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# The Practical PEV: Removing Barriers to Plug-In Electric Vehicle Charging and Ownership

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# **The Practical PEV: Removing Barriers to Plug-In Electric Vehicle Charging and Ownership**

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In partial fulfillment of a Bachelor of Arts Degree in Environmental Analysis,  
2010/11 academic year, Pomona College, Claremont, California

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## Acronyms

<b>Battery Electric Vehicle</b>	<b>BEV</b>
<b>California Public Utilities Commission</b>	<b>CPUC</b>
<b>California Independent System Operator</b>	<b>CAISO</b>
<b>Electric Power Research Institute</b>	<b>EPRI</b>
<b>Electric Vehicle Service Equipment</b>	<b>EVSE</b>
<b>Environmental Protection Agency</b>	<b>EPA</b>
<b>Greenhouse Gas</b>	<b>GHG</b>
<b>Internal Combustion Engine</b>	<b>ICE</b>
<b>Kilowatt (1000 Watts)</b>	<b>kW</b>
<b>Kilowatt-Hour</b>	<b>kWh</b>
<b>Los Angeles Department of Water and Power</b>	<b>LADWP</b>
<b>Light Duty Vehicle</b>	<b>LDV</b>
<b>Megawatt-Hour</b>	<b>MWh</b>
<b>Natural Resources Defense Council</b>	<b>NRDC</b>
<b>Oak Ridge National Laboratory</b>	<b>ORNL</b>
<b>Pacific Northwest National Laboratory</b>	<b>PNNL</b>
<b>Plug-in Electric Vehicle</b>	<b>PEV</b>
<b>Plug-in Hybrid Electric Vehicle</b>	<b>PHEV</b>
<b>Southern California Edison</b>	<b>SCE</b>
<b>Time of Use</b>	<b>TOU</b>

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## **Introduction**

The paradigm of personal transportation is changing. Electric vehicles are here. The arrival of the Tesla Roadster, Nissan Leaf, and Chevy Volt has changed the way in which we have to think about the energy that fuels our transportation needs. As PEVs find their way into garages this year and especially in the coming years, the neighborhood, city, state, and regional electric infrastructure will take on a new importance for many people as their interactions with it become significantly more complex and intimate as a result of regular electric vehicle charging.

The transition to PEVs has been motivated by a variety of factors. Greenhouse gas (GHG) emissions reductions, energy independence, and decreased operating costs are all areas where PEVs come out ahead in comparison to conventional, internal-combustion vehicles. At the root of all of these is the enormous reduction in oil consumption that PEVs promise to bring as a result of shifting from gas stations to power plants as a source of energy<sup>1</sup>.

The emissions reduction potential of a large-scale transition from conventional vehicles to PEVs in the light duty vehicle (LDV) fleet is probably the single most significant benefit that PEVs offer. On a national scale, a move to PEVs from conventional vehicles would represent a huge reduction in GHG emissions. The authors of a Pacific Northwest National Labs study on the technical potential of existing grid resources to accommodate PEVs find that if 73 percent of the existing LDV fleet were displaced by PEVs (the maximum technical potential given current grid resources), total vehicle GHG emissions would be reduced by 27 percent<sup>2</sup>. Looking at California specifically, the authors find that statewide LDV GHG emissions would be reduced by

about 40 percent if 23 percent of the state LDV fleet (again, the maximum technical potential given current resources) were replaced by PEVs<sup>3</sup>. GHG emissions are not the only emissions that would be reduced with a move to PEVs. As Figure 1 shows, a switch to PEVs would also represent a significant decrease in emissions of pollutants like carbon monoxide, volatile organic compounds, sulfur oxide, particulate matter, and nitrogen

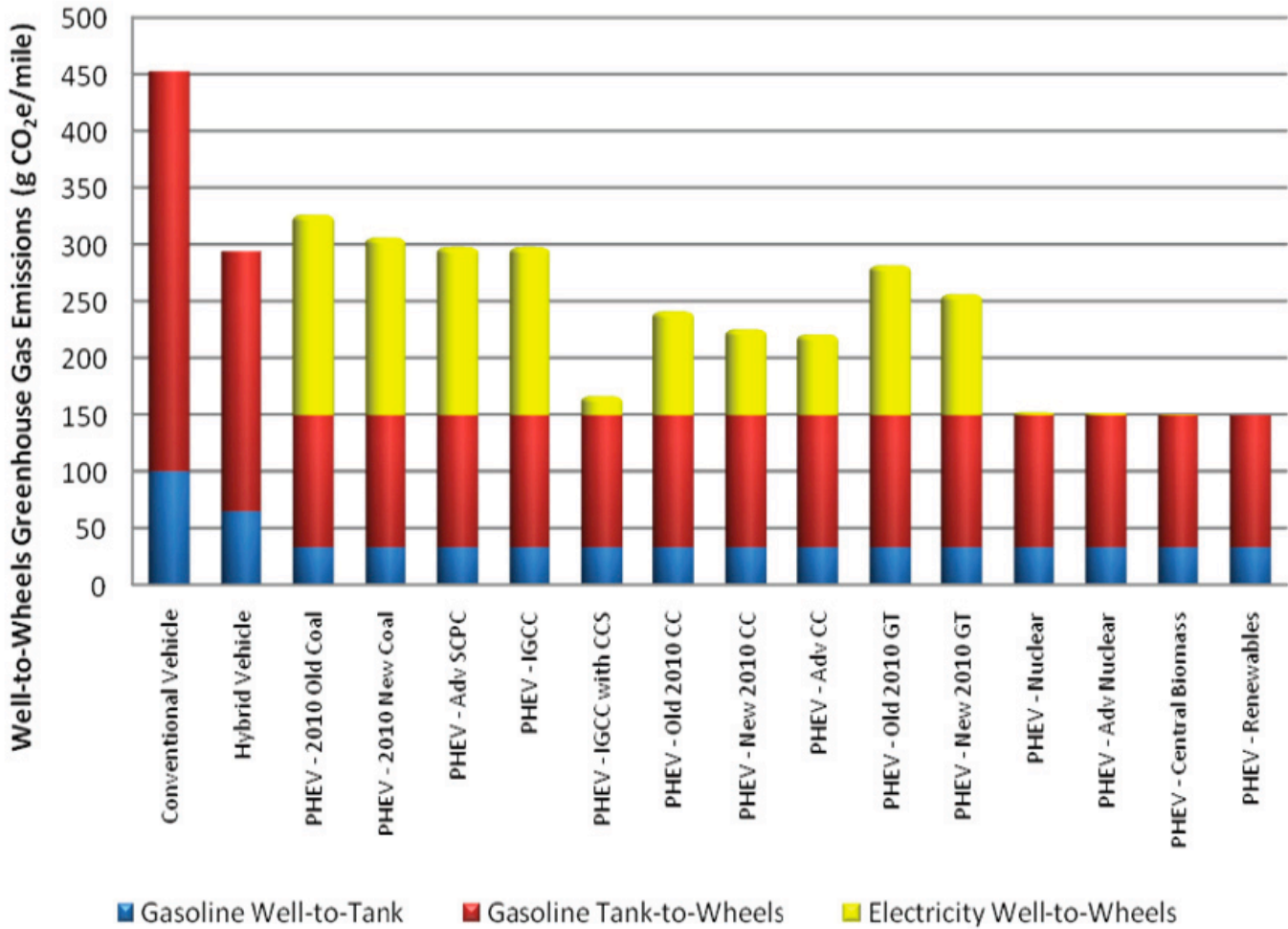
**Figure 1. Emissions Results of PEVs Using the GREET Model<sup>4</sup>**

