Table 19. TOU Rate Private and Societal Benefit-Cost Ratios

Light-Trucks	PHEV10			PHEV20			PHEV40			BEV		
	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030
Private Benefit-Cost Ratio												
Operational Savings	2.96	5.08	7.80	1.33	2.40	4.48	1.30	2.53	2.96	0.96	2.17	3.86
Societal Benefit-Cost Ratios												
Petroleum Displacement	0.33	0.53	0.69	0.16	0.29	0.47	0.17	0.33	0.36	0.11	0.25	0.42
GHG Emission	0.08	0.15	0.27	0.04	0.07	0.17	0.04	0.08	0.12	0.02	0.06	0.14
NOx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM	0.11	0.11	0.01	0.08	0.09	0.00	0.10	0.12	0.00	0.07	0.10	0.00
VOC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Societal	**0.52**	**0.79**	**0.97**	**0.28**	**0.45**	**0.65**	**0.31**	**0.54**	**0.48**	**0.21**	**0.42**	**0.55**

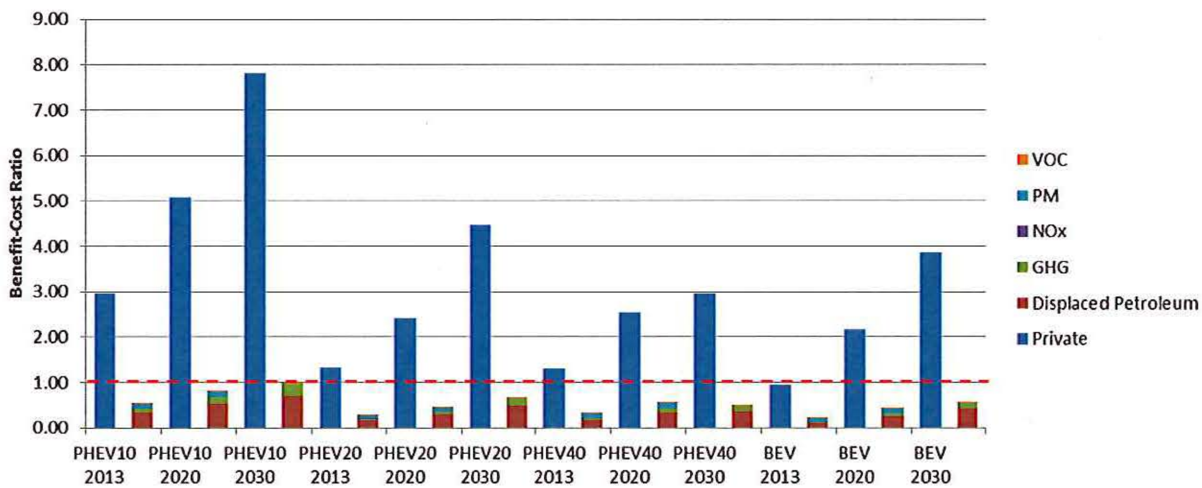

Figure 4. Benefit-Cost Ratio for Light Trucks - TOU Rate

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Table 20. Domestic Rate Private and Societal Benefit-Cost Ratios

Light-Trucks	PHEV10			PHEV20			PHEV40			BEV		
	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030
Private Benefit-Cost Ratio												
Operational Savings	2.77	4.56	6.80	1.19	1.99	3.43	1.12	1.95	2.00	0.82	1.68	2.61
Societal Benefit-Cost Ratios												
Petroleum Displacement	0.33	0.53	0.69	0.16	0.29	0.47	0.17	0.33	0.36	0.11	0.25	0.42
GHG Emission	0.08	0.15	0.27	0.04	0.07	0.17	0.04	0.08	0.12	0.02	0.06	0.14
NOx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM	0.11	0.11	0.01	0.08	0.09	0.00	0.10	0.12	0.00	0.07	0.10	0.00
VOC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Societal	**0.52**	**0.79**	**0.97**	**0.28**	**0.45**	**0.65**	**0.31**	**0.54**	**0.48**	**0.21**	**0.42**	**0.55**

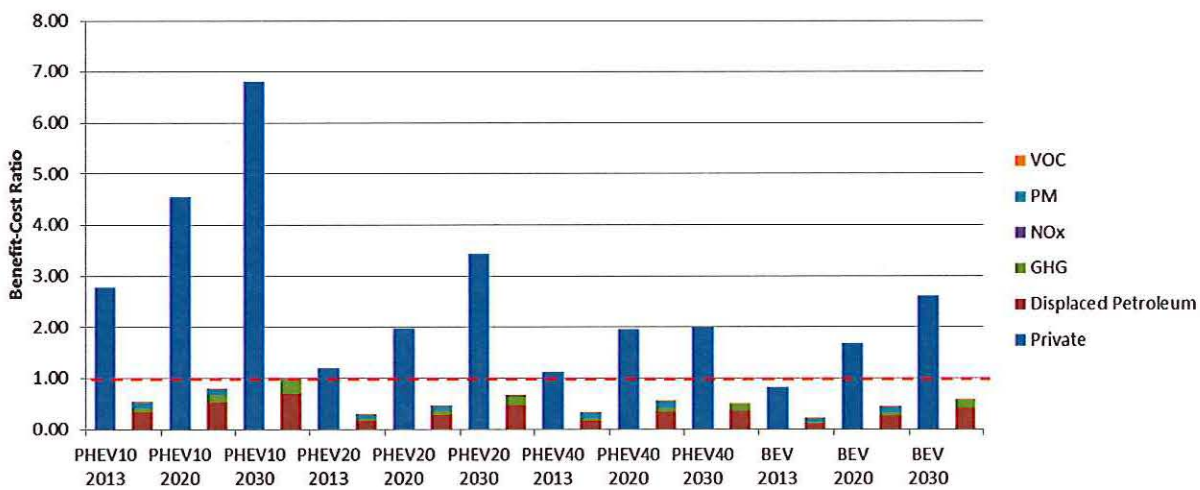

Figure 5. Benefit-Cost Ratio for Light Trucks - Domestic Rate

Figure 4 and Figure 5 show that the private and total benefit-cost ratios for all technologies and classes other than BEVs in 2013 are above one (the dotted red line) and significantly above one for 2020 and 2030. Figure 4 and Figure 5 show that for 2013, differences between the benefit-cost ratio from the TOU and domestic rates are much smaller than in 2030. This is due to rate differences of only $0.065 per kWh in 2010 and $0.14 in 2030. The ratio differences are also accentuated by the dramatic reduction of the incremental cost (denominator of the ratio) between 2013 and 2030. We can also see that due to increasingly more stringent tailpipe emission standards the 2030 NOx, PM and VOC reductions, and hence their resulting societal benefits, are almost zero.

3.1.3 Summary

Table 21 below shows a summary of the TOU benefit-cost ratio for PEV passenger cars and trucks and the "Aggressive Adoption" case in 2030 societal benefits. It is important to understand both the benefit-cost ratio of technology and the technology's potential for total societal benefits. The total benefit cost ratio represents the sum of private plus societal benefits.

Table 21. TOU Benefit-Cost Ratio and Societal Benefits of the "Aggressive Adoption" Case in 2030

PEV	Private B-C Ratio	Societal B-C Ratio	Total	Petroleum Displaced (Mil GGE/yr)	GHG Reductions (Mil MT/yr)	NOx (tons/yr)	ROG (tons/yr)	PM (tons/yr)
PHEV10 - PC	12.53	1.54	14.07	236	2.35	83	220	7.64
PHEV10 - LT	7.80	0.97	8.77					
PHEV20 - PC	7.49	1.13	8.62	316	2.91	146	353	14.5
PHEV20 - LT	4.48	0.65	5.13					
PHEV40 - PC	3.84	0.67	4.52	799	7.00	427	987	43.7
PHEV40 - LT	2.96	0.48	3.44					
BEV - PC	8.89	1.28	10.17	615	5.15	406	860	45.0
BEV - LT	3.86	0.55	4.41					

For each vehicle technology (PHEV10, PHEV20, PHEV40 and BEV), passenger cars have a slightly better benefit-cost ratio from an increase in societal benefits per vehicle while the private benefit-cost ratios are identical. PEVs, as shown in Table 21, and Table 14 and Table 15 in Section 2.3, have the highest potential for petroleum displacement and GHG reductions compared to other electric technologies.

3.2 Forklifts

The analysis for forklifts has been divided into two technologies: 8,000 lb forklifts that displace gasoline and propane lifts and 19,800 lb larger forklifts that displace larger diesel lifts. This is due to differences in incremental capital costs and fuel consumption between the two classes of vehicles. For each forklift the results are for new 2013 forklifts. The detailed analysis, data sources and assumptions can be found in Appendix B.

Table 22 below shows the resulting private and societal benefit-cost ratios. There is a high and low cost for each size lift to demonstrate the ranges of costs found from local dealers. To develop the benefit-cost ratio shown in Figure 6, the annual private benefits and monetized societal benefits are divided by the annualized costs. A private benefit-cost ratio exceeding one (1) means the technology has lifecycle savings. The red line in Figure 6 delineates a benefit-cost ratio of one (1).

