Plug-In Hybrid Electric Vehicles and Environmentally Beneficial Load Building: Implications on California's Revenue Adjustment Mechanism

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ABSTRACT

Plug-in hybrid electric vehicles (PHEVs) are poised to allow, for the first time, large-scale interaction between the transportation and electric utility sectors. Electricity is a more efficient vehicle fuel than are liquid fossil fuels, and it can reduce system-wide greenhouse-gas (GHG) emissions by transferring energy demand and emissions from the transportation to the electric utility sector.[1] Furthermore, PHEVs represent a new type of load for electric utilities that can ultimately result in increased utilization of renewable generation. Since PHEVs would be charged primarily at night when California's wind resource is strong, PHEVs could further offset emissions by using power with a lower GHG emissions intensity than California's average electricity mix (Fripp & Wise 2006).

However, although PHEVs offer a way for reducing system-wide GHG emissions, mitigating utility rates, and possibly increasing revenues, these benefits cannot be fully realized under California's existing regulatory structure. As the market penetration of PHEVs rises, so do electricity demand and GHG emissions from the electric utility sector. These trends conflict with regulatory requirements that require significant reductions in statewide GHG emissions and are designed to encourage energy efficiency.

This tension creates an interesting problem for the electric utilities: what is the best way to reconcile the increase in *electricity demand* and subsequent increase in power-sector *GHG emissions* due to PHEV penetration in the utility sector under California's regulatory structure? Here, we explore this issue and suggest policy and regulatory alternatives that the State could pursue to encourage electric utilities to invest in both end-use efficiency and PHEVs.

I. Why PHEVs?

PHEVs have the potential to provide a variety of benefits system-wide, as well as to the electric utility and the consumer. This paper distinguishes between different categories of electric vehicles, according to the following definitions:

- **Plug-in hybrid electric vehicle (PHEV)**—a vehicle with both an internal combustion engine (ICE) and significant battery capacity that is able to operate on both the hybrid ICE and battery exclusively; it has the ability to charge the battery from an external source, namely, the electric grid.
- **Electric vehicle (EV)**—a vehicle with only battery capacity, completely powered by electricity from an external source, namely, the electric grid.
- **Vehicle-to-grid capability (V2G)**—the ability of a PHEV or EV to receive electricity from the electric grid and also to send electricity onto the electric grid, thereby acting as distributed, mobile energy storage.

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[1] The reduction will be the difference in the average emissions of these two sources multiplied by the all-electricity miles traveled.

Each of these functional types is associated with different operational requirements and electric grid impacts. This paper focuses primarily on PHEVs, as well as PHEVs with V2G capability.

System Benefits

Electricity is a more efficient fuel than gasoline or diesel, so the widespread use of PHEVs can result in system-wide GHG reductions. Preliminary modeling estimates[2] of potential emissions reductions indicate that if PHEVs accounted for 50 percent of vehicles in California, the system-wide emissions reductions could be as high as 36 million metric tons of carbon dioxide ($MtCO_2$) per year.[3]

Consumer Benefits

Aside from potential State tax credits for purchasing an electric vehicle, spending on gasoline could be reduced by $800 per PHEV per year.[4] The potential ability to sell energy back to the grid (through V2G) offers consumers an additional financial incentive to adopt this technology. Studies estimate potential net returns from V2G to reach as high as $2,000 per year per vehicle (Kempton & Tomić 2005). Long-run, incremental costs are projected to be $8,000–11,000 above the cost of a conventional vehicle for a PHEV20 and a PHEV40,[5] respectively; current costs are substantially higher (Simpson 2006). Considering all these factors, the simple payback for PHEVs with V2G capability could be on the order of 2.5 to 4 years.[6] In addition, advances in efficient platform physics could result in reduced battery size and improved payback.

Electric Utility Benefits

Case studies have shown that with a regional[7] PHEV market penetration of approximately 50 percent, the total energy required for fleet charging would be approximately 10 to 20 percent of regional electricity generation (Denholm & Short 2006).[8] Most consumers would likely charge their vehicles at night—during a utility's off-peak period—when conventional electricity demand is the lowest, when electricity is the cheapest, and when most utilities have idle capacity. A conservative estimate of electricity capacity usage, estimates that 84 percent of the nation's cars could be powered overnight using this existing capacity (based on an average vehicle miles traveled (VMT) of 33 miles) (Meyer, Schneider & Pratt 2006).