	ECAR	ERCOT	MACC	MAIN	MAPP	NPCC	FRCC	SERC	SPP	NWP	AZN& RMP	CNV	U.S. total
<b>Power Generation Composition</b>													
Natural Gas	32%	94%	74%	42%	1%	91%	69%	57%	78%	43%	63%	93%	
Coal	68%	6%	26%	58%	99%	9%	31%	43%	22%	57%	37%	7%	
<b>Emissions Ratio (Electric Vehicle/Gasoline Vehicle)</b>													
<i>Emissions</i>													
GHGs	0.87	0.60	0.69	0.83	1.01	0.61	0.71	0.76	0.66	0.84	0.73	0.61	0.73
VOC: Total	0.11	0.04	0.06	0.10	0.14	0.04	0.07	0.08	0.06	0.10	0.07	0.04	0.07
CO: Total	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NOx: Total	1.02	0.38	0.59	0.93	1.35	0.41	0.64	0.76	0.54	0.93	0.71	0.39	0.69
PM10: Total	1.55	0.81	1.06	1.45	1.94	0.86	1.13	1.26	0.99	1.46	1.19	0.84	1.18
SOx: Total	3.94	0.42	1.68	3.59	5.96	0.64	2.05	2.67	1.34	3.77	2.35	0.53	2.25
VOC: Urban	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CO: Urban	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOx: Urban	0.10	0.11	0.11	0.10	0.09	0.11	0.11	0.10	0.11	0.10	0.10	0.11	0.10
PM10:Urban	0.60	0.62	0.62	0.60	0.58	0.62	0.61	0.61	0.62	0.61	0.61	0.62	0.61
SOx: Urban	0.35	0.04	0.14	0.30	0.51	0.05	0.17	0.22	0.12	0.31	0.20	0.04	0.19

oxide. Each column in Figure 1 represents a region of the United States electric grid: ERCOT represents Texas while CNV represents California and a very small portion of Nevada. As the six rows under the “Emissions” heading of the table shows, emissions would be reduced across the board with a switch from gasoline vehicles to PEVs. In addition, the five rows at the bottom of the table illustrate how emissions in urban centers would decrease with a switch to PEVs. These urban air quality improvements would be a significant benefit for areas with air quality concerns like Los Angeles.

The authors of the Pacific Northwest National Labs study are not the only ones who conclude that PEVs would be a boon for emissions reduction efforts. Stanton Hadley, the author of an Oak Ridge National Laboratory study<sup>5</sup> and Mark Duvall, an author of a joint report on the environmental impacts of PEVs conducted by the Electric Power Research Institute (EPRI) and the Natural Resources Defense Council (NRDC) also conclude that in most cases, PEVs promise emissions reductions compared to conventional vehicles<sup>6</sup>. This is true even for a generation mix that includes a large portion of coal-generated electricity. As the authors write in the EPRI-NRDC report, “In 2010, current coal technologies result in 28% to 34% lower GHG emissions compared to the conventional vehicle and 1% to 11% higher GHG emissions compared to the hybrid electric vehicle.”<sup>7</sup> Figure 2 provides a helpful breakdown of the emissions impacts of a PHEV with 20 miles of electric range charged with various forms of generation. The importance of the data presented in Figure 2 is that it demonstrates that PEVs are emissions winners compared to conventional vehicles no matter how the electricity to power them is generated.

**Figure 2: Year 2010 comparison of PHEV 20 GHG emissions when charged entirely with electricity from specific power plant technologies (12,000 miles driven per year).<sup>8</sup>**



It should be noted that PEVs with greater than 20 miles of electric range such as the Chevy Volt (40 miles of electric range) and the Nissan Leaf (100 miles of electric range) will not match the emissions breakdown shown in Figure 2. The reason for this is that as a result of their increased electric range, the Volt and Leaf will shift emissions from gasoline consumption to electricity generation, or from the blue and red areas of the graph to the yellow. The overall results of this will be highly dependent on the generation mix, such that a shift to greater electric ranges charged by old coal plants may represent a



net increase in emissions compared to the graph in Figure 2 while a shift to greater electric ranges charged by natural gas, nuclear, or renewables may result in a net decrease compared to the graph. The reduction in oil consumption at the heart of the emissions reductions from PEVs also brings with it a decreased dependence on foreign oil. As the authors of the PNNL study write:

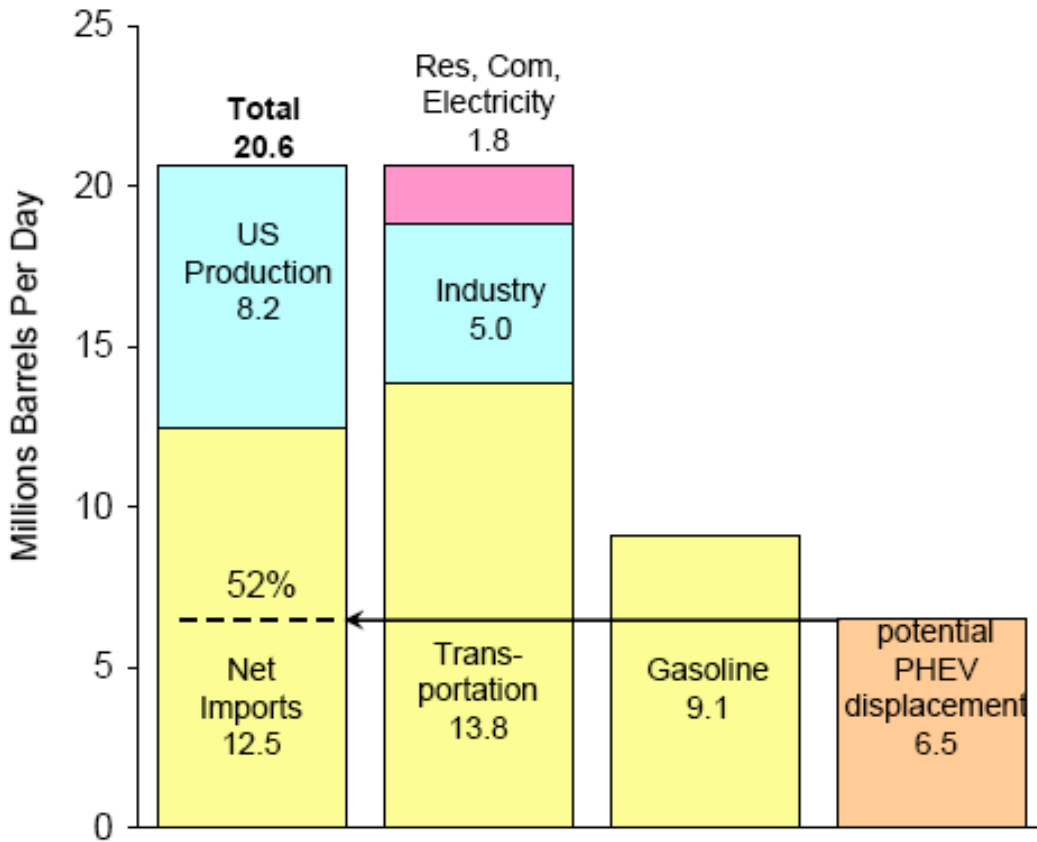
Considering that the LDV fleet consumes 97% of the entire gasoline supply, the conversion of 73% of the LDV fleet to PHEVs could reduce gasoline consumption by a crude oil equivalence of 6.5 million barrels per day (MMBpd). This reduction in the U.S. gasoline consumption is the equivalent of 52% of foreign petroleum imports<sup>9</sup>.

