Electric Vehicles:

A Ratepayer Perspective

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Preface and Disclaimer:

Electrification of personal transportation is among the most promising avenues for reducing greenhouse gas emissions. This paper examines costs and benefits of electric vehicle (EV)-related infrastructure investments from multiple perspectives, with emphasis on the residential ratepayer perspective. Transition from gasoline-fueled personal transportation to electricity-fueled transportation can simultaneously benefit EV owners, electric utility shareholders, electric ratepayers, and the environment. However, such a win-win-win-win outcome is not assured; a necessary condition is that non-EV owning ratepayers are not burdened with EV-related electric infrastructure costs.

Examples presented herein are only illustrative. Further, although the author of this paper is an employee of the Division of Ratepayer Advocates of the California Public Utilities Commission, the content does not necessarily reflect the positions of that Division or of the Commission.

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I. **Abstract**:

Electrification of personal transportation is among the most promising avenues for reducing greenhouse gas emissions. In an ongoing California PUC rulemaking, many parties, including most of California's major electric utilities, mentioned the need for major near-term investments in electric distribution infrastructure to prepare for and/or facilitate EV market development. This paper examines costs and benefits of EV-related infrastructure investments from multiple perspectives, with emphasis on the residential ratepayer perspective. As illustrated herein, EV market growth can be a win-win-win-win situation, in which the environment can benefit, as well as utilities, EV owners, and non-EV owning utility ratepayers.

Accordingly, potential utility investments in EV infrastructure could well be in the public interest. These could include public EV charging stations, in-home EV charging infrastructure; residential metering and submetering; local utility distribution grid upgrades; and EV-related research and customer outreach. However, given the evident uncertainties in the number and types of EVs sold over the next half-decade, a measured approach to EV-related utility investments, is recommended. In addition, as some parties have pointed out, sales of EVs are likely to cluster in affluent residential areas, which would raise equity issues if EV-related distribution infrastructure costs are spread to all ratepayers.

Many parties have noted that marginal cost-based time-of-use energy rates provide the economically correct price signal for electric usage and are vital to encourage off-peak EV charging. If time-of-use electric rates are set appropriately, and EV owners as a class bear responsibility for the costs of utility distribution upgrades caused by EV electric demands, then both EV-owners and non-EV-owning electric ratepayers can benefit from incremental sales of energy to EV owners.

II. **Introduction**

Electric vehicles[1] stand to be a major transformative technology of the early 21st century. Numerous authors have noted the environmental benefits of EVs. Coupled with low-carbon and renewable-fueled electric generation, widespread adoption of EVs for personal and commercial transport is among the most promising avenues of reducing GHG emissions.

In recognition of environmental and other benefits of EVs, the federal government and some states have enacted income tax credits for EV purchases. This paper treats such credits as "given", it does not analyze whether or not such credits are in the public interest, or the appropriate magnitude of tax credits.

Even with tax credits, however, there will be costs associated with EV purchase and usage. In addition to costs of the EVs and their batteries (or fuel cells), costs may include[2]:

- public EV charging stations,
- in-home wiring upgrades needed for EV charging;
- residential metering, submetering, and load management;
- local utility distribution grid upgrades; and
- EV-related research and customer outreach.

A key issue for regulators is how such costs are to be shared among private (nonutility) investors, utilities, individual EV owners, and, potentially, non-EV owning electric utility customers. This question is a central topic of this paper.

As discussed below, the infrastructure costs required for transition to EV-based personal transportation are nontrivial and can become major barriers to EV adoption. Managing these costs equitably and efficiently will be key to the rapid adoption of EV technology. The following are suggested as general principles to guide regulatory agencies and state legislatures in formulating policies to promote EV ownership[3]:

- Minimize barriers to EV ownership;
- Maximize the environmental benefits of EVs;
- Maximize electric grid efficiency while minimizing costs and reliability impacts; and
- Ensure that costs are allocated equitably between EV owners and non-EV owning utility customers.

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[1] The term "electric vehicles" (EVs) is used in this paper to include "plug-in" electric vehicles only (both battery-only vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs)). Excluded from this definition are hybrid-electric vehicles (that do not take power from the electric grid). .

[2] Not included here are costs for possible upgrades to transmission networks and generation capacity. A key feature of EV charging loads is that most charging can occur at night, when transmission networks and generation facilities typically have spare capacity. A major objective of utilities and regulators should be to design rates to encourage nighttime charging, and thereby avoid or postpone upgrades to transmission networks and generation capacity.

[3] Although stated in slightly different terms, the principles stated here are largely the same as those stated in Comments Prepared by the "Environmental Coalition On Alternative-Fueled Vehicle Policies" and filed in the California PUC proceeding R.09-08-009 of October, 2009. These principles reflect a shared interest among environmental groups and consumer groups to encourage the growth of EV markets.

Of course, these objectives involve tradeoffs. Ideally, consumers should face prices which include all environmental benefits and costs caused by their energy consumption. In this ideal case the cost-benefit logic would determine how best to make these tradeoffs.[4]

Keeping EV operating costs low will be an essential element in overcoming the barriers to growth of EV markets. Thus, another key issue for regulators is what rates to charge for sales of electricity for vehicle fuel. Many utilities offer lower electric rates for nighttime usage. This is a feature of time-of-use (TOU) rates.[5] TOU rate design is especially advantageous for EV owners[6][7]. Therefore, utilities should offer TOU rates to their EV-owning customers, educate potential EV owners about TOU rate offerings, and encourage their EV-owning customers to be on TOU rates.

Prerequisite for a TOU rate design is installation of a TOU-capable meter. Such meters are often available at extra cost to customers of utilities that have not yet upgraded their systems to advanced, (or "smart") meters. Customers of utilities that have upgraded to Advanced Meter Infrastructure (AMI) need incur no incremental cost to go on TOU rates. Non-AMI utilities should encourage EV owners to install TOU-capable meters even if they are not planning system-wide "smart" meter rollouts.

Promotion of EV Ownership Is a Desirable Social Goal

A basic premise of this paper is that displacement of internal combustion engines by electric-fueled transportation is a desirable long-term social goal. Numerous authors have described potential benefits of EVs both to the environment, and to utilities[8]. An earlier conference paper by this author [Levin, 2008][9] identified four distinct stakeholder groups who can benefit from EVs, as follows:

1. Economic benefits to EV owners. Potentially, reduced vehicle operating costs over the life of the vehicle could more than offset the initial EV cost premium and other one-time EV charging installation costs. In the near term, however, economic benefits to EV owners

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[4] This discussion of tradeoffs among objectives was suggested by comments from Professor Lee Friedman of the University of California's Goldman School of Public Policy, whose paper on TOU pricing is cited below.

[5] Time-of-use rates vary by the time of day that electric consumption occurs. Such rates are typically lower at night because nighttime demands are typically lower and less efficient generation can be idled. Such rates would benefit residential EV owners to the extent they typically charge at home at night. Although overnight charging would increase night loads, the extent of such an increase is unlikely to exceed the daytime peak within the next decade, due to limitations on the growth rate of EV markets.