Mobile Storage & Load Flattening. Cost-effective energy storage is something of a Holy Grail for the electric utility sector. While utility-scale batteries are price-prohibitive, PHEVs with V2G capability represent distributed, mobile energy storage that is financed by the vehicle owner. The use of PHEVs as mobile storage devices has the potential to significantly change a utility's load shape. PHEVs alone will increase nighttime load, thereby flattening a utility's daytime load.

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[2] RMI analysis.

[3] This reduction is greater than the total annual emissions output from all natural gas systems in the U.S. (U.S. Greenhouse Gas Emissions Inventory; based on year 2000 data). This model assumes that only 40 percent of the PHEV miles are "all-electric," and that the system generation composition is unchanged from its current state.

[4] RMI analysis.

[5] The notation PHEVx refers to the number of all electric miles that a PHEV is capable of traveling (e.g., a PHEV20 can travel 20 miles on only its electric charge).

[6] Assuming $800/year fuel savings, $2,500/year net return for V2G sales, and $8,000–11,000/vehicle incremental cost.

[7] Based on defined utility power control areas (Northeast, Southwest, Northwest, Midwest, Southeast, Central). Average per capita electricity usage assumed equal to state average within region (total state electricity usage divided by state population) – See Denholm & Short 2006.

[8] Based on an average daily PHEV electricity demand of 4.77 kWh per car, with 40 percent of VMTs being derived from electricity.

Incorporating this storage onto the grid should reduce generation costs by building flexibility into these loads. Such storage could further improve system performance by making stored power available during expensive peak demand periods, thereby reducing the need to ramp up inefficient peaking generation in the short-run, and overbuild baseload capacity in the long run.

There are many advantages to load flattening. The demand created by PHEVs will help fill in the overnight valleys in the load curve, tapping otherwise idle capacity and avoiding some costly cycling activity of generation facilities. Many large generation facilities have overhead costs that are associated with their basic operation but are not correlated with the amount of their electrical production. In addition, since load flattening allows for the increased use of cheaper baseload power generation, the average electricity cost will decline, particularly since the overnight load can be supplied with electricity obtained at more favorable rates.

Firming Intermittent Renewables and Ancillary Services. A V2G system could be a significant driver of large-scale incorporation of intermittent renewable energy into the grid. Used properly, the storage capabilities of PHEVs could help balance the normal fluctuations of demand and intermittent renewable supply. In particular, wind power can benefit greatly from distributed storage such as V2G. Studies show that the storage capacity of PHEVs on average will more than adequately suffice for the periods of intermittency when wind farms are not operating at or near their rated capacities (Kempton & Dhanju 2006).

V2G is also well-suited to providing stabilizing and emergency services for the utility grid. Specifically, the nearly instant response time of the battery makes V2G well-suited for providing the second-by-second balancing of generation to load (frequency regulation) and for ensuring that sufficient generation capacity is available in the event of a power station or transmission failure (spinning reserves). Historically, these “ancillary services” have been provided by reserving some capacity of traditional thermal plants, but currently in California, roughly half of the services are provide by bidders in the ISO market. The market clearing prices for these services are much greater than wholesale electricity prices making ancillary services an attractive initial market for up to tens of thousands of V2G capable vehicles.

II. Laws And Regulations That Impact Utility Benefits From PHEVs And V2G

California’s regulatory structure ensures that state consumers receive ever-cleaner energy and that utilities focus on efficiency instead of supply generation; however, these same regulations limit the benefits California utilities can derive from PHEVs. In particular, greenhouse-gas emissions requirements and utility energy efficiency requirements have the largest impact. These are further discussed below.

Greenhouse-Gas Emissions Reduction Policies

Several laws and regulations in California require utility and transportation sectors to reduce greenhouse-gas (GHG) emissions. The primary GHG emissions limitation law is the Global Warming Solutions Act of 2006 (Act).[9] The Act requires that the California Air Resources Board (CARB) oversee the development and implementation of a plan that will reduce California’s aggregate greenhouse-gas emissions to 1990 levels by 2020. CARB must adopt rules and regulations to achieve maximum, technologically feasible and cost-effective greenhouse-gas emissions reductions.

