vehicles return to the company for distribution to preferred recycling vendors.

<sup>45</sup> Ibid.

<sup>46</sup> CARB Resolution 09-3 to the Low Carbon Fuel Standard. April 23, 2009: 13.

<sup>47</sup> AB 1493, Chapter 200. Legislative Counsel’s Digest. <http://www.calcleancars.org/ab1493.pdf>.

<sup>48</sup> October 2008 CARB Scoping Plan P. C-59.

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minimum of 7,500 ZEVs.<sup>49</sup> Automakers may deploy multiple partial-zero emission vehicles, such as approximately 58,000 PHEVs, as a deployment option to meet the baseline requirement during 2012-2014. After 2015, phase III will streamline ZEV to focus ZEV phase II on hydrogen, PHEV, and BEVs.<sup>50</sup>

**Executive Order S 01-07 - Low Carbon Fuel Standard (LCFS).** The LCFS mandates a 10 percent reduction in the average fuel carbon intensity for all fuels distributed in California by 2020. Carbon intensity units are measured in gCO<sub>2</sub>/MJ, measured on a lifecycle basis, including equivalent amounts of CO<sub>2</sub>e emitted from producing, transporting, and using the fuel in the vehicle.<sup>51</sup> CARB expects the LCFS will achieve annual reductions of approximately 15 million metric tonnes of CO<sub>2</sub> equivalent (MMT CO<sub>2</sub>e) annually when fully implemented 2020. CARB adopted the rules to implement the LCFS on April 23, 2009. The regulation will take effect January 1, 2011.

California Executive Order S 01-07, which established the LCFS, states “The Public Utilities Commission, in the implementation of the GHG emissions cap adopted by Decision 06-02-032, is requested to examine and address how the investor-owned utilities can contribute to reductions in GHGs in the transportation sector.” Electricity fuel is an eligible fuel pathway in the LCFS, along with other petroleum alternatives, including CNG, propane, biofuels and hydrogen. The total carbon intensity value for electricity is 41.37 gCO<sub>2</sub>e/MJ for the California average electricity mix, and 34.9 gCO<sub>2</sub>e/MJ for California marginal electricity mix of natural gas and renewable energy sources. The total emissions include direct emissions, adjusted by an efficiency factor to account for electric drive vehicle power train efficiency improvements over gasoline engines.<sup>52</sup> For electricity used as an on-road transportation fuel, the regulated party will be either the load service entity (LSE) supplying the electricity to the vehicle or another party that has

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<sup>49</sup> A ZEV is “based on a fuel cell vehicle” Green Car Congress “CARB votes to modify ZEV program in short-term, complete overhaul to begin for new ZEV II.” 27 March 2008, <http://www.greencarcongress.com/2008/03/california-air.html>, (accessed May 12, 2009).

<sup>50</sup> Ibid

<sup>51</sup> CARB Staff Report: Proposed Regulation to Implement the Low Carbon Fuel Standard - Initial Statement of Reasons V. 1 (March 5, 2009): ES-2 [http://www.arb.ca.gov/fuels/lcfs/030409lcfs\\_isor\\_vol1.pdf](http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf). Proposed regulation adopted April 23, 2009.

<sup>52</sup> Ibid, Table IV-1, p. IV-3/145



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a mechanism to provide electricity to vehicles and has assumed the LCFS compliance obligation.<sup>53</sup>

**Executive Order S-3-05 / Assembly Bill 32 (Nuñez), the Global Warming Solutions Act.** AB 32 requires CARB to adopt a statewide GHG emissions limit equivalent to statewide GHG emissions levels in 1990 to be achieved by 2020. AB 32 is a complementary air quality policy to local, state, and federal ambient air quality standards consistent with the State Implementation Plan.<sup>54</sup> AB 32 requires the maximum technologically feasible and cost-effective emissions reductions in all sectors, including electricity.<sup>55</sup> California Executive Order S-3-05 requires the statewide GHG levels to be 80% below 1990 levels by 2050. It suggests that further deployment of existing technologies will allow California to achieve the 2020 goal, whereas the long term goal requires reductions from all areas including lower GHG vehicle/fuel systems, increased transportation efficiency, changes in the delivery of goods and services, expanded transit, and more efficient land use patterns.<sup>56</sup> As a potential cost-effective, technologically feasible technology, a CEC analysis found that LDV electrification may enable California to reduce aggregate CO<sub>2</sub> emissions 80% below 1990 levels by 2050, under certain assumptions about PEV market penetration and the resource mix for grid electricity.<sup>57</sup>

AB 32 required CARB to adopt discrete early action measures. In July 2007 and December 2007, respectively, CARB approved the LCFS and ship electrification at ports as discrete early actions to reduce emissions in the transportation sector.

AB 32 further directed CARB to consider a cap-and-trade market trading scheme for emissions. CARB adopted the AB 32 scoping plan in December 2008, which references a cap-and-trade scheme to complement other emissions reductions measures. The aggregate California GHG cap establishes a limit on emissions that declines over time. The cap-and-trade market mechanism will create a price for GHG emissions that reflects

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<sup>53</sup> Ibid, Table ES-4, p. ES-10

<sup>54</sup> CEC State Alternative Fuels Plan AB 1007, P. 36.

<sup>55</sup> Assembly Bill No. 32 Text, Chapter 488

<sup>56</sup> P. C-23

<sup>57</sup> Beemis, Gerry “Developing a methodology to allocate AB 118 funds.”

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the cost of the reductions needed to meet the environmental goal.<sup>58</sup> The electricity sector will be regulated within the cap-and-trade market when the program begins in 2012, and transportation fuels are anticipated to be rolled into the program in 2015.

**AB 1007 - State Alternative Fuels Plan.** In AB 1007, the Governor and the Legislature directed the CEC and CARB to develop a state plan to increase the use of alternative fuels, including biofuels, hydrogen, electricity, and others. AB 1007 included petroleum reduction goals established in AB 2076. AB 2076 set a goal to reduce petroleum consumption to 15% below 2003 levels by 2020. AB 1007 directed CEC to draft a plan to determine the feasibility of this goal.<sup>59</sup> Additional established policy goals recognized by the alternative fuels plan included the 2006 California Bioenergy Action Plan. The plan recommends a suite of policies to facilitate increased alternative fuel consumption and achieve AB 2076 goals.

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<sup>58</sup> CARB Staff Report. "Cap and Trade background" Climate Change Scoping Plan." Pursuant to the AB 32, The California Global Warming Solutions Act of 2006. p. C-11

<sup>59</sup> CEC State Alternative Fuels Plan AB 1007, p. 36

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### **3. Economic Benefits, Costs, and Barriers to Entry**

This section outlines potential economic benefits, costs, and barriers to entry associated with increased PEV adoption and electrification. The section is divided into three areas of analysis: PEV users, electricity utilities, and utility ratepayers.

#### **A. PEV Users**

Experts estimate an average additional initial capital cost of \$10,000-\$16,000 for certain factory produced PEV technologies relative to a CV in 2010 when automaker production volumes are low.<sup>60</sup> Initial additional cost estimates for PEV technologies vary depending on the on-board battery capacity, battery type, and vehicle size and weight. One estimate places that initial cost for a PHEV with a 16 kWh battery a \$16,000 more than a CV, assuming a battery cost of \$1,000 per kWh.<sup>61</sup> In comparison, a gasoline engine costs \$2,000.<sup>62</sup> As previously stated, the PEV battery cost premium relative to a CV may decrease as the market moves up the technology-cost learning curve. For example, the U.S. Environmental Protection Agency (EPA) estimates the additional initial capital cost for higher volume production costs for a small car PHEV at \$4500.00, increasing with vehicle size.<sup>63</sup> Low production volumes are generally in the low 10,000 or lower.

Offsetting the additional initial capital cost to the vehicle consumer, PEV operating costs are significantly lower than gasoline-fueled CV operation across a wide range of electricity rates. Assuming a CV efficiency of 25 miles per gallon, a PEV

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<sup>60</sup> Upper bound (\$16,000) from meeting communication with Luke Tonachel, NRDC, 10/09/08

<sup>61</sup> Lemoine, D. M., 2008. Valuing plug-in hybrid electric vehicles battery capacity using a real options framework, UC-Berkeley, USAEE Working Paper 08-015. \$1000/kwh is a conservative case, as GM argues the cost is closer to a fourth of the case found by Lemoine (2008). Green Car Congress (3/4/09) "GM: Volt Pack now hundreds less than \$1000/kwh; headed to \$250/kwh": <http://www.greencarcongress.com/2009/03/gm-volt-pack-no.html>

<sup>62</sup> Ashuckian, D. "Who (or What) killed the electric vehicle: the rest of the story." Presentation to Division of Ratepayer Advocates. 01/07/09

<sup>63</sup> "EPA costs account for both the direct manufacturing costs and the indirect costs. These indirect costs include production-related costs (research, development, and other engineering), business-related costs (salaries, pensions), or retail-sales-related costs (dealer support, marketing), and profits." In EPA. "EPA Staff Technical Report: cost effective estimates of technologies used to reduce LDV CO2 emissions." (EPA, March 2008), <http://www.epa.gov/OMS/climate/420r08008.pdf> (accessed May 15, 2009).

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efficiency of 0.25 kWh per mile, an off-peak electricity cost of \$0.056/kWh,<sup>64</sup> and a gasoline cost of \$2.50/gallon, the cost per mile for a plug-in vehicle in all-electric mode and gasoline-fueled CV is \$0.01/mile and \$0.10/mile, respectively.<sup>65</sup> Holding all else constant, but assuming an on-peak electricity cost of \$0.284/kWh,<sup>66</sup> the cost per mile for a PEV in all-electric mode and gasoline-fueled conventional vehicle is \$0.07/mile and \$0.10/mile, respectively.

Lower gasoline prices (i.e., \$2.00/gallon), make PEV economics unfavorable absent vehicle purchase incentives, petroleum fuel taxes, or explicit alternative fuel subsidies. For example, assuming a \$15,000 initial PEV cost premium, \$2.00/gallon gasoline, 30 mpg fuel efficiency for the comparison CV, 3 miles/kWh for electricity, 12,000 miles/year in all-electric mode, and \$.010/kWh for off-peak service, CPUC staff analysis finds the PHEV owner will break even at 37.5 years, well beyond the conventional vehicle lifespan. At \$4.00/gallon, under identical behavior, efficiency, and electricity cost assumptions, the payback period is reduced to 12.5 years.<sup>67</sup>

There is a substantial electricity usage and bill increase at the customer level due to PHEV or BEV load.<sup>68</sup> Each IOU currently offers a residential PEV Time of Use (TOU) tariff. Each PEV TOU tariff is either for bundled household load and vehicle load, or segregated vehicle load. A vehicle load rate requires separate metering. Costs associated with separate meters and the cost of dedicated devices to communicate vehicle load to a “smart meter” are discussed below. A TOU schedule offers reduced rates per kWh on a pro-rated basis for off-peak charging, with incremental rate increases for vehicle charging during partial peak and on peak demand times. A TOU schedule is intended to send a more accurate price signal to the electricity customer depending on demand and congestion, which would encourage off-peak vehicle recharging.

One issue associated with PEV rates is the current bill-tier structure, also known as increasing-block pricing (IBP). California adopted ICB pursuant to AB1X in response to

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<sup>64</sup> PG&E Rate B “Off-peak” summer rate, for baseline usage and 101%-130% of baseline usage.

<sup>65</sup> Mui, Simon, NRDC “PEV and ICE comparison model” NRDC does not use this model for official NRDC analysis.

<sup>66</sup> PG&E Rate B “On-peak” summer rate, for baseline usage and 101%-130% of baseline usage.

<sup>67</sup> Mui, Simon, NRDC “PEV and ICE comparison model”

<sup>68</sup> Levin, Robert. CPUC DRA. “Will plug-in hybrids roll to the rescue”? Presentation January 7, 2009

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the 2001 electricity crisis. IBP raises marginal prices for residential consumption in steps.<sup>69</sup> The marginal price is held constant for up to 130% of residential baseline usage, and then increases for additional marginal consumption for off-peak, partial peak, and on-peak rates. The rationale for IBP is to discourage usage through higher marginal price, at least for price-responsive customers. PG&E E-9 EV rates are TOU rates and are subject to IBP. SDG&E and SCE EV rates are not subject to IBP.

If the PEV electricity usage borne by the residential electricity customer is bundled with anticipated PHEV battery capacity and usage (~8-10 kWh/charge), total monthly usage could increase by approximately 300 kWh/month. The average residential monthly load in California is 549 kWh, although individual usage depends on the season and climate associated with household location.<sup>70</sup> An average California household that charges 10 kWh/night will incur a 55% increase in usage, assuming the usage is not separately metered from household usage. Under this scenario, PHEV usage included with average customer household electricity load increases residential demand beyond the 130% of baseline value. Combined PEV usage with household usage, subject to IBP, would increase the cost of all consumption, including PEV consumption. This would be a particular concern if households adopt more than one PEV. Consequently, while IBP is intended to discourage higher usage which, in turn, would decrease the pollution associated with usage, to the extent that it discourages PEV adoption it actually prohibits an opportunity for net emissions reductions.

Another potential PEV tariff issue is the disparate and potentially confusing range of PEV rate options offered by different utilities to electricity customers/EV drivers. PEV rates differ amongst the IOUs and municipal utilities. The rate difference may be particularly problematic for residential electricity customers/EV drivers that charge at home in one utility service territory, and charge at work or another residential location in another utility service territory. As an example, a residential electricity customer/PEV

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<sup>69</sup> Borenstein, Severin. (2009) "To what price do residential electricity customers respond?" 03/20/2009 POWER conference presentation

<sup>70</sup> David Silverman, "The California Energy Crisis." (California Energy Data, <http://www.physics.uci.edu/~silverma/crisis.html>.) (accessed May 21, 2009).