Table 22. Forklift Private and Societal Benefit-Cost Ratios

	8,000 lb Low Cost	8,000 lb High Cost	19,800 lb Low Cost	19,800 lb High Cost
Private Benefit Cost Ratio				
Operating Savings	3.49	1.32	2.94	2.21
Societal Benefit Cost Ratios				
Petroleum Displacement	0.56	0.21	0.71	0.53
GHG Emission	0.12	0.04	0.13	0.10
NOx	0.04	0.02	0.04	0.03
PM	0.27	0.10	0.44	0.33
VOC	0.01	0.00	0.00	0.00
Total Societal	**0.99**	**0.37**	**1.32**	**0.99**

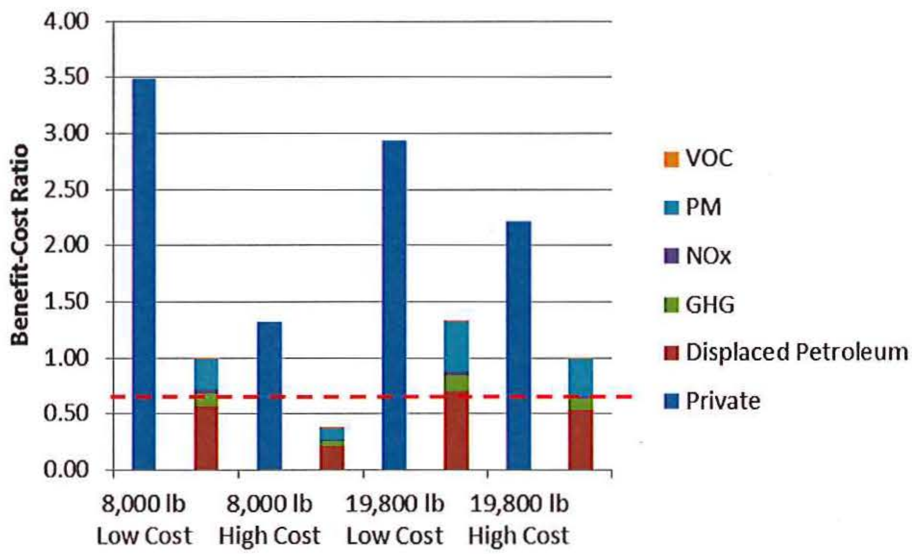

Figure 6. Benefit-Cost Ratio for Forklifts

Figure 6 shows that even the highest costs found when contacting dealers yield positive benefit-cost ratios for both the 8,000lb and 19,800lb forklifts. For the 8,000lb and 19,800 lb forklifts, the largest societal benefits are from petroleum displacement with the next largest monetized benefit from PM reduction.

3.2.1 Summary

Table 23 below shows a summary of the 2030 benefit-cost ratios and "Aggressive Adoption" case societal benefits. It is important to understand both the benefit-cost ratio of the technology and the technology's potential for total societal benefits.

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Table 23. Benefit-Cost Ratio and Societal Benefits of the "Aggressive Adoption" Case in 2030

	Private Ratio	Societal Ratio	Total	Petroleum Displaced (Mil GGE/yr)	GHG Reductions (Mil MT/yr)	NOx (tons/yr)	ROG (tons/yr)	PM (tons/yr)
8,000 lb Lift Low Cost	3.49	0.99	4.48	383	3.41	2,770	58.3	1,610
8,000 lb Lift High Cost	1.32	0.37	1.69					
19,800 lb Low Cost	2.94	1.32	4.26	43.4	0.331	216	6.21	57.8
19,800 lb High Cost	2.21	0.99	3.20					

For both the high and low cost scenarios, 19,800lb forklifts lifts have a slightly better benefit-cost ratio. Forklifts, as shown inTable 23, and Table 14 and Table 15 in Section 2.3, have the second highest potential for petroleum displacement and GHG reductions compared to other electric technologies and are only behind PEVs.

3.3 Truck Stop Electrification (TSE)

The analysis for TSE has been divided into two technologies: plug-in APUs/Shorepower and IdleAir. Plug-in APUs/Shorepower is TSE technology where drivers plug into parking stalls to power their onboard technologies. IdleAir, formerly IdleAire, does not require a truck to plug-in or any truck side capital costs. IdleAire filed for bankruptcy in 2008 and closed in January 2010. Convoy Solutions acquired the former IdleAire assets and launched IdleAir in 2010. The IdleAir system supplies all of the amenities through a unit that attaches to the cab window. For each technology there is a low and high cost from variations in truck side and truck stop infrastructure costs. The results are for new 2013 plug-in APUs and TSE. The detailed analysis, data sources and assumptions can be found in Appendix B.

Table 24 below shows the resulting private and societal benefit-cost ratios. There is a high and low cost for each technology based on variations in plug-in APU and truck stop infrastructure costs. To develop the benefit-cost ratios shown in Figure 7, the annual private benefits and monetized societal benefits are divided by the annualized costs. A private benefit-cost ratio exceeding one (1) means the technology has lifecycle savings. The red line in Figure 7 delineates a benefit-cost ratio of one (1).

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Table 24. TSE Private and Societal Benefit-Cost Ratios

All Values are Per Truck Stop	Plug-In APU/ Shorepower – Low Cost	Plug-In APU/ Shorepower High Cost	IdleAir Low Cost	IdleAir High Cost
Private Benefit-Cost Ratio				
Operating Savings	12.72	5.68	3.52	1.76
Societal Benefit-Cost Ratio				
Petroleum Displacement	2.31	1.03	1.40	0.70
GHG Emission	0.53	0.24	0.32	0.16
NOx	1.60	0.71	0.97	0.48
PM	4.31	1.92	2.61	1.30
VOC	0.02	0.01	0.01	0.01
Total	**8.77**	**3.91**	**5.30**	**2.65**

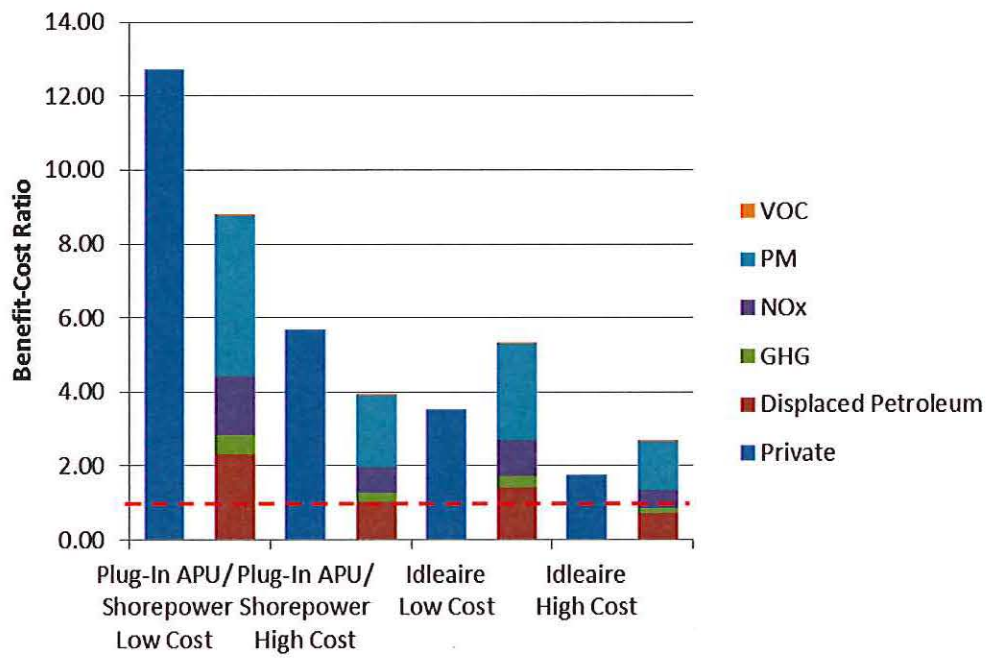

Figure 7. Benefit-Cost Ratio for TSE

Figure 7 shows that even the highest costs yield private benefit-cost ratios of greater than one, with plug-in APU benefit-cost ratios significantly greater than one. The largest monetized societal benefits are from reductions in PM with the next largest from petroleum displacement.

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3.3.1 Summary

Table 25 below shows a summary of the 2030 benefit-cost ratio and the "Aggressive Adoption" case in 2030 societal benefits. It is important to understand both the benefit-cost ratio of technology and the technology's potential for total societal benefits.

Table 25. Benefit-Cost Ratio and Societal Benefits of the "Aggressive adoption" Case in 2030

	Private Ratio	Societal Ratio	Total	Petroleum Displaced (Mil GGE/yr)	GHG Reductions (Mil MT/yr)	NOx (tons/yr)	ROG (tons/yr)	PM (tons/yr)
Plug-In APU Low Cost	12.72	8.77	21.49	5.43	0.0513	362	3.16	21.3
Plug-In APU High Cost	5.68	3.91	9.59					
IdleAir Low Cost	3.52	5.30	8.82	1.81	0.0171	121	1.05	7.10
IdleAir High Cost	1.76	2.65	4.41					

For both the high and low cost scenarios, plug-in APU/Shorepower technologies have significantly better benefit-cost ratios. TSE, as shown in Table 25, and Table 14 and Table 15 in Section 2.3, has high benefit-cost ratios and can be implemented in the near-term with positive returns, but the relatively low aggregate societal benefits highlight the limited role TSE can play in contributing to overall emission reduction and petroleum displacement.

3.4 Transport Refrigeration Units

The analysis for TRUs has been divided into four categories: semi in-state, semi out of state, bobtail and bobtail <11 hp. The difference between semi in-state and out of state is whether the TRUs are based within California or out of state. This analysis assumes that while outside out of California, out of state TRUs do not plug-in. The main difference is the number of hours per year the TRU spends within California. The technology for semi, bobtail and bobtail <11 hp categories are the same except for the size of the engines, where semi corresponds to 25-50 hp, bobtail to 25-50 hp, and bobtail <11hp to <11hp engines. For each category there is a low and high cost from variations in TRU and facility side infrastructure costs. The results are for new 2013 TRUs and facility side infrastructure. The detailed analysis, data sources and assumptions can be found in Appendix B.

Table 26 below shows the resulting private and societal benefit-cost ratios. There is a high and low cost for each technology based on variations in TRU and facility side infrastructure costs. To develop the benefit-cost ratio shown in Figure 8, the annual private benefits and monetized societal benefits are divided by the annualized costs. A private benefit-cost ratio exceeding one (1) means the technology has lifecycle savings. The red line in Figure 8 delineates a benefit-cost ratio of one (1).