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[9] The Global Warming Solutions Act of 2006, 2006 CA ALS 488 (codified in scattered sections of Cal. Health & Safety Code beginning with §38500).

The Act requires the California Air Resource Board (CARB) to:

- Adopt regulations for the reporting and verification of statewide GHG emissions;
- Determine the 1990 statewide GHG emissions level;
- Develop a scoping plan for achieving maximum technologically feasible and cost-effective reductions in GHG emissions; and
- Establish a system of market-based, declining annual aggregate emissions limits. The reductions must be verifiable and enforceable.

Regulations to implement the Act are still being developed. The Act sets the goal of having the GHG rules and market mechanisms adopted, in effect, and enforceable by January 1, 2012. Currently, CARB is establishing:[10]

- Discrete early actions that can be adopted and implemented by January 1, 2010;
- Regulations for mandatory GHG reporting by January 1, 2008;
- Definition of the 1990 baseline to be adopted as the 2020 cap by January 1, 2008; and
- Adoption of GHG regulations with rules governing market mechanisms by January 1, 2011.

Investor-Owned Utility and Transportation GHG regulations. In addition to the Global Warming Solutions Act, California has GHG emissions performance standards for all new, long-term financial commitments to investor-owned utility (IOU) baseload power generation and procurement. These standards require GHG emissions levels be no higher than those of combined-cycle gas turbine plants.

The California transportation sector has additional GHG emissions reduction requirements to uphold. These include the Pavley Act[11] and a low-carbon fuel standard. The Pavley Act regulates vehicles, and the low-carbon fuel standard regulates fuel. The Pavley Act, when implemented, will require the reduction of GHG emissions from passenger vehicles, light-duty trucks, and other non-commercial vehicles on a fleet-wide basis. The low-carbon fuel standard requires a 10 percent reduction in the carbon intensity of vehicle fuels by 2020. This standard is a "well-to-wheels" policy, meaning that the fuel's lifecycle will be assessed according to its carbon intensity.

Electric Efficiency Policy

California has several energy efficiency regulations, the principal being the 2001 requirement that the California Public Utility Commission sever the link between utilities' revenues and sales, or decouple the investor-owned utilities.[12] This law was implemented by the CPUC as a revenue adjustment mechanism, also known as "decoupling." It is a ratemaking and regulatory tool intended to break (or decouple) the link between a utility's recovery of fixed costs and a consumer's energy consumption, thereby aligning utilities' profits with the acquisition of all cost-effective energy efficiency. By reducing the impact of energy consumption on a utility's recovery of its fixed costs, decoupling also creates a disincentive to load growth.

Since decoupling removes all the disincentives a utility may have for using energy efficiency measures to reduce demand, the effects are significant for several reasons. First, decoupling allows the utility to explore using any cost-effective efficiency measures to simply reduce load instead of building

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[10] Market Advisory Committee to the California Air Resource Board.

[11] Pavley Act, 2002 CA ALS 200 (codified in California Health & Safety Code §42823, 43018.5)

[12] Public Utilities Code Section 739.10, enacted by Assembly Bill 29x, provides that, "the Commission shall ensure that errors in estimates of demand elasticity or sales do not result in material over or under collections of the electrical corporation."

supply-side measures to meet load growth. Second, decoupling—as opposed to other lost revenue adjustment mechanisms—allows the utility to fully support efficiency policies such as more stringent building codes and emissions standards. Other lost revenue adjustment mechanisms that support efficiency, such as cost recovery of energy efficiency program expenditures and lost revenues, do not achieve the same goal because the utility's profits are still linked to sales.