[6] For an excellent general discussion of the merits of time-of-use electricity pricing, see Friedman, Lee S., The Importance of Marginal Cost Electricity Pricing to the Success of Greenhouse Gas Reduction Programs, a . conference draft for presentation on November 6, 2009 at the Annual Research Conference of the Association for Public Policy Analysis and Management, Washington, DC.

[7] Levin, R. 2008 CRRI Conference Paper "Pricing Electricity for Cars" discusses of the applicability of TOU pricing to EV charging.

[8] A good summary of potential EV benefits is contained in a California PUC "Staff White Paper": "Light Duty Vehicle Electrification in California: Potential Barriers and Opportunities", by Matthew Crosby (primary author), May 2009.

[9] Levin, R. "Pricing Electricity for Cars", conference draft: June 2008, presented at the 2008 CRRI Western Conference, Monterey CA, June 2008

depend on federal and possibly state income tax credits for EV purchases. Justification for such tax credits is outside the scope of this paper.[10]

2. Benefits to non-EV owning electric ratepayers. Potentially, revenue from EV loads, in excess of the marginal cost of serving those loads, could be used to hold down rates for non-EV owning electric utility customers. Looked at another way, all utility customers can benefit from more efficient use of electric facilities enabled by EV charging loads. As discussed below, this benefit depends on EV owners bearing the costs of EV-related electric distribution infrastructure improvements.

3. Benefits to utility shareholders. As California utilities have pointed out, EV loads will ultimately result in additions to utility distribution ratebase. This is generally seen as a benefit to utility shareholders. Also, potentially, a portion of revenue from EV loads, in excess of the marginal cost of serving those loads, would be returned to shareholders in states that have not decoupled utility profits from electric energy sales.[11]

4. Environmental benefits. Benefits of reduced greenhouse gas (GHG) emissions vary depending on the type of electric generation that is "on the margin", i.e., supplying the EV load at any given time. Because of the efficiency of electric motors vs. internal combustion engines, even coal-fueled electricity results in fewer emissions per mile than gasoline. For natural gas-fired generation, per mile GHG emissions are reduced by about 50%, according to an estimate contained in a joint research report by the Electric Power Research Institute (EPRI) and the Natural Resources Defense Council (NRDC).[12]. For solar or wind-generated electricity, reductions of 90% are possible. Environmental benefits, of course, also flow to EV owners, other electric ratepayers, and utility shareholders and are in addition to the direct economic benefits described above.

In addition, authors have noted system benefits. For example, a large EV fleet, acting as distributed energy storage, could assist with load management and integration of wind energy, thus providing additional environmental and grid management benefits[13].

To obtain these benefits for the public, political and regulatory institutions should promote EV ownership. The degree to which these benefits can be realized, and the pace of market development, depend on many factors. Some of these factors, such as the price of gasoline, are

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[10] Tax credits could possibly be justified as a temporary measure to jump-start EV markets, and be phased out over time as battery costs, and the EV cost premium decrease. The justification for tax credits would need to rely on longer-term environmental or national security benefits not captured here. Ideally, in a few years the EV cost premium could decline to the point where tax credits are no longer needed; when operating cost savings would be sufficient to justify an EV purchase even without a tax credit.

[11] In some states, such as California, regulators have "decoupled" utility shareholder returns from sales, to avoid a disincentive for utilities to promote energy conservation. Such a mechanism would also ensure that ratepayers receive the full benefit of contribution to margin from increased sales (e.g., for EV charging).

[12] EPRI & NRDC: Environmental Assessment of Plug-in Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions. EPRI, Palo Alto, CA: 2007. 1015325, Executive Summary, p.7. The 50% reduction is for a plug-in hybrid electric vehicle with a 20-mile all-electric range. Single-fuel EVs will have greater GHG reductions.

[13] See, for example, "The Integration of Plug-In Hybrid Electric Vehicles (PHEVs) for Wind Balance", Conference Paper presented in the 2010 Western Conference of the Center for Research in Regulated Industries, Marcus Alexander, EPRI.

largely beyond the control of state PUCs and even state legislatures. Other factors, such as incentives and EV-friendly electricity rate options, are well within the purview of state institutions.

However, stakeholder interests can conflict if regulators fail to set electric rates equitably. For example, if rate increases are imposed on non-EV owners to pay for facilities required to serve EV loads, such actions could be inequitable and could negate the benefits that non-EV owners might otherwise receive from the growth of EV loads. Regulators must exercise care to ensure that EV-related costs are recovered equitably in rates.

Finally, a crucial fifth stakeholder perspective, that of the taxpayer, is not explicitly considered in this paper.

III: **Costs and Benefits of EV Ownership from Multiple Stakeholder Perspectives**

The following sections briefly describe each of the four major stakeholder perspectives discussed above and provide an illustrative quantitative estimate of EV costs and benefits. We start with the utility perspective because that defines the infrastructure costs considered in this paper.

A. **Electric Utility Costs and Benefits of In-Home EV Charging**

This analysis includes the following utility costs:[14]

- A [separate] TOU meter;
- An EV Supply Unit[15];
- A [possible] upgrade of the distribution line transformer(s) serving the EV customer; and
- A possible (or imputed average) cost per kW to upgrade the upstream distribution system serving the customer to accommodate EV charging demand.

These utility distribution infrastructure investments, which are discussed in more detail below, may or may not be required for any specific residential (home) EV charging installation, but may be required for many such installations in clusters or scattered across utility service areas. All the costs listed below are intended as purely illustrative:

- **TOU Metering:** For utilities that have installed Advanced Metering Infrastructure (AMI), the customer's meter is capable of registering household usage (including EV usage), by time of use, and a separate meter may not be required. On the other hand, there may be significant reasons to install a separate meter to register EV usage separately from household usage. The case for separate metering of EV loads is discussed below.
  For non-AMI utilities, in most cases residential meters register cumulative kWh only, and hence cannot be used to bill TOU rates. Such utilities should be directed to install TOU-

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[14] Costs for home wiring upgrades (e.g., to accommodate Level 2 (240 volt) charging) are included in the EV owner's perspective and excluded from the utility perspective. Typically, household wiring costs are borne by the homeowner and are not included in utility ratebase.

[15] For the purpose of this illustrative analysis, it is assumed that meters and EVSE will be owned and ratebased by the utility. However, other ownership arrangements should not be precluded.

capable meters for residential EV owners, either for the entire household load, or for separate measurement of EV loads. As discussed below, the latter alternative may be preferable. In either case, an incremental metering cost of $600 is assumed for this illustrative analysis.[16]

- **EV Supply Equipment (EVSE):** Such equipment would supply power to the EV battery packs, typically at 240 volts, with a standard (J1772) plug, and may contain hardware and logic for load management (i.e., to allow either utility control, or customer-programmable control of the timing of EV charging, or both). EVSE may or may not include submetering. A cost of $850 is assumed.