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driver may have a primary charging location in a small utility whose service territory is embedded in a larger IOU service territory.

In addition, to be eligible for IOU PEV rates for segregated PEV load, the customer's service requires an advanced meter that can communicate sub loads to the utility and a second hardware device to communicate PEV sub load to the advanced meter. The CPUC has authorized the installation cost of an advanced meter for every customer by 2012-2013 pursuant to the Advanced Meter Infrastructure proceeding A.05-03-016. The cost of the second device would be born by the customer, as it is located on the "customer side" of the meter.<sup>71</sup> Utilities are working toward standardizing the cost and technical aspects of the second device.<sup>72</sup>

One other related economic benefit for PEV users is the potential for V2G applications associated with advances in meter technology (energy storage and ancillary services) that could accrue to the PEV owner. This issue is discussed more fully in the following subsection on electricity system benefits.

***B. Electricity System / Utilities***

Evaluating the impact of electrification on utilities and the grid requires an estimate of PEV impact on distribution infrastructure, energy demand and peak load. Consumer adoption patterns and behavior are the primary drivers of possible energy and peak load demands due to electrification. Consumer adoption models factor battery size (kWh charge requirement) of a particular vehicle, along with driving patterns that predict how often the driver will plug in. Table 2 makes identical vehicle adoption, battery capacity, charge timing, and behavior assumptions as were introduced for Table 1.<sup>73</sup> Table 2

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<sup>71</sup> Modisette, Dave. CalETC. Letter to CARB re Comments of the CalETC on the December, 2008, Draft California LCFS Regulation. December 30, 2008.

<sup>72</sup> Email communication, Jim Larson, PG&E Clean Transport Group, 12/12/08

<sup>73</sup> This vehicle configuration approximates expected technology parameters for the Chevrolet Volt. The Volt battery capacity is anticipated to be 16 kWh per charge. The additional capacity is to extend battery life accounting for temperature variations over a purported 150,000 mile vehicle life

-Email communication, 10/30/08. Sunil M. Chhaya, PhD. Senior Manager, PHEV development programs, EPRI

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further assumes a discount factor to account for a diversity of charging patterns, rather than uncontrolled, simultaneous charging.<sup>74</sup>

**Table 2: Demand and peak load scenarios**

<b>PHEVs in 2020</b>	<b>GWh/yr</b>	<b>GWh/yr % increase</b>	<b>Peak load MW increase</b>	<b>Peak load MW % increase</b>
3,000 BEVs 58,000 PHEVs	202	0.1	10	0.01
33,000 BEVs 312,000 PHEVs	1,136	0.3	56	0.08
455,000 BEVs 2,500,000 PHEVs	9,645	3	474	0.64

The upper bound penetration scenario shows a 3% electricity generation increase. This analysis supports the hypothesis that utilities are positioned to accommodate increasing total energy demand load due to gradual PEV market growth in the near term.<sup>75</sup>

Additional load due to electrification represents incremental annual revenue in excess of marginal cost (margin) for utilities. This additional marginal benefit above marginal cost could fund investment in PEV charging infrastructure, be passed through to the PEV customer/ratepayer, or benefit utility shareholders. In terms of electricity sales, previous staff analysis finds that each million PEVs or PHEVs could potentially add 2,400 to 4,000 GWh to utility sales, and bring in annual revenues of \$240 million to \$1.2 billion, depending on usage and the effective incremental utility rate (price) for the energy used to charge PEV batteries.<sup>76</sup>

<sup>74</sup> The model divides energy (kWh during high load hours) due to PEV demand by the number of high load hours (4,880) to simulate diverse, controlled charging. It assumes a 76%/24% on-peak/off-peak split.

<sup>75</sup> Ashukian, David. "Who (or what) killed the electric vehicle, The rest of the story" Division of Ratepayer Advocate presentation, 01/07/09

<sup>76</sup> Levin, Robert. "Pricing electricity for cars: impact of electric rate design on EV markets, the environment, and utilities." Conference Draft: June 2008. Center for Research in Regulated Industries: p.12.

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Assuming that approximately 76% of drivers charge during a normally low-demand “off-peak” period, additional PEV load can flatten the daily load curve and improve grid load factors. A flattened load shape results in more efficient utilization of power plants and transmission / distribution assets, which lowers average electricity costs.

In addition to the value of additional electricity sales, higher load factors, and more efficient use of grid assets, research indicates PEV storage services, and V2G more broadly, enable potentially more valuable economic benefits for utilities and PEV drivers/electricity customers.<sup>77</sup> The literature categorizes electricity storage benefits as capacity, dynamic, and strategic benefits.<sup>78</sup> Research states that the “key to realizing economic value from V2G is precise timing of its grid power production to fit within driving requirements while meeting the time-critical power “dispatch” of the electric distribution system.”<sup>79</sup>

As stated previously, V2G may improve renewable resource integration in the long term. V2G may also provide valuable responsive capacity to the grid during high demand hours. The value of additional capacity, particularly during high demand hours, represents avoided costs of additional on-peak central peaking generation, bulk transmission, or local distribution. Additional off-peak load and on-peak capacity is particularly valuable to the extent it lowers average fixed costs of generation. Dynamic benefits of V2G include “quick-response” services to respond to voltage regulation and emergency power supply for unexpected equipment failures. Demand response is another potential dynamic benefit related to PEV load. The utility may be able to interrupt PEV demand during high demand hours to mitigate PEV load impacts, if the PEV load occurs at a responsive Smart Meter-equipped account. Demand response to interrupt PEV load would require a contract between the PEV owner and the utility.

Additional dynamic benefits include load following capability and improvements in the capacity factor of a power plant.<sup>80</sup> According to experts, the value of these services

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<sup>77</sup> Ibid

<sup>78</sup> Schoenung, et al. (1996) in [Kempton, W. and A. Dhanju, "Electric Vehicles with V2G: Storage for Large-Scale Wind Power"](#). Windtech International 2 (2), pp 18-21 (March 2006).

<sup>79</sup>“What is V2G?” <http://www.udel.edu/V2G/>

<sup>80</sup> Ibid.



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accounts for 5-10% of electric service cost.<sup>81</sup> Literature suggests that strategic benefits derive from the reduction of uncertainty in total energy supply. This storage capacity has been valued at a 40% savings relative to procuring additional peak generation capacity.<sup>82</sup>

Capacity and dynamic services may potentially be priced in ancillary service markets on the wholesale side of the electricity market, provided the utility or a third party aggregator bids these services into the wholesale market. In anticipation of this value, stakeholders have suggested that the utility could pass the value of the service to the PEV customer / ratepayer, provided the utility has a contract with the customer to aggregate and bid the service into the ancillary service markets.

***C. Utility Ratepayer Costs***

Costs on the utility side of the meter due to electrification of vehicles or any other demand are factored under General Rate Cases (GRCs) and Cost of Service proceedings (COS) subject to CPUC authorization. Authorized costs are apportioned to different ratepayer classes in GRCs. Utilities have underscored a variety of potential costs to ratepayers due to the widespread use of PEVs.

First, demand due to electrification is additional load, resulting in increased electricity procurement costs. The high PEV market penetration case in Table 1 predicts a 3% increase in total energy demand by 2020. However, one utility impact scenario analysis projects up to an 11% total energy demand in 2020 within its service territory due to on-road and non-road electric vehicle load.<sup>83</sup> Experts have recommended that utilities factor a gradual total energy demand due to PEV market growth into CPUC-authorized utility Long Term Procurement Plans.<sup>84</sup> The current Long Term Procurement Plan proceeding (R.08-02-007) convened an Electrification Working Group on March 10, 2009 to assess potential total energy demand due to electrification. Based on information provided at this meeting, CPUC's lead LTPP staff analyst concluded that "demand impacts of

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<sup>81</sup> Kempton, Tomic. "Vehicle-to-grid power fundamentals: calculating capacity and net revenue." *Journal of Power Sources* 144 (2005): 268.

<sup>82</sup> Schoenung, et al. (1996) in [Kempton, W. and A. Dhanju, "Electric Vehicles with V2G: Storage for Large-Scale Wind Power"](#). Windtech International 2 (2), pp 18-21 (March 2006).

<sup>83</sup> SCE. "Assessment of electrification of transportation and potential impacts" February 27, 2009: 2-8

<sup>84</sup> Meeting communication, Mark Duvall, EPRI, Electrification working group meeting, 3/10/09.

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electrification are potentially significant, but not in the 2020 timeframe of the 2010 LTPPs. The 2010 LTPP should address the potential impact of electrification in broad terms, but explicit scenario analysis is not required. Future LTPP cycles (2012 and beyond) will probably need to analyze the issue in more depth."<sup>85</sup>

PEV charge timing will also influence electricity system load shapes. This white paper analysis adopts the EPRI/NRDC assumption that 76% of drivers will charge during off-peak hours. However, other studies suggest this assumption may not be realized through actual PEV driver/electricity customer charging behavior if not properly managed through tariffs or command and control. For example, the SCE system impact analysis shows that PEV load could radically increase load capacity requirements and alter daily load shapes during summer and winter seasons within its service territory, particularly if a significant number of drivers plug in immediately upon returning home for the day (which would result in a peak load shift from 5:00 p.m. to 7:00 p.m.). A shifted peak would extend heat stress to transformers when they typically begin cooling down at night, potentially decreasing equipment longevity. The analysis reports that widespread PEV charging without utility involvement, either through demand response programs or tariffs, may shift SCE's peak hour to 7:00 p.m. and increase peak load by several thousand megawatts by 2020.<sup>86</sup>

Across the California system, CPUC staff analysis finds that in an extreme, "worst case" uncontrolled scenario, assuming three million vehicles charge simultaneously, 5,400 MW are needed in additional connected load capacity if the vehicles charge at 120 Volt (V) outlets, or 19,800 MW for 220 V outlets.<sup>87</sup> California's electricity system capacity would have difficulty meeting this additional load if it occurred on-peak in the summer. Although this is a worst case scenario, a 2008 Oak Ridge National Laboratory Study points out that consumer behavior and charge timing is not predictable, and that consumers may elect to charge when convenient, rather than when utilities would prefer.

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<sup>85</sup> Email communication. 3/12/06. Simon Baker, CPUC Energy Division Lead LTPP Staff Analyst, to Electrification working group

<sup>86</sup> Southern California Edison. "Assessment of electrification of transportation and potential impacts" February 27, 2009: 2-8

<sup>87</sup> Assumes 1.8 kw charge rate for 120v outlet, and 6.6 kw for 220v outlet. Worst case assumes simultaneous, uncontrolled charging.

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The ORNL study finds that if 25% of the U.S. vehicle fleet is replaced with PHEVs, and these vehicles all charge at 6pm, up to 160 new power plants may be needed across the nation.<sup>88</sup> The discrepancy between impact analyses highlights the need for accurate data regarding actual charging behaviors of early PEV adopters in California, and the potential need to influence them through metering controls and tariff incentives.

Finally, additional demand due to electrification will also raise the total renewable energy generation cost required to comply with the 20% RPS, and the proposed 33% renewable energy goal. Opponents of RPS policies claim that renewable energy generation is incrementally more costly than fossil fuel resource generation, although this claim may not accurately capture macroeconomic, fossil fuel cost risk, or social benefits of renewable energy sources.<sup>89</sup>

To estimate the additional renewable generation required to meet the proposed 33% renewable targets, the additional GWh/year due to electrification should be divided by three. For example, the aggressive stress case of 3 million PHEV proxies in this model will require an additional 11,250 GWh/year, of which 3,750 GWh will need to be from renewable resources to meet a 33% target. Currently, California IOU resource portfolios are below the trajectory required to meet the 20% RPS compliance mark by 2010 due to several energy infrastructure related factors. Therefore, increased load due to electrification increases the cost of compliance in an already constrained renewable energy market. However, as described in Section 2, potential PEV nightly load and potential PEV storage capacity inherent in PEVs may stabilize renewable generation resources, in effect mitigating the cost of RPS compliance.

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<sup>88</sup> Oak Ridge National Laboratories, Hadley, (2008) <http://www.greencarcongress.com/2008/03/ornl-study-expl.html>

<sup>89</sup> <http://www.renewableenergyworld.com/rea/news/article/2007/03/state-rps-policies-projected-costs-benefits-for-the-u-s-47742>

## 4. Other Barriers to PEV Commercialization

A variety of consumer preference and technological/market barriers to PEV commercialization exist beyond the straightforward barriers that affect the cost/benefit evaluation described in Section 3. Consumer preferences influence PEV consumer acceptance. Technological and market barriers represent challenges faced by the use of a battery as a fuel storage for a LDV and the challenges faced by a nascent industry to “scale up” operations and infrastructure to accommodate the broad societal transformation associated with electrification of this traditionally petroleum-based means of transportation. These barriers are summarized in this section.

### A. Consumer Preference Barriers

**Initial PEV cost and bounded rationality.** The up-front additional capital expense differential described in Section 3 for BEV and PHEV technologies relative to a CV is a primary cost barrier to the vehicle consumer, even if reduced operation expenses result in lower total lifetime costs than CV alternatives. Consumers sometimes fail to calculate net present value at the purchase decision point, a market failure sometimes described as bounded rationality.<sup>90</sup> While early PEV adopters may be savvier than the average consumer, a larger market segment may demonstrate bounded rationality, particularly in view of fluctuating gasoline prices. Consumer willingness to pay may include non-monetary benefits, though, such as reduction of CO<sub>2</sub> emissions. Willingness to pay is also influenced by other factors, including limited access to credit (which many consumers face in a recession).