Table 26. TRU Private and Societal Benefit-Cost Ratios

All Values are Per Facility	Semi In-State Low Cost	Semi In-State High Cost	Semi Out of State Low Cost	Semi Out of State High Cost	Bobtail Low Cost	Bobtail High Cost	Bobtail <11 HP Low Cost	Bobtail <11 HP High Cost
Private Benefit Cost Ratios								
Operating Savings	1.45	1.10	0.25	0.18	5.17	4.50	3.93	3.44
Societal Benefit-Cost Ratios								
Petroleum Displacement	0.47	0.35	0.08	0.06	2.11	1.84	0.98	0.85
GHG Emission	0.10	0.07	0.02	0.01	0.43	0.38	0.21	0.19
NOx	0.37	0.28	0.06	0.05	2.60	2.26	1.00	0.87
PM	0.34	0.26	0.06	0.04	5.02	4.36	1.93	1.68
VOC	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Total	**1.28**	**0.97**	**0.22**	**0.16**	**10.17**	**8.85**	**4.13**	**3.59**

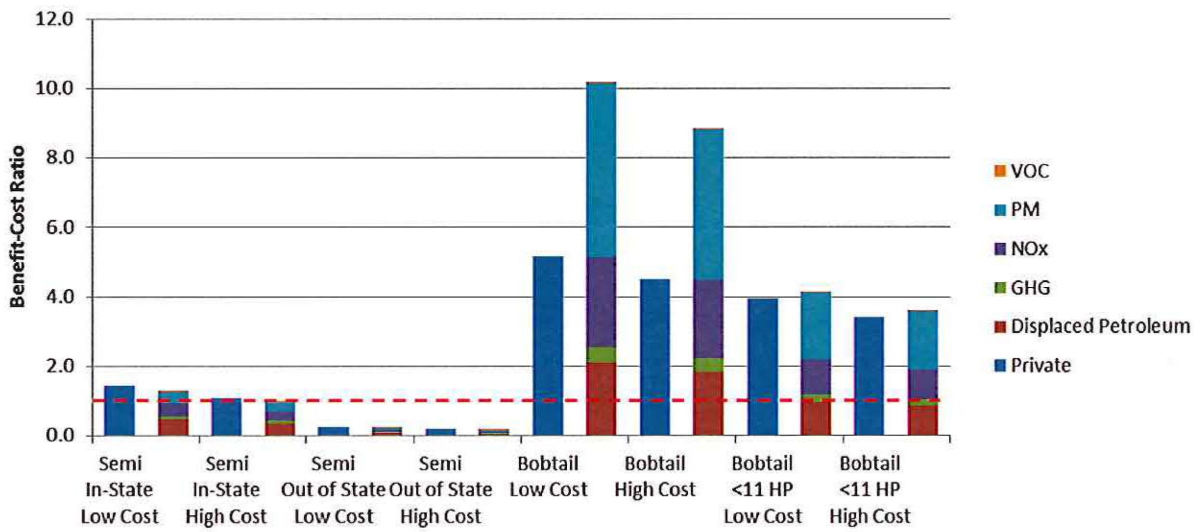

Figure 8. Benefit-Cost Ratio for TRUs

Figure 8 shows that bobtails yield significant private benefit-cost ratios of greater than one but in-state semi TRUs barely achieve private benefit-cost ratios. Semis from out of state do not yield private or total benefit-cost ratios greater than one due to their limited amount of time spent within California. The largest monetized societal benefits are from reductions in PM and NOx with the next largest from petroleum displacement.

3.4.1 Summary

Table 27 below shows a summary of the 2030 benefit-cost ratio and the "Aggressive Adoption" case in 2030 societal benefits. It is important to understand both the benefit-cost ratio of technology and the technology's potential for total societal benefits.

Table 27. Benefit-Cost Ratio and Societal Benefits of the "Aggressive Adoption" Case in 2030

	Private B-C Ratio	Societal B-C Ratio	Total	Petroleum Displaced (Mil GGE/yr)	GHG Reductions (Mil MT/yr)	NOx (tons/yr)	ROG (tons/yr)	PM (tons/yr)
Semi In-State Low Cost	1.45	1.28	2.73	16.7	0.172	1379.6	3.8	43.5
Semi In-State High Cost	1.10	0.97	2.06					
Semi Out of State Low Cost	0.25	0.22	0.46	10.5	0.108	869.3	2.4	27.4
Semi Out of State High Cost	0.18	0.16	0.34					
Bobtail High Cost	5.17	10.17	15.34	4.40	0.0453	564.8	0.4	11.8
Bobtail Low Cost	4.50	8.85	13.34					
Bobtail <11 HP Low Cost	3.93	4.13	8.06	0.0467	0.000474	6.7	0.0	0.1
Bobtail <11 HP High Cost	3.42	3.59	7.01					

For both the high and low cost scenarios, bobtail technologies have significantly better benefit-cost ratios than semis. TRUs, as shown in Table 27, and Table 14 and Table 15 in Section 2.3, have the potential for substantial societal benefits but most would come from semi TRUs that have private benefit-cost ratios just greater than one for in-state or significantly less than one for out of state. The bobtails have high private benefit-cost ratios and can be implemented in the near-term with positive returns, but the relatively low aggregate societal benefits highlight the limited role bobtail TRUs can contribute to overall emission reduction and petroleum displacement.

4 Transportation Electrification Grid Benefits

One of the key concerns about electrification of the transportation sector is the potential impact to the electric grid. If vehicle charging occurs coincident with peak demands, increased loads will drive a need for new investment in generation, transmission and distribution capacity. If charging can be managed to occur primarily in off-peak periods, much of the load will potentially be served with existing infrastructure such that impacts on the electric grid will be significantly reduced and there will be a potential for significant grid benefits.

Evaluating the costs and benefits of transportation electrification on the electric grid has similarities and differences with the evaluation of energy efficiency. The categories of costs and benefits are similar and the definitions of the standard cost tests are the same. The key difference is that energy efficiency provides benefits by reducing load, while transportation electrification provide benefits by increasing load. This notion of increasing load runs counter to long established energy efficiency programs. However, in the case of transportation, increased load provides societal benefits as described in Section 3. Increasing the use of electricity for transportation provides net benefits for both society and utility ratepayers.

The analysis and quantification of the grid benefits of PEVs will be presented in the Phase 2 report, based on the cost-effectiveness test[41] adopted by the CPUC for evaluating distributed energy resources such as energy efficiency, demand response and distributed generation. While the Phase 2 report only looks at the grid benefits from light-duty PEVs, we can assume similar benefits would be seen from medium- and heavy-duty PEVs and off-road electrification.

4.1 Objectives

The grid impact cost-benefit analysis focuses on the cost and benefits of PEVs from the perspective of the utility and its ratepayers addressing three key questions:

1. What are the system costs and impacts associated with increased PEV load?
2. Will increased PEV load cause utility rates to increase or decrease?
3. By how much can dynamic rates and managed charging reduce the costs of serving PEV load?

4.1.1 Grid impacts

The grid benefit analysis provides a much more detailed and robust analysis of distribution grid impacts than has heretofore been published. PG&E, SCE, SDG&E and SMUD all provided detailed data for individual substations and feeders, including:

- Equipment ratings
- Peak day loads and load shapes
- Load growth forecasts

[41] http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/Cost-effectiveness.htm

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- Representative costs of load growth related feeder and substation upgrades
- Geolocation

With this data, we mapped PEV clusters at the Zip+4 level to individual feeders for each of the four utilities. A distribution impact model, developed in Analytica, allows us to model the PEV related load and cost impacts under a variety of vehicle adoption, charging pattern and alternative rate scenarios, which will be presented in the Phase 2 report along with other grid costs.

4.1.2 Ratepayer Benefits

Volumetric rates include both fixed and variable utility costs for delivering electricity to retail customers. The analysis in Phase 2 will show the revenue from PEV charging will exceed the marginal cost of generation to serve the load and the additional costs incurred by the utility to serve PEV load even under the "worst-case" assumptions for grid impacts. We also will show that the GHG reductions from reduced gasoline consumption exceed the emissions associated with increased electricity generation.

4.1.3 Utility Managed Charging

With the shift to off-peak, retail rate revenue is reduced as compared to an unmanaged scenario. The cost of supplying and delivering electricity is also reduced. Across a wide range of scenarios studied, net revenues are still positive with managed charging, but tend to be lower than the unmanaged scenario. Managed charging also reduces the costs to the state as a whole of serving PEV load.

4.1.4 Environmental Benefits

Public Utilities Code section 740.8 characterizes the reduction of health and environmental impacts from alternative-fuel vehicles as in the interest of utility ratepayers (e.g. greenhouse gas and air pollutant reductions). The grid impact analysis in Phase 2 will show the effect of quantifying and including these impacts in utility and ratepayer cost-benefit evaluation.

4.1.5 Vehicle Grid Integration

Managed charging (without vehicle to grid (V2G)) can absorb excess renewable and minimum fossil generation to reduce morning and evening ramps under higher renewable penetration scenarios. An in-depth analysis is beyond the scope of this study, but the analysis in Phase 2 will illustrate how PEVs can support additional renewable generation.

5 Market Gaps, Barriers, and Potential Solutions to Increased PEV Market Penetration

PEV sales have been strong to date, particularly in California: More than 40 percent of all PEVs sold nationally were sold in California through the end of 2013.[42] Despite the near-term successes of PEV deployment, there are still significant markets gaps and barriers that prevent increased adoption and maximization of the associated benefits.

To help address these issues, Governor Brown issued Executive Order B-16-2012 in March 2012 laying the foundation for 1.5 million zero emission vehicles (ZEVs) on California's roadways by 2025. The Executive Order was followed in 2013 by the development of the ZEV Action Plan,[43] prepared by the Governor's Interagency Working Group on Zero-Emission Vehicles. The ZEV Action Plan lays out the following four goals:

- Goal 1: Complete needed infrastructure and planning
- Goal 2: Expand consumer awareness and demand
- Goal 3: Transform fleets
- Goal 4: Grow jobs and investment in the private sector

The goals and associated actions related to planning have been addressed through extensive research, analysis, and outreach in various regions throughout California. For instance, public agencies – primarily air pollution control districts and metropolitan planning organizations (MPOs) – have led planning efforts in California to help achieve PEV readiness. These efforts have focused on a) building codes, b) permitting and inspection, c) zoning, parking rules, and local ordinances, d) incorporating PEV deployment into Sustainable Community Strategies,[44] and e) stakeholder training and education. The underlying principle of these efforts is that consistency in planning at the local and regional level will help simplify and reduce the administrative costs of EVSE deployment.

At the national level, the Transportation Research Board of the National Academy of Sciences released *Overcoming Barriers to Electric-Vehicle Deployment: Interim Report* in 2013. The report focuses on the "infrastructure needs for electric vehicles, the barriers to deploying this infrastructure, and the possible roles of the federal government in overcoming these barriers." The report considers a) customers, manufacturers, and dealers; b) the charging infrastructure; and c) the electric grid.