- **Neighborhood Distribution Transformer Upgrade:** California utilities have pointed out that clustering of EVs in affluent neighborhoods is likely, and that such clustering could require upgrades to distribution line transformers. As a relatively conservative estimate, we assume the cost of a transformer replacement is about $5,000, but only occurs on average once per every 10 residential EV installations. This yields an average transformer upgrade cost per residential EV installation of $500.

- **EV-related Upstream Distribution Capacity Upgrade:** A typical Level 2[17] charging installation could impose a demand of 3.6 kW (240 volts, 15 amps), though a small percentage of residential charging installations could draw up to 40 amps of current. It is anticipated that most charging will occur off-peak (i.e., in the overnight hours). However, distribution planners must plan for the occurrence of some peak-hour charging. As an illustration, a 25% peak coincidence factor is assumed for this analysis, i.e., on average, 0.9 kW would occur on peak. A typical value of marginal distribution capacity cost in California is $50 per kW-year. Assuming a 10% annualization factor, the marginal cost of distribution capacity is about $500 per kW, or $450 on average, per 0.9 kW (peak) EV charging installation load.

The following table summarizes our illustrative utility residential EV-infrastructure costs per vehicle:

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[16] Costs for home wiring, metering and EVSE are from the DOE. DOE (2008), *Plug-In Hybrid Electric Vehicle Charging Infrastructure Review*, Final Report, Battelle Energy Alliance, Contract no. 58517. U.S. Department of Energy Vehicle Technologies Program – Advanced Vehicle Testing Activity. INL/EXT -08-15058. Cost estimates from this DOE report were cited in Comments of the "Environmental Coalition" in the California PUC's EV rulemaking, R.09-08-009, dated October 5, 2009.

[17] Most in-home EV charging will either be at 110 volts (Level 1), or 240 volts (Level 2). California utilities generally expect Level 2 charging to predominate. The illustrative examples presented here are based on Level 2 charging. Level 1 charging would be less costly initially than Level 2 charging, both for EV owners and utilities, but would also be less versatile.

Table 1: Illustrative Utility Costs for Home EV Charging Infrastructure

Cost Item	Utility Cost	Annualized Cost[18]	Monthly Cost
Metering	$600	$60	$5
EVSE	$850	$85	$7.08
Line Transformer Upgrade	$500	$50	$4.17
Upstream Dist. Capacity Upgrade	$450	$45	$3.75
TOTAL COST	**$2,400**	**$240**	**$20**

These costs could add a total of $2,400 in utility rate base per EV, as illustrated above. This does not include costs of public charging infrastructure, or costs of in-home wiring upgrades (e.g., installation of new 240 volt circuits).

With 1,000,000 EVs expected by the next decade, the need to accommodate EV energy demand could increase utility rate base by $2.4 billion, and utility return by $216 million annually[19] (per million EVs).

B. **<u>EV Owner's Costs and Benefits</u>**

Typically, an EV owner must pay a substantial premium above the cost of a comparably equipped gasoline powered vehicle. This cost premium could be partially offset by tax credits. In exchange, the EV owner can expect to benefit by reduced operating costs over the life of the vehicle, primarily for lower fuel costs. The amount of the savings will depend on gasoline costs as well as electric utility energy rates and fixed charges.

In addition to the one-time costs of the EV (i.e., a $12,000 premium is assumed, offset by a $7,500 tax credit), many homeowners who wish to charge at 240 volts will need a home wiring upgrade, estimated by DOE at $1,296.[20] This analysis assumes that the electric utility will own the meter and the EVSE, and that the EV owner may (or may not) pay monthly fixed charges for these items. In either case, it is assumed that the EV owner will not incur "up front" costs for these items.

Offsetting these one-time fixed costs, the EV owner can normally expect to save on operating costs, due to the lower cost per mile of electric energy "fuel" vs. gasoline.

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[18] For utility capital investments with multiyear service lives, utilities often annualize costs by applying a real economic carrying cost (RECC) (levelizing the cost in real terms over the equipment service life). The RECC is typically about 10% for distribution facilities. The illustrative examples presented herein are based on a 10% RECC.
[19] Assuming the utility is allowed a 9% return on ratebase.
[20] Per DOE(2008), *Plug-In Hybrid Electric Vehicle Charging Infrastructure Review*, Final Report, Battelle Energy Alliance, Contract no. 58517. U.S. Department of Energy Vehicle Technologies Program – Advanced Vehicle Testing Activity. INL/EXT -08-15058. This estimate includes $216 in "administration costs". Obviously, home wiring upgrade costs can vary widely.

In the illustrations presented below, EV charging is assumed to take place off-peak at a flat TOU energy rate of 10 cents per kWh. Appendix A presents alternative scenarios of 15 cents and 30 cents per kWh, respectively. The latter price (30 cents) is about the marginal price many California electric customers would face under the current, non-time-differentiated increasing block rates. We illustrate the EV Owner's costs and benefits under 2 scenarios for gasoline, $3 per gallon, and $5 per gallon, as follows:

Table 2a below, shows a net vehicle life cycle cost of $1,053, given 10 cent electricity and $3 gasoline. This analysis includes an assumption that the EV owner will pay a fixed charge of $20 per month to defray the costs of a [separate] TOU-meter, an EV Supply Unit, and the average cost per EV installation of replacing a neighborhood distribution line transformer, plus the average (incremental or marginal) cost of upstream utility distribution upgrades as a function of the EV's demand. These charges, and the rationale for imposing them, are discussed below.

Table 2a: Illustrative EV Owners Net Cost Assuming $3 per Gallon of Gasoline and 10 Cents per kWh For Electric Energy. Cost Includes a Monthly Fixed Charge of $20 for Metering & Distribution

ONE-TIME COSTS		
Vehicle Cost Premium	$	12,000
Tax incentive	$	(7,500)
Net Vehicle Premium	$	4,500
Home wiring upgrade	$	1,296
Meter	$	-
EVSE	$	-
Total One-Time Cost	**$**	**5,796**
NPV Operating Savings		**($4,743)**
NPV Overall Net Cost		**$1,053**

MONTHLY COSTS			
Meter Chg. (incl. EVSE)			$12.08
Elect Dist. Upgrade Chg.			$ 7.92
Electric Energy			$ 25.00
Gasoline offset			($120.00)
TOTAL Monthly Cost			**($75.00)**
INPUT ASSUMPTIONS			
Annual Miles driven		12000	miles
Miles/kWh		4	mi/kwh
Electric rate		**$0.10**	**per kWh**
Miles/gal		25	mi/gal
Cost of Gasoline		**$3.00**	**per gal**
Vehicle life		7[21]	years
Cost escalators	Elec.		3%
	Gas.		3%
Owners Cost of Capital			10%

[21] Reviewers have pointed out that assumption of a 7-year life may be overly conservative.