In particular, gasoline price volatility is found to be a short term market barrier to sustained consumer demand for alternative vehicles, including HEVs, and potentially BEVs and PHEVs.<sup>91</sup> Gasoline price trends are found to be indicators of consumer

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<sup>90</sup> Dyner, Franco. “Consumers’ bounded rationality: the case of competitive energy markets.” *Systems Research and Behavioral Science* V.21 I. 4 (2004): 376.

<sup>91</sup> Sperling, Daniel and Sonia Yeh. Winter 2009. “Low Carbon Fuel Standards.” *Issues in Science and Technology*: V. 25 I. 1 (2009): 57.

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interest in HEVs, measured in vehicle sales and consumer internet searches for HEVs.<sup>92</sup> HEV sales increased during the 2008 summer fuel price spike, and decreased with the gasoline price decrease in the mid to late fall of 2008.<sup>93</sup> HEV demand may be a proxy for PEVs, given the increased capital cost and improved fuel economy associated with HEVs relative to a CV. In the long term, however, research indicates the price of gasoline is likely to increase due to increasing petroleum demand in India and China, amongst other factors. For example, the International Monetary Fund calculates that the number of cars worldwide will grow from 600 million in 2005 to 2.9 billion in 2050.<sup>94</sup>

**Consumer behavior as a “socio-technical” obstacle.** Electricity recharging rates are determined by the outlet capacity. For example, a 110 V has a charge rate of 1.8 kW, and a 220 V has a charge rate of 6.6 kW. Depending on battery state of charge, the charge rate of the outlet, and the battery capacity, a typical PHEV may require 2 and 8 hours to achieve a full state of charge. Obviously, PEVs require longer refueling times relative to gasoline, which requires consumer behavioral change. To accelerate charge time, several companies are investigating fast-charge, high wattage charging equipment. Stakeholders suggest that fast-charging equipment or a battery swapping network would reduce a perceived consumer psychological barrier to PEV adoption and market growth by making refueling time comparable to gasoline refueling time. However, many drivers will elect to charge for longer charge times at lower voltage outlets at home or at their business to take advantage of TOU tariff rate differentials, and to maximize the vehicle battery charging efficiency.

Research indicates that consumer behavior may be difficult to shift from the operational behavior associated with the incumbent technology, particularly for range limited BEVs. One reading of the history of other energy transitions suggests that

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<sup>92</sup> HybridSUV.com Staff, “Hybrid vehicle interest levels are tied to gas prices,” (HybridSUV.com, December, 2007): <http://www.hybridsuv.com/popular-searches/hybrids-gas-prices> (accessed May 12, 2009).

<sup>93</sup> Granted, demand for new HEVs declined with a reduction in demand for all new vehicles, including conventional powertrain vehicles in late 2008. However, HEV sales were particularly hard hit given higher sticker prices. <http://blogs.edmunds.com/greencaradvisor/2008/12/november-hybrid-sales-plunge-as-gas-prices-fall-credit-tightens.html>

<sup>94</sup> *The Economist*. “The art of the possible,” (The Economist, Nov. 13, 2008), [http://www.economist.com/specialreports/displaystory.cfm?story\\_id=12544947](http://www.economist.com/specialreports/displaystory.cfm?story_id=12544947), (accessed May 12, 2009).

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“socio-technical obstacles” may be just as important as technical obstacles to PEV commercialization and the implementation of V2G. Ultimately, consumers will make rational (or bounded) decisions based on economic, behavioral, and environmental criteria to meet transportation needs.

**Principal-agent barrier at rental properties.** A principal-agent barrier to residential energy efficiency is a well-known topic of energy policy research.<sup>95</sup> Principal-agent problems arise when two parties engaged in a contract have different goals and different levels of information.<sup>96</sup> This problem is also known as a landlord/rental problem for energy efficiency residential installations. The renter is incented to contract with the landlord for housing. The renter must pay for individually metered utilities, such as electricity, consumed at the rental property. It is the landlord’s responsibility to install energy efficiency appliances or weatherization investments; however the renter, rather than the landlord, pays the cost of energy for those investments, and so receives benefit in the form of reduced energy bills. The landlord receives less or no benefit to invest in energy efficiency, other than the cost of replacement of the appliance or weatherization investment. The landlord is therefore “insulated from the price signal” of the new efficiency investment.<sup>97</sup>

A principal-agent problem may present a related barrier to PEV commercialization for renters. PEV drivers/residential electricity customers will optimize the cost of PEV operation if they plug the vehicle into a dedicated plug at a rental property that has an upgraded 220/240 V plug, upgraded wiring, separate meter or sub-meter installation to segregate PEV load from household load. However, as described above, this is a cost on the customer side of the meter borne by the property owner, who may benefit less or not at all from the cost upgrades. In cities with a higher percentage of rental properties, the principal-agent barrier may present a barrier to PEV

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<sup>95</sup> International Energy Agency 2007. Mind the gap: quantifying principal-agent problems in energy efficiency. p. 13 [http://www.iea.org/textbase/nppdf/free/2007/mind\\_the\\_gap.pdf](http://www.iea.org/textbase/nppdf/free/2007/mind_the_gap.pdf)

<sup>96</sup> Ibid, p. 15

<sup>97</sup> Ibid, p. 41

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commercialization. New building codes could address the barrier by mandating separate meters for PEVs if requested by new tenants for newly constructed properties.

***B. Technological / market barriers***

**Energy storage to weight ratio technical barrier.** The initial cost premium is a function of battery size, amongst other factors. PEV batteries currently face an energy storage to weight ratio barrier.<sup>98</sup> For example, a 30 kWh battery pack with a limited electric range weighs approximately 1,000 lbs.<sup>99</sup> As stated previously, PEVs use a variety of chemistries with different storage to weight ratios. Leading chemistry designs include lithium-ion, lithium polymer, lead acid, and nickel metal hydride. Each manufacturer's battery system varies in weight and design; by way of comparison, the Tesla Roadster (BEV) battery pack or energy system is a 53 kWh battery, while the Chevrolet Volt (PHEV) is a 16 kWh battery that will use only 8-10 kWh per charge. BEVs use much larger battery packs than PHEVs, since they do not have a secondary energy source to switch to at the end of the charge (e.g., gasoline or biofuels).

**Vehicle availability and domestic battery manufacturing capacity.** Vehicle availability is another limiting factor to PEV commercialization under low production volume scenarios. Automaker willingness to make and sell PEVs depends on there being a market for their products such that they see a future marginal profit above marginal cost. While the number of automakers with plans to release PEVs is unprecedented, a portion of the initial vehicle production offering in California markets may be limited in the short to medium term, depending on sales. PEV manufacturing capacity to increase production and achieve improved economies of scale is uncertain. While HEVs have exceeded early industry projections for vehicle sales, some analysts argue that they are still not profitable.<sup>100</sup> GM concedes it will lose money on every Volt PHEV produced

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<sup>98</sup> Ashuckian, D. "Who (or What) killed the electric vehicle: the rest of the story." Presentation to Division of Ratepayer Advocates. 01/07/09.

<sup>99</sup> Ibid

<sup>100</sup> MSNBC. "Plug-in cars don't come cheap" <http://www.msnbc.msn.com/id/27900919/> (accessed May 12, 2009).

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until scale economies are achieved.<sup>101</sup> PEV manufacturers may be betting that long-term viability and profitability will result from more stable electricity fuel prices relative to gasoline. However, lack of short term microeconomic profitability may limit the long term availability for some vehicle models.

In addition, the U.S. currently faces a competitive disadvantage for battery manufacturing, but is ramping up production capacity with the support of federal stimulus funding. Domestic battery manufacturing is a goal of current U.S. policy and firm action. A number of U.S. technology companies have formed a coalition called the National Alliance for Advanced Transportation Battery Cell Manufacture that recently petitioned the Obama administration for assistance to start manufacturing. The U.S. Department of Energy is expected to extend \$25 billion in loans for the Advanced Technology Vehicle Manufacturing Loan Program (AVTML). Leading battery systems technology companies like A123 systems, Ener1, and Tesla Motors have petitioned the program for \$480 million.<sup>102</sup> Domestic battery production may support U.S. PEV commercialization if domestic production reduces increased costs associated with imported batteries. China and Japan currently manufacture the majority of batteries needed for PEVs.<sup>103</sup> At the same time, domestic batteries may not necessarily be cheaper, given lower labor costs overseas.

**Charging and distribution system infrastructure barriers.** As indicated in Table 1, electricity generation capacity is not anticipated to be a limiting factor for PEV commercialization, assuming utilities can control and/or incent PEV load to off-peak and shoulder peak periods. However, other electricity system infrastructure investment in the near term will likely be needed to support PEV market growth, including on-site charging equipment in residential, commercial and public charging sites, and electricity distribution system upgrades.

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<sup>101</sup> Chuck Squatrigilia. "GM says Chevrolet Volt won't 'pay the rent'", Wired Magazine Autopia, <http://blog.wired.com/cars/2009/04/gm-says-the-che.html> (accessed May 12, 2009).

<sup>102</sup> Pending access to additional loans from the AVTML, the Massachusetts-based startup A123 systems expects to spend a total of \$2.3 billion on several factories in Michigan, supplying Detroit automakers with enough lithium-ion batteries for 500,000 plug-ins or 5 million hybrid vehicles by 2013.

<sup>103</sup> Kanellos, Michael. "Will the U.S. move from Arab Oil Dependence to Asian Battery Dependence?" (Greentech media, 12.29.08), <http://www.greentechmedia.com/articles/will-the-us-move-from-arab-oil-dependence-to-asian-battery-dependence-5431.html>, (accessed May 13, 2009).



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The U.S. Department of Energy (US DOE) finds that increased availability of daytime commercial and public charging infrastructure away from the primary residential charge location can reduce the onboard energy storage requirement for PEVs, and consequently reduce PEV cost.<sup>104</sup> BEVs and PHEVs have different infrastructure requirements, based on vehicle charging parameters, and daily driver range. PHEVs have dual sources of energy, while BEVs are limited to electricity. BEV drivers are likely to charge more often: even if a BEV range accommodates the primary commute trip, additional, shorter trips will require additional electricity charging.

PHEVs have different onboard battery sizes and available charge-depleting range in all-electric drive.<sup>105</sup> Additionally, vehicles are expected to allow different PEV charging levels, which describe voltage and power parameters.<sup>106</sup> Level 1 uses a standard 120 VAC, 15 amp or 20 amp branch circuit that is the lowest common voltage found in residential and commercial buildings in the U.S.<sup>107</sup> Level 2 is preferred method to Level 1 due to increased power and a higher level of safety required by the National Electric Code (NEC). Level 3 describes quick charge facilities, which may charge up from 33 kW up to 60kw to fully charge an 8 kWh battery in 15 minutes. Quick charging places acute demands on the distribution system. The charge level predicts the time a driver must charge to fully recharge the battery, and consequently the number of charge events. There is a battery efficiency loss associated with increased charge rates.<sup>108</sup> However, automakers may make 110/120V charging and 220/240V available to meet consumer preference.

Commercial and curbside public charging stations will enable greater electricity fuel availability for PEV drivers. There are five times as many cars as garages in the U.S.,

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<sup>104</sup> US Department of Energy Vehicle Technologies Program. "PHEV Charging Infrastructure Review." (US DOE, Nov. 2008), <http://avt.inel.gov/pdf/phev/phevInfrastructureReport08.pdf>, p. 3 (accessed May 13, 2009).

<sup>104</sup> Frank, Andy. Meeting Communication, 4/3/09

<sup>105</sup> Mark Duvall, EPRI. Meeting Communication, CPUC Electrification Working Group, 3/10/09

<sup>106</sup> Charge power (kw) is used to mean charge rate

<sup>107</sup> US Department of Energy Vehicle Technologies Program. "PHEV Charging Infrastructure Review." (US DOE, Nov. 2008), <http://avt.inel.gov/pdf/phev/phevInfrastructureReport08.pdf>, p. 16 (accessed May 13, 2009).

<sup>108</sup> Frank, Andy. Meeting Communication, 4/3/09

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indicating a clear demand for on-street charging stations.<sup>109</sup> Between 1,000 and 3,000 mapped curbside and garage public charging stations remain in operation from the effort in the 1990s to support PEV commercialization.<sup>110</sup> While public charging station availability may be greater currently than other alternative fuel options, this infrastructure will need to be expanded and upgraded to support increased PEV battery charging. Existing charging stations do not support updated J1772 conductive plugs, requiring on-site capital upgrades.<sup>111</sup> CEC AB 118 program funding, described in further detail in section five, is available to fund public charging station infrastructure upgrades in addition to expanding state funded public charging stations.

Private investment in public charging stations will support utility investments in charging equipment. Coulomb Technologies has sold public charging stations to municipalities throughout the Bay Area with plans to expand public charging sites as part of their ChargePoint charging network. In addition, Project Better Place's business model plans to offer battery swapping, public charging, and residential and commercial charging as part of a subscription service plan.