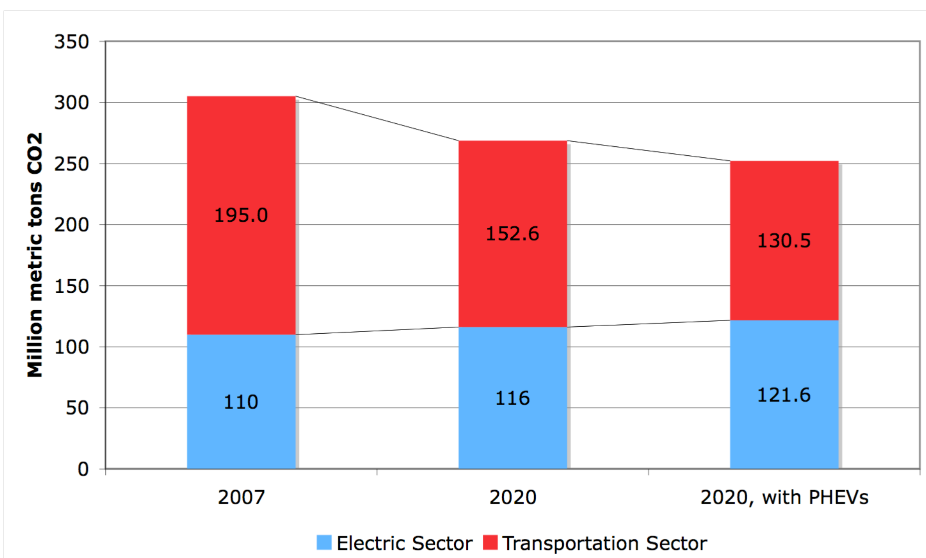
III. The Problem: Increased Sector Emissions And Decreased System Emissions

Both the introduction of PHEVs and California's laws and regulations regarding GHG emissions reductions and energy efficiency are positive actions that help reduce GHGs in the following ways:

- PHEVs can reduce system-wide emissions by transferring a vehicle's source of power from liquid fuel combustion to electricity.
- California's GHG emissions reduction policies mandate system-wide GHG emissions reduction.
- Decoupling removes the incentive for utilities to engage in load building and promotes the least-cost path to meeting demand.

However, PHEVs, decoupling, and State GHG policy are not necessarily compatible. As shown in Figure 1, GHG emissions from the electric and transport sectors could be significantly affected by the introduction of PHEVs. Assuming a 30 percent penetration of PHEVs by 2020 (approximately nine million PHEVs), the transportation sector's GHG emissions are reduced by 22 million metric tons, while the electric sector's emissions are increased by 6 million metric tons—all directly due to PHEV penetration (Duvall 2006).

Figure 1. PHEV impact on sector-specific GHG emissions



The challenge, then, is how to best reconcile the increase in *electricity demand* and subsequent increase in *GHG emissions* due to PHEV penetration in the utility sector under California's regulatory structure.

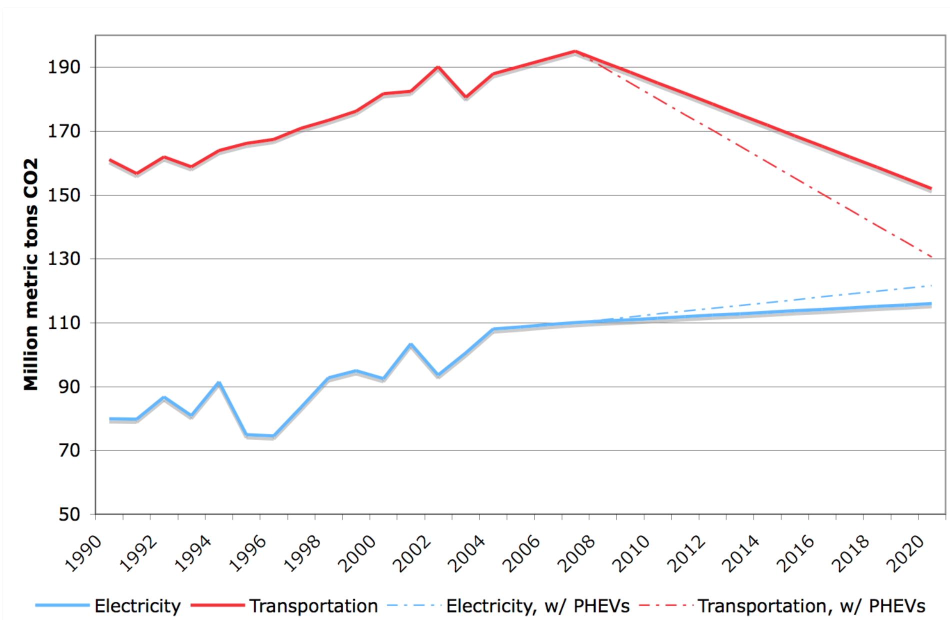
Increased GHG emissions

It is obvious that increased electricity generation will ultimately result in increased GHG emissions for a utility; however, it is unclear how utilities will be regulated under the Global Warming Solutions Act. Prompted by the Act, several discrete early actions[13] have been adopted by the CARB. These early action items include a low-carbon fuel standard, restrictions on refrigerants that have high global warming potential, and landfill methane capture. Currently, none of the discrete early actions are targeted at the electric sector in California. However, it is very likely that the electric utility industry will eventually be subject to the Act.