If the cost of gasoline rises to $5 per gallon, instead of the $3 shown in Table 2a, the EV owner would realize a net present value *benefit* of slightly over $4,000, assuming electricity remains at 10 cents per kWh[22] (see, Table 2b). A 15 cent electricity price would reduce the NPV benefit to about $3,200 (Appendix A, Table 2c). A 30 cent electricity price (typical for increasing block, non-TOU rates) would reduce the NPV benefit by nearly 80%, to under $1,000, making the purchase of an EV marginal, even with $5 gasoline (Appendix A, Table 2d). EV owners should not be on tiered, non-TOU rates.

The illustrative $20 monthly fixed metering and distribution upgrade charge reduces the customer's net present value operating benefit by about $1,264 over the assumed seven year vehicle life. Removal of these fixed charges would make the EV marginally economic, even with $3 gasoline. Tables 2e and 2f (see Appendix B), repeat these examples, but without utility monthly fixed charges. Clearly, EV owners would be better off without such fixed charges, but, as discussed below, if EV-related distribution infrastructure costs are collected instead from non-EV owning ratepayers, that latter group may be harmed by costs resulting from EV ownership.

Table 2b: Illustrative EV Owners Net Cost Assuming $5 per Gallon of Gasoline and 10 Cents per kWh For Electric Energy. Cost Includes a Monthly Fixed Charge of $20 for Metering & Distribution

ONE-TIME COSTS			**MONTHLY COSTS**		
Vehicle Cost Premium	$	12,000	Meter Chg. (incl. EVSE)		$12.08
Tax incentive	$	(7,500)	Elect Dist. Upgrade Chg.		$ 7.92
Net Vehicle Premium	$	4,500	Electric Energy		$ 25.00
			Gasoline offset		($200.00)
Home wiring upgrade	$	1,296	**TOTAL Monthly Cost**		**($155.00)**
Meter	$	-	**INPUT ASSUMPTIONS**		
EVSE	$	-	Annual Miles driven	12000	miles
Total One-Time Cost	**$**	**5,796**	Miles/kWh	4	mi/kwh
			Electric rate	**$0.10**	**per kWh**
NPV Operating Savings		**($9,802)**			
			Miles/gal	25	mi/gal
NPV Overall Net Cost		**($4,006)**	**Cost of Gasoline**	**$5.00**	**per gal**
			Vehicle life	7	years
			Cost escalators	Elec.	3%
			Gas.		3%
			Owners Cost of Capital		10%

[22] Since gasoline and electric energy are partial substitutes, it is reasonable to assume that electricity could be somewhat more expensive in a $5 per gallon gasoline scenario, compared to its price when gasoline is $3 per gallon. Appendix A contains a scenario with $5 per gallon electricity and 15 cents per kWh electricity. To illustrate the effect of increasing block (tiered) pricing, a second scenario of $5 gasoline paired with 30 cent per kWh electricity is also provided.

C. Impact of Home EV Charging on Non-EV Owning Electric Ratepayers

Development of residential EV home charging could be either beneficial or harmful to non-EV owning electric ratepayers, depending on how the utility recovers the incremental costs of providing distribution and metering services to residential EV owners.

In the utility perspective illustrated above, the utility spends $2,400 in capital per EV owner, for metering and distribution upgrades. On an annualized basis, this translates to about $240, or $20 per month. If the EV owner pays this amount as a monthly fixed charge, then there is no impact from these utility investments, on average, to non-EV owning ratepayers.

With an illustrative $20 monthly fixed EV-owner Distribution upgrade and metering charge, the EV owner will contribute $540 in annual revenue: $240 to offset distribution and metering costs, and $300 for energy. The non-EV owner will benefit by the contribution to margin in the EV-owner's energy rate.[23] In our illustrative example, it is assumed that the EV owner will pay an off-peak rate of 10 cents per kWh for charging, and that the off-peak marginal energy cost is 7.5 cents per kWh. Utility marginal costs would total $465: $225 for energy (3,000 kWh) and $240 for metering and distribution. In this case, EV owners contribute $75 ($540-$465) to margin, and ratepayers benefit by 2.5 cents for every kWh sold, as this contribution to margin is used to offset the utility's fixed costs. According to the illustration below, ratepayers would benefit by $75 million annually for every 1,000,000 EVs on the road.

Now, consider the consequences of *not* imposing a distribution upgrade charge on EV owners. Utility costs are still $465, but EV owners are only contributing $300. In this case, there is a negative contribution to margin of $165, which must be made up by other ratepayers. Without a monthly EV owners fixed charge, ratepayers are harmed in the amount of $165 million per year per 1,000,000 vehicles on the road. Table 3 shows the impact of residential EV charging on non-EV-owning utility customers.

Clearly, fundamental principles of equity suggest that EV owners be assessed the costs of EV-related metering and distribution upgrades. This may require utilities and PUC's to create new ratemaking mechanisms[24], since, normally, costs of shared distribution upgrades are borne by all ratepayers. With respect to the allocation of EV-related infrastructure costs to EV owners, what sets this situation apart from other electric uses such as swimming pool heaters, plasma TVs, etc is the sheer scale of the power consumption of a large residential EV charging installation. For

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[23] This assumes that utility profits are decoupled from sales, as they are in California. Absent decoupling, a portion of the contribution to margin from increased electricity sales to EV owners could go to utility shareholders. However, even without decoupling, non-EV owning ratepayers should benefit from EV sales.

[24] In California, investments needed to serve major incremental loads can fall under Special Facilities (Tariff Rule 2) or Line Extension provisions (Tariff Rules 15 and 16) when such investments are dedicated to a single customer. Where transformers are dedicated to individual customers (typical for medium & larger businesses), existing tariff rules may grant an "allowance" for upgrades due to increased customer load. Amounts in excess of that allowance are borne by the individual customer. For residential and small nonresidential users, transformers normally serve several customers. There is currently no tariff mechanism to assign shared facility upgrade costs to subgroups of customers; such costs would be borne by ratepayers generally. The author believes that these tariff rules may be inadequate to handle EV-related investments in distribution infrastructure that is shared by two or more customers. New tariff rules may be needed to deal with, for example, neighborhood transformer upgrades caused by residential EV charging installations.

example, a 240 volt, 30 amp installation would draw 7.2 kW, more than the maximum power consumption of a typical house. Even one such installation could trigger a transformer upgrade, two such installations on the same block would likely cause the utility to upgrade its neighborhood distribution circuit. If EV markets take off, these distribution upgrade costs become significant.

One way to proceed would be to require the utilities to track the cost of EV-related upgrades, and create a balancing account for distribution upgrade charges. These charges would be adjusted periodically to ensure that EV infrastructure charge revenues and EV-related infrastructure upgrade costs are roughly in balance. Such a mechanism would create a "pool" of money to be used for EV-related distribution upgrades. EV owners would pay a fixed monthly fee into the pool, in proportion to the kW rating of their EV charging installation. In most cases, this would be in the range of $5 to $25 per month and would not significantly deter EV purchases. It would, however, alleviate equity concerns that consumer groups like DRA would have about rate impacts on non-EV owners.