EV charging supply equipment is subject federal requirements stipulated in NEC Article 625, published by the National Fire Protection Association. Per a 2008 U.S. DOE report,<sup>112</sup> Article 625 lists requirements concerning:

- “Wiring methods, including PEV coupler design, construction, and functionality,
- PEV coupler requirements, including polarization, non-interchangeability, construction and installation, unintentional disconnection, and grounding pole requirements
- PEV charging equipment construction requirements, including rating, markings, means of coupling, cable, interlock, and automatic deenergization of the charge cable
- PEV charging equipment control and protection, including overcurrent protection, personnel protection, disconnecting means, loss of primary source, and interactive systems

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<sup>109</sup> Meeting communication, Coulomb Technologies, Inc. 2/11/09

<sup>110</sup> <http://www.evchargermaps.com/?Address=Anaheim&Want=SPI%20LPI%20AVC%20OC&Zoom=9>

<sup>111</sup> Telephone communication. Dave Modisette 3/24/09

<sup>112</sup> US Department of Energy Vehicle Technologies Program. “PHEV Charging Infrastructure Review.” (US DOE, Nov. 2008), p. 20 <http://avt.inel.gov/pdf/phev/phevInfrastructureReport08.pdf>, (accessed May 13, 2009).

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- EV charging equipment location requirements, including hazardous (Classified) locations, indoor sites and ventilation requirements for indoor installations (where applicable), and outdoor site requirements.”

Vehicle plug standards are developed through the Society of Automotive Engineers (SAE). The EPRI-led Infrastructure Working Council (IWC), founded in 1991, convenes SAE, electric code officials, and electricity utilities to develop common codes and requirements for charging infrastructure.

PEV charging supply equipment requirements depend on whether the station is in a residential, commercial or public site. As described below, IOUs have established utility “interface” requirements through PEV tariff requirements for residential and commercial charging. Utility interface requirements for residential charging on the customer side of the meter typically include on-site sub-metering, wiring, and service panel upgrades. Charging infrastructure cost depends on a number of factors, including charge level, as described below, existing charging infrastructure, labor, permits, and signage costs.

EV charging infrastructure in commercial environments must conform with standards not applicable to residential charging environments. These include siting requirements, Americans with Disabilities Act Requirements, lighting and shelter recommendations, access control and customer support recommendations, and signage recommendations.<sup>113</sup>

In addition to on-site capital infrastructure, utilities will also need to identify locations with clustered PEV adoption to make infrastructure upgrades at the distribution level. New energy technology adoption is found to occur in geographic clusters, or diffusion networks.<sup>114</sup> Utility transportation electrification planners are studying potential load pockets due to PEV clusters that may stress the distribution system, particularly during summer high-load peak hours. Potential distribution system impacts may occur at the transformer at the neighborhood or sub-neighborhood level, depending on the vehicle penetration under the branch connection, and the timing of system loading, according to

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<sup>113</sup> US Department of Energy Vehicle Technologies Program. “PHEV Charging Infrastructure Review.” (US DOE, Nov. 2008), <http://avt.inel.gov/pdf/phev/phevInfrastructureReport08.pdf>, p. 21-24 (accessed May 13, 2009).

<sup>114</sup> Rogers. E (2005) The Diffusion of Innovations. 5<sup>th</sup> Ed. Free Press. p. 331.

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one analysis.<sup>115</sup> A typical residential customer has about a 7 kW load; the addition of PEV load could double transformer loading.<sup>116</sup> Regarding harmonic frequency issues, PEV load is anticipated to be “clean load,” with a power factor of approximately 1.0.<sup>117</sup> If several households that adopt PEVs are served by a single transformer substation, the utility will have to upgrade distribution infrastructure to avoid transformer overheating. Utilities may need to test transformer capacity on a case-by-case basis, depending on the transformer life, original transformer capacity, and potential for PEV clustering.<sup>118</sup> Smart charging is a key technology to reduce distribution system impacts.<sup>119</sup> Smart charging implies coordinating customer demand for electricity with times when utilities can most economically and efficiently charge a given cluster of vehicles. As referenced in the next section, the CPUC will hold a workshop in July 2009 to discuss, amongst other issues, how smart charging technologies can reduce distribution system stress.

Distribution system stress is potentially exacerbated by a number of firms that are exploring on-peak “fast charging” high voltage options.<sup>120</sup> Fast charging is designed to make the consumer indifferent to allocating five minutes to fill up at the gasoline pump versus filling up at a 33 Kw or 400 amps for five minutes.

EPRI is partnered with PG&E and SCE to study distribution level impacts at the neighborhood transformer and substation level, and expects to release data to utilities within a 6 month timeframe.<sup>121</sup> Forecasting required distribution upgrades due to PEV load is an area where a utility has the capacity to facilitate a transition to PEV commercialization, as discussed in Section 5.

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<sup>115</sup> John R. Kennedy. Distribution reliability manager: Georgia Power Co. “Utility Concerns with PHEV and BEVs.” Presentation.

<sup>116</sup> Ibid.

<sup>117</sup> Telephone communication, Marcus Alexander, EPRI

<sup>118</sup> EPRI. “PHEV distribution impact study, power utilization and delivery.” 2009.

<sup>119</sup> Ibid, Slide 49.

<sup>120</sup> Green Car Congress. “eTec and V2Green to Evaluate PHEV Fast-Charging and Smart Grid Interactions; V2Green and Coulomb Also Partner,” (Green Car Congress, July 23, 2008), <http://www.greencarcongress.com/2008/07/etec-and-v2gree.html>, (accessed May 13, 2009).

<sup>121</sup> Telephone communication, Mark Alexander, Manager, Vehicle Systems Analysis, ET, EPRI, 3/17/09.

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## 5. Existing and Pending Policies/Programs Supporting PEV Commercialization

There are numerous existing and pending U.S., California, and IOU programs and policies that directly support LDV electrification. This section reviews relevant funding allocations in the 2009 American Recovery and Reinvestment Act (ARRA), California energy agency alternative fuel and vehicle programs for fiscal year (FY) 2009-2010, and recent IOU alternative vehicle procurement and authorized Low Emission Vehicle (LEV) program investments. It also reviews recent U.S. Federal Energy Regulatory Commission (FERC) Smart Grid policy statement and action plan and corresponding CPUC proceeding efforts to implement Smart Grid technologies. The section also includes a review of measures currently being taken by the California IOUs to promote electrification. It concludes with a discussion of advantages and disadvantages of CNG vehicles, and discusses utility programs in support of CNG, which is seen to complement PEV commercialization.

### *A. Federal and state programs*

**2009 ARRA.** The 2009 ARRA bill invests more than \$14.4 billion in loan guarantee programs, advanced battery manufacturing grants, plug-in vehicle tax credits, advanced energy manufacturing tax credits, automobile purchase sales tax credits, infrastructure/vehicle deployment, federal purchases of high-efficiency vehicles, Clean Cities grant program, alternative refueling property tax credits, and the advanced technology vehicles manufacturer loan program referenced above.<sup>122</sup>

ARRA funding will assist in reducing identified barriers by stimulating a consumer market for PEVs, reducing automaker and battery manufacturer risks associated with manufacturing and deploying PEVs and PEV batteries, and potentially supporting infrastructure investments at residences and in public charging infrastructure. The greatest amount of ARRA funding is apportioned to the Innovative Technology Loan

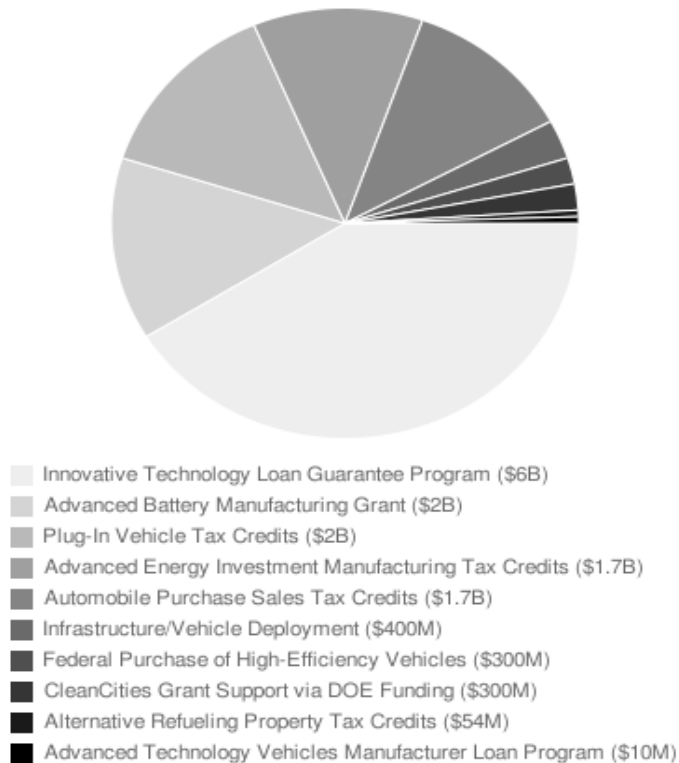
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<sup>122</sup>Plug-in America. "How did plug-ins fare?" (Plug-in America, February 17, 2009). <http://www.pluginamerica.org/> (accessed May 13, 2009).

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Guarantee Program, which adds \$6 billion for development and implementation of advanced PEV battery research and manufacturing to the Energy Policy Act’s (EPA) Title 17. The program guarantees \$60 Billion in DOE loans to eligible projects that “avoid, reduce, or sequester air pollutants or anthropogenic emissions of GHGs.”<sup>123</sup> The DOE has been slow to approve and disbursed loans under the program, although this is expected to change.<sup>124</sup>

\$14.4B for Plug-ins in the Stimulus Bill



Source: [www.pluginamerica.org](http://www.pluginamerica.org)

In order to support a consumer market for PEVs, the ARRA modifies a previously authorized federal PEV tax credit based on a graduated scale according to vehicle battery size (4 kWh-16 kWh). The credit will reduce the initial additional cost barrier by \$2500-\$7500 per vehicle. The tax credit is now available for up to 200,000 vehicles per

<sup>123</sup> BioMass Magazine “Loan Guarantees under the ARRA 2009,” (Biomass Magazine, April 2009), [http://www.biomassmagazine.com/article.jsp?article\\_id=2501](http://www.biomassmagazine.com/article.jsp?article_id=2501) (accessed May 13, 2009).

<sup>124</sup> eNewsUSA “Senate Hearing on EPA Act Loan Guarantee Program,” (eNewsUSA, February 13, 2009), <http://enewsusa.blogspot.com/2009/02/senate-hearing-on-epact05-loan.html> (accessed May 13, 2009).

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manufacturer for vehicles sold after December 31, 2009. A phase-out program for declining tax credits is described below. ARRA tax credits are also available for electric motorcycles, three-wheel electric vehicles, including NEVs, plug-in hybrid conversions of HEVs and CV-electric drive conversions.<sup>125</sup>

Notably, the ARRA also makes available a home and commercial alternative fuel refueling infrastructure tax credit. Homeowners and utilities are eligible for the installation tax credit. The credit is up to 50% of the cost of electricity conduits for refueling and 50% of the cost of a natural gas refueling unit, also known as a PHIL unit.<sup>126</sup> In addition, the CleanCities solicitation for the Transportation Sector Petroleum Reduction Technologies program makes \$300 million available for refueling infrastructure for alternative fuels, incremental costs of dedicated alternative fuel vehicles, education and outreach, and pilot demonstration program grants. \$400 million is further dedicated for federal alternative vehicle fleet procurement and infrastructure needed to support fleet investments.<sup>127</sup>

Most recently, the U.S. DOE National Energy and Technology Laboratory announced an amended funding opportunity DE-FOA-0000028. From the announcement, “A key objective of the program is to accelerate the development and production of various electric drive vehicle systems to substantially reduce petroleum consumption. One of the electric drive technologies that will be emphasized in this project are PHEVs, which directly supports the President’s goal to Get One Million Plug-In Hybrid Cars on the Road by 2015. Furthermore, advanced electric drive technologies will allow manufacturers to meet increased fuel economy standards while reducing vehicular emissions of GHGs. The resulting grants are intended to assist U.S. economic recovery by creating US based jobs as outlined in the ARRA of 2009.”<sup>128</sup> IOU and other state and local government entities are eligible, and applying for, grant funding. CPUC

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<sup>125</sup> Plug-in America. “How did plug-ins fare?” (Plug-in America, February 17, 2009). <http://www.pluginamerica.org/> (accessed May 13, 2009).

<sup>126</sup> ARRA Section 1131 <http://www.irs.gov/pub/irs-drop/n-07-43.pdf>, p. 211

<sup>127</sup> Ibid

<sup>128</sup> “Project Description” DE-FOA-0000028, p. 6.



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staff is presently working with IOU electric transportation managers to assess responses to the funding opportunity.

**California Alternative Fuel Incentive Program, Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), and Air Quality Improvement Program (AQIP) vehicle incentive and infrastructure funding.** To match federal tax and infrastructure grant incentives, California is implementing programs for BEV and PHEV purchase rebates as part of a bundle of vehicle incentives and clean equipment and infrastructure deployment initiatives. These initiatives are pursuant to the 2007 AB 118 Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act. Programs are administered jointly by CEC, CARB, and the Bureau of Automotive Repair (BAR).

AB 118 is the guiding legislation for the AQIP and the ARFVTP. The AQIP and the ARFVTP are funded through 2015 via increases to the smog abatement, equipment registration, and vessel registration fees. The programs are meant to be complementary in order to achieve comprehensive emissions reductions through a variety of vehicle and fuel technologies. For example, the AB 118 statute specifies that CEC is charged with infrastructure investment, while CARB programs offer vehicle incentives. Also, as described below, vehicle purchase rebates PEVs administered by CARB may be complemented by CNG and propane vehicle purchase rebates administered by CEC.<sup>129</sup>

ARFVTP funds infrastructure investments that would support PEV commercialization. In February 2009, CEC released regulations guiding review of projects that seek funding from the AB 118 Investment Plan for its ARFVTP. The program provides up to \$120 million annually to the CEC for alternative and renewable fuels, fueling infrastructure, clean vehicles, and workforce training.<sup>130</sup> CEC announced in March 2009 \$46 million for fiscal years (FY) FY2009 and FY 2010 to be allocated for electric drive category investments.<sup>131</sup> These include \$3.5 million for PHEV retrofits for public fleets, \$10 million for anticipated medium- and heavy-duty research, development

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<sup>129</sup> CARB. "Proposed AB 118 AQIP funding plan for FY 2009-2010," (March 23, 2009), p. 5.