Although the authors concede that a 73 percent PEV conversion rate and 52 percent oil import reduction are the theoretical maximum and thus unlikely, the numbers they present do indicate just how significantly a market-wide transition to PEVs would reduce oil consumption. Figure 3 is a graphical representation of the petroleum supply and consumption in the United States and is useful for understanding the potential positive impact PEVs could have in reducing oil imports. Even if the conversion of the LDV fleet is only half or a quarter of the theoretical maximum used by the authors, it would still represent a reduction in oil imports of 26 and 13 percent, which would be equivalent to approximately \$260 million and \$130 million per day given an oil price of \$80/barrel as of December 2010<sup>10</sup>. These are not small numbers and show the potential impact that PEVs could have in terms of oil imports.

A third motivating factor for a switch to PEVs from conventional vehicles is the reduced operating cost. According to a consumer survey conducted by Southern California Edison (SCE) and EPRI<sup>11</sup>, this may be the most powerful motivation for many

consumers, who may or may not be concerned with or have knowledge of the environmental and energy security benefits.

**Figure 3. Petroleum Supply, Consumption, and PEV Displacement Potential<sup>12</sup>**



The low operating cost of PEVs is primarily a result of the low price of electrical energy compared to petroleum energy. For example, the Environmental Protection Agency has rated the Chevy Volt and Nissan Leaf as requiring approximately 0.36 kWh and 0.34 kWh to travel one mile<sup>13</sup>. Multiplying this by an average residential cost of electricity in California in August 2010 of \$0.1573/kWh<sup>14</sup> gives a cost per mile of about \$0.06 for the Volt and \$0.05 for the Leaf. By comparison, the average fuel efficiency of passenger cars on the road in 2008, the most recent year statistics are available, was 22.6 miles per gallon<sup>15</sup>. The average price of a gallon regular grade gasoline as of November

29, 2010 was \$3.15<sup>16</sup>. Dividing \$3.15 by 22.6 results in a cost of about \$0.14 per mile. For a potentially more relevant comparison, the average fuel efficiency of a new passenger car in 2009 was 32.6 miles per gallon. Using the same formula as above, the cost to travel one mile in an average new car from 2009 would be about \$0.10. Finally, the most fuel-efficient car available for sale in the United States that isn't a PEV, the Toyota Prius, is rated at 50 miles per gallon<sup>17</sup>, which results in a cost per mile of just over \$0.06, the same driving cost as the Volt.

Although the Toyota Prius has the same direct operating cost as the Volt and nearly the same as the Leaf, it is important to keep some things in mind when comparing PEVs to non-PEVs. First, the price of gasoline is inherently more volatile than the consumer price of electricity, so while gasoline may increase by \$1.00, or 33 percent, in the near future, it is extremely unlikely that consumer electricity rates will also increase by the same factor, to nearly \$0.20 per kWh over the same time period. Furthermore, the average price of \$0.1573 per kWh used in the above calculations does not take into account the discounted electricity rates that PEV owners would enjoy if they opted to charge their vehicles during off peak periods. In the case of SCE, the off-peak rate for charging a PEV would be less than half the \$0.1573 rate<sup>18</sup>. Assuming PEV owners charge mostly during off-peak periods, the actual direct operating costs of a PEV would likely be about half those of even a Prius, excluding the lower maintenance costs of PEVs compared to non-PEVs.

As this introduction illustrates, the expected environmental, energy security, and economic benefits of PEVs compared to conventional vehicles are real and significant. Given this, there is no reason to believe that a market transition to PEVs should not be

encouraged and expected over the course of the next decade. Much of the research on PEVs has focused on the impact that the electrification of the United States' transportation sector will have on the existing electric grid (CPUC, PNNL, ORNL, SCE). The first chapter of this paper will draw on the body of existing work on PEV impacts to show that while the impacts of PEVs on the grid may be significant in the long term, the effects of PEVs on energy consumption and demand will be relatively minor and entirely manageable with current generation assets for at least the next decade as a result of adequate generation, smart metering practices and effective pricing methods.

The second part of this paper attempts to explore the relationships that will emerge between drivers and the electric grid as consumers begin to exchange gas tanks for battery packs and gas pumps for electric chargers. Specifically, this paper will explore the important issues that must be successfully addressed in order for PEV charging and ownership to expand beyond the confines of the single-family home garage and successfully transform the broader market by also expanding into additional residential spaces such as multi-family housing and especially urban apartment buildings.

By analyzing the demographic composition and living situations of downtown Los Angeles residents and comparing them to those of current and former hybrid vehicle owners, this paper argues that although urban areas like downtown Los Angeles are poised for an influx of PEVs they are simultaneously completely unprepared in terms of available charging infrastructure and a coherent framework to facilitate residential charging for those who do not live in single-family homes with private garages. To demonstrate the complexity of residential charging in urban areas and to inform future discussions of such charging, this paper concludes with three hypothetical use cases that

encompass the variety of challenges posed by urban charging while also presenting possible solutions.

## **Chapter 1: The Impacts of PEVs on California's Electric Grid**

The question about electric vehicles is no longer whether they will come to market but rather how many and when. Estimates for the market penetration of electric vehicles have an enormous range. California is one of a group of states predicted to contain a large number of PEVs fairly soon due to its large population of early adopters and its energy policy that actively encourages the adoptions of electric vehicles. However, the estimates of how many PEVs will appear on the road vary widely. In a whitepaper examining the impact of PEVs on California's electric grid, the California Public Utilities Commission estimates the number of PEVs likely to appear on California's roads under low, medium, and high market penetration scenarios by 2020. At the low end, the CPUC estimates 61,000 PEVs subdivided between 3,000 BEVs and 58,000 PHEVs. The medium estimate predicts 33,000 BEVs and 312,000 PHEVs for a total of 345,000 PEVs. The high prediction has 455,000 BEVs and 2.5 million PHEVs for a total of just under 3 million PEVs by 2020<sup>19</sup>. The difference between 61,000 and 3 million PEVs is clearly substantial and this enormous range is the result of the large number of difficult to predict factors that will ultimately determine how many PEVs reach the market.

One of the largest factors in PEV purchasing decisions is the cost to the consumer. In a survey of 900 Southern California Edison customers, one of the main determinants of whether consumers would buy a PEV was economics: would the premium paid for a PHEV or BEV be recouped in reduced fuel costs over a reasonable amount of time?<sup>20</sup> Obviously, the larger the price premium of the PEV, the more unlikely that it will be recouped, and the fewer cost-conscious consumers will choose PEVs in

favor of conventional ICE or non-plug-in hybrids. Currently, the only PEV a consumer could purchase today is the Tesla Motors Roadster, a \$110,000 sports car.

Understandably, the Tesla Roadster has not sold in huge volumes; there are currently about 1600 of them on the road globally. A lower-priced PEV, the Nissan Leaf, is scheduled to come to market in December 2010 and has garnered advance orders of around 16,000 cars at a price of \$32,000<sup>21</sup>. Although comparing Tesla sales to Nissan pre-sales is far from a conclusive argument that cost is the most important factor in PEV purchasing decisions, it does seem to indicate that PEVs such as the Leaf, comparably priced and equipped to a conventional vehicle, will achieve a meaningful degree of market penetration and consumer acceptance going forward.

Besides purchase price, a very significant factor affecting the potential market penetration of PEVs is the availability of charging infrastructure<sup>22</sup>. In the same study in which SCE customers named cost as a significant factor in PEV purchasing decisions, the researchers conducting the study concluded that the single greatest PEV adoption barrier is charging capability, or whether or not consumers believe that they will be able to reliably charge their vehicle in a way that doesn't limit them compared to a conventional vehicle<sup>23</sup>.

Currently, the landscape of public electric vehicle chargers capable of charging new PEVs such as the Chevy Volt and Nissan Leaf is fairly sparse. Part of this is a chicken-and-egg problem where municipalities, retailers, and employers are hesitant to purchase and install PEV charging stations because of the uncertainty about where PEVs will end up, when that will happen, or if it will happen at all. This creates a paradox where potential consumers are uncertain and uneasy about the availability of charging

infrastructure and potential charging providers are uncertain and uneasy about consumers, and the result is that charging stations remain sparse.