Table 3: Non-EV Owning Ratepayer Perspective

	With $20 Monthly Fixed Distribution Upgrade and Meter Charge			**With No Fixed Charge**		
		Per Vehicle-Year			**Per Vehicle-Year**	
	Per kWh	**kWh**	**Total**	**Per kWh**	**kWh**	**Total**
Revenue (Energy Charge)	$0.10	3000	$300	$0.10	3000	$300
Revenue (Fixed Charges)			$240			$0
Total Revenue			**$540**			**$300**
Marginal Energy Cost	$0.075	3000	$225	$0.075	3000	$225
Marginal Dist.+Meter Cost			$240			$240
Total Incremental Cost			**$465**			**$465**
Contribution to margin (CTM)			**$75**			**($165)**
CTM per 1,000,000 vehicles		**$75,000,000**			**($165,000,000)**	

D. Environmental Benefits of EV Ownership

In 2007, EPRI estimated that Greenhouse Gas (GHG) emissions per mile for a PHEV-20[25] would be about one-half of the comparable emissions for a comparable gasoline powered vehicle, on the assumption that electricity is generated by a conventional natural gas-fired power plant. EPRI's results for other electric generation technologies are shown in Appendix C. Based on EPRI 2007 data[26], the environmental benefits of PHEVs can be summarized in the following table.

Table 4a: GHG Reductions for Displacement of Gasoline Vehicles By PHEVs

	GHG emissions (Grams per mile)	**GHG emissions (Tons per vehicle-year)**	**GHG Emissions (Tons per million vehicle-years)**
Gasoline-powered vehicle	450	5.4	5.4 million
PHEV	225	2.7	2.7 million
GHG Benefit	225	2.7	2.7 million

The GHG reduction potential of a BEV is significantly greater than for a PHEV. According to EPA GHG emission standards for a BEV, a GHG emission rate of 177 grams per mile can be expected, as compared to the EPRI estimate of 225 grams per mile from a PHEV[27]. Table 4b summarizes the GHG benefits for a BEV.

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[25] A midsize plug-in hybrid electric vehicle capable of traveling 20 miles in all-electric mode. Only about one-half of the comparable gasoline-fuels vehicle miles were assumed displaced in this EPRI analysis.

[26] EPRI & NRDC: Environmental Assessment of Plug-in Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions. EPRI, Palo Alto, CA: 2007. 1015325, Executive Summary, p.7

[27] Per e-mail correspondence from Simon Mui of NRDC, the U.S. Environmental Protection Agency's final GHG emission standards for vehicles included the following, which ends up getting 177 grams CO2/mile for the EV on the average national grid:
"Production beyond the cumulative vehicle production cap for a given manufacturer in MY2012-2016 would have its compliance values calculated according to a methodology that accounts in full for the net increase in upstream GHG emissions. For an EV, for example, this would involve: 1) measuring the vehicle electricity consumption in watt-hours/mile over the 2-cycle test (in the example introduced earlier, a midsize EV might have a 2-cycle test electricity consumption of 230 watt-hours/mile), 2) adjusting this watt-hours/mile value upward to account for electricity losses during transmission and vehicle charging (dividing 230 watt-hours/mile by 0.93 to account for grid/transmission losses and by 0.90 to reflect losses during vehicle charging yields a value of 275 watt-hours/mile), 3) multiplying the adjusted watt-hours/mile value by a nationwide average electricity upstream GHG emissions rate of 0.642 grams/watt-hour at the powerplant (275 watt-hours/mile multiplied by 0.642 grams GHG/watt-hour yields 177 grams/mile), and 4) subtracting the upstream GHG emissions of a comparable midsize gasoline vehicle of 56 grams/mile to reflect a true net increase in upstream GHG emissions (177 grams/mile for the EV minus 56 grams/mile for the gasoline vehicle yields a net increase and EV compliance value of 121 grams/mile). The full accounting methodology for the portion of PHEV operation on grid electricity would use this same approach."

Table 4b: GHG Reductions for Displacement of Gasoline Vehicles By BEVs

	GHG emissions (Grams per mile)	GHG emissions (Tons per vehicle-year)	GHG Emissions (Tons per million vehicle-years)
Gasoline-powered vehicle	450	5.4	5.4 million
BEV	177	2.1	2.1 million
GHG Benefit	273	3.3	3.3 million

Dollar values of the GHG benefits from a fleet of one million EVs for the two cases discussed above are estimated in Tables 4c and 4d:

Table 4c. Value of GHG Reduction From A Fleet Consisting of PHEV-20s[28]

	Annual Dollar Value of GHG reduction, per million vehicles	Net Present Value of GHG reduction, per million vehicles, over the vehicle life
Benefit @ $8 per ton	$22 million	$114 million
Benefit @ $30 per ton	$81 million	$427 million

Table 4d. Value of GHG Reduction From A Fleet Consisting of BEVs[29]

	Annual Dollar Value of GHG reduction, per million vehicles	Net Present Value of GHG reduction, per million vehicles, over the vehicle life
Benefit @ $8 per ton	$26 million	$139 million
Benefit @ $30 per ton	$99 million	$522 million

These calculations account only for the GHG reductions from substitution of electricity for gasoline, and do not include other potential environmental benefits of EV, such as their use as distributed storage to assist in integrating wind generation. The distribution of these GHG reduction benefits amongst members of society is currently uncertain, though utilities and EV owners may be impacted to the extent these costs are internalized through a cap and trade market of carbon allowances, or by the allocation of other environmental credits.[30]

[28]Based on the 2007 EPRI Data for PHEVs used in Table 4a.

[29]Based on the EPA emissions data for BEVs used in Table 4b.

[30] For example, California EV owners could potentially receive credits under that state's Low Carbon Fuel Standard program.

E. Summary Of EV Benefits to Four Stakeholder Groups

Table 5 summarizes the benefits to the four stakeholder groups under varying assumptions: $3 and $5 per gallon gasoline; and EV owners or all ratepayers pay for EV-related infrastructure costs.

Table 5: Do Stakeholders Benefit From EV Market Development

Stakeholders	$3 Gasoline EV Owners Pay for Dist. Upgrades	$3 Gasoline Ratepayers Pay for Dist. Upgrades	$5 Gasoline EV Owners Pay for Dist. Upgrades	$5 Gasoline Ratepayers Pay for Dist. Upgrades
Utility Shareholders	Yes	Yes	Yes	Yes
EV Owners	No	Marginal	Yes	Yes
Ratepayers	Yes	No	Yes	No
Environment	Yes	Yes	Yes	Yes

While regulators cannot control the price of gasoline, they can certainly ensure that EV owners pay for the costs of EV-related infrastructure upgrades. Doing so will promote equitable rates. While charging EV owners for the costs of EV-related infrastructure will not ensure a desirable win-win-win-win outcome, it appears to be a necessary condition for such an outcome. Further, these examples suggest that, while modest fixed monthly charges for metering and distribution upgrades can be significant in a low gasoline price scenario, such charges are not likely to deter EV purchases when gasoline prices increase.