ICF has drawn from the NAS report as well as confidential interviews with staff at multiple California utilities engaged in this project. We also reviewed an extensive list of other reports and plans related to PEV and charging infrastructure deployment, including but not limited to: EDTA's *Driving Forward: An*

[42] ICF analysis of national PEV sales data and data from the CVRP.

[43] 2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025, available online at: http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf

[44] Per SB 375, Steinberg, Statues of 2008.

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Action Plan for the Electric Drive Era, Governor Brown's ZEV Action Plan, documents from the Electrification Coalition, the California Plug-in Electric Vehicle Collaborative's *Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace*, the National Petroleum Council's *Advancing Technology for America's Transportation Future*, and the Department of Energy's *EV Everywhere Grand Challenge: Road to Success* report. These documents have served as a useful starting point to identify the critical market gaps and barriers to PEV deployment in California. Some of the issues identified in the interim report are not covered here; however, we have identified what we consider the most salient issues given our understanding of PEV adoption to date, namely:

- Consumer costs
- Charging infrastructure deployment
- The sustainability of third-party owner/operators of PEV charging infrastructure or networks
- Consumer education and outreach
- Limitations on vehicle features

In the following subsections, we identify and characterize gaps and barriers associated with each of these issues. Each subsection concludes with our recommendations as potential solutions to help fill the gaps and overcome the barriers identified. When developing our recommendations and outlining the potential solutions, ICF paid particular (but not exclusive) attention to the role(s) of utilities and public agencies. These recommendations are not meant to minimize the role of other stakeholders (e.g., automobile manufacturers) in developing solutions to increase PEV market penetration.

5.1 Consumer Costs

5.1.1 Identification of the Gaps and Barriers

Upfront Vehicle Costs

Consumers' willingness to pay for new technology, as well as the extent to which they value their convenience will play a large role in PEV deployment. Consumer surveys indicate the manufacturer's suggested retail price (MSRP) of a PEV is of paramount importance, with nearly 70% claiming it is the most important factor in deciding their purchase.[45] Additionally, consumers expect PEVs to be cost-competitive with similar internal combustion engine (ICE) vehicle models, with a majority desiring a sticker price under $30,000.[46] While consumers do acknowledge the higher cost of PEVs and are willing to pay more, the price differential between a PEV and a conventional vehicle or even an HEV remains too high to induce larger volumes of vehicle sales.

[45] Deloitte Touche Tohmatsu Ltd, "Gaining Traction: A Customer View of Electric Vehicle Mass Adoption in the U.S. Automotive Market," 2010.

[46] Ibid.

Despite a recent survey by Accenture finding that 57% of Americans would consider purchasing a PEV for their next vehicle,[47] consumers' expectations regarding price, range, and charging time are in many cases not met by PEVs available today.[48] These barriers make converting potential consumers into actual purchasers a significant challenge. As discussed previously, vehicle price is the primary barrier to widespread PEV adoption in the near-term. Even with incentives, the initial costs of PEVs generally remain higher than HEVs and ICE vehicles. In a 2011 Los Angeles PEV market survey, for example, more than 80% of respondents said price is an important factor in the decision to purchase a PEV, and 71% believe that "EVs cost too much for what they offer."[49] There have been some decreases in vehicles cost (e.g., Nissan cut the price of the LEAF in 2013 by about $6,400) and over the last year there have been some aggressive leasing offers. PEV adopters' preference and potential doubt over the lifespan of batteries may have contributed to the fact that 50% of PEV placements in California have been financed through leasing.[50] However, there are concerns about the long-term viability of the PEV market if it is dependent on leasing, largely because this may decrease the upfront costs of vehicles, but it does not help the long-term total cost of ownership. For instance, a market reliant on low-priced leasing will require a robust secondary market for PEVs, which will accelerate with 2010 and 2011 PEV leases expiring soon.

Upfront EVSE Costs

Further research is needed to determine which level of charging consumers will ultimately prefer. In single family residences, duplexes, and townhomes, Level 1 charging is readily available and inexpensive and appears to be practical for many PEV users, other than BEV users with daily vehicle miles travelled (VMT) exceeding 40 miles. A Level 2 EVSE could potentially charge a vehicle in a fraction of the time of a Level 1 EVSE, but requires a dedicated space to install the EVSE (in multi-family dwellings) and is considerably more expensive.[51]

Consumer willingness to purchase EVSE depends in large part on the price of the infrastructure in light of the consumer's perceived driving requirements. As charger speed and "intelligence" increase, the expense of the equipment and installation rises commensurately. Currently, a residential Level 2 EVSE is estimated to cost approximately $2,000, including installation; however, survey results show that only 28% of respondents would pay more than $500 for the capability, with the average respondent willing to pay up to $400.[52] Consumer unwillingness to add this additional expense to the purchase of the

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[47] Accenture, "Plug-in electric vehicles: Changing perceptions, hedging bets," 2011.

[48] Deloitte, "Gaining Traction: Will Consumers ride the electric vehicle wave?" *Deloitte Global Services Ltd.*, 2011.

[49] Dr. Jeffrey Dubin, et.al, "Realizing the Potential of the LA EV Market," *University of California Los Angeles Luskin Center for Innovation*, May 2011.

[50] Clean Vehicle Rebate Project User Survey, http://energycenter.org/clean-vehicle-rebate-project/survey-dashboard. As a comparison, Experian reports in its State of the Automotive Finance Market report that only 25% of all new vehicle sales were financed through leasing in Q1 2014 (up from 15% in Q1 2009)

[51] This can also contribute to the previous barrier discussed regarding upfront vehicle costs if the purchase of the EVSE is included at ht point of the PEV sales transaction process.

[52] Charul Vyas et al., "Executive Summary: Electric Vehicle Consumer Survey," *Pike Research*, 2012.

vehicle presents a significant barrier to the larger scale deployment of Level 2 EVSE in residences. For instance, Tony Posawatz, formerly the Vehicle Line Director for the Volt and Global Electric Vehicle Development at General Motors (GM) indicated in a presentation that GM has been surprised that "most" Volt drivers have opted for Level 1 charging over Level 2 charging at home. He noted that it takes longer to charge, but that consumers believe the chargers work "well enough" and "suffice for overnight charging".[53] Furthermore, Nissan has reported that 10% to 20% of LEAF buyers are opting for the lower cost Level 1 charging cord set that come with the purchase of the vehicle.

Vehicle Operating Costs

PEV operating costs tend to be significantly lower than those of conventional vehicles. Although this is driven by both the lower cost of electricity compared to gasoline as well as by the lower maintenance costs associated with PEVs, the fuel price differential is the most significant driver for PEV ownership savings. As such, it is critical that utilities provide competitive charging rates for PEVs. The traditional billing paradigm for electricity consumption, however, is not optimized for PEV charging. For instance, domestic rates are generally tiered and penalize higher electricity usage, thereby creating a price barrier for fuel switching (from gasoline to electricity). Furthermore, some whole house on-peak time-of-use (TOU) rates are even higher than the highest domestic tier.[54] In these cases, if a consumer has a non-shiftable load (e.g., air conditioning) that would penalize a switch to a TOU rate, then the consumer is more likely to stay on the standard tiered domestic rate. Finally, a consumer may be interested in moving to a TOU rate for the vehicle to obtain lower energy costs for off-peak charging. However, if it is a separately-metered PEV TOU rate (i.e., a rate specific to the PEV charging load that does not require shifting the rest of the household load), many consumers may pass on this option because of the additional installation cost for separate metering.

5.1.2 Potential Solutions

Ensure availability of incentives

Although PEV adoption to date has been successful in California – with sales nearly double the rate of hybrid electric vehicles when they were first deployed[55] – the availability of new vehicle purchase subsidies remains the most critical incentive available to consumers. Stakeholders in the transportation electrification market need to continue making the case to policy makers that grant money from state programs such as AB 118 should continue to be directed towards vehicle purchases to complement the federal tax credit incentive. Similarly, PEV access to high occupancy vehicle (HOV) lanes should be

[53] Ernst & Young, Cleantech matters: moment of truth for transportation electrification, 2011 Global Ignition Sessions Report, 2011.

[54] This is not true for all utilities. For both SMUD and SDG&E for instance, this has not been the case to date. SMUD's whole house TOU rate is designed to be revenue neutral and will likely result in a lower bill for residential customers currently in the highest domestic tier rate.

[55] California Center for Sustainable Energy, California Plug-in Electric Driver Survey Results, February 2014. Available online at: https://energycenter.org/clean-vehicle-rebate-project/vehicle-owner-survey/feb-2014-survey.

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continued. Apart from the obvious importance of reducing the upfront cost of the vehicle, state-level leadership is required given the scale of the challenge associated with mass light-duty PEV deployment. Regional and local governments simply do not have the spending capabilities of impacting the market significantly.

Apart from vehicle incentives, it is important for utilities and other stakeholders in the PEV ecosystem to identify the incentives that are most successful in impacting vehicle adoption. For instance, a recent survey of PEV buyers by the California Center for Sustainable energy (CCSE) indicated that Plug-in Prius drivers were largely motivated by the availability of the Green Sticker that provides single occupancy access to HOV lanes.[56]

Moving forward, here are two recent developments that should be tracked that may help to diminish the high first cost barrier. First, OEMs and dealerships are implementing creative ways to increase the sales or leases of PEVs, such as low lease rates, low down payments, low interest rate vehicle financing, dealership discounts, free public charging for a limited time, and marketing messages that emphasize the lower fuel costs and incentives. Second, beginning in 2014, many of the PEVs leased in 2010 and 2011 will be rolling off their leases, promising a potentially lower cost used PEV market.

Creative use of LCFS credits

California's Low Carbon Fuel Standard (LCFS) provides utilities with an opportunity to earn credits for selling electricity as a transportation fuel. Per the LCFS regulation, however, utilities must use LCFS credit proceeds to benefit current PEV drivers; furthermore, IOUs have to seek CPUC approval for their plans regarding the use of LCFS credit proceeds. A variety of proposals have been put forth to the CPUC – including vehicle buy-down programs and rate reductions (see Table 28 below). As the market for PEVs evolves and the LCFS credit market matures, utilities should be encouraged to continue to explore opportunities to find innovative mechanisms to spur adoption using LCFS credits that are in line with CARB's LCFS Program requirements. The LCFS program is an excellent opportunity for utilities to explore creative ways to engage consumers.