The second part of this problem is that current PEVs, with their relatively large time requirements for charging, do not fit nicely into the gas station model of fast fill ups that has been the norm since the advent of automotive transportation. Adjusting to a new model of fewer locations to “refuel” such as homes, workplaces, and a few public locations will take time as will the longer “refueling” times for PEVs: 4 to 10 hours for a full charge versus 5 to 10 minutes for a full tank of gas.

To understand the overall impact that PEVs will have on any given local and regional electric grid, it’s helpful to look at the impacts of just one PEV plugged in at home. Like any other electrical device, the amount of electricity required by a PEV is determined by the voltage and current at which it charges. In the case of PEVs, the voltage and current will most often be determined by the electrical specifications of the charging device that regulates the flow of electricity between the electric grid and the vehicle battery pack. For the PEVs coming to market in the next few years, there will be two basic charging methods: 120V/15A, a typical household electric socket, and 240V/30A, a less prevalent socket often installed in homes for clothes dryers. In terms of actual power demands or load, PEVs charging at 120V/15A will represent about 1.4kW while a PEV charging at 240V/30A would be about 6kW<sup>24</sup>. To put this into perspective, in 2008 the average home in California consumed 587 kWh per month, which works out to about 21 kWh per day for an average load of about 0.88 kW<sup>25</sup>. Averaging consumption perfectly throughout a 24-hour day is not very realistic nor does it help to illustrate how the demand of an electric vehicle charging would compare to typical household load. A



more useful exercise is to assume 12 hours of high consumption in the home and 12 hours of minimal consumption, which would yield an average load of right around 1.4 kW, approximately equivalent to a PEV charging at 120V/15A. Of course, from a total energy consumption perspective, it's probably easiest to just compare the 21 kWh/day average to the 24 kWh battery pack of the Nissan Leaf<sup>26</sup> or the 16 kWh battery in the Chevy Volt<sup>27</sup>. Looking at these numbers it's easy enough to see that PEVs, depending on how they are charged, will in some cases both double the daily electricity consumption of a typical California home and increase the load of a household by two to three times the average when a vehicle is charging<sup>28</sup>.

Increasing the load of a household by two to three times its average can have significant impacts at the neighborhood level. The reason for this is the fact that the electric transformers that serve small groups of homes are sized based on the average load of those homes. If a PEV begins charging and doubles or triples a home's load, this is the same as adding one or two houses to the neighborhood from the transformer's perspective. In most cases, one PEV's load added to a transformer will not be a significant issue. The problem arises when multiple PEVs begin charging in the same neighborhood. In this situation, if two or three, or more PEVs were all charging from a transformer that is not meant to handle a high level of load, it could, in extreme cases, malfunction and interrupt service to the whole neighborhood. The more likely outcome is simply a shortened service life for the transformer. According to Johannes Rittershausen, a manager in SCE's PEV Readiness Group, the impact that PEVs could have on neighborhood-level transformers is the single-most pressing concern for SCE in regards to PEVs<sup>29</sup>. That being said, replacing transformers in neighborhoods with PEVs is

entirely manageable and already underway in neighborhoods where residents have indicated their intention to purchase PEVs to the utility<sup>30</sup>.

## **Chapter 2: The Adequacy of the California Electric Grid to Handle PEVs Today**

Chapter 2 will draw on the conclusions reached in Chapter 1 as well as on other research to show that California's electric grid has adequate generation capacity to accommodate even the highest projections of PEVs for the next decade. Chapter 2 will also show that the ability of California's grid to accommodate PEVs is based upon the assumed existence of a "smart" charging framework that functions to concentrate system-wide charging load into the "valleys" of low demand that occur at night and in the early morning and provides price signals that are reflective of the real market price of electricity.

Although this is only one piece of the story, from a pure energy, or kilowatt/hour (kWh), standpoint, the California electric grid can accommodate electric vehicles right now. In a Pacific Northwest National Laboratory study that examined the ability of the various electric reliability council regions around the country to support the charging load of electric vehicles, the authors estimated that the California-Southern Nevada reliability council sub-region generation capacity could meet the energy requirements of between 3.9 and 6 million PEVs<sup>31</sup>. This estimate is based upon a light duty vehicle fleet split evenly among compact sedans, mid-size sedans, mid-size SUVs, and full-size SUVs, requiring 8.6, 9.9, 12.5, and 15.2 kWh of electricity to charge<sup>32</sup>. The separate estimates of 3.9 and 6 million vehicles are based upon a valley-filling approach where all of the unused generation capacity, excluding inefficient, high-cost peaker plants, is utilized from 6pm-6am for the 3.9 million estimate and for the full 24-hour period for the 6 million vehicle estimate<sup>33</sup>. In a whitepaper prepared by the California Public Utilities Commission (CPUC), the authors estimate that PEVs will increase generation

requirements by between 202 and 9,645 GWh per year by 2020, depending on how many PEVs end up on California's roads<sup>34</sup>. According to the CPUC, these increases would represent an increase in total energy consumption and energy generation of between 0.1 and 3 percent as a result of between 61,000 to about 3 million PEVs by 2020.

The Pacific Northwest National Labs study's conclusions indicate there is existing charging capacity for significantly more vehicles using only a 12-hour charging period scenario than even the highest case projected in the CPUC whitepaper (3.9 million compared to ~3 million<sup>35</sup>). The reason for this is that the 3.9 million PEVs estimate of the Pacific Northwest National Labs study is based upon some generation assets in southern Nevada and vehicle energy requirements that are significantly lower than the 66 kWh<sup>36</sup> and 16 kWh that the CPUC whitepaper assumes for PEVs. Although it is difficult to make a direct comparison between the projections put forth in the CPUC whitepaper and the capacity estimations in the PNNL study, discounting the 6 million PEVs in the PNNL study based upon its lower vehicle energy requirements and Nevada generation assets, there would still appear to be significant capacity to accommodate at least as many PEVs as are projected to be the high case by the CPUC (~3 million). This lends credibility to the relatively minor increases in consumption and load that the CPUC projects to be attributed to PEVs by 2020.

While the capacity to generate adequate energy to meet the power demands of all the PEVs projected to plug in to the California grid exists today, a more pressing concern has been whether or not there is adequate generation "capacity" (i.e., the ability to create the instantaneous rates of flow necessary to serve load) to meet the hourly demand that large numbers of PEVs will add to the grid. For example, a worst-case scenario would be

if the approximately 3 million PEVs the CPUC projects could be on the grid by 2020 were all plugged into 220V chargers at exactly the same time. Under this scenario, the 3 million PEVs would add roughly 20,000 MW of load to the grid<sup>37</sup>. For comparison, the summer peak load on the entire California grid in 2009 was just under 46,000 MW<sup>38</sup>, so an increase of 20,000 MW would represent about a 44 percent increase and exceed the net supply of available electricity in California, which was about 61,000 MW during the summer of 2009<sup>39</sup>.

Looking at the absolute worst-case scenario for PEV charging can make PEVs seem like much more of a menace to the grid than they actually are likely to be. The worst case can also help to illustrate why PEVs are unlikely to be a threat to the integrity of the grid. Going back to summer 2009 data from the California Independent System Operator (CAISO), there was a reserve capacity of about 15,000 MW (61,000-46,000), which provides for a reserve margin of 34.5 percent. Electric grids are required to have reserve margins to accommodate for unexpected events that may shut down generation facilities. To maintain reliability on the grid, reserve margins of around 18 percent are usually required<sup>40</sup>. This means that the 34.5 percent margin indicated in the CAISO report for the summer of 2009 could not be used entirely to charge PEVs. Table 1 uses the reserve capacity data from CAISO as well as the power requirement assumptions for charging PEVs from the CPUC whitepaper to show approximately how many PEVs California's electric grid could handle while maintaining various levels of reserve margins and thus reliability if every PEV were charging simultaneously at the highest peak moment of 2009.