<sup>130</sup> Ibid, p. 4.

<sup>131</sup> John Sheers. "AB118 Implementation", (Cleanpower.org), [http://www.cleanpower.org/section\\_02/Projects/CleanerTransportation.html](http://www.cleanpower.org/section_02/Projects/CleanerTransportation.html), (accessed May 13, 2009).



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and demonstration projects, \$11.5 million for non-road deployment projects for ports and truck stop electrification, \$12 million for upgrading existing electric charge stations and new charge station construction, and \$9 million to recruit, retain, and expand PEV manufacturers and PEV component part manufacturers in California.<sup>132</sup>

In addition, CARB AQIP funding is expected to provide vehicle incentive rebates for new zero emission vehicles (classified as BEVS) and PHEVs deployment and commercialization, in addition to advanced technology demonstration programs. CARB shares AB 118 program implementation responsibility with CEC through AQIP.<sup>133</sup> AQIP, which is scheduled for Board consideration at the April 23, 2009 CARB board meeting, complements the structure of the currently exhausted Alternative Fuel Incentive Program (AFIP).<sup>134</sup> Projected AQIP funding for FY2009 and FY 2010 is \$42.3 million for deployment/commercialization projects, and advanced technology demonstration.<sup>135</sup> \$25 million, the bulk of deployment commercialization project funding, is directed to hybrid truck and bus voucher incentive projects.<sup>136</sup>

AQIP recommended funding for the “zero-emission and plug-in hybrid LDV rebate project” is targeted at \$5 million for FY 2009-2010 for LDVs purchased in California, to be revised each FY with budgetary adjustments. For FY 2009-2010, BEVs are eligible for \$5,000 purchase rebate, PHEV are expected to be eligible for a \$3,000-\$5,000 rebate, depending on the size of the on-board battery, and NEVs eligible for a \$1,500 rebate. Additionally, AQIP allocated \$1 million for an electric motorcycle rebate, up to \$1 million dollars of funding. The AQIP funding applies at the point of purchase, whereas the ARRA funding applies as a tax rebate.

**Senate Bill 375 (Steinberg).** SB 375 “requires metropolitan planning organizations to align their regional transportation, housing, and land-use plans and prepare a ‘sustainable community strategy’ to reduce VMT and transportation-related

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<sup>132</sup> CEC. “Investment Plan for the ARFVTP.” Draft Committee Report. (March, 2009), p. 17.

<sup>133</sup> CARB. “Proposed AB 118 AQIP funding plan for FY 2009-2010,” (March 23, 2009), p. i.

<sup>134</sup> The California Center for Sustainable Energy, which administers AFIP funding, reports that limited funding may be available soon specific to the AFIP rebate.

<http://www.energycenter.org/ContentPage.asp?ContentID=473&SectionID=508>

<sup>135</sup> Funding amounts are based on the FY 2009-1020 State Budget, which may be adjusted.

<sup>136</sup> CARB. “Proposed AB 118 AQIP funding plan for FY 2009-2010,” (March 23, 2009), p. i.

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emissions.”<sup>137</sup> Approximately 60% of U.S. passenger vehicle trips are traveled by vehicles driving less than 30 miles per day.<sup>138</sup> Research indicates that small-capacity PEVw, when charged every 20 miles or less, are less expensive and release fewer GHG emissions than HEVs or CVs.<sup>139</sup> Accordingly, dense land use planning directed by SB 375 supports PEV capacity configurations that are found to maximize environmental benefits to society and minimize initial cost impacts to consumers.

***B. FERC and CPUC Smart Grid Policies***

In addition to federal and state tax incentives, vehicle purchase incentives, and infrastructure grants, U.S. and California policymakers are preparing interoperability standards to integrate plug-in vehicles efficiently to a broad range of electricity system upgrades that are characterized as “Smart Grid.” According to the March 19, 2009 FERC Smart Grid Policy Statement, Section 1301 of the 2007 Energy Independence and Security Act states that it is the policy of the U.S. to support modernization of the U.S.’ electricity and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve several goals and characteristics of a Smart Grid.<sup>140</sup> “Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and HEVs” are classified in the policy statement as one of ten identified goals and characteristics.

In December of 2009, the CPUC has also opened proceeding R.08-12-009, “Order Instituting Rulemaking to Consider Smart Grid Technologies Pursuant to Federal Legislation and on the Commission’s own Motion to Actively Guide Policy in California’s Development of a Smart Grid System.” According to CPUC staff, the OIR hopes to provide for a logical roll-out of distribution system upgrades to allow for PEVs to provide grid support during peak and/or constrained periods by acting as storage, as

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<sup>137</sup> The California Secure Transportation Energy Partnership (CAL Step) “Progress and related highlights.” For Target 2030: Solutions to secure California’s Transportation Energy and Climate Future conference, January 14-15, 2009.

<sup>138</sup> US Department of Transportation. The 2001 National household travel survey, U.S. Department of Transportation, Bureau of Transportation Studies, 2003, p. 4.

<sup>139</sup> Siau, Samaras, Hauffe, Michalek (February 2009). “Impact of battery weight and charging patterns on the economic and environmental benefits of plug-in hybrid vehicles.” Carnegie Mellon University. *Energy Policy* Feb. 2009.

<sup>140</sup> 126 FERC 61,253. 18 CFR Part Chapter I. [Docket No. PL09-4-000], p. 5

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well as allowing customers the ability to sell back stored electricity during peak hours in or other constrained periods. Further, by coordinating pricing, electricity distribution and/or transmission system status, and customer choice, the smart grid will encourage off-peak charging based on price or generation mix, where available. CPUC Smart grid staff is planning a series of workshops to discuss consumer issues, distribution system issues, transmission system issues, PEV issues, and regulatory approach issues. The July 15, 2009 PEV workshop will invite panelists on a number of subjects, including vehicle and grid communication standards, energy storage, vehicle market projects, distribution system impacts, and smart charging protocols to reduce system impacts.

***C. Utility LEV policies and programs that support LDV electrification***

The 1992 and 2005 EActs, most recently updated by the 2007 U.S. Executive Order # 13423, direct California utilities and other energy agencies to procure alternative fuel vehicles for a portion of the utility new LDV fleet. EAct compliance for alternative fuel providers, including electricity utilities, currently requires 90% of new LDVs or their “credit equivalent” to be alternative fuel vehicles.<sup>141</sup> The ARB fleet rule<sup>142</sup> for public agencies and utilities complements the federal fleet acquisition requirement under EAct.<sup>143</sup> There may be additional local Air Quality Management District compliance rules for alternative fuel vehicle procurement within each service territory. According to the requirements, electric drive vehicles qualify as alternative fuel vehicles, along with hydrogen fuel cell vehicles, flex fuel vehicles, CNG vehicles, and propane vehicles.

Statutory authority for ratepayer funded LEV programs is found in Public Utilities (PU) Code sections 740.3,<sup>144</sup> 740.8,<sup>145</sup> and 901 (c).<sup>146</sup> The Codes instruct the CPUC to analyze utility investments in LEV programs to determine if they are in the interests of ratepayers. The most recent (2005) amendment to PU Code § 740.8 defines “interests” as

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<sup>141</sup> Standard Compliance Chart, <http://www.ogs.state.ny.us/supportservices/vehicles/cleanfuel/epact.html>

<sup>142</sup> California Code of Regulations § 202, § 2022, and § 2022.1. Title 13.

<sup>143</sup> “Update Response to PG&E”, Email communication from Jill Egbert, Sidney Dietz to Eugene Cadenasso, March 2008.

<sup>144</sup> Passed in 1990. Stats 1990 ch 791 § 2 (SB 2103)

<sup>145</sup> Passed in 1994. Stats 1994 ch 1000 § 1 (AB 3239), Amended Stats 1999 ch 1005 § 41 (AB 1658); Amended Stats 2005 ch 91 § 5 (SB 76).

<sup>146</sup> Loomis, Pamela. “SB 1737 (Kehoe) Low Emissions Vehicles.” <http://docs.cpuc.ca.gov/Published/Report/83593.htm>, May 28, 2008.

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“short- or long-term, direct benefits that are specific to ratepayers in the form of safer, more reliable, or less costly gas or electrical service, consistent with Section 451, and activities that benefit ratepayers and that promote energy efficiency, reduction of health and environmental impacts from air pollution, and GHG emissions related to electricity and natural gas production and use, and increased use of alternative fuels.”

Based on these statutory authorities, the CPUC has opened various rulemakings and investigations to explore the role of utility involvement in the market for LEVs, including PEVs, beginning in 1991 with I.91-10-029 and R.91-10-028.<sup>147</sup> In 1995, D. 95-11-035, approved utility LEV programs until 2001. These programs have been reauthorized by the Commission to the present day.<sup>148</sup> The Commission's policies on utility LEV programs were updated in D.03-10-086 and D.05-05-010. D.03-10-086 expressed continuing support for the environmental benefits of utility LEV programs, and approved continued funding of utility LEV programs through the end of 2005. D.05-05-010 states that the Commission will evaluate future requests for discretionary LEV on a multi-year basis in each of the utilities' next GRCs or COS proceedings.<sup>149</sup> The latest CPUC decisions to address electric drive LEV programs are found in GRC decision settlement is D07-03-044, settlement D.08-07-046, and A.07-01-011.

The existing IOU LEV programs authorize ratepayer funding for utility costs for incremental costs of PEV procurement over comparable gasoline vehicles, in addition to electric transportation programs (electricity system impact assessment, PEV research and development, vehicle demonstration, safety testing, customer education and outreach, and partnerships with local clean transportation organizations, automakers, and trade organizations). A major portion of LEV funding is also directed to non-road electric vehicles and infrastructure at ports and truck stops. LEV programs further support CNG fueled vehicles, hydrogen vehicle technologies, propane vehicle technologies, and biofuels vehicle technologies.

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<sup>147</sup> Ibid

<sup>148</sup> Loomis, Pamela May 28, 2008 “SB 1737 (Kehoe) Low Emissions Vehicles.”  
<http://docs.cpuc.ca.gov/Published/Report/83593.htm>

<sup>149</sup> Ibid

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Total projected 2009 & 2010 IOU ratepayer funds for LEV programs amount to \$47.9 million. LEV program authorization includes electrification and CNG vehicle investments. As the focus of this paper is on LDV electrification, utility electric transportation programs are detailed below. However, gas utilities are also actively conducting CNG and hydrogen vehicle demonstration projects, including medium to heavy duty CNG vehicle fleet applications. The subsequent subsection analyzes advantages and disadvantages of natural gas vehicles and utility programs that support them. PG&E projects \$8.1 million per year, SCE projects \$11.1 million per year, and SDG&E/SoCalGas projects \$3.0 million per year for the following alternative fuel vehicle investments.<sup>150</sup>

In addition to alternative fuel vehicle fleet procurement regulatory compliance, California utilities continue to invest in LEV programs and enroll in partnerships to support PEV commercialization along with CNG, hydrogen and other alternative vehicle and fuel commercialization. California IOUs, Sacramento Municipal Utility District (SMUD), and Los Angeles Department of Water and Power (LADWP) are presently engaged with automakers, battery manufacturers, research partners, public agencies, private trade organizations, and consumer groups to develop programs to incent PEV commercialization and ready standardized infrastructure to meet PEV demand. For example, each IOU has enrolled the IWC for charging codes and plug standardization work, announced a research and development collaboration with EPRI, General Motors and 31 other utilities across the U.S.,<sup>151</sup> as well as partnered with the CalETC and the Electric Drive Transportation Association (EDTA). The following are examples of recent program utility-specific activities in support of electric drive LEV programs authorized by CPUC. The following IOU activities represent many but not all utility activities in recent years.

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<sup>150</sup> Email communications, 3/13/09, Jill Egbert, PG&E; Dean Taylor, SCE, and Ed Hart, Sempra Utilities

<sup>151</sup> Perry, Clay, Hansen, Heather. "EPRI, GM, 34 utilities collaborate to advance PHEVs," (EPRI, July 22, 2008),

[http://my.epri.com/portal/server.pt/gateway/PTARGS\\_0\\_237\\_317\\_205\\_776\\_43/http://uspalecp604:7087/publishedcontent/publish/2008\\_07\\_22\\_phev\\_collaboration\\_da\\_580194.html](http://my.epri.com/portal/server.pt/gateway/PTARGS_0_237_317_205_776_43/http://uspalecp604:7087/publishedcontent/publish/2008_07_22_phev_collaboration_da_580194.html) (accessed May 13, 2009).