[56] California Center for Sustainable Energy, California Plug-in Electric Driver Survey Results, February 2014. Available online at: https://energycenter.org/clean-vehicle-rebate-project/vehicle-owner-survey/feb-2014-survey

Table 28. Descriptions of Utility Programs for Use of LCFS Credits

Utility	Description of Proposal to CPUC
Pacific Gas & Electric	• On-bill credit to PHEV and BEV drivers; credits based on vehicle battery size. • Provide information about availability of credit to customers
San Diego Gas & Electric	• Return credits to drivers under the manner in which they were generated • Provide information about availability of credit on website featuring the credit as an additional benefit for PEV drivers
Southern California Edison	• Propose a Clean Fuel Reward offered to PEV adopters through dealers at the time of vehicle purchase • Provisions for new and used-vehicles (purchase or lease)
Sacramento Municipal Utility District	• Propose a Clean Fuel Reward at the time of vehicle purchase • Support public charging infrastructure investment
Los Angeles Department of Water and Power	• Provide rebates for PEV charging infrastructure

Battery second life

ICF maintains that the development of a robust market for batteries after their useful automotive life will be one of the early indicators of success in the PEV market. As the market for batteries in non-automotive applications develops, there may be a way to monetize the value of the secondary life of batteries and pass those benefits on to consumers at the point of purchase. For instance, in April 2013, the CPUC approved PG&E's request to implement a Plug-In Electric Vehicle Pilot [57] to evaluate whether there is a sufficient business case for light-duty automobile manufacturers to provide grid services from second life batteries and PEVs in service to the utility.

Improve PEV charging rates

Utility rate structures are one of several key decision factors for potential PEV consumers, and can represent the difference between a consumer accruing a return on their investment or realizing a net loss. As noted above, the most significant savings for PEV drivers are from a reduction in fuel expenditures. Utilities should continue to evaluate their rate structures in the context of the potential impact on PEV consumers. These include an analysis of secondary meter options, alternatives to the traditional tiered rate structure, and options for existing or future of TOU rates. For example, SDG&E's VGI Pilot Program application with the CPUC (filed April 11, 2014, A.14-04-014) features a dynamic rate for workplace and MDU settings that reflects grid conditions and the changing cost of energy throughout the day.

[57] State of California Public Utilities Commission, Advice Letter 4077-E-B, April 2, 2013, http://www.pge.com/nots/rates/tariffs/tm2/pdf/ELEC_4077-E-B.pdf

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5.2 PEV Charging Infrastructure Deployment

5.2.1 Identification of the Gaps and Barriers

Charging at single family homes

For the most part, PEV readiness plans have identified the gaps and barriers to residential charging, especially at single family residences, including issues such as expedited permitting. The market gaps and barriers for charging at single family residences are small and likely near-term issues that can be addressed as part of the expected market evolution. For instance, over the last two years, the number of consumers opting for Level 1 charging is indicative of consumer reaction to EVSE pricing and installation: Chevrolet reports that as many as 70% of Volt drivers opt for Level 1 charging and Nissan reports that 10% to 20% of LEAF drivers opt for Level 1 charging. These data are largely consistent with survey data from the Clean Vehicle Rebate Project reported by the California Center for Sustainable Energy.[58] Considering that the EV Project and ChargePoint America–projects funded by the American Recovery and Reinvestment Act (ARRA)–both focused on deploying Level 2 EVSE, including at residences, it is clear that consumers have reacted differently than anticipated. Deciding between Level 1 and Level 2 charging at home may continue to be an issue if potential PEV buyers do not have the tools to assess their charging needs carefully and accurately in the context of their personal travel behavior.

Charging infrastructure at multi-dwelling units

Multi-dwelling units (MDUs) or multi-family units are a commonly identified gap in the PEV market today because little progress has been made in deploying charging facilities at these locations. The degree to which this barrier will have an impact on PEV adoption is more obvious in areas with high population density and high levels of MDUs (e.g., Los Angeles, San Diego, and San Francisco), where there is a strong argument to be made that lack of charging infrastructure will negatively impact long-term PEV adoption. For the most part, until solutions are created to address this gap, consumers living in MDUs are severely constrained in their ability to participate in the PEV market, excluding a major portion of the vehicle buying or leasing market. For example, charging installations (at Level 1 or Level 2) at multi-family units generally have high deployment costs, including trenching, new poles or transformers, and often involve more stakeholders (e.g., Homeowners' Associations (HOAs), property management) than at single family residences.[59] Metering the PEV load and billing users may require potentially complex arrangements if connecting to the premises meter or to the tenant meter is not feasible. Because many MDUs are under commercial rates, it is also possible that vehicle charging may result in bill increases due to commercial rate demand charges, which would apply to the entire facility under that commercial account. These issues continue to make deployment of charging installation at

[58] California Plug-in Electric Vehicle Owner Survey, February 2014. Available online at: https://energycenter.org/clean-vehicle-rebate-project/vehicle-owner-survey/feb-2014-survey.

[59] For a more detailed overview of the complexities of the MDU issues, please review the California PEV Collaborative document entitled Plug-in Electric Vehicle Charging Infrastructure Guidelines for Multi-unit Dwellings, available online at: http://www.pevcollaborative.org/sites/all/themes/pev/files/docs/MUD_Guidelines4web.pdf.

multi-family units challenging. Finally, HOAs or property managers may have ultimate say over charging infrastructure installations at MDUs; unfortunately, they may not be willing to bear the costs of installation. Even if an HOA or property manager is willing to bear the cost of charging infrastructure installation, they may not understand the operational aspects, such as payment for use or regulating the use of charge points and associated parking spots.

This situation may be exacerbated by the perception that Level 2 networked EVSEs with payment capabilities are essential for all PEV drivers. While residential deployment of Level 2 EVSEs is required to serve those BEVs with a daily VMT that exceeds 40 miles, many PEV users can reliably charge their vehicle at Level 1. A 110 V outlet or a basic EVSE (Level 1 or Level 2) may save several thousand dollars per charge point (payment for the charging transactions may be handled offline through various billing arrangements). Incidentally, Level 1 charging or some types of multi-port Level 2 charging[60] will have less impact on the grid and may avoid demand charges. The number of decisions for the site owner and PEV owner to make can be overwhelming, and no party or website in this space plays the role of helping them understand the many complex options or advocating for the low cost solutions (e.g., avoiding perimeters, trenching, networked charging, demand charges, and utility line drops).

Senate Bill 880 (SB 880, Corbett, Statues of 2012)[61] voids any policies or provisions that prohibit or restrict the installation or use of EVSE in a common interest development with owner-designated parking spaces. However, if property managers and HOAs do not have adequate information and education to help them navigate the different decisions that need to be made, the issues listed above may act as barriers and reduce the likelihood, or at least slow down the process, of deploying charging infrastructure at these properties.

Workplace charging

Most analysts agree that after residential charging, the next most likely place for PEV drivers to charge their vehicle will be at workplaces, largely because of the long dwell times. Unfortunately, the majority of away-from-home charging installations deployed today have not been at workplaces, and instead have been at public parking locations that typically have shorter parking durations. It appears that the costs of the EVSE and installation costs continue to be the most significant challenges to EVSE deployment at workplaces.[62] By definition, workplace charging does not offer the everyday reliability of charging at home (and as such may have only limited impact on PEV adoption), but workplace charging

[60] For example Level 2 charging with multiple ports can be either sequenced or throttled so that the total load per station does not exceed 6.6 kW (or less).

[61] Senate Bill 880 (Corbett), Common interest developments: electric vehicle charging stations. Available online at: http://leginfo.ca.gov/pub/11-12/bill/sen/sb_0851-0900/sb_880_bill_20120229_chaptered.pdf. Note that SB 880 was signed into law as an urgency statute to clean up Senate Bill 209 (Corbett); more specifically, SB 880 was intended to 1) correct constitutional flaws posed by SB 209, 2) resolve a conflict with Civil Code Section 1363.07 and 3) correct ambiguities within the language of SB 209.

[62] California Plug-in Electric Vehicle Collaborative, Amping up California Workplaces: 20 Case Studies on Plug-in Electric Vehicle Charging at Work, 2013. Available online at: http://www.evcollaborative.org/sites/all/themes/pev/files/WPC_Report4web.pdf

provides an opportunity to extend significantly the eVMT of many PEVs. PHEVs, such as the Toyota Prius Plug-in or the Ford C-Max Energi, carry a battery that may not have the capacity to cover the driver's daily VMT. Those drivers may have to rely on gasoline to complete their daily driving unless workplace charging is available.

Other away-from-home charging

Other away-from-home charging is distinguished from residential and workplace charging by generally shorter parking durations, and covers a wide range of situations where a PEV driver could potentially charge when away from home and/or work. Within this category, there are different sub-categories specific to the venue type –such as retail parking lots, on-street parking, airport long- and short-term parking, cultural and recreational centers, etc. We distinguish these locations based on dwell times in Table 29 below, and provide broad categorization as well as the likely charging method at these locations.

Table 29. Example of Charging Type based on Purpose

Dwell Time	Typical Venues	Charging Rate	Purposes	Use
Short < 1.5h	Supermarket, big box retailers,	At the retailer's discretion	Opportunistic top-off charging Increase foot traffic Unlikely to serve an actual need because of likely proximity with home	Weekly
	Highways / Freeways	DCFC	For BEVs only Extend eVMT on longer (non-commute) trips	Occasional
Medium 1.5–6 h	Shopping Centers, Cultural/ Sports Centers	Combination of L1 for PHEVs and L2 for BEVs	Extend eVMT	
Long >6 h	Airport Parking (long-term)	L1		
	Hotels /Convention Centers/Theme Parks	Combination of L1 for PHEVs and L2 for BEVs		

As increasing numbers of away-from-home EVSE are deployed in California by an array of providers, it will be important for charging providers to ensure that there are multiple ways for consumers to access their EVSE networks without holding multiple memberships or paying unnecessary premiums. While California passed SB 454 in 2013 to require networks to offer one-off charging transactions to non-members, pricing of these transactions is not regulated and could potentially be used to circumvent the new law. However, it is important to note that any entity can install EVSE, and not all installations require a service provider.