IV. Overcoming Barriers to EV Ownership

Prospective EV owners have a lot of issues to think about, beyond those posed by purchase of a conventional vehicle. A nonexhaustive list of such issues follows:

- The initial vehicle cost, as compared to the cost of a comparable conventional vehicle;
- The operating cost of the EV, including electricity costs, gasoline costs (for PHEVs) and maintenance costs;
- The vehicle's range (for BEVs);
- Where and when the vehicle will be charged;
- The cost of any home wiring and metering upgrades needed;
- Any permits required by local authorities; and
- Notification of the local utility and any special metering and rate options to be considered;

The largest single barrier for many potential EV owners is the initial cost on an EV. While the decision to purchase an EV will, in many cases, be made on other than purely economic grounds, in many cases the issue of whether operating cost savings will offset the purchase cost premium can be decisive. The availability of low-cost electric energy looking forward over the vehicle's useful life is a key factor in vehicle purchase economics.

Perhaps the second largest barrier, at least for [prospective] BEV purchasers, is the issue of the vehicle's range. This is closely coupled with the availability of public charging stations.

Another potentially significant barrier for many prospective BEV purchasers is the cost and "hassle" of upgrading home wiring to accommodate 240 volt charging. While many PHEV owners may experience satisfactory charging times at 110 volts, many BEV owners will want to charge at 240 volts to allow for a complete charge in 8 hours or less (e.g., overnight). Installation of a new 240 volt circuit can cost $1,000 to $2,000 or more depending on the existing house wiring and the desired electric current capacity (amperage).

In addition to possible voltage upgrades, EV owners must decide whether to notify their utility and discuss with their utility their options to separately meter their EV, install a TOU meter, install load control (if so, what type), and what rate options are available. These options could also add $1,000 to $2,000 to the initial cost of owning an EV.

<u>Costs of Transitioning to EV-Based Personal Transportation</u>
Potential EV transition costs discussed here include costs of public charging facilities, wiring and metering for in-home charging facilities, reinforcement of utility electric distribution grids, and customer education. A key issue for regulators is how such costs are to be shared among private (nonutility) investors, utilities, and individual EV owners.

Among the key levers influencing these costs will be:

Vehicle choice:
- Battery-only EVs (BEVs) vs. Plug-In EV (PHEVs)

Incentives:
- Taxpayer-funded vs. Ratepayer-funded vs. None; and
- Vehicle purchase, home wiring upgrade, both, or neither

Charging Behavior
- Public vs. In-home charging;
- Daytime vs. Nighttime charging; and
- Level 1 (110 volt) charging vs. Level 2 (240 volt) charging

Metering and load control:
- Time-of-use (TOU) metering vs. non-TOU metering;
- Separate metering of residential EV loads vs. single metering of combined EV and household loads; and
- EVSE with load control vs. No automatic load control

Electric pricing (rates) for EVs:
- EV-friendly residential rates vs. Standard household rates;
- TOU rates vs. Non-TOU rates;
- Flat rates vs. tiered rates;
- Discounted ("Economic Development"rates) vs. Undiscounted Rates; and
- Separate Residential EV rate class vs. No separate residential EV rate class;

Infrastructure cost responsibility--
- EV owners bear in-home wiring & meter upgrade costs vs. All ratepayers bear upgrade costs; and
- EV owners bear neighborhood distribution upgrade costs vs. All ratepayers bear upgrade costs

Many of the levers listed above are interrelated. All can influence the cost of owning and operating an EV, and some may impact costs for non-EV owners, as well. Many of these levers will be set by consumer choice. Among the most important will be consumer preference for BEVs vs. PHEVs. This choice will have a profound effect on many of the other levers, particularly charging behavior and the need for additional in-home and utility electric infrastructure.

While consumer choice is key, actions by state Public Utilities Commissions (PUCs) can have a profound impact on the initial costs and ongoing costs faced by [prospective] EV owners. The remainder of this paper focuses on the key actions, primarily with respect to rate design, that PUCs can take to minimize the barriers to adoption of EV technology.

Minimizing Barriers to EV Ownership: Vehicle Costs

In the longer term, the initial EV cost barrier can be overcome to some extent by funding research to encourage improvements in battery technology, e.g., through tax incentives or tax credits. In the shorter term, direct tax credits for EV purchase incentives can be provided.[31] Perhaps the most important action that PUCs can take is to ensure that utilities offer EV-friendly TOU rate options, to maximize the likelihood that operating cost savings will, over the vehicle's useful life, offset the initial cost premium.

Minimizing Barriers to EV Ownership: Range Anxiety and Public Charging Facilities

Range concerns should best be dealt with by streamlining the development of commercial public charging stations and perhaps through tax incentives for development of public charging infrastructure. Beyond tax incentives, funding for commercial public charging stations should be largely from private, rather than public, or ratepayer funds. For reasons enumerated below, it would be unwise to direct substantial public or ratepayer funds to building commercial public charging facilities.

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[31] Ratepayer funded incentives for EV purchases would raise significant equity issues, due to undesirable income redistribution effects.

First, such facilities are unnecessary for PHEV owners, who can charge exclusively at home without "range anxiety"[32]. Second, commercial public charging facilities are likely to see primarily daytime use, which places far more stress on grid capacity and also usually entails use of more polluting electric generation. Third, a rapid utility-funded or taxpayer-funded development of commercial public charging facilities risks "putting the cart before the horse" with attendant risks of stranded costs should EV markets develop slowly or market development indicates that most EV owners prefer home charging.

Initially, most EV charging is likely to occur at home[33]. It is unclear whether a network of public charging stations is a necessary precursor to development of EV markets; it may be that EV markets and charging stations will develop in parallel. As EVs become more popular, many public facilities such as shopping centers may offer charging facilities as a means to lure customers, and private investors will perceive opportunities to invest in charging infrastructure. Such investments do not require subsidies provided by public or ratepayer funds.

In summary, the use of public and/or ratepayer funds, if any, would be better directed toward customer research, education, and outreach, rather than in developing commercial public charging facilities, which can largely be left to market forces.

Minimizing Barriers to EV Ownership: Separate Metering for EVs

A separate meter is not necessary for EV charging. Many PHEV owners and some BEV owners may simply plug in to existing household circuits, typically at 110 volts[34]. Nevertheless, as discussed above, EV owners should be strongly encouraged to arrange for a TOU-capable meter for their household, to be able to take advantage of lower nighttime rates for overnight charging. A single TOU-capable meter and a "whole-house" TOU rate could be the least-cost option for some customers, in the short run.

Installation of a separate (second) meter to measure EV charging consumption separately from household electricity consumption would increase the cost of EV ownership and therefore should remain optional, at least for Level 1 charging, during the early phases of EV market development. However, there are several good reasons for separately metering EV loads:
First, as electric energy displaces gasoline as a transportation fuel, the amount of tax revenue collected for transportation infrastructure maintenance will decline relative to vehicle miles travelled. At some point, it will likely be necessary to tax electric energy used for transportation, to support road maintenance. Separate metering would facilitate collecting such a tax.