**Table 1. Maximum Number of PEVs Able to be Charged On-Peak Given Current California Generation Assets<sup>41</sup>**

<b>System Reliability</b>	<b>Grid Reserve Margin</b>	<b>MW Available On-Peak</b>	<b>PEVs</b>
Reliable	34.50%	0	0
	30.00%	2120	317,974
	25.00%	4475	671,278
	20.00%	6831	1,024,583
<b>Reliability Threshold</b>	<b>18.00%</b>	<b>7773</b>	<b>1,165,904</b>
	15.00%	9186	1,377,887
	10.00%	11541	1,731,191
	5.00%	13897	2,084,496
Highly Unreliable	0.00%	16252	2,437,800
Unfeasible	-23.00%	20000	3,000,000
*Assuming PEV demand of 6.67kW/PEV and generation assets totaling 60,988 MW			

As Table 1 shows, over 1 million PEVs could be charged simultaneously, on-peak, without compromising the reliability of the California electric grid beyond an acceptable threshold. Charging over a million PEVs simultaneously during peak demand periods is not a desirable or sustainable practice. However, the fact that the current California electric grid could handle it while maintaining a high level of reliability serves as a sound indicator that from a power adequacy perspective, California certainly has the generation resources to meet the demand of PEVs in the short term and will not have to add significant new generation in the long term on account of PEVs.

The practical reality of PEV charging is much less worrisome than the above theoretical nightmare scenario. As Figure 4 shows, the CPUC estimates that the increase in peak load as a result of PEV charging will range from a miniscule 0.01 percent to 0.64 percent<sup>42</sup>, both of which are very manageable increases.

**Figure 4. Demand and Peak Load Scenarios of PEVs in California in 2020<sup>43</sup>**

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

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

The primary reasons for the CPUC’s low projection of increased peak load are the important assumptions concerning when and how PEV charging will occur. To reach its conclusions, the CPUC assumes that 76 percent of PEVs will charge off-peak and 24 percent will charge on-peak<sup>44</sup>. Furthermore, the CPUC assumes that all charging will be controlled such that load will be distributed equally over the charging period<sup>45</sup>. By basing its conclusions on these assumptions the CPUC is excluding the possibility of large peak load increases as a result of large numbers of PEVs charging simultaneously, on-peak. Although an exact split of 76/24 may not happen in terms of on and off-peak charging, the assumption that most charging will not occur on-peak is reasonable given the abilities of PEV charging equipment and the economic incentives consumers have not to charge their vehicles during peak periods.

Implicitly contained in the assumption that PEV charging will occur in a controlled fashion is the assumption that PEV charging will occur via some sort of smart charger. Smart charging regulates load on the electric grid by virtue of some kind of time or load dependent charging logic. In the simplest case, this logic can simply be a built-in

timer that only allows a vehicle to charge during certain time periods to ensure that charging coincides with off-peak periods of low demand. In the most complex cases, the logic of a smart charger can be based on bidirectional communication between the charger and the grid operator whereby generation availability and PEV charging demand can be communicated continuously in real time to most efficiently charge PEVs while minimizing load impacts on the electric grid. To achieve the assumed “valley-filling” charging scenarios used in the PNNL study and CPUC whitepaper, the latter charging logic would most likely have to be utilized.

Regardless of whether a simple timer or a more complex bidirectional communicating charger is utilized, the nightmare scenario of 3 million PEVs all plugged in at the same time right at the period of peak demand is all but eliminated. Besides the fact that smart charging can simply avoid charging during on-peak in extreme emergency situations, there are two additional components of smart charging that further reduce the possibility of overloading the grid and bring PEV charging more in line with the utopian scenarios presented by the aforementioned studies.

The first component is price. Because smart meters and smart chargers can record when electricity is delivered, they offer utilities and customers the option of time-of-use (TOU) pricing. TOU pricing reflects the real-time resource cost of producing electricity much more than a fixed rate does. As a result, the off-peak rate under a TOU rate schedule is significantly lower than the on-peak rate. A real example of this is the PEV TOU rate option that SCE offers to customers with PEVs. Under this rate schedule, the summer on-peak rate is about twice that of the off-peak rate<sup>46</sup>. Clearly, an off-peak rate that would more than halve a consumer’s operating cost for a PEV should provide a



significant incentive to charge off-peak, which simultaneously shifts load away from on-peak from SCE's perspective.

The second component of smart meters that validates assumptions about valley-filling charging is their ability to act as relief valves for the grid during times of peak load. Because smart meters and chargers with two-way communication can halt PEV charging and thus shed load, they provide a safety net against an onslaught of PEV charging and thus eliminate the possibility that the grid could be overloaded by PEV charging to the point of instability or collapse. From a customer relations perspective, any practice where PEVs are cut off from charging will certainly have to be handled delicately, and may ultimately have to take the form of an "opt-in" program, where enrollment is entirely voluntary.

The point here is not that utilities and grid operators don't need to prepare for the impact of PEVs, but rather that the existing generation capacity is sufficient to the degree that even a very unrealistic charging load of 2 million PEVs could be met, on peak, right now. Combine this with the CPUC and PNNL estimates about the minimal increase in energy production required to charge PEVs and the fact that most PEV charging will occur through a smart meter, thereby rectifying any concerns about simultaneous charging or nightmare scenarios, and it becomes clear that there shouldn't be any fear or valid opposition to PEVs on the basis of the impact they will have on the generation adequacy of grid in the near future.

### **Chapter 3: PEVs and Urban Areas: A Natural Fit**

The discussion about where privately-owned PEVs will ultimately end up plugging in has focused almost entirely on the single-family home. This makes sense given the fact that most homeowners would be expected to have convenient access to a standard, 3-prong, 120V electrical outlet within a minimal distance of where they typically park their car. This logical assumption has been confirmed by a survey of SCE customers. In the survey, 70 percent of respondents living in single-family homes indicated that they had a readily available 120V outlet within 25 feet of their parking location compared to 37 percent of apartment or condominium residents<sup>47</sup>. In addition to the widespread availability of 120V outlets, single-family homes are also more likely to be wired for 240V service as a result of preexisting 240V appliances such as clothes dryers, electric stoves, and most commonly, central air conditioning<sup>48</sup>.

All of these factors point to single-family home charging being a mainstay of PEV charging, but in doing so they also overshadow other types of home charging such as multi-family homes, townhomes, and most importantly, urban high-rise apartment buildings. The problem of focusing solely on single-family home charging as the exclusive residential charging use case is twofold. First, it is indicative of an apathetic approach to preparing for PEVs on the grid. Second, and most crucially, by focusing on single-family home charging while mostly ignoring apartments and urban high-rises, the discussion surrounding charging fails to encompass a large segment of the environmentally-conscious early adopter market that stands to make or break the large-scale success of electric vehicles over the next ten years.

Single-family home charging fits easily into today's electric grid: one house, one electric meter, one electric car – simple. From a stakeholder point of view, single-family home charging is great. With 120V charging, the only adjustment that might need to be made is a switch from a flat rate for electricity to a time-of-use (TOU) rate. Other than that, nothing has to change. With 240V charging, things get somewhat more involved, but are still fairly minimal. A 240V-capable charger will have to be installed. This installation needs to be done by an electrician, but isn't significantly different from installing 240V for a washer or air conditioner. In houses without 240V, it may need to be added, but with the exception of some early 20<sup>th</sup>-century homes, this isn't a huge endeavor. Finally, as discussed earlier, utilities may need to install larger transformers in neighborhoods where multiple PEVs may be likely to charge simultaneously.