5.2.2 Potential Solutions

In addition to the recommendation to revisit the CPUC ruling prohibiting utility investment in charging station infrastructure (discussed in more detail in Section 5.3 below), ICF highlights the recommendations related to charging infrastructure noted in the following sections.In general, utilities can help develop awareness about the multiple charging options available to residential and commercial customers. Unlike other industry players that may not find it in their best business interest, utilities could conduct programs to demonstrate low cost/low complexity charging solutions that also benefit the grid and ratepayers. These may help remove perceived barriers to deployment of charging infrastructure and show a pathway for adopters to follow.

Engage MDUs/HOAs, employers, and workplace parking providers

There is considerable overlap between the barriers to deploying charging infrastructure at multi-family units and at workplaces. It is important that utilities, as trusted energy advisors, engage these stakeholders in meaningful discussions to help identify optimal solutions for consumers/drivers, HOAs, employers, and other parties interested in providing MDU or workplace charging.

It is also important to note that workplace charging is more complicated than simply the employer-employee-utility interface. There are opportunities to provide charging infrastructure near commuter exchanges, which involve local and regional transit agencies, or to provide charging infrastructure at parking structures in which the employer is not necessarily the owner.

Utilities have a critical role to play in this space and can help ease the burden that has been borne by early market entrants, who have spent a significant amount of time educating potential site hosts:

- City CarShare for instance, has been at the forefront of EVSE deployment in the Bay Area to support the PEVs in its fleet. Their role is relevant because their fleet of PEVs require non-residential charging as a base. City CarShare has sought to install EVSE at a variety of locations and have been engaged with an array of parking providers to help expand the deployment of PEVs in its carsharing fleet. City CarShare reports it may take up to four months to educate these stakeholders about the issues associated with EVSE. Because this can be a significant barrier to deployment, utilities can play an important role through engagement and education.
- Daimler's car2go launched the first all-electric car share program in the US in San Diego in 2011-2012. As it launched its all-electric fleet, it was dependent on city of San Diego parking ordinances being changed. SDG&E played a critical role in supporting car2go by working with the City of San Diego and the EV Project to help deploy charging infrastructure to support the electric fleet.

Engagement with employers and workplace parking providers today is also important because in the near- to mid-term future, widespread workplace grid-integrated charging could serve as an opportunity to provide lower cost charging by taking advantage of those times during the year when there is surplus energy production, particularly from renewable energy resources, that occur during the typical work day. This could increase overall system efficiency and avoid the installation of additional storage capabilities.

5.3 Third-Party Ownership of Charging Infrastructure

5.3.1 Identification of the Gaps and Barriers

The previous section focused on the general deployment of charging infrastructure at residences, workplaces, and publicly accessible locations. This section addresses the role of third-party EVSE owners and network operators in California's PEV charging industry. By way of background, the CPUC ruled that IOUs cannot own EVSE at customers' facilities because it found that utility ownership of EVSE is unlikely to provide safety advantages or reduce customer service costs. Furthermore, the CPUC made the assumption that the IOUs may negatively impact what is referred to as the electric vehicle service provider (EVSP) market; however, this ruling was not evidentiary based and did not include an examination of the viability of the EVSP business models (Phase 2 of Rulemaking 09-08-009).

This section explores the challenges that third-party owners and operators of EVSE face in the PEV charging market, namely:

- The underlying revenue model for EVSE is based on the resale of electricity, a commodity that is inexpensive compared to the high cost of infrastructure for PEV charging.
- The demand for non-home charging is unclear due to a variety of variables, including BEV vs. PHEV deployment, battery technology, availability of free charging, consumer willingness to pay, and driver behavior (e.g., non-residential dwell time and daily VMT).

Table 30 below includes an overview of the services that PEV charging industry participants provide:

Table 30. Services Provided by PEV Charging Industry Participants

Market Participant	Brief Description
Hardware Manufacturer / Equipment Retailer	Manufactures the EVSE that is installed; may be branded or unbranded. Manufacturers may also sell their equipment directly to market or to network managers/operators (i.e., retailer).
Installers / Maintenance providers	Installs EVSE; in some cases installers also provide routine maintenance for the equipment.
Charging station owner / host	Entity that owns or hosts the equipment, such as a retail outlet. May also resell electricity to PEV driver.
Charging Station Network Operator	Has the ability to connect, control, and monitor charging stations on its network; generally provides metering capability. Collects payment from users (potentially on behalf of charging station owners); may also resell electricity to PEV driver.
System operator	The California Independent System Operator (ISO) provides open and non-discriminatory access to the state's wholesale transmission grid. There are several Publicly Owned Utility-based organizations that provide system operations as well.
Utility provider	Electrical utilities in California–including investor- and publicly-owned utilities.

For the purposes of this report, a third-party owner/operator is broadly defined as an entity that owns and/or operates PEV charging equipment (i.e., Level 1, Level 2, or DC fast charging EVSE) or sells/leases the charging equipment and sells the network transaction services. In either case, the third-party owner/operator is neither a utility nor the vehicle owner. In the context of the table above, this includes charging station owners and charging station network operators. In some cases (e.g., eVgo Network), the owner and operator of the charging station is the same organization. In other cases, the charging station network operator acts as an agent of the charging station owner. The latter bears the investment risk by paying for the installation. It owns the equipment and sets pricing. Meanwhile, the charging station network operator collects revenues from users, withholds a fee and remits the balance to the charging station owner.

It is also important to mention that an EVSE is not a gasoline pump. Not only does an EVSE deliver much cheaper transactions, it does so at a much slower pace than a gasoline pump. This has major implications for the business model for away-from-home charging and is a paradigm shift for vehicle users compared to gasoline vehicles. While drivers may be willing to wait for a few minutes to fill up their tanks, the longer time associated with charging will likely mean that drivers seek to complete other activities while their PEV is charging (e.g., work, shop, sleep, etc.). In addition, unless a PEV driver actually needs to charge away from home, the cost of charging and the required charging time will play a major role in the decision to use out-of-home charging. As a result, out-of-home charging is likely to be mostly opportunistic, and will likely occur if the cost is less than the cost of charging at home and/or less than the cost of gasoline (and if the PEV driver can spare the time). This significantly limits the price elasticity of demand as out-of-home charging competes with home charging (unlike gasoline stations which do not have any competing models).

Sustainability of revenue model

The high costs of the infrastructure to provide publicly accessible EVSE make it difficult to earn a profit because the commodity (i.e., electricity) being sold is comparatively inexpensive. Publicly accessible installations of Level 2 EVSE can cost in excess of $10,000 in some cases; whereas DC fast charge EVSE installations can cost in excess of $150,000. As a result of these high costs, many industry observers and market analysts believe that investing in publicly accessible charging infrastructure may be predicated on an unsustainable revenue model if the charging transactions are the sole source of revenue and the only business driver to deploy charging stations. The National Academy of Sciences (NAS) report,[63] for instance, states that the high cost of installing public charging stations and the minimal revenue obtained from providing electricity present challenges for developing business models.

ICF conducted a breakeven analysis of non-home EVSE ownership for Level 2 (AC) and DC fast charging. We assumed an installed cost of approximately $10,000 for a Level 2 EVSE and $100,000 for a DC fast charge EVSE.[64] Our analysis also included electricity costs, including the energy charge, customer charge

[63] National Academy of Sciences, *Overcoming Barriers to Electric-Vehicle Deployment: Interim Report,* 2013.

[64] EVSE deployment costs can vary significantly, especially for public installations. The costs presented here are representative of ICF's recent research as it relates to Level 2 and DC fast charging equipment. It is worth noting,

(assuming several EVSE per meter), demand charges, and peak demand pricing. For the purposes of our analysis, the EVSE was assumed to be installed at either a small facility with demand less than or equal to 200 kW (e.g., a parking facility or small office building) or a medium facility with demand greater than or equal to 200 kW (e.g., a large office building, grocery store, or hotel). The breakeven analysis considered operations, maintenance, and networking costs for both types of equipment. Our analysis also assumed that the third-party EVSE provider opted into California's Low Carbon Fuel Standard (LCFS) program as a regulated party selling electricity as a transportation fuel in order to generate potentially valuable credits. A discount rate of 7% was employed.

The results were calculated as breakeven pricing – defined as the price per charging event that an EVSE provider would need to charge in order to break even on the initial investment by a given year of operation. Note that these estimates assume no profits generated for the EVSE provider prior to the breakeven year. The profit in any year will depend on operating costs and revenue generated from charging events; however, the initial capital investment for EVSE–including hardware and installation–would be recouped by the breakeven year. There are other analyses that seek to determine the cost per unit of electricity that an EVSE provider would have to charge in order to turn a profit of a particular percentage in a given year. It is important to reiterate that this analysis makes no assumptions about profitability. Our analysis indicates that:

- Even at an assumed charging level of up to 6.6 kW, the breakeven pricing for Level 2 EVSE is similar to standard residential rates, and much higher than TOU residential rates that utilities generally offer to customers who own a PEV (which are as low as $0.06/kWh for overnight charging). For instance, the breakeven pricing indicates that for an EVSE provider to have its investment paid off in five years—without any profit—it would need to charge $0.26 to $0.43 per kWh, depending on the rate schedule. Although the cost on a per gallon of gasoline equivalent is competitive with gasoline at a cost of $2.35 to $3.86 per gallon, it is much higher than the residential rates that drivers may be charged.
- The breakeven pricing for DC fast charging EVSE is highly sensitive to energy demand charges. If one assumes that an EVSE provider, for instance, is responsible for 50 days of demand charges – with a maximum demand from DC fast charging EVSE estimated at 45 kW – then the breakeven pricing can change dramatically. It can increase the breakeven pricing for a 5-year payback by nearly a factor of three.
- In almost every scenario modeled by ICF, the breakeven pricing in a reasonable timeframe (defined here as less than five years) is considerably higher than what consumers are likely to pay for residential charging. The breakeven pricing in the out years (e.g., 8 to 10 years), indicates that there are scenarios that can offer a rate competitive with residential charging. However, it

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however, that there are Level 2 installations that can cost significantly more or less than $10,000 depending on local conditions. Similarly, there are DC fast charging installations that can cost significantly more or less than $100,000 depending on local conditions. Regardless of these variations, the costs employed in the revenue model fairly represent EVSE deployment costs for the purposes of our assessment.

is difficult to make the case that a private stakeholder will make investments with a ten-year payback in mind.