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[32]BEVs can also charge at home provided they are used for short trips.

[33] A recent EPRI study, cited in a workshop held by San Diego Gas and Electric Co. on January 22, 2010 found that over 95% of potential PHEV owners would prefer to charge at home.

[34] California utilities believe that EV owners will predominantly prefer to charge at 240 volts (Level 2). The utilities cite shorter charging times and greater flexibility to control the timing of charging. Level 2 charging entails significantly greater costs, both for in-home charging infrastructure and for EV-related distribution upgrades.

Second, PUCs may require electric utilities to pass environmental compliance credits back to their EV-owning customers. An example would be California's Low Carbon Fuel Standard (LCFS).[35] The LCFS mandates a 10 percent reduction in the average fuel carbon intensity for all fuels distributed in California by 2020. The regulation will take effect January 1, 2011. California Executive Order S 01-07, which established the LCFS, states "The Public Utilities Commission, …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. Separate metering would facilitate EV-owning customers receiving compliance credit for their EV usage.

Finally, it will become increasingly important for the utilities to gather data on the hourly usage profiles of their EV loads. As one possible application, once sufficient EV load data has been gathered, PUCs can order regulated utilities to establish a separate rate class for residential EV charging usage. Thus, as EV markets develop, PUCs should consider encouraging separate metering of EV loads with TOU-capable meters, as a transitional step toward making separate metering mandatory.

A Separate Rate Class for Utility Sales for Residential EV Charging?

There are good reasons that PUCs may ultimately want to establish a separate rate class, with its own cost-of-service, for residential EV charging. First, the hourly load profile for EV charging is likely to be very different than for non-EV household usage. This proposed "Residential EV" class is likely to have a significantly lower cost of service, per kWh, than the Residential class. This is because most residential EV charging is expected to occur at night, when marginal energy and capacity costs are lower. For states which base rates on marginal costs, such as California, lower marginal costs translate to a lower cost-of-service, lower revenue responsibility, and lower rates[36].

Second, some utilities may be reluctant[37] to offer "whole-house" TOU rates that are highly time differentiated, for fear of revenue loss if household energy usage is shifted from day to night hours. This concern would not apply to separately metered EV loads, and there should be no reluctance to sell energy for EV charging at very low overnight rates, provided such rates are above the nighttime marginal cost of electricity. Though separately metered EV loads are certainly possible without establishing a separate EV charging class, the rates themselves could be even lower with a separate class because of the use of EV class-specific billing determinants to develop rates.

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[35] This discussion of California's LCFS program is excerpted from the May 2009 California PUC "Staff White Paper" "Light Duty Vehicle Electrification in California: Potential Barriers and Opportunities", by Matthew Crosby (primary author), May 2009.

[36] For a discussion of the role of marginal costs in ratesetting, See Friedman, Lee S., The Importance of Marginal Cost Electricity Pricing to the Success of Greenhouse Gas Reduction Programs, a . conference draft for presentation on November 6, 2009 at the Annual Research Conference of the Association for Public Policy Analysis and Management, Washington, DC.

[37] While utility preferences are not a valid economic criterion for setting rates, in recent years all major comprehensive rate design proceedings in California have been settled.

V. **Conclusion**

Transition from gasoline-fueled personal transportation to electricity-fueled transportation can simultaneously benefit EV owners, electric utility shareholders, electric ratepayers, and the environment. However, such a win-win-win-win outcome is not assured; a necessary condition is that non-EV owning ratepayers are not burdened with EV-related electric infrastructure costs. This can be accomplished with modest monthly fixed charges assessed by utilities to EV owners, to cover the average cost of EV-related distribution upgrades. Such charges should also be assessed for utility-owned second meters and electric vehicle supply equipment (EVSE), if any. While such EV infrastructure charges may not be negligible, they are unlikely to be large enough to significantly impede EV market growth if the price of gasoline increases faster than the price of off-peak electricity.

With appropriate EV infrastructure charges, and provided that most EV charging takes place at night and under appropriately set time of use rates, EV owners would provide a revenue stream which [slightly] exceeds the marginal cost of serving them. This revenue stream would partially cover utility fixed costs that would otherwise be borne by existing utility customers. This "contribution to margin" should enable utilities to keep rates lower than they would otherwise be, thereby providing a benefit to all ratepayers.

If regulators fail to assess appropriate fixed infrastructure charges to EV owners, but instead pass EV-related infrastructure costs on to the general body of ratepayers, these costs could negate the potential benefits of contribution to margin from EV loads. Non-EV owners could be harmed, instead of benefitting, from EV market development. Such an outcome would be inequitable and could even contribute to a ratepayer backlash over high electric rates that could slow the transition to electric transportation.

In summary, regulators must proceed with care to ensure that electric rates to EV owners are both cost-based and equitable. Such a course would maximize the likelihood of a win-win-win-win outcome that would benefit all — EV owners, utilities, ratepayers, and the environment — and facilitate the rapid adoption of electric vehicles for personal transportation.

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Appendix A: EV Owners Perspective: Alternative Electric Rate Scenarios

Table 2c: Illustrative EV Owners Net Cost Assuming $5 per Gallon of Gasoline, and 15 Cents per kWh For Electric Energy. Costs for Metering & Distribution Upgrades Assumed Borne By EV Owners

ONE-TIME COSTS		
Vehicle Cost Premium	$	12,000
Tax incentive	$	(7,500)
Net Vehicle Premium	$	4,500
Home wiring upgrade	$	1,296
Meter	$	-
EVSE	$	-
Total One-Time Cost	**$**	**5,796**
NPV Operating Savings		**($9,011)**
NPV Overall Net Cost		**($3,215)**

MONTHLY COSTS			
Meter Chg. (incl. EVSE)			$12.08
Elect Dist. Upgrade Chg.			$ 7.92
Electric Energy			$ 37.50
Gasoline offset			($200.00)
TOTAL Monthly Cost			**($142.50)**
INPUT ASSUMPTIONS			
Annual Miles driven		12000	miles
Miles/kWh		4	mi/kwh
Electric rate		$0.15	per kWh
Miles/gal		25	mi/gal
Cost of Gasoline		$5.00	per gal
Vehicle life		7	years
Cost escalators	Elec.		3%
	Gas.		3%
Owners Cost of Capital			10%

Table 2d: Illustrative EV Owners Net Cost Assuming $5 per Gallon of Gasoline, and 30 Cents per kWh For Electric Energy. Costs for Metering & Distribution Upgrades Assumed Borne By EV Owners

ONE-TIME COSTS		
Vehicle Cost Premium	$	12,000
Tax incentive	$	(7,500)
Net Vehicle Premium	$	4,500
Home wiring upgrade	$	1,296
Meter	$	-
EVSE	$	-
Total One-Time Cost	**$**	**5,796**
NPV Operating Savings		**($6,640)**
NPV Overall Net Cost		**($844)**