PEV charging for single-family homes does not require new ways of selling or using electricity. It is true that 240V charging does require action by the consumer, an electrician, and the electric utility, but the stakeholders are all clearly defined and the way in which electricity functions is not markedly different from a typical home appliance. Nothing fundamental has to change or be modified in the single-family home charging scenario. From a utility standpoint, this is a wonderful thing, and that's the problem. The major discussion about PEV charging has focused on single-family homes because PEV charging in single-family homes is easy; no one has to reinvent the wheel. The problem with this approach is that although preparing for PEVs under the assumption that they will only be charged in single-family homes may be convenient, it does not guarantee that this will actually happen and leaves room for a scenario where utilities find

themselves unprepared for PEV charging that occurs somewhere other than a single-family home.

PEVs are a unique product in that they are very much tied to the existence and availability of electrical infrastructure. From this perspective, it makes sense that utilities and others have centered the discussion of electric vehicle charging around single-family homes. After all, why would someone buy a PEV if they didn't have anywhere to plug it in? This is the logic that has brought us to where we are now and runs the risk of keeping us here indefinitely. Focusing on those locations where PEV charging will be easy and convenient automatically excludes a large consumer base for PEVs on the basis of what kind of home they live in.

Excluding and potentially alienating consumers from a product at the outset is not an effective way to make it succeed. This is especially true in the case of PEVs, which endured a boom and bust cycle in the United States when they came to market unsuccessfully in the early 90s. If consumers, especially mainstream ones, find that there are barriers to them becoming PEV owners, there is no reason to believe that they will not forsake PEVs quickly and be loathe to consider them in the future. An enormous part of industry preparation for PEVs has centered on “getting the customer experience right the first time<sup>49</sup>.” At the moment, it looks like utilities and others are going to “get it right” for single-family-home owners. Unfortunately, it also seems that if the discussion continues to focus exclusively on single-family-home owners, there won't be a customer experience for anybody else.

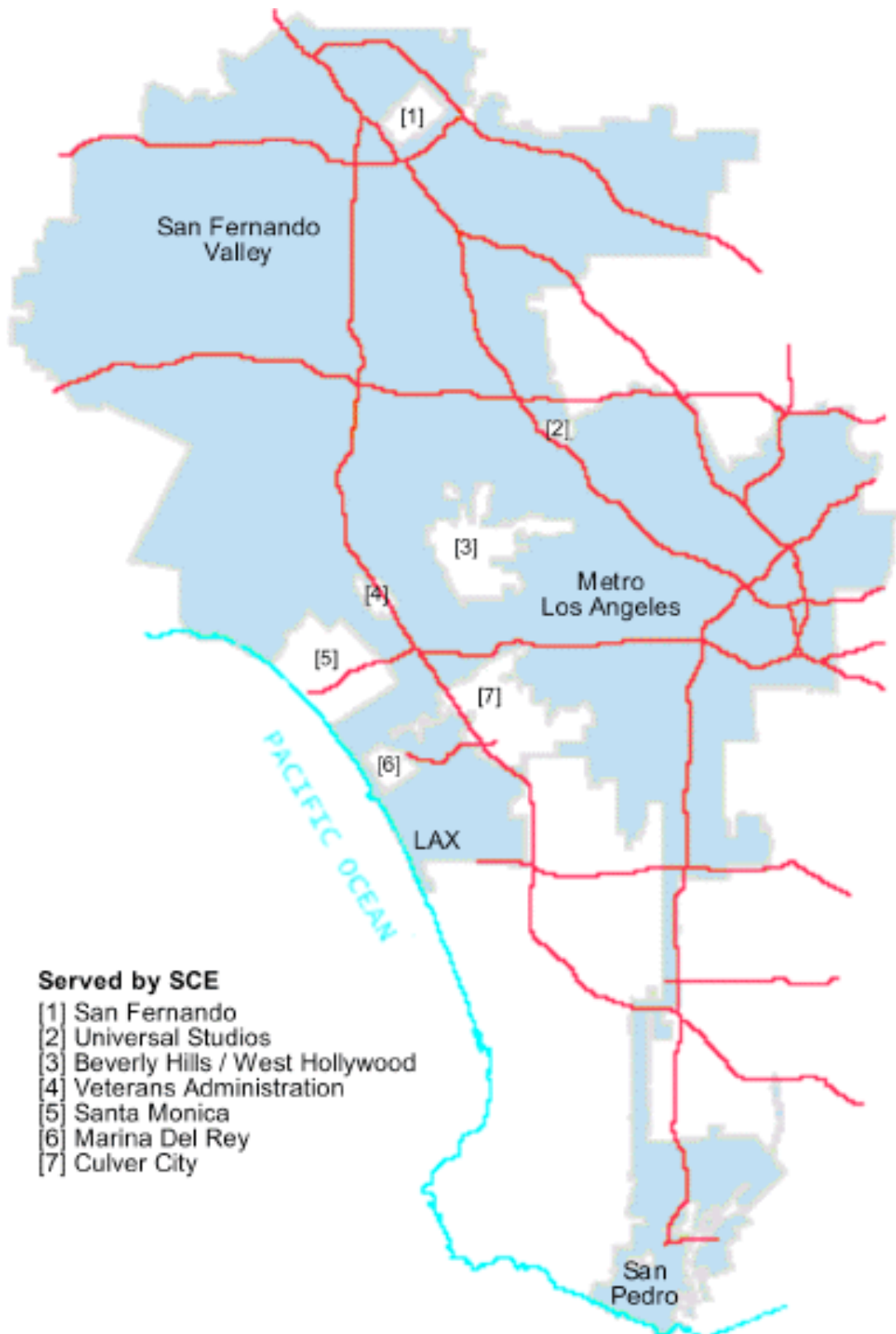
One of the reasons the PEV charging discussion has focused on single-family homes is because it is easy, but another reason is because there is a genuine belief, fueled

by surveys like the SCE/EPRI survey, that charging is going to happen primarily in private garages. While it is true that the SCE/EPRI survey on PEVs seems to indicate single-family home charging as the dominant case going forward, there is one important aspect of the survey that needs to be considered before such conclusions can be drawn. The SCE survey was limited to SCE customers, and therefore SCE service territory<sup>50</sup>. Knowing this, it is worth looking at SCE's service territory to determine which geographic locations are, and more importantly, are not represented by those surveyed. Figure 5 is a map of Southern California Edison service territory. As it illustrates, SCE'S territory is composed of the majority of the greater Los Angeles area with one exception. As both Figures 5 and 6 show, the city of Los Angeles is not in SCE service territory and instead has its electrical service provided by the Los Angeles Department of Water and Power.

Figure 5. Southern California Edison Service Territory<sup>51</sup>



Figure 6. Los Angeles Division of Water and Power Service Territory<sup>52</sup>



The fact that the city of Los Angeles is not included in the SCE survey is important because it means that the high-density, urban, car-driving population of downtown L.A. is not represented. Downtown L.A. is unique in the L.A. area in that it is one of the few places that has a sizable and growing population of people living in high-density, high-rise apartment buildings<sup>53</sup>. Put another way, downtown LA has a large population of car-driving residents who do not live in single-family homes with private garages.