The sustainability of investing in and owning publicly accessible charging stations will come under increasing scrutiny if public agencies seek to scale back the role of government-funded projects. For instance, we have witnessed several high profile failures in the charging infrastructure market to date. Most notably, ECOtality's bankruptcy and 350 Green's financial and legal troubles; both organizations received significant levels of public funding. Better Place, although they did not spend any public funds during their deployment projects, is another high profile failure in the charging infrastructure market. Apart from these individual failures, there are other signs in the market place that should give public agencies pause about committing additional funding, including companies withdrawing from the market and significant consolidation. For instance, Siemens announced in 2013 that it was withdrawing from the public charging infrastructure business.

Despite these challenges in the market for charging infrastructure, many industry players continue to advocate for increased public spending on publicly accessible EVSE as a way to solve the sustainability conundrum. Some stakeholders speak of a gap of up to $1 billion in funding for publicly available EVSE by 2020. These discussions of funding gaps are complemented by commentary such as the following from the Director of Electric Vehicles at Schneider Electric: "We still have to put in pervasive EV charging infrastructure within cities that allows people to identify that the infrastructure exists out there." Meanwhile, others such as BMW Board Member Herbert Diess have commented that "this public infrastructure is not really very important because most people are charging their cars at home".[65] Given the extent to which PEV drivers have adapted their charging behavior to their driving behavior–as evidenced by the larger-than-expected proportion of PHEV and BEV drivers using Level 1 charging, for instance–it is increasingly difficult to make the case that high levels of public investment in publicly available EVSE infrastructure are warranted.

The demand for non-home charging is unclear

Despite there being consensus that PEVs will continue to increase their share of the light-duty vehicle market, it is unclear what the demand will be for non-home charging. This market is impacted by variables such as the vehicle type or architecture that consumers purchase, consumer willingness to pay for charging, and driver behavior. These factors are particularly important because the PEV charging industry needs to demonstrate how it is taking steps to provide the pricing and technology to influence charging decisions that demonstrate advancement toward the vehicle-grid integration (VGI) that the CPUC recently outlined in a white paper.[66]

[65] Ward's Auto, January 20, 2014 " BMW Exec Sees Little Need for Public Charging" (http://goo.gl/EMtQQM)

[66] CPUC, Energy Division Staff White Paper, Vehicle-Grid Integration: A Vision for Zero-Emission Transportation Interconnected throughout California's Electricity System, November 2013. Available online at: http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M080/K775/80775679.pdf.

Vehicle purchasing behavior

It is unclear what type of vehicles–BEVs or PHEVs–consumers in the various regions of California will be more likely to purchase in the future. The distribution of vehicle types will have a significant impact on business strategies in the EVSE market as most BEVs do not need any out-of-home charging on a daily basis (because their battery range typically covers more than the daily VMT) and current PHEVs do not have DC fast charging connectors.

Our analysis makes credible assumptions about the split between PHEVs and BEVs; however, this estimate carries considerable uncertainty. For instance, OEMs are generally making more significant investments in PHEVs, as indicated in a recent survey of automotive executives.[67] There has been a drop in executives' interest (from 2013) in battery technologies with increased interest in internal combustion engine (ICE) downsizing and optimization. Furthermore, 24% of survey respondents identified plug-in hybridization and battery vehicles with range extenders as their main investment over the next five years compared to just 9% of respondents identifying pure battery electric vehicles. Finally, 35% of survey respondents reported that PHEVs are the most likely to attract consumer demand by 2019. Meanwhile, just 17% and 14%, respectively, responded that battery vehicles with range extenders and pure BEVs will attract consumer demand, by 2019.

Conversely, the improvement in battery technology has the potential to change consumer preferences: Although most BEV models available today have a range of about 100 miles or less–including the Nissan LEAF, Chevrolet Spark, Ford Focus Electric, and Mitsubishi iMiEV– the potential for battery technology improvements leading to longer vehicle ranges, or simply the decision by OEMs to offer larger batteries, may translate into improved attractiveness and an increased market share for BEVs. The increased availability of non-home charging may also influence the demand for BEVs, as well as increase eVMT for PHEVs.

Consumer willingness to pay for charging

Industry estimates indicate that about 20% of non-home charging stations collect a fee for charging.[68] As a result, there is little data available to understand consumer willingness to pay for away-from-home charging. A recent Navigant survey, for instance, found that 40% of respondents had a high degree of interest in public charging. When those respondents were asked how much they would be willing to pay for a 15-minute charge that provides 6 to 7 miles of range, more than 20% of them indicated that they would only use this service if it was free. The rest of the results – including ICF's analysis of the equivalent electricity pricing – are shown in Table 31 below.

[67] KMPG, *Global Automotive Executive Survey 2014*, Available online at: http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/global-automotive-executive-survey/Documents/2014-report.pdf

[68] Number attributed to Pasquale Romano, CEO of ChargePoint in a CNBC article entitled Payback is a switch: Business Case for EV Charging. Accessed online in April 2014 at http://www.cnbc.com/id/101388967.

Table 31. Consumer Willingness to Pay Survey Results and Equivalent Pricing

Willing to Pay for 15-Minute Charge; Range of 6-7 miles	Percentage of Respondents	Equivalent Electricity Pricing
free	23%	--
< $1	29%	<$0.43/kWh
$1 to $2	29%	$0.43-$0.87/kWh
$2 to $3	11%	$0.87-$1.30/kWh
$3 to $5	5%	$1.30-$2.17/kWh
>$5	3%	>$2.17/kWh

For the equivalent electricity pricing, ICF assumed total energy delivered of 2.3 kWh based on a 0.35 kWh/mi efficiency of electric drivetrains and a range of 6-7 miles.

These types of surveys provide valuable insights; however, they lack a critical feature such that the results are skewed: Survey respondents are not provided equivalent pricing for residential charging. The survey implicitly assumes that the respondents would not understand how much they are paying for residential charging and would make decisions for publicly accessible EVSE based on some arbitrary assumption of convenience and willingness to pay. ICF posits, however, that one of the most significant areas of uncertainty moving forward is the amount that consumers will be willing to pay when they become increasingly accustomed to attractive TOU rates at residences or even modest residential rates when charging at Level 1. Other analyses of the viability of third-party ownership/operation of PEV charging networks overlook another critical factor, which is comparing the cost of a public charging event to the price of gasoline. Deloitte, for instance, makes this comparison in an analysis it conducted regarding the breakeven costs of EVSE installation and operation.[69] This comparison may make sense in the context of discussion about PEV adoption; however, as PEV drivers become accustomed to paying at-home charging rates, the comparative focus will likely shift away from electricity prices vs. gasoline prices and shift towards residential electricity rates vs. non-home electricity rates.

Charging needs and behavior

It is largely unclear where, when, and for how long PEV drivers will seek to charge their vehicles when away from home. Many publicly available EVSE have very low utilization rates: The EV Project generally reports utilization rates well below 10%. To some extent, this is the result of providing free charging stations and associated installation costs. The sites selected for The EV Project were not always vetted for maximum utilization; rather, they focused on willing hosts and potentially high profile locations (e.g., City Halls).

[69] Deloitte, *Plugged In: The Last Mile*, Available online at: http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Energy_us_er/us_er_PluggedInLastMile_June2013.pdf

Based on the National Household Travel Survey, the average driver makes three trips per day with an average of 9.7 miles for each trip; 80% of all trips are less than 15 miles. These numbers suggest that most BEV drivers (whose electric range varies from 62 miles, for the Mitsubishi iMiev, to 265 miles, for the Tesla Model S) do not need to charge outside their home on most days (i.e., out-of-home charging will lead to load shifting, not load increase). PHEV drivers, using a vehicle with an electric range of 10 to 40 miles depending on the model, may find it worthwhile to charge out of home to extend their eVMT and avoid using gasoline. However, if the cost of charging is too high, or if charging cannot take place while conducting other activities, such as working or shopping, PHEV drivers have the option of using their gasoline-powered range extender and foregoing charging out-of-home.

5.3.2 Potential Solutions

Alternatives to additional public investment in charging infrastructure deployment

To date, public agencies have made significant investments in PEV charging infrastructure. The US Department of Energy (DOE), using funds allocated as part of ARRA, spent more than $130 million on programs to deploy charging infrastructure. Public agencies in California–including the California Energy Commission (CEC) and air pollution control districts–issued match funding to support ARRA-funded programs, and made their own investments with additional public funding for other statewide and regional deployment programs. The CEC, air pollution control districts, and metropolitan planning organizations (MPOs) have made varying levels of commitment to continue funding charging infrastructure deployment for the near-term future.

Given the uncertainty in the charging infrastructure marketplace, ICF recommends that public agencies seek alternatives to additional public investment in charging infrastructure. This will help reduce public agencies' exposure to failed endeavors and potentially stranded assets. These alternatives should have an increased focus on "no regrets" solutions such as make-readies and EVSE deployment in areas where it is needed the most, notably at MDUs and workplaces.

Revisit ruling regarding utility investment in charging infrastructure

There are early signs that benefits are being left on the table by limiting utility investment in charging infrastructure, a topic which will be explored and quantified further in the Phase 2 report. Given the legitimate concerns regarding the sustainability of third-party owner/operators of PEV charging networks, ICF recommends revisiting the CPUC ruling regarding utility investment in charging infrastructure. The Assigned Commissioner's recent Scoping Memo and Ruling (Scoping Memo)[70] indicates that the CPUC is willing to take up this issue. The Scoping Memo outlines 13 issues that are to be addressed in Phase 1 over the next 18 months, including the following:

[70] R.13-11-007, Phase 1 Scoping Memo, July 16, 2014, available online: http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M098/K861/98861048.PDF

2. Should the Commission consider an increased role for the utilities in PEV infrastructure deployment and, if so, what should that role be? If the Commission should consider utility ownership of PEV charging infrastructure, how should the Commission evaluate "underserved markets" or a "market failure" pursuant to D.11-07-029? What else should the Commission consider when evaluating an increased role for utilities in EV infrastructure deployment?