California's regulatory structure establishes a disincentive to load growth—yet PHEVs represent exactly that. Until these trends are reconciled, the electric utility industry will have little incentive other than the possibility of rate-basing some portion of these assets, at least in their regulated business, to support the development of a PHEV market or the corresponding infrastructure necessary to enable it.

Furthermore, conflict will inevitably arise around whether GHG reductions due to PHEVs should be allocated to the transportation sector or the electric utility sector, or whether emission allowances or offsets will be traded between the sectors. In large part, this allocation depends on regulations currently under development by the California Air Resources Board and the determination of sector-specific baselines. However, general strategies can be proposed to address the issue.

Figure 2. PHEV impact on sector-specific GHG emissions, 1990–2020



There is the possibility that the transportation and electric sectors will be regulated disproportionately, due to the cost-effective requirements of the Global Warming Solutions Act. The more the electric industry is regulated, the greater the negative fiscal impact PHEV penetration will have. This observation implies that the introduction of PHEVs would enable a greater share of the regulatory burden for emission reductions to be assigned to the transportation sector.

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[13] Greenhouse-gas reduction measures underway or to be initiated by ARB that meet the AB 32 legal definition as identified by California Health and Safety Code Section 38560.5. Discrete early actions are regulations to reduce greenhouse-gas emissions adopted by the ARB and enforceable by January 1, 2010.

Increased Electricity Demand

Increased electricity generation due to the widespread deployment of PHEVs is problematic for utilities in California because they do not generate revenue based on kilowatt-hour sales. Instead, the Public Utility Commission determines an appropriate amount of revenue for each IOU in the state. If PHEV penetration is high, it will exceed the current supply available during the night in California, and the utility will have to procure, or save, more power. While the regulatory structure creates a disincentive to grow electricity demand, it does not address the appropriate way to deal with environmentally beneficial load growth, and it creates little financial incentive for regulated utilities to encourage PHEV penetration other than the possible ability to rate base some PHEV assets (because all of the financial incentives lie in reducing demand).

While both of these solutions could solve the issue of procuring additional power without creating additional GHGs, they both burden the utility with additional costs. If the utility chooses to pursue nighttime efficiency programs, it must design the programs carefully and prove that the programs are cost-effective to ratepayers before it may implement them. If the utility chooses to increase renewable energy absorption onto the grid at night, it must ensure that they are firm, dispatchable resources. Or in the case that additional renewable energy generation is needed, the utility must ensure that the appropriate amount of renewable energy generation is available and can be procured.

IV. Strategies To Address Regulatory Barriers

While California's GHG and decoupling policies pose barriers to the development of a large-scale PHEV market, neither is insurmountable. High-level strategies for addressing these barriers include:

- Replace the current decoupling policy with a modified regulatory structure;
- Keep decoupling, but create a separate rate class for PHEVs; and
- Give utilities offsets for GHG reductions made in the transportation sector.

1. Replace The Decoupling Policy

As discussed earlier in this paper, decoupling is a positive trend because it aligns utility profits with the acquisition of all cost-effective efficiency. California began using decoupling to promote efficiency in 2001. Recently, several other states have expressed interest in electric utility decoupling, including Idaho, Connecticut, and Indiana.

One option available to California policy makers and regulators who wish to eliminate one of the disincentives to PHEVs is to replace the decoupling policy with rate of return regulation and other incentives (such as cost-recovery and shareholder incentives). This would remove the disincentive to promote load growth because it would allow a utility to recover costs on every kilowatt-hour it sells, thereby creating an incentive for the utility to sell electricity generated by PHEVs. Unfortunately, allowing a utility to recover its costs based on sales creates no incentive for the utility to reduce costs or promote efficiency. RMI does not recommend eliminating, or replacing decoupling as an option to create utility incentives to address PHEV load growth due to the overarching negative implications on the entire electric procurement system.

2. Independently Meter PHEV Load For Multiple Benefits

Rather than changing the rate design of the entire electric system, independently metering PHEV load can enable the creation of a separate PHEV rate class that can be designed to promote development of the PHEV market while still encouraging household and building energy efficiency through decoupling.