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**PG&E's Activities.** PG&E reports on-road and off-road electric drive LEV programs that include demonstration projects, ancillary service demonstration projects, codes and standards, infrastructure maintenance and deployment, electric drive fleet testing, non-road electric drive vehicle support, and customer outreach. In 2007 and 2008, PG&E reports demonstration projects including a partnership with International Company, Eaton and others on a Hybrid Class single bucket field trial project. PG&E also partnered with Tesla Motors, Inc., on an ancillary services demonstration to test PEV ability to accept controls from the California Independent System Operator (ISO) to provide regulation using charger cycling.<sup>152</sup> Like the other IOUs, PG&E worked during this time period and continues to work on customer outreach, safety standards, and standards for plug standardization and NEC standardization through the IWC. PG&E continues to work on communication and charging standards and the integration of these standards into the Advanced Meter Initiative (AMI) meter and Home Area Network (HAN) protocols. PG&E is also working on PEV public charging infrastructure, non-road truck stop and port electrification, issues, as well as development of a medium duty trouble truck demonstration project.<sup>153</sup> In terms of customer outreach, PG&E offers and plans to update a PEV supply installation manual on its website. The manual discusses PEV battery charging essentials, Code requirements for PEV supply equipment, PEV tariff options, and information for single family residence customers, fleet facilities, and public access and commercial charging installations.<sup>154</sup>

**SCE's Activities.** According to a 2008 SCE GRC filing, SCE on-road and off-road electric transportation program activities are organized into five areas: fleet compliance with federal, state, and local regulations, customer service and information delivery, system impact and evaluation, technology demonstrations, and studies for electric drive LEVs other emerging technology LEVs, conducting load management and

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<sup>152</sup> "Update Response to PG&E", Email communication from Jill Egbert, Sidney Dietz to Eugene Cadenasso, March 2008

<sup>153</sup> Ibid.

<sup>154</sup> <http://www.pge.com/mybusiness/environment/pge/cleanair/electricdrivevehicles/charging/index.shtml>

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conservation activities for customers, safety training for customers and vehicle operators, and providing utility-specific customer outreach and education information.<sup>155</sup>

SCE complies with federal, state, and local fleet procurement requirements. It maintains a fleet of over 300 PEVs, primarily Toyota RAV-4 BEVs, but also includes PHEV, fuel cell PEVs, and PHEV with fuel cells. The fleet travels over 100,000 miles monthly.

The SCE Electric Vehicle Technical Center studies data fleet testing and utility customer studies of on-peak versus off-peak charging behavior, electrical system impact studies, system utilization data, and safety-related issues.<sup>156</sup> Data from the PEV Technical Center testing provided results for a load impact analysis referenced herein. It also conducts regular alternative fuel vehicle demonstrations and advanced V2G studies for ancillary service applications. The data develops internal SCE electrical system planning at the distribution level and total demand level. The Technical Center is a U.S. DOE test site approved to test PEV baseline performance and vehicle and fleet operation. In addition, like the other IOUs, SCE provides customer outreach support for PEV infrastructure and tariff inquiries. This includes safety programs that evolve with changing LEV technologies.

In addition, SCE maintains partnerships with Ford, GM, EPRI, other utilities, and local community organizations to support PEV commercialization. In particular, these partnerships are intended to develop standards and new protocols for utility communication with the electric LEV.

Regarding PEV load management program expenses, the CPUC directed load management for electric LEV programs be part of other load management and conservation programs, such as Demand Response program authorization.<sup>157</sup>

**SDG&E's Activities.** SDG&E reports partnerships in support of on-road and off-road LDV electrification with a range of community organizations, including the Clean Cities Coalition, the San Diego Regional Sustainable Partnership Transportation

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<sup>155</sup> SCE. "Customer Service Volume 3 – Customer Service and Information Delivery" GRC Filing SCE - 04-V. 3, p. 52.

<sup>156</sup> Ibid, p. 61.

<sup>157</sup> Alternate Decision, SCE 2009 GRC A.07-11-011, I.08-01-026, p. 117

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Committee, the Alternative Fuels Committee of the San Diego Regional Planning Association (SANDAG), the Chamber of Commerce Transportation Committee, the San Diego Unified School District's Transportation Curriculum Committee, the Port and International Airport of San Diego, the San Diego EcoCenter, local universities and Naval and Marine bases.<sup>158</sup>

With regards to testing and infrastructure impact assessment, SDG&E reports implementation of a PHEV demonstration program,<sup>159</sup> and a SANDAG regional alternative fuel infrastructure study. The study, according to SDG&E, is a preliminary report of regional needs and existing resources for alternative fuel advancement.

With regards to customer service programs, SDG&E provides a PEV TOU rate assessment and assistance for customers for rate optimization as well as responding to inquiries for information on on-road, non-road and idle reduction electric technologies. Further, on March 23, 2009, SDG&E launched the San Diego Regional Electric Vehicle Fleet and Infrastructure Partnership with Nissan and the community partners referenced above.

***D. Utility policies and programs that support CNG/LNG market growth and CNG/LNG infrastructure***

In addition to electric transportation LEV programs, utilities are active in development of natural gas as a vehicle fuel, in cryogenic liquid and compressed form. Natural gas has been used since 1785 for a variety of lighting, electricity generation fuel, and transportation applications.<sup>160</sup> CARB staff reports CNG is a feasible, mature fuel technology that qualifies as an eligible fuel pathway pursuant to the LCFS. CNG vehicles are currently the only vehicle classified as a “AT-PZEV” pursuant to the CARB ZEV program.<sup>161</sup> Natural gas vehicles may be fueled with CNG (pressurized to 3,000 to

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<sup>158</sup> 3/18/09 Email communication. Joel Pointon, SDGE Clean Transportation Program, Manager, Electric Transportation

<sup>159</sup> The test consisted of two Hymotion conversions Toyota Prius to demonstrate PHEV viability and use of electricity as a transportation fuel. - demonstrated a 60% increase in MPG over HEV fuel economy.

<sup>160</sup> CARB. “Proposed regulation to implement the LCFS V.1” Approved April 23, 2009. p. III-10/130.

<sup>161</sup> PG&E. “Natural gas technologies,” ([www.pge.com](http://www.pge.com)), <http://www.pge.com/myhome/environment/pge/cleanair/naturalgasvehicles/technologies/>, (accessed May 15, 2009).



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3,600 pounds per square inch) or cryogenic liquefied natural gas (LNG) at 20-15 psi.<sup>162</sup> In addition, biomethane captured from landfills may be refined to CNG for electricity generation or on-board vehicle fuel. Total carbon intensities (the amount of CO<sub>2</sub> released per megajoule of energy accounting for direct emissions and indirect land use change or other effect) for CNG depend on the natural gas pathway. California natural gas delivered via pipeline, compressed in California, is 75.22 gCO<sub>2</sub>e/MJ. North American natural gas delivered via pipeline, compressed in California, amounts to 75.65 gCO<sub>2</sub>e/MJ. Landfill gas cleaned up to pipeline quality natural gas, compressed in California, amounts to 12.51 gCO<sub>2</sub>e/MJ. Landfill gas cleaned up for pipeline quality offers the cleanest carbon intensity per MJ, both for CNG, and electricity fuels, because the fuel source is municipal and agricultural solid waste.

The reported advantages of CNG/LNG for transportation include:<sup>163</sup>

- Nearly 87% of U.S. natural gas used is domestically produced
- 60-90% less smog-producing pollutants
- 30-40% less GHG emissions
- Less expensive than gasoline

The reported disadvantages include:

- Limited vehicle availability
- Less readily available than gasoline & diesel
- Fewer miles on a tank of fuel

The Honda Civic GX CNG is currently the only new commercially available vehicle in California markets. CVs can be retrofitted to run on CNG. Globally, a wider range CNG vehicles are available to consumers. CNG vehicle drivers have the option to

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<sup>162</sup> Ibid.

<sup>163</sup> U.S. DOE. "Natural Gas," ([www.fueleconomy.gov](http://www.fueleconomy.gov)), <http://www.fueleconomy.gov/FEG/bifueltech.shtml>, (accessed May 15, 2009).

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refuel vehicles using in-home CNG fueling equipment, although a major home refill unit company recently declared insolvency.<sup>164</sup>

As with electric transportation, utilities are actively promoting CNG and LCNG projects, and offer special CNG tariffs to customers. Southern California Gas Company (SoCalGas), a Sempra Energy Company utility, reports investments in two major CNG projects.<sup>165</sup>

- **CNG Port Project**

SoCalGas with support of several other entities is demonstrating the viability of four CNG Fuel powered class 8 drayage trucks at the LA Port location. The trucks will be retrofitted with new CNG Cummins/Westport ISL G engines that already meet 2010 CARB emission standards. This effort will support the Ports of Los Angeles and Long Beach Clean Air Action Plan. The trucks will be leased for three years and will be operated by Cal Cartage. The project is being cofunded by the Los Angeles and Long Beach Port Authorities and by the SCAQMD. In addition to demonstrating the trucks, construction of a refueling station is also planned.

- **In-Home Refueling**

Demonstrating the benefits of using in-home refueling equipment to fill natural gas vehicles. The Gas Company has been involved in the field testing of six residential refueling compressor systems throughout the Los Angeles area.

PG&E reports active involvement in development of natural gas as a vehicle fuel. The utility operates 1,138 natural gas vehicles in their fleet. PG&E operates 37 CNG stations, more than half of which are accessible to the public.

Like PEVs, CNG vehicles tend to cost consumers more than a comparable CV. CNG analysts report that CNG may be a viable option for medium and heavy duty vehicle applications, which would complement LDV electrification as an overall fuel technology strategy to reduce transportation sector emissions and avoid petroleum consumption. While electricity outperforms CNG from a carbon intensity metric, CNG from landfill gas is a more environmentally friendly option. CNG refueling infrastructure is presently

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<sup>164</sup> Fehrenbacher, K. "Phill maker goes bankrupt, bad sign for natural gas vehicles." (earth2tech.com, April 6, 2009), <http://earth2tech.com/2009/04/06/phill-maker-goes-bankrupt-bad-sign-for-natural-gas-vehicles/>, (accessed May 15, 2009).

<sup>165</sup>

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at a disadvantage to electricity in terms of commercial and public access. However, as the state policy approach tends to avoid picking a winner, the CPUC may consider a policy to remain neutral or equivalent in its support of PEVs and CNG vehicles.

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## **6. Conclusion: Additional State Agency Options for Reducing PEV Barriers**

Based on the potential environmental and economic benefits identified in this paper, staff recommends that state agencies explore options to reduce the barriers to PEV adoption that could complement the existing and pending programs and policies identified in Section 5. The recommendations are divided into subsections for options available to the CPUC, CEC, the Franchise Tax Board, and ARB, respectively.

### ***A. CPUC Options***

In order to maximize potential economic and environmental benefits for ratepayers, the CPUC can act to remove policy barriers to maximize emissions reductions, increase distributed generation renewable energy resources to support PEV load, support utility investments in metering and related infrastructure, support utility distribution system impact studies and distribution system upgrades, and continue to support IOU recovery of prudent investments in capital and operating costs in support of electrification.<sup>166</sup>

Staff recommend that the CPUC open a rulemaking to consider a variety of measures that could be taken by this agency to reduce barriers to electrification, including

- Rate design options, including the potential for a statewide electricity rate for PEVs;
- Vehicle incentives to encourage Californians to buy and operate PEVs, including ratepayer funded incentive programs;
- Options for development of metering and charging infrastructure for PEVs;
- Options to streamline permitting requirements and contractor installation of residential PEV charging equipment;
- Development of policies that encourage partnerships between regulated and unregulated companies that are beneficial to ratepayers;
- Consideration of options to incorporate PEV charging with renewable energy supply, including, but not limited to, PV arrays over charging

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<sup>166</sup> However, the CPUC should be aware that PEVs are one of several competing vehicle designs and vehicle fuel alternatives to petroleum-fueled conventional vehicles. A portfolio of technologies and policies, rather than a single approach, are required to significantly reduce emissions from the transportation sector.

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- stations or off-peak charging that takes advantage of overnight wind resources expected in the utility resource portfolio; and
- Quantification of the value of electric system efficiency and potential credits for emissions reductions under various PEV market penetration scenarios, and options for passing the value of PEV commercialization through to PEV customers/ratepayers in the form of reduced bill payments, reduced PEV rates, and other utility financial incentives such as purchase rebates, and rate-based on-site capital costs currently born by the customer.

These topics are discussed below (with the exception of encouraging renewable energy resources, as this discussion is integrated into each applicable topic).

**Tariff / rate design options.**<sup>167</sup> The CPUC could consider separating PEV load from the IBP rate schedule for household load. To simplify the diversity of PEV rates, the CPUC could also consider working with other agencies to expand this effort into a program that develops a statewide PEV rate. However, a statewide PEV tariff, like any other residential or commercial tariff, may not be advisable given geographic, climate and other variable cost inputs of service provision. Moreover, IOU rates are subject to CPUC authority while municipal tariffs are not. Drivers who refuel with electricity across utility district boundaries may need to accept the potential for different fuel charges, as they would in the gasoline distribution market.<sup>168</sup>

Utilities are studying means to address PEV charging across electricity utility service territories. Utilities are studying various means to address PEV charging across electricity utility service territories. For example, an off-vehicle module is currently in development by SDG&E,<sup>169</sup> which is targeted to communicate with AMI systems to capture vehicle sub-metering and apply the appropriate PEV TOU tariff. Other options presently being investigated for the marketplace include smart card or credit card swipe options at public charging stations, which immediately apply the cost of usage to

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<sup>167</sup> Note that details associated with the various IOU current PEV tariff structures are provided in Appendix A.

<sup>168</sup> A communication chip is under development to identify the car's home service territory and charge the applicable rate. A driver in a service territory that charged non-tiered PEV rates, for example in SDG&E service territory, would be incented to want to apply the reduced rate out of the SDG&E service territory. Electric vehicle subscription service providers also employ computer chip technology to communicate the car's charge to their network hub, and charge the applicable plan rate.

<sup>169</sup> 3/18/09 Email communication, Joel Pointon, SDG&E.

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the customer's utility account or charge card. Mobile metering issues are also relevant to battery charging subscription service plans proposed by Project Better Place and Coulomb Technologies. The CPUC could include discussion of these options in a separate PEV proceeding.