Where they live is not the only thing that distinguishes many of downtown Los Angeles residents. According to a demographic study of downtown residents conducted in 2008 by the Downtown Business Improvement district, residents of downtown are exceptionally educated, relatively young, and earn significantly more than non-downtown residents<sup>54</sup>. The study states that 78 percent of downtown residents had completed college education or above, the average age of downtown residents was 32 years old, and the median annual household income of residents was \$96,200<sup>55</sup>. Furthermore, over one fifth of downtown residents had a household income of over \$150,000<sup>56</sup>. For comparison's sake, the median household income for the rest of the city of Los Angeles was about \$46,000 and the median income for Los Angeles County was just under \$53,000<sup>57</sup>. Going even further into the demographic composition of downtown Los Angeles, the study reports that the average household size of downtown residents was 1.8 people, and that nearly 81 percent did not have any children<sup>58</sup>. To put it simply, downtown L.A. is full of well-paid and well-educated young professionals living in small households.

The wealthy, educated, professionals of downtown are important in the context of this paper because of all the similarities they share with the demographics of hybrid



vehicle owners. According to a 2007 demographic study of hybrid vehicle owners by the major research firm, Scarborough, the typical hybrid vehicle owner has a lot in common with the typical downtown Los Angeles resident. As a summary of the Scarborough report states:

Scarborough's analysis finds that almost half (42 percent) of the households in the U.S. that own or lease at least one hybrid vehicle have an annual income of \$100,000 or more. That is more than twice the national average. The adults who live in these households, "Hybrid Owners," are more than twice as likely as all U.S. adults to have a college degree. This includes the twenty-seven percent of Hybrid Owners who have a post graduate degree, compared to nine percent of adults overall<sup>59</sup>.

The household income numbers from the Scarborough study are also quite similar to those of downtown L.A. While the Scarborough study found that 42 percent of hybrid vehicle owners had household incomes of over \$100,000/year, the Downtown Business Improvement District Study reports that about 45 percent of downtown residents had household incomes over \$100,000<sup>60</sup>.

The other similarity between hybrid owners and downtown residents is their level of education. As the Scarborough study shows, hybrid owners tend to have a significantly higher level of education with a large portion possessing post-graduate degrees. This squares well with the downtown population, 78 percent of whom have a four-year college degree or higher<sup>61</sup>. A third overlap and interesting indication of the similarities between hybrid owners and downtown residents is their grocery shopping habits. As the Scarborough study states, "When it comes to their grocery cart, Hybrid Owners are more than twice as likely as the average consumer to have used organic foods in their household during the past month<sup>62</sup>." While there is not currently a large organic grocery chain in downtown L.A., the 2008 survey showed that Trader Joes and Whole Foods

were far and away the most desired grocery stores downtown with 89 percent of residents naming Trader Joes as their first choice and 69 percent naming Whole Foods<sup>63</sup>. Although similarities in grocery store taste is not an indisputable indicator of downtown Los Angeles residents' predisposition to buy hybrid vehicles it is an interesting indicator of a similar lifestyle and value system between downtown residents and hybrid owners that fits well with the aforementioned similarities in income and education.

The fact that downtown L.A.'s residents' demographics indicate that they would be very likely to already own or consider buying a hybrid vehicle is significant because hybrid vehicle owners are projected to be amongst the largest adopters of PEVs. As the authors of the EPRI/SCE survey state:

PHEV acquisition interest is highest among Hybrid Owners, as 20% say they will "definitely" purchase or lease the vehicle compared to Non-Hybrid Owners (8%). In addition, Hybrid Owners self-report being the first to acquire new technologies, again suggesting they may be early adopters of PHEV technology<sup>64</sup>.

The findings of the EPRI/SCE survey about hybrid owners' predisposition towards PEVs is important because it indicates that the residents of downtown Los Angeles may very well be a prime market for PEVs based upon their similarities to hybrid owners.

In addition to their demographic similarities with hybrid owners, the commuting habits of downtown residents further support the hypothesis that they will be likely buyers of PEVs. According to the Downtown Business Improvement District 2008 Demographic survey, 35 percent of those who live downtown commute alone by car, and 21 percent of those who both live *and* work downtown commute alone by car<sup>65</sup>. Based on the relatively small geographic area of downtown,

the distances of commutes taking place from a downtown residence to a downtown workplace are not likely to be very far. This characteristic of intra-city commuting means that PEVs would be particularly well suited to the daily commuting habits of many downtown residents due to their limited range and regenerative braking ability in non-highway travel.

Another indicator that downtown residents are well suited to PEVs is their sensitivity to the price of gasoline. In the 2008 Business Improvement District Survey, a large portion of residents indicated that high gasoline prices had an impact on their commuting habits. According to the survey, 17 percent of downtown residents changed their mode of commuting to a public bus or train some or all days, 24 percent drove less, and only 36 percent made no change in their commuting mode of transportation<sup>66</sup>. Although their sensitivity to the price of gas does not definitively show that downtown residents will buy PEVs, it does indicate that the low cost of “fueling” a PEV relative to a conventional vehicle could very well be a selling point for those living downtown.

Based on the demographic similarities between current hybrid owners and downtown Los Angeles residents, the EPRI/SCE survey findings about hybrid owners being inclined towards PEVs, and the suitability of PEVs to many downtown residents’ commuting behavior, it is difficult to imagine a situation where members of the downtown population will not demonstrate a significant interest in purchasing PEVs. Given this, there is no reason to believe that downtown PEV owners will expect anything less than those PEV owners living in homes with private garages in terms of convenient access to charging where they park their cars.

What this ultimately means is that although most of the focus in preparing for PEVs has been centered on single-family homes up to this point, there will be other forms of residential charging, and there will be expectations that this charging will be just as convenient and available as it would be in a home garage. For these expectations to be met, utilities with urban populations like LADWP, as well as other stakeholders such as landlords, tenants, and city governments, need to first, acknowledge that demand for PEVs will exist amongst urban populations, and second, begin to work out the logistics of PEV charging in high-density, urban areas, which promises to be significantly more complex than single-family-home charging. If these things don't happen soon, there is the real and likely possibility that the well-educated, well-paid, urban population will forsake PEVs and inhibit a mainstream transition to them amongst the larger consumer base.

## **Chapter 4: Preparing Urban Centers for PEVs**

As Chapter 3 demonstrates, downtown Los Angeles is poised for an influx of plug-in electric vehicles. Unfortunately, as things stand now, the downtown area is unprepared for PEVs. The public charging landscape is mostly barren or outdated with few publicly available chargers currently functioning in convenient areas<sup>67</sup>. More problematic still is the lack of a uniform framework for private, residential chargers to be installed for the use of downtown's many high-rise apartment and condominium residents. By investigating the current state of PEV charging infrastructure downtown, identifying the many stakeholders in downtown PEV charging, and exploring a number of hypothetical charging use cases, Chapter 4 will attempt to construct a framework for the provision of "home" charging in the downtown area and serve as a reference for urban PEV charging going forward.