The cornerstone of this strategy is the ability to independently meter PHEV load. There are three possible ways to achieve this:

- **Conventional dual metering**—A second conventional meter could be installed on each home's circuit that would charge the PHEV, probably with a distinct plug connection. The utility could read both meters and provide separate line items on a customer's bill—possibly with separate rate classes for each. As discussed later in this section, dual metering of this kind is currently available to many California customers.
- **Advanced dual metering**—Advanced meters record and report electricity demand dynamically over time. When coupled with two-way communications capability, advanced meters can be used to separately meter PHEV load as well as enable the use of PHEVs for the provision of ancillary services, peak shaving, absorption of nighttime renewables generation, and other uses. There are currently many initiatives underway to develop advanced metering infrastructure.
- **On-board metering**—While the above strategies allow for a separate rate class to be applied to PHEV load, they are both limited to PHEV charging at the PHEV user's residence or another dedicated charging station. To truly optimize the system, PHEVs should be able to charge (or potentially discharge) anywhere, such as at the user's place of business or in a commuter parking lot. For this flexibility to be possible, PHEVs would require on-board electric meters that track and bill electricity usage by the car, rather than by the circuit the car plugs into.

Depending on which of the above strategies is pursued, independently metering PHEVs can enable:

- **Accurate information and data tracking**—The axiom "you can't manage what you don't measure" is especially true for PHEVs. Before an electric utility can truly optimize its portfolio of demand- and supply-side resources, it must understand what those resources are. More accurate tracking can also inform the design of state policies regarding greenhouse-gas emissions reductions and energy-efficiency targets. As discussed in the next section, any policy put in place to recognize the transfer of emissions from the transportation sector to the electric utility sector should be based on four criteria: (1) a clear measurement of the quantity of emissions being transferred, (2) gasoline avoided, (3) the quantity and carbon intensity of electricity used, and (4) potential to make greater use of renewable generation.
- **Utility control for system optimization**—Advanced communications and metering technology would allow the utility to use PHEVs to improve the operation, reliability, and cost-effectiveness of the system rather than adding yet another source of uncontrollable load.
- **Different rate structures**—Separately metering PHEV load means that it is significantly easier to implement a different rate structure for them. Specifically, decoupling could be maintained for all loads except PHEV loads, and conventional rate-of-return regulation could be applied to PHEV loads. This would directly remove the disincentive to environmentally beneficial load growth currently presented by decoupling. Also, highly time-differentiated time-of-use (TOU) rates could be applied to PHEVs to ensure mostly off-peak, nighttime charging.

Many of California's utilities have existing programs for dual metering. California's five largest utilities currently offer dual metering capability for residential customers, which could allow "residential uses" to remain on a fixed residential electric rate while PHEVs could be metered separately according to a steep TOU rate. The business model for dual metering varies by utility, with some charging the customer for the installation of the second meter and others charging a monthly fee. The customer is also responsible for additional wiring costs. However, these current programs do not *require* the PHEV to be metered separately, and according to PG&E, some customers opt to take advantage of TOU pricing for their *entire* load and not dual meter.

Pacific Gas & Electric (PG&E) conducted a study on which California utilities currently have time-TOU rate structures and/or specific electric vehicle rate classes (Thesen 2006). The results of the study are that eight of the largest ten utilities in California have TOU rates, and seven of these utilities have EV rates.

California's investor-owned utilities (IOUs) are also in the process of exploring advanced metering technologies and some are rolling them out to customers. For example, PG&E plans to have its "SmartMeters" installed at all customer sites by 2011.[14] SCE is working with a coalition of vendors and consultants to develop an advanced meter as part of its "Edison SmartConnect" program.[15]

While these IOU advanced metering initiatives are encouraging, additional advances in metering technology will be required to truly enable the optimization of a utility's energy portfolio, including control of PHEV load. Specifically, most advanced metering technology is primarily designed to track loads on an hourly basis and electronically communicate that information to utilities for more efficient billing. Hourly information can be made available to customers to take advantage of TOU rates and achieve better efficiency.