Another PEV tariff issue is whether PEV rates should apply to small battery capacity low-speed PEVs and electric motorcycles. The PG&E electric schedule E-9 tariff currently excludes “low-speed electric vehicles and electrically powered motorcycles as defined by the California motor vehicle code.”<sup>170</sup> The U.S. Department of Transportation classifies low-speed electric vehicles as a NEV. Although federal regulations certify NEVs as “street legal,” NEVs are not required to have air bags and cannot travel on highways or freeways.<sup>171</sup> NEVs are therefore restricted to roads with a 35 mile per hour speed limit or less.

While NEVs are not intended to replace highway VMT, they are an important means of reducing short trips under three miles, which comprise nearly half of all trips.<sup>172</sup> The U.S. DOE states that NEVs are “very efficient in terms of initial capital costs, fuel costs, and overall operating expenses.” The CARB ZEV mandate provides credits for NEVs used. The ARRA also makes NEVs eligible for consumer tax credits, and the AQIP program funds NEV purchase incentives. Moreover, the 2005 NEC Article 625.2 incorporates NEVs into the definition of electric vehicles.<sup>173</sup> Therefore, to the extent that the PEV rate incents increased PHEV, BEV, and NEV usage, it would seem illogical to exclude NEVs from rate applicability. The CPUC should consider the benefits of NEV usage in future rate Advice Letter and GRC rate design phase proceedings.

Another issue associated with PEV tariffs is currently disparate public charging tariff structure. IOUs have not and do not currently offer a public charging tariff, only residential and commercial PEV TOU tariffs. However, street and public garage public

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<sup>170</sup> PG&E. “Applicability” Electric Schedule E-9. Experimental residential time-of-use service for low emission vehicle customers.

<sup>171</sup> US Department of Transportation. National Highway Traffic Safety Administration 49 CFR Part 571 Federal Motor Vehicle Safety Standards.

<sup>172</sup> FHWA 2006. Federal Highway Administration University Course on Bicycle and Pedestrian Transportation: Student Workbook (second edition). Report No. HRT-05-133.

<sup>173</sup> US Department of Energy Vehicle Technologies Program. “PHEV Charging Infrastructure Review.” <http://avt.inel.gov/pdf/phev/phevInfrastructureReport08.pdf>, Nov. 2008, p. 20. (accessed May 13, 2009).

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charging stations are necessary to expand fuel availability to PEV drivers, particularly with range-limited lower capacity BEVs. Historically, public charging stations have offered electricity to drivers for free, with the rate charged to the public charging station owner linked to a garage circuit. On-street charging stations may be tied to a streetlight or other tariff. In particular, streetlight tariffs are problematic because they do not have a TOU component to incent off-peak charging. If the city pays a tariff to the IOU for public charging that does not have a TOU component, the city is not incented to promote off-peak charging. The CPUC could develop a specific TOU tariff for public charging facilities. The CPUC does not regulate municipal utilities or municipalities, and so does not directly regulate a public charging facility offered by a municipality. However, it could make recommendations to municipalities for statewide public charging tariffs, or require that IOUs establish a public charging tariff.

Regarding future PEV rate and bill adjustments, the CPUC has the authority to implement other tariff adjustments and bill reductions to encourage PEV commercialization and PEV usage that maximizes environmental benefits. For example, a “Green PEV” tariff could incorporate incremental energy generation costs of the additional wind and other renewable resources the CPUC RPS anticipates in the portfolio in ten years or so. The incremental tariff could fund PEV fueling infrastructure or carbon reduction measures, similar to PG&E’s ClimateSmart tariff.

Additionally, a demand response/load control program for PEV load could specify the terms of PEV battery charging to coincide (ramp and regulate) with intermittent renewable wind energy, or defer on-peak charging during high peak/emergency hours. As indicated in the ancillary services section, the value of this program depends on a bid aggregator to bid PEV load into the CAISO ancillary service market. While many PEV drivers/electricity customers will choose to or need to charge on-peak, some customers may elect to participate in this program if the value of their aggregated load reduction is greater than the cost of switching to gasoline, for PHEV drivers. The value of this program could be passed on to participating PEV customers via bill reduction, or via regular payments.

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Finally, in assessing PEV rate changes, the CPUC should consider the marginal cost of electricity delivery for off-peak usage. The lack of marginal capacity costs associated with incremental off-peak usage indicates that there may be room to reduce rates for off-peak PHEV and PEV battery charging. For example, CPUC staff analysis has found that off-peak rates for PEV battery charging remain above off-peak marginal energy costs, shown as 5.24 cents (winter) to 5.44 cents (summer) in SCE's current GRC Phase 2 filing (for 2009). Moreover, the CPUC could pass the potential value of LCFS credit sales (assuming the value originates from credit sale in the LCFS market), and the value of increased load factor in PEV driver/residential customer bills.

**Vehicle Incentives.** Stakeholders and IOU electrification managers suggest that utilities offer purchase rebates for PEVs as part of a suite of incentives to encourage PEV market growth in California. Rebate advocates argue utilities may be a logical source for a pilot rebate program due to potential utility industry revenues if PEVs achieve significant market penetration and if off-peak charging improves load factors.<sup>174</sup> All ratepayers would benefit from reduced average fixed costs of service if enough vehicles charged off-peak, flattening the load curve. Ratepayers would also benefit from emissions reductions. Further assuming costs decline, prospective PEV owners who are electricity ratepayers would benefit from reduced PEV initial cost, and potentially benefit from reduced PEV operation relative to a CV. Rebates would reduce the initial cost premium barrier, one of the primary barriers to PEV commercialization. As an example, Austin Energy municipal utility has set aside \$1 million for PHEV rebates when the vehicles become widely available.<sup>175</sup>

To sustain PEV commercialization, this paper suggests a potential limited California IOU vehicle rebate program could extend, but not duplicate, available consumer federal and state tax incentives and vehicle purchase incentives for plug-in vehicles. As described above, the ARRA tax incentive offers a \$2500 to \$7500 credit for plug-in LDV for up to 200,000 vehicles sold per manufacturer after December 31, 2009. The credit is

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<sup>174</sup> Plug-in partners national campaign. "Electric utilities rebates for consumers," (Austin Energy, 2009), <http://www.pluginpartners.org/campaignOverview/rebatesIncentives.cfm>, (accessed May 13, 2009).

<sup>175</sup> Ibid.



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reported to be phased out by each maker after 200,000 vehicles.<sup>176</sup> In the first and second quarter of the phase-out, all consumers buying plug-in LDVs from the manufacturer that has reached the vehicle limit will receive 50% of the previous credit; in the third and fourth quarter consumers will receive 25% of the previous credit. There is no termination date for the credit, or limit to manufacturers that can offer the credit. A limited, CPUC-authorized vehicle purchase incentive program could extend the incentive beyond existing regulatory requirement limitations, depending on the state of the PEV market.

**Development of metering and charging infrastructure.** In addition to a potential vehicle purchase incentive, stakeholders suggest the CPUC consider a rate-based subsidy or low-finance loan incentive program for customer-site energy-related capital improvements, including wiring, wall-box, and additional sub metering costs.<sup>177</sup> CPUC staff suggests that a pilot subsidy or low-interest on-bill finance program could be useful for early PEV adopters who purchase PEVs prior to receiving a “smart meter.” All IOU customers are expected to receive a second generation AMI meter between now and 2012, pursuant to a deployment plan approved by the CPUC. The AMI meter requires a secondary sub-meter device to measure the PEV load and communicate it back to the primary second generation AMI meter. Customers who want an AMI meter prior to the utility scheduled installation pay for the cost of AMI installation. Accordingly, the CPUC could approve a carve-out to the deployment plan for PEV owners. It could also provide a low-interest loan or explicit rate-based subsidy for the sub-meter secondary device.

While on-site residential charging equipment cost is anticipated to be much less than the battery cost, a socialized or low-interest loan cost program for the residential electricity customer/EV driver could attract customers at the margin. Residential PEV charging infrastructure, depending on the existing infrastructure, is estimated to amount to \$500-\$1,000 if an electrical panel upgrade is not required. If a panel upgrade is

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<sup>176</sup> Project Get Ready. “Lean more about plug-in related stimulus funding,” (Rocky Mountain Institute, 2009), <http://projectgetready.com/resources/implications-of-american-recovery-and-reinvestment-act-of-2009-for-plug-ins>, (accessed May 13, 2009).

<sup>177</sup> CEC. “State Alternative Fuels Plan,” p. C-21

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required, the installation cost approaches \$2500.<sup>178</sup> Utilities should continue working with local governments to ensure that updated on-site capital PEV charging equipment for PEV drivers / residential electricity customers be installed in an efficient and cost-effective manner. Utilities, in conjunction with local government permitting offices and licensed electricians should work to develop rapid response programs to avoid long capital installation delays.

An on-bill low-interest financing program could be spread over time over the life of the PEV, factoring vehicle depreciation. This financing program could be offered in conjunction with other customer-site capital improvements, including energy efficiency measures and roof-top solar PV and other customer-site solar energy capture technologies such as solar heaters. On-bill financing for bundled energy efficiency, renewable installation, and PEV installations could offer the customer compounding returns on efficiency and reduced energy bills.

For example, CSI provides a mechanism to reduce the cost of solar PV systems for residential electricity customers. CSI provides a mechanism to potentially integrate increased PEV load with increased-size PV systems. The CSI Handbook states: “In the case of Applicants ... where the existing electric bill does not reflect the Applicants expected consumption, the Applicant must include an estimate of the expected expanded consumption.”<sup>179</sup> Expected expanded consumption may be for increased site expansion, and must be documented by an engineering estimate. Potential documentation for expected expanded consumption could include a California Department of Motor Vehicle title of registration for a plug-in vehicle.

Accordingly, the CPUC has an opportunity to integrate PV energy for transportation at the micro-level through a CSI policy accommodation for PEV load for residential customers and commercial customers that could aggregate PEV load for PV systems over larger parking garages. Solar integration with PEV load would increase the total MW

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<sup>178</sup> PG&E. “EV Infrastructure Installation Guide.” (PG&E, 1999), <http://www.pge.com/includes/docs/pdfs/about/environment/pge/electricvehicles/ev6pt4.pdf>, p. 21. PG&E plans to update the installation guide, including infrastructure installation costs, which may have risen since publication.

<sup>179</sup> CPUC. “California Solar Initiative Handbook” Posted 1/27/2009 [http://www.gosolarcalifornia.org/documents/CSI\\_HANDBOOK.PDF](http://www.gosolarcalifornia.org/documents/CSI_HANDBOOK.PDF), p. 20.

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served by distributed solar systems. Further, studies indicate solar generation supply resources approximate load. Particularly for PEV battery charging that cannot be avoided, integrating PEV load into the CSI could have the impact of reducing the charging impact due to electrification during high demand, on-peak hours.

**Encouraging partnerships between regulated and unregulated companies.** PU Code § 740.3 instructs the CPUC's policies to ensure that utilities do not unfairly compete with nonutility enterprises. For example, D.93-07-054 and D.05-05-10 instructs IOUs to avoid promoting, selling, or recommending specific electric drive LEVs purposes of customer outreach and education programs. This statutory requirement may apply to private capital investment in plug-in vehicle charging infrastructure.

CPUC's Legal Division has performed a preliminary examination of the potential for legal issues relating to third-party electric vehicle charging service providers, and it has determined that Public Utilities Code section 218 likely discourages the use of certain business models, while acknowledging that the issue is highly fact-dependent.

In terms of the sale and distribution of electricity fuel, with the suspension of direct access, IOUs do not face competition from liquid fuel distributors or other unregulated corporations.<sup>180</sup> Certain liquid fuel distributor companies identified this issue in their comments to ARB regarding the LCFS regulation:

“A Note Regarding Electricity

While the California IOUs plan to provide electricity for the transportation sector, others may be faced with a barrier to entry. Under current law (AB1X), only the IOUs are authorized to provide “retail” electricity. Others are blocked from access to this market by suspension of Direct Access. As a total energy provider, BP is, in effect, prohibited from participating in this future segment of the fuels market. CARB's contemplated point of regulation for electricity in the LCFS could exacerbate this current barrier to entry. CARB and CEC must act to reconcile this issue.”<sup>181</sup>

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<sup>180</sup> With the exception of Qualifying Facilities, such as certain Combined Heat and Power facilities.

<sup>181</sup> British Petroleum America, Inc., May 9, 2008 BP America Comments CARB's Proposed Concept Outline for the LCFS Regulation.

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The alleged barrier to market entry may not prevent unregulated companies from providing electrification services, such as battery swapping or access to public charging stations and on-site customer charging services. Investment structures that invite private firm investment should be explored to offset ratepayer costs for electrification. For example, subscription services proposed by companies like Project Better Place and revenue sharing agreements are a potential means to offset ratepayer risk and address the block to competition in the electricity fuels market.

***B. Franchise Tax Board Options***

Another PEV tariff issue that may be applicable to both the CPUC and the California Franchise Tax Board is the question of whether and how to apply transportation taxes to PEV rates. Alternative fuel taxes, if they apply to electricity fuel and other alternatives, may require California Legislative or other coordinated state agency action. The California and Federal Departments of Transportation rely on highway tax and sales tax from gasoline for highway construction and maintenance. California tax, federal tax, and sales tax<sup>182</sup> amounts to \$0.735/gallon.<sup>183</sup> This tax equates to \$0.02/kWh on BTU basis or \$0.08/kWh per mile basis, which is currently not assessed on PEV rates.<sup>184</sup> Stakeholders suggest a policy to levy an equal tax on all alternative fuels, including biofuels or hydrogen, to avoid significant loss of transportation network funding.<sup>185</sup> Alternatively, such a tax may be implicitly achieved via the cap-and-trade pricing mechanism, once transportation fuels are included in the cap. At that point, all fuels, including petroleum and alternative fuels, will effectively be internalizing the cost of CO<sub>2</sub>e from well-to-wheels.