Based on ICF's research as part of our light-duty PEV market assessment, the answer to the first part of the first question is "yes". We arrive at that answer by considering, for instance, that California utilities have a history of forwarding services to society that are not typically cost-effective, such as early renewable energy installations and energy efficiency measures. There are analogous concerns with the nascent PEV charging infrastructure market that utilities should be able to help address.

The second part of the first question (i.e., the role for utilities in PEV infrastructure deployment) is much more nuanced. In this case, ICF is informed by interviews with each of the utilities–both IOUs and MOUs–conducted as part of this project regarding the potential role(s) for utilities in the charging infrastructure market. The key takeaway from our interviews was that while there was unanimity regarding an increased role for utilities in PEV charging infrastructure deployment, the role and strategy that each utility will pursue is considerably different. With that in mind, ICF recommends that utilities be afforded flexibility in their ability to engage in the charging infrastructure market. The role(s) of the utility should reflect the dynamic nature of the PEV and charging infrastructure markets to date. The solutions that will accelerate deployment of PEVs and charging infrastructure consistent with the ZEV Program and Governor Brown's ZEV Action Plan are not uniform across utilities (whether they be IOUs or MOUs). In other words, the solutions that will be required to achieve the targets of the ZEV Program and the goals of the ZEV Action Plan in 2025 are much different than those that are required to support the nascent market today. The risk of narrowly defining the role of utilities based on our understanding of the market today may well impede the ability of utilities to help provide the solutions needed in the future.

As the CPUC considers evaluating an increased role for utilities, they should consider factors such as the following, recognizing that these factors should be researched expeditiously and within the timeframe of the Phase 1 proceedings as they relate to the Guiding Principles and Current Program Issues:

- A market assessment (informed by existing literature) of the PEV/EVSE ecosystem including a review of revenue models, installation, maintenance and equipment costs, market performance, and EVSE utilization in various deployment schemes.
- A review of PEV driver behavior to date – including VMT, eVMT, location of charging, common charging rates, vehicle types (PHEVs vs. BEVs given that the vehicle architecture impacts policy planning), consumer satisfaction surveys, and EVSE host site owner/manager satisfaction surveys.

These considerations will enable the CPUC to assess current market performance, to determine objectively if it is feasible to facilitate and accelerate PEV charging infrastructure deployment via utility involvement, and to identify the potential role(s) for utilities moving forward.

The CPUC's recent white paper on vehicle grid integration (VGI) also influences our recommendation to revisit the ruling regarding utility investment in charging infrastructure. The CPUC has outlined a vision whereby solutions are developed that achieve grid optimization through grid integrated charging. This requires technology and pricing that leads to or influences PEV customers' charging decisions (e.g., location, rate of charge, frequency and duration of charging and staying plugged in). In order to accomplish this, steps need to be taken to explore VGI further. Since utility rates are cost based, for example reflecting grid conditions such as capacity and energy, the utility is ideally suited to lead the developmental effort toward VGI, especially if this creates increased long-term performance assurances. Accordingly, an increased role for utilities in VGI possibilities requires revisiting the potential for utility investment in charging infrastructure.

The potential of utility investment in charging infrastructure should help facilitate the first recommendation of exploring alternatives to additional public investment in charging infrastructure deployment. Furthermore, there is a philosophical question regarding efficiency of capital that must be considered in this equation. Grant funding from programs like the Electric Program Investment Charge (EPIC) and the Alternative and Renewable Fuel and Vehicle Technology Program are ultimately funded by ratepayers. Both of these programs, to some extent, have helped or likely will help subsidize potentially unsustainable third-party ownership of PEV charging networks – so which approach is the most societally efficient? Utility investment in PEV charging infrastructure does not preclude a role for non-utility market participants since EVSE hardware, installation, operation and maintenance, and network systems will still need to be procured.

Finally, the CPUC's decision primarily reflects a concern for preserving the nascent EVSP market with the finding that "the benefits of utility ownership of electric vehicle service equipment do not outweigh the competitive limitation that may result from utility ownership".[71] As the PEV market is now in its fifth year, and more is known about the gaps and barriers that limit adoption, utilities are in a unique position to support the PEV market and reap the value of the PEV load more than any other industry players. If utilities were authorized to undertake and committed to implementing initiatives that help bridge critical gaps and barriers, competiveness in the marketplace could not only be preserved, but even encouraged by the resulting increased demand for charging products and services. This would probably be welcome news for a sector that has seen several prominent players file for bankruptcy in recent months.

Improved evaluation of charging infrastructure deployment

One of the critical aspects of The EV Project, originally led by ECOtality and recently assumed by CarCharging Group, is the reporting on EVSE utilization. Unfortunately, there is a gap in the reporting done to date between the utilization data and the costs of EVSE (including installation, maintenance, etc.). Furthermore, there has been little reporting on the utilization of EVSE infrastructure funded by other sources–including the CEC and air pollution control districts in California. Anecdotal evidence

[71] Alternative Fueled Vehicles OIR, Phase 2 Decision, July 14, 2011, page 82.

suggests that the original deployment of EVSE has been less-than-optimal (e.g., focusing on siting EVSE in places where it is inexpensive to install rather than where it is most likely to get utilized the most). Moving forward, and assuming that public entities continue to provide some funding (e.g., grants) for deployment, it will be important for public agencies to identify evaluation metrics, as part of the funding process, that quantify the impact in terms of net results (e.g., reducing the cost of EVSE through increased production and passing value along to the host). It is often difficult to evaluate the cost-effectiveness of funding initiatives after the money has been spent due to the absence of provisions for the recipient to report adequately on information required to conduct a proper evaluation. To the extent that public agencies can incorporate evaluation into the process at the outset of funding, the more valuable the evaluation will be, especially if results are readily available for policy makers and market participants. The Metropolitan Transportation Commission (MTC) in the Bay Area, for instance, is evaluating grants received under the Climate Initiatives Program. An evaluation contractor has been working with the grantees since the inception of the project, enabling a rigorous accounting of benefits (e.g., GHG emission reductions) and lessons learned. This type of ex ante evaluation is unusual; transportation programs are generally subject to ex post evaluations or no evaluations at all. The utility sector is accustomed to programmatic evaluations through energy efficiency programs, for instance, and can play a critical role in promoting similar levels of evaluation in the PEV ecosystem.

5.4 Consumer Education and Outreach

5.4.1 Identification of the Gaps and Barriers

The introduction of new technologies like PEVs requires careful coordination and continuous outreach to consumers to deliver high-level messaging at the local and regional levels to highlight PEV availability and benefits, including total cost of ownership as well as environmental, health, and community benefits. Furthermore, it is important to communicate on a frequent basis the direct financial and nonfinancial benefits to drivers including tax credits, grants, and the PEV driving experience (e.g. fast acceleration and quiet vehicle operation) and the differences associated with fueling from the grid rather than from a gas station.

Lack of PEV Awareness and Knowledge

Except for high-level messaging, there is a general lack of awareness of PEVs in the consumer market today. For instance,

- Navigant reports that the awareness of EVs other than the LEAF and Volt among survey respondents is less than 25%. Even with the Volt and LEAF, only 44% and 31% are extremely familiar or somewhat familiar with these vehicles, respectively.
- Disappointingly, the numbers from Navigant's 2013 survey are not too dissimilar from those reported in a 2010 survey by Ernst & Young. Ernst & Young found that 62% of respondents had never heard of PHEV technology or have heard of it but don't know what it is. Similarly, 40% of respondents have never heard of PEV technology or had heard of it but don't know what it was.

- Even in the San Francisco Bay Area, one of the top markets for EVs, a survey of City CarShare members showed that only 47% of respondents were very familiar or somewhat familiar with EVs. (Note: at the time, City CarShare only had about 10 PEVs in its fleet). Other responses to the survey indicate that consumers may not be as familiar with PEVs as these surveys indicate. For instance, respondents were asked to identify specific PEV model names. Despite 84% of respondents saying they considered themselves at least "slightly familiar" with PEVs, nearly 20% of respondents identified a vehicle that was neither a BEV nor a PHEV. Rather, the respondents regularly identified an HEV (e.g., Toyota Prius) or a small fuel efficient car such as the SmartCar.

Total Cost of Ownership

Consumers' unwillingness or hesitancy to pay for the additional upfront cost of PEVs (as discussed previously) is coupled with an undervaluation of fuel savings. Ideally, consumers would have an idea of the payback period for the purchase of a PEV – the period of time required for the consumer to recoup the incremental cost of the vehicle–or would understand the total cost of ownership. These values are dependent on variables such as the price of gasoline, the price of electricity, the price of the vehicle, the cost of maintenance, resale value, and the availability of purchasing incentives. Unfortunately, research has shown that consumers generally undervalue future fuel savings and capture only the potential benefits of more fuel efficient vehicles that accrue over a period of two to four years, when actual ownership is two to three times longer than that.[72] In other words, even if the present value of fuel savings over a vehicle's lifetime outweighs the difference in initial cost, it typically will not be enough to convince consumers to pay more up front.[73]

Calculating the total cost of ownership may prove complex to most customers, as there are limited data available regarding the resale value of PEVs (due to the low volume of sales and limited historical data available in a nascent market).

Finally, consumer concern about the life of the batteries, despite OEM vehicle warranties, will likely continue to limit the resale PEV market until the batteries' lifespan and their residual value in their post-automotive life are clearer.

Improved PEV Education

The familiar aspects of car ownership – such as vehicle pricing, fuel pricing, vehicle range, availability of refueling infrastructure – changes with PEV ownership. Consumers and property owners can often have a difficult time finding the practical and concrete information required to make an informed purchase. PEV ownership often requires a better understanding of vehicle availability, charging options, networking needs, installation costs, contractors capable of performing the installation, etc. There is abundant information available online; however, it is often in multiple places – at the utility website, or with air pollution control districts, permitting departments, OEMs, etc. There are information

[72] D. Greene and S. Plotkin, "Reducing Greenhouse Gas Emissions from U.S. Transportation," *Pew Center on Global Climate Change*, 2011.

[73] Indiana University, "Plug-in Electric Vehicles: A Practical Plan for Progress," *Indiana University*, 2011.