MONTHLY COSTS		
Meter Chg. (incl. EVSE)		$12.08
Elect Dist. Upgrade Chg.		$ 7.92
Electric Energy		$ 75.00
Gasoline offset		($200.00)
TOTAL Monthly Cost		**($105.00)**
INPUT ASSUMPTIONS		
Annual Miles driven	12000	miles
Miles/kWh	4	mi/kwh
Electric rate	$0.30	per kWh
Miles/gal	25	mi/gal
Cost of Gasoline	$5.00	per gal
Vehicle life	7	years

Appendix B: Additional EV Owners Perspective Cost-Benefit Analyses

Table 2e: Illustrative EV Owners Net Cost Assuming $3 per Gallon of Gasoline, and 10 Cents per kWh For Electric Energy. Costs for Metering & Distribution Upgrades Assumed Borne By Other Ratepayers

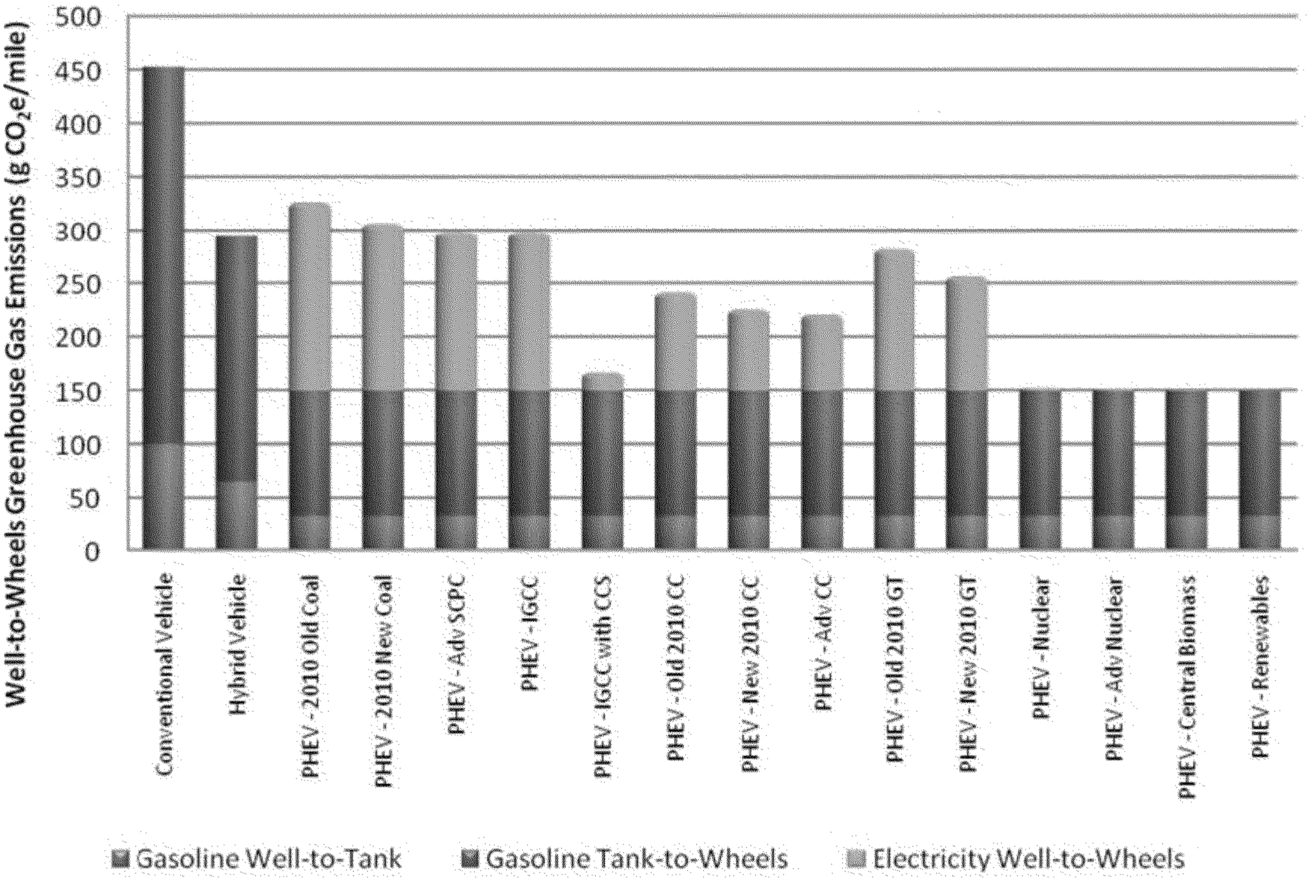
ONE-TIME COSTS			**MONTHLY COSTS**		
Vehicle Cost Premium	$	12,000	Meter Chg. (incl. EVSE)		
Tax incentive	$	(7,500)	Elect Dist. Upgrade Chg.		
Net Vehicle Premium	$	4,500	Electric Energy		$ 25.00
			Gasoline offset		($120.00)
Home wiring upgrade	$	1,296	**TOTAL Monthly Cost**		**($95.00)**
Meter	$	-	**INPUT ASSUMPTIONS**		
EVSE	$	-	Annual Miles driven	12000	miles
Total One-Time Cost	**$**	**5,796**	Miles/kWh	4	mi/kwh
			Electric rate	$0.10	per kWh
NPV Operating Savings		**($6,007)**			
			Miles/gal	25	mi/gal
NPV Overall Net Cost		**($211)**	Cost of Gasoline	$3.00	per gal
			Vehicle life	7	years

Table 2f: Illustrative EV Owners Net Cost Assuming $5 per Gallon of Gasoline, and 10 Cents per kWh For Electric Energy. Costs for Metering & Distribution Upgrades Assumed Borne By Other Ratepayers

ONE-TIME COSTS			**MONTHLY COSTS**		
Vehicle Cost Premium	$	12,000	Meter Chg. (incl. EVSE)		
Tax incentive	$	(7,500)	Elect Dist. Upgrade Chg.		
Net Vehicle Premium	$	4,500	Electric Energy		$ 25.00
			Gasoline offset		($200.00)
Home wiring upgrade	$	1,296	**TOTAL Monthly Cost**		**($175.00)**
Meter	$	-	**INPUT ASSUMPTIONS**		
EVSE	$	-	Annual Miles driven	12000	miles
Total One-Time Cost	**$**	**5,796**	Miles/kWh	4	mi/kwh
			Electric rate	$0.10	per kWh
NPV Operating Savings		**($11,066)**			
			Miles/gal	25	mi/gal
NPV Overall Net Cost		**($5,270)**	Cost of Gasoline	$5.00	per gal
			Vehicle life	7	years

Appendix C:

Year 2010 comparison of PHEV 20 GHG emissions when charged entirely with electricity from specific power plant technologies (2007 Joint EPRI/NRDC Report on PHEV Emissions[38])



[38]EPRI & NRDC: Environmental Assessment of Plug-in Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions. EPRI, Palo Alto, CA: 2007. 1015325, Executive Summary, p.7