While on-board metering seems to be the most desirable strategy from a system optimization perspective, there is likely to be some resistance from California's electric utilities since on-board meters would not necessarily be owned, maintained, or controlled by the utility. As such, on-board meters could be susceptible to being tampered with more easily than conventional, stationary meters. To address this concern, California's regulators, utilities, and potential PHEV manufacturers should work together to design a metering system that meets the requirements and specifications of both the car owner and the utility.

3. Allocate GHG Emissions Reductions Due To PHEV Use

As discussed above, the transportation sector is likely to meet its 1990 emissions levels by 2020 due to existing regulation (assuming that California is able to implement the Pavley Act), expected vehicle performance improvements, and continued increases in hybrid-electric vehicle purchases. Therefore, additional GHG reductions due to the introduction of PHEVs will likely result in the transportation sector meeting and exceeding its targets.[16]

Based on this scenario, a third strategy that could be employed to address regulatory barriers to large-scale PHEV implementation is to allocate a portion of the GHG emissions reductions from PHEV use to the electric utility sector rather than to the transportation sector.

Determining the actual allocation of emission allowances is largely dependent on the basic structure of California's GHG reduction policy, which is still being developed and outside the scope of this paper. However, factors to consider when determining how to allocate GHG emission allowances include:

- **GHG impact of PHEVs**—Use of PHEVs will prompt a larger decrease in transportation-sector emissions than the corresponding increase in electric utility-sector emissions. However, the exact amount of both GHG decrease attributable to transportation and the GHG increase attributable to

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[14] PG&E website.
[15] SCE website.
[16] This scenario, of course, assumes that each sector will be required to reduce emissions to that sector's 1990 emissions level. As discussed in Section III, the structure of California's GHG reduction policy has not yet been determined, and the final result could change the scenario put forth here.

the electric utility sector are based on the number of PHEVs, the baseline liquid fuel consumed in vehicles, and the electric generation sources used to charge PHEVs.
- **Forecasted emissions without PHEVs**—Both the transportation sector and the electric utility sector are currently subject to a number of policies and regulations that will result in reduced GHG emissions over time. Furthermore, consumers are increasingly demanding clean vehicles, such as hybrid-electric vehicles and flex-fuel vehicles, that run on biofuels. Therefore, the importance of PHEVs in meeting each sector's GHG reduction targets depends largely on how the baseline vehicle fleet changes over time.
- **Investment required to bring PHEVs to market**—Developing a market for PHEVs and for V2G requires substantial investment by both the transportation and electric utility sectors. Specifically, the transportation sector must invest in research and development, and new manufacturing and re-tooling. Also, the electric utility sector must invest in more advanced technology for managing PHEV load and possibly additional generation, some or all of which could be from renewable resources.

Based on these factors, one possible strategy is that the utility sector should be compensated for its increased emissions by receiving emissions allowances equal to the expected emission increase. That is, the utility sector should be "made whole" in terms of GHG emissions.

The remainder of the GHG reductions produced as a result of the use of PHEVs should be credited to the transportation sector. This would offer substantial incentives both to the utility sector (in the form of no emissions penalty and rate-of-return regulation for PHEVs) and the transportation sector (in the form of actual reductions and cost savings).

This strategy would also require independently metering PHEVs, as discussed above. But it could also be implemented in conjunction with a separate rate structure for PHEVs, or as a stand-alone policy. Creating a separate rate class for PHEVs clearly addresses the regulatory barrier brought about by California's existing decoupling policy. Likewise, allocating PHEV-based GHG emissions allowances to the electric utility sector clearly addresses the potential regulatory barrier brought about by California's GHG reduction policy.

Moreover, it is possible that either strategy could be structured so that both barriers were could be overcome. For example, allocating a large portion of PHEV-driven GHG emissions allowances to the electric utility sector could provide a large enough financial incentive to compensate for any lost revenue due to decoupling. What combination of these strategies should be employed therefore depends largely on the structure of each, and on the ongoing development of California's GHG reduction policy.

V. Conclusions

Plug-in hybrid electric vehicles will result in lower system-wide greenhouse-gas emissions in California, and adoption should therefore be encouraged. However, existing California policies and regulations that are designed to reduce GHG emissions and encourage energy efficiency may discourage the electric utility sector from supporting the implementation of PHEVs. To address this challenge, the State of California should examine possible mechanisms for providing financial or other incentives to the utility sector. Some options include creating a separate rate class for PHEVs, or allocating transportation sector emissions reductions due in part to PHEVs to the utility sector.

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