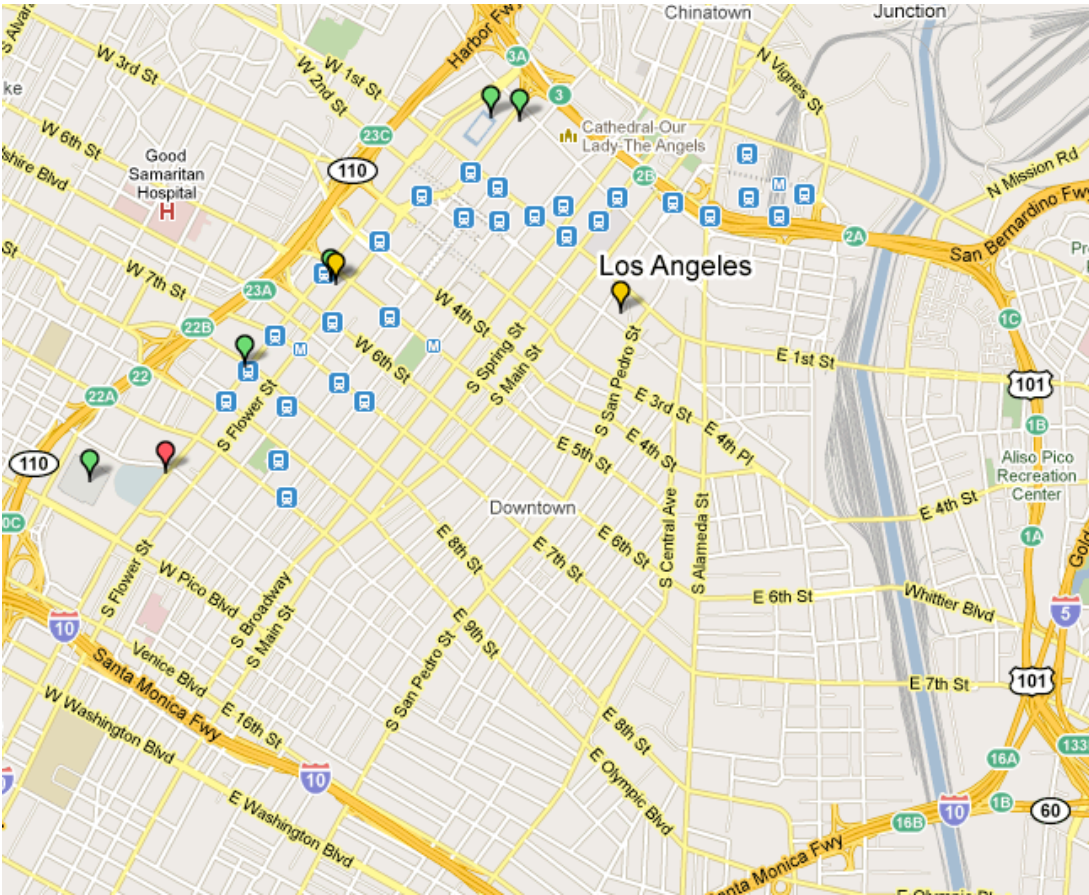
Based on Los Angeles' reputation as a forward thinking, trend-setting metropolis filled with early adopters, one might think that the city, and its downtown area specifically, would have taken the appropriate steps to make L.A. a welcoming environment for the waves of PEVs headed its way in the very near future. Sadly, this does not seem to be the case. Figure 7 shows the existing PEV charging locations in downtown that are available for public use. As the map of

charging locations shows, there are currently only five functioning PEV charging locations accessible to the public located in downtown. Four of the locations are on the westernmost periphery of downtown and therefore are not very convenient for residents' daily charging needs. The fifth charging location is Los Angeles City Hall, and its chargers are in a state of disrepair<sup>68</sup>. The lack of chargers and their locations is disappointing in and of itself, but even more worrisome is the fact that of all the individual chargers at the five charging stations in downtown L.A., only *one* has a J1772 connector<sup>69</sup>. What this means is that while owners of PEVs of the 1990s vintage can theoretically charge their decade-old vehicles at five, inconvenient locations downtown, potential buyers of new PEVs such as the Nissan Leaf, Chevy Volt, Tesla Roadster, and any other new PEV that comes to market will have to fight over a single parking spot at the Los Angeles Convention center with its sole J1772 charger.

**Figure 7. Public Electric Vehicle Charging Locations in Downtown L.A.<sup>70</sup>**

The small quantity of charging locations downtown, their locations, and their inability to charge new PEVs are all legitimate issues standing in the way of a PEV-friendly downtown. However, the current charging infrastructure is flawed in a more fundamental way. Although the existing chargers downtown, if increased in quantity and retrofitted with J1772 connectors, would fulfill their purpose of ad-hoc public charging fairly well, they still would fail to serve as reliable primary charging locations for a variety of reasons.

The first reason is simply a matter of logistics: it would not be practical, from



the city’s perspective, to attempt to ensure that there would be an available charger for every single PEV that “lives” downtown to charge every day. The more inherent

problem with attempting to thoroughly prepare downtown for PEVs by expanding the current system of public charging locations goes back to the consumer preferences voiced in the EPRI/SCE survey that the overwhelming majority of consumers indicated that they would prefer to charge their vehicles at home<sup>71</sup>.

Although the survey did not capture the motivation behind respondents' choice of home as the most preferred charging location, it is simple enough to hypothesize about the reasons for this choice. The two most compelling reasons for the home charging preference would logically seem to be convenience and reliability. Charging where one's car is regularly parked is much more convenient than charging at a remote location and then having to move back to the "home" location when charging is complete. Home charging is also desirable because it is always available; there is not any uncertainty about whether access to charging won't be available because it is being utilized by someone else. In short, home charging is preferred because it creates a situation where there is a guaranteed availability of charging all the time.

Because of its exclusivity, home charging is also a crucial factor in enabling smart, off-peak charging. If PEV owners are not able to plug in their vehicles and "forget" about them overnight knowing they are secure conveniently located for use the next day, then the large off-peak time window in which grid-efficient charging can "smartly" take place disappears. This happens because there is a motivation to have individual PEVs plugged in for as little time as possible as a result of competition for charging access. This competition would naturally emerge in a situation like downtown L.A. where there are a limited number of charging locations



and a lack of exclusive charging rights.

The inability of the current PEV charging framework in downtown to provide guaranteed charging access to PEV owners demonstrates why there must be a new framework that facilitates “home” charging regardless of whether home is a single family house and garage or a rented apartment located on the 20<sup>th</sup> floor of an urban high-rise. A crucial part of establishing this new framework is identifying the many stakeholders in PEV charging downtown and the roles they will play.

PEV owners are an integral part of PEV charging. Clearly, owners provide the demand for PEV charging by their acquisition of vehicles and their desire to charge them. Residents of downtown may be owners, of apartments or townhomes, or they may be renters. In downtown L.A., the mix of residents skews towards those who rent with 60 percent renting their residence and 30 percent owning<sup>72</sup>.

The high percentage of renters in downtown coupled with the fact that most downtown parking is not in single-car garages means that PEV charging must involve more stakeholders than it would in single-family homes where the charging transaction takes place between the homeowner and the utility. In an urban apartment context, the renter or owner and the utility are still important participants, but the landlord/building management entity also enters into the picture. In residences where parking is provided by the building management entity, their role as the intermediary between the resident/owner and the utility is key to enabling or inhibiting the installation of charging infrastructure. For situations where parking is not provided by a building management entity, the parking provider, whether a parking lot or garage owner or company, replaces the building

management company as the intermediary between the utility and the consumer. Besides those stakeholders already mentioned, retailers/merchants and the city government may play significant roles depending on the specific charging situation.

To more thoroughly define the parts played by various stakeholders in urban PEV charging, the following use cases will be examined: (1) a rented residence with assigned parking, (2) a residence without on-site parking, and (3) a third-party subscription charging model where a private company provides the charging equipment. In each of these cases, the focus will be on establishing an exclusive, “home” charging arrangement where the PEV owner’s ability to plug in is never compromised. Furthermore, the question of who will bear the costs of purchasing and installing PEV charging equipment is investigated.

### **1. Rented Residence & Assigned Parking**

To establish a “home” charging situation for a renter in a building with assigned parking, the areas that inhibit “home” charging must be modified or circumvented. In this case, those areas are designated parking spots and exclusive access to a charging station. For renters with assigned parking, achieving an exclusive, designated parking location for PEVs should not be a significant hurdle. Although individual assigned parking spots may not currently exist, the fact that there is ample enough parking to offer to residents as a component of their living space indicates that designating spots for PEV charging would not be a serious issue. The second requirement of “home” charging, exclusive access to a charging station that is tied to the PEV does not