***C. CEC Options***

The CEC is distributing funds pursuant to the ARFVTP requirements to charging infrastructure providers. Eligible parties include IOUs and third party electric vehicle

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<sup>182</sup> The general sales tax applies to gasoline, on top of the California fuel tax.

<sup>183</sup> Ashuckian, David. "Who (or What) killed the electric vehicle, the rest of the story." DRA presentation, 01/07/09.

<sup>184</sup> Ibid

<sup>185</sup> Stakeholder meeting communication, 9/25/2008, ARB meeting with utilities regarding LCFS draft regulation.

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charging service providers. Eligibility is not subject to whether the fund recipient is a regulated entity subject to PUC authority. As stated above, Public Utility Code § 218 may discourage certain business models. However, AB 118 ARFVTP applicants should clearly represent whether they are a regulated entity subject to CPUC regulatory authority.

In addition, the CEC directs Public Interest Energy Research program funding to the University of California at Davis PHEV research center. The center is partnered with IOUs, U.S. DOE, EPRI, South Coast Air Quality Management District, and other stakeholders. The center has recently published novel research concerning PHEV consumer preferences for charging, lifecycle costs of PHEVs, and impacts of PHEV charging on the electricity grid, amongst other topics.<sup>186</sup>

***D. CARB Options***

Section 2 described the existing CARB transportation sector pollution reduction policies that are anticipated to drive demand for PEVs and other petroleum alternative fueled vehicles. This section provides an analysis of the potential impacts of one of these policies, the LCFS, to the electricity sector.

Within California, the electricity sector accounts for only 25% of economy wide emissions, yet the sector is responsible for reducing 40% of emissions to meet 2020 goals, according to CARB's Scoping Plan. The Plan recognizes that the transportation sector must be responsible for reducing its share of the economy wide emissions and not expect other sectors, such as electricity, to make up the difference.<sup>187</sup>

Cal ETC and IOUs suggest electricity deliverers face a disincentive to support electrification if penalized for emissions due to load supplied to electric vehicles. Assuming CARB allocates allowances on a sectoral basis, failure to make available additional allowances to the electricity sector due to electrification to the electricity sector risks overburdening ratepayers with the cost of transportation sector emissions. Provided that electrification occurs at a significant scale, CARB should consider a policy to shift

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<sup>186</sup> UC-Davis PHEV research center. "California's cooperative research center." (UC-Davis, 2009), <http://phev.ucdavis.edu/>, (accessed May 13, 2009).

<sup>187</sup> CARB. Climate Change Scoping Plan, p. C-55

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allowances from the transportation sector to the electricity sector, while not changing the total cap on the pool of allowances.

The draft regulation of the LCFS provides that IOUs may export LCFS credits into AB 32 and other carbon markets. Experts suggest that the rationale for this policy is that the LCFS credit for electricity fuel is not likely to find a market in the LCFS scheme. Staff has identified a number of problems with the one-way transfer of LCFS credits into the AB 32 cap and trade scheme.

The LCFS credit is an intensity value, while the currency for AB32 is a fixed amount, tCO<sub>2</sub>e. Environmental experts contend that there is a problem with importing an intensity based credit into a supply fixed market because intensity cannot guarantee actual emissions reductions.<sup>188</sup> For example CNG is approximately 10% less carbon intensive than regulated gasoline in CA.<sup>189</sup> A CNG vehicle that replaces a CV, assuming no behavioral change, will release 10% less emissions. However, behavior assumptions risk compromising actual verifiable emissions reductions. If the CNG driver, factoring a reduced operation cost relative to gasoline per mile, drives 10% more, the utility supplying natural gas would be credited for an emissions intensity reduction. However, no net emissions reductions would result in this scenario. CPUC staff has asserted in comments to the LCFS that if electricity retail providers can convert surplus credits into allowances or offsets, this will result in an increase in the allowable level of emissions, increasing the statewide GHG level, rather than decreasing.

To conclude, based on the potential environmental and economic benefits identified in this paper, staff recommend continued CPUC participation in a coordinated state agency approach to ready the electrical system for and incent the widespread use of PEVs in California. This approach can be better defined from the CPUC perspective in the existing Smart Grid proceeding and in a new proceeding to address PEV related issues not captured under existing CPUC proceedings.

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<sup>188</sup> Environmental Defense Comments to the Draft Outline of the LCFS.

## **Appendix I -- IOU Tariff Details**

### EV Tariffs

The following information describes current IOU rates for PEVs.

### ***PG&E***

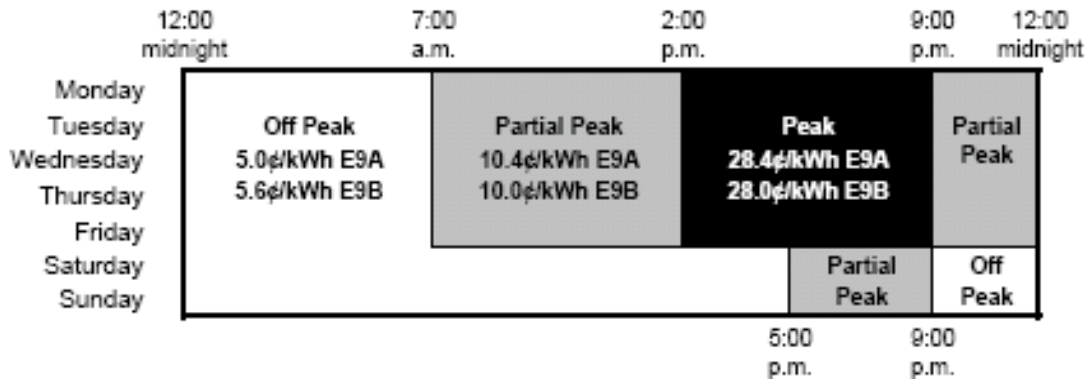
PG&E offers a TOU E-9 (LEV Fueling Rate) to residential electricity customers/EV drivers and natural gas vehicle drivers. The rate does not apply to commercial customers. Per CPUC Advice Letter 3319-E, the rate was revised to make the TOU E-9 schedule mandatory for customers recharging a PHEV. Prior rate applicability requirements restricted PHEVs from E-9 service, as they are fueled with electricity and gasoline or another fuel. According to the schedule, low speed electric vehicles, as defined by the California Motor Vehicle Code, are not eligible for this rate option.

The rate has two options, rate E9-A and rate E9-B. Rate E-9A applies to a single-metered, whole household load, including PEV load. Rate E9-B applies to dual-metered, where standard metering applies to household load, and a second TOU meter for a dedicated PEV charging circuit

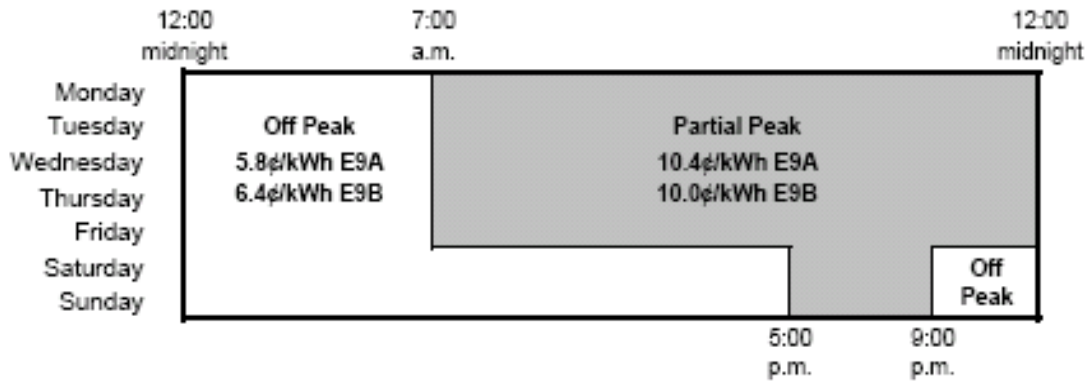
The following chart illustrates off-peak, partial Peak, and peak times and corresponding baseline rates for E-9 A and E-9B customers in the summer and winter.

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**Summer (May 1 through October 31)**



**Winter (November 1 through April 30)**



Source: <http://www2.pge.com/myhome/environment/pge/electricvehicles/fuelrates/index.shtml>

The chart shows total bundled service charges for baseline usage, and usage up to 130% of baseline. Customer baseline quantities differ depending on service territory and season, and apply to segregated load or all bundled load. Rates increase for 131%-200% of baseline, 201%-300% of baseline, and over 300% of baseline usage. This pricing scheme is known as IBP. The rationale for IBP and issues associated with IBP is discussed in further detail below. In addition, PG&E assesses a \$0.218 per meter per day Meter Charge Rate, and \$0.147 per meter per day Total Minimum Charge Rate.



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*SCE*

SCE offers three TOU PEV rates depending on customer class and usage. TOU PEV rates are required to be separately metered, although a customer can place PEV load under one household standard rate, which is subject to IBP. SCE TOU EV rates were recently updated to reflect CPUC’s adjustment for upgrading the electrical grid. SCE anticipates PEV rates may be more favorable pursuant to CPUC GRC Phase 2 effective October 2009.<sup>190</sup>

SCE rate TOU-EV-1 applies to residential customers with less than 20 kW demand. TOU-EV3 applies to small commercial customers with less than 20 kW demand. TOU-EV4 applies to medium-sized commercial customers with a demand between 20-500 kW. On-peak hours are from 12 noon to 9 pm all year, every day; off-peak hours are all other hours. The following chart shows costs per kWh that a customer will be charged under EV TOU rates 1 and 3, including total delivery service costs and generation costs.

	On-peak	Off-peak
TOU EV1 Summer	\$0.247	\$0.166
TOU EV 1 Winter	\$0.189	\$0.155
TOU EV 3 Summer	\$0.252	\$0.129
TOU EV 3 Winter	\$0.158	\$0.29
TOU EV 4 Summer	\$0.143	\$0.060
TOU EV 4 Winter	\$0.080	\$0.060

Source: Email communication, 4/6/09 Coleen Tessema, SCE Project Manager, Electric Transportation

In addition, SCE assesses a TOU EV-1 Meter Charge of \$0.155/meter/day, and a \$0.168 per meter per day Minimum Charge. The Meter charge for The EV 3 is \$0.246/day. SCE EV rates are not subject to IBP surcharges.

<sup>190</sup> Email communication, 4/6/09 Coleen Tessema, SCE Project Manager, Electric Transportation.

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**SDG&E**

SDG&E has three residential voluntary PEV rates. Schedule EV-TOU domestic TOU for PEV charging is for separate home and vehicle consumption. Schedule EV-TOU 2 bundles PEV and household usage under one TOU meter. Schedule EV –TOU 3 is for PEV charging with a dual meter adapter for EV load, where the house remains on standard residential rate. The following chart depicts SDG&E EV rates with super off-peak, off-peak, and peak periods.

**San Diego Gas & Electric Co. Energy Costs as of 1.1.09**

Electric Tariff Book - Residential Rates

DOMESTIC TIME-OF-USE FOR ELECTRIC VEHICLE CHARGING

This is an illustration showing the combined total cost per kWh of electricity on the EV TOU Rates excluding taxes and San Diego Franchise Fee (SDFFD)

Summer 5/1-10/31	12:00 a.m.	5:00 a.m.	12:00 pm	8:00 p.m.	12:00 midnight
	<b>Super Off Peak</b>	<b>Off Peak</b>	<b>Peak</b>	<b>Off Peak</b>	
EV TOU*	¢ 13.775 /kWh	¢ 16.79 /kWh	¢ 29.113 /kWh	¢ 16.789 /kWh	
EV TOU 3*	¢ 13.769 /kWh	¢ 16.78 /kWh	¢ 29.11 /kWh	¢ 16.784 /kWh	
EV TOU 2*	¢ 13.775 /kWh	¢ 16.79 /kWh	¢ 29.11 /kWh	¢ 16.79 /kWh	
	<b>Total</b>	<b>Total</b>	<b>Total</b>	<b>6:00 PM</b>	
Winter 11/1-4/30	12:00 a.m.	5:00 a.m.	12:00 pm	8:00 p.m.	12:00 midnight
	<b>Super Off Peak</b>	<b>Off Peak</b>	<b>Peak</b>	<b>Off Peak</b>	
EV TOU*	¢ 14.028 /kWh	¢ 17.08 /kWh	¢ 17.936 /kWh	¢ 17.079 /kWh	
EV TOU 3*	¢ 14.022 /kWh	¢ 17.07 /kWh	¢ 17.922 /kWh	¢ 17.074 /kWh	
EV TOU 2*	¢ 14.028 /kWh	¢ 17.08 /kWh	¢ 17.933 /kWh	¢ 17.08 /kWh	
	<b>Total</b>	<b>Total</b>	<b>Total</b>		

EV TOU and EV TOU 2 necessitate a monthly meter fee of \$3.81  
EV TOU 3 necessitates a monthly meter fee of \$13.81

Rev 4/7/09

Source: SDG&E EV Rates and Notes, 4/7/9 email communication, Joel Pointon

As with other IOU rates, SDG&E assesses a metering charge of \$3.81/month for EV-1 and EV-2 rates; the charge for EV-3 rate is \$13.03/month. The SDG&E EV TOU rate is not subject to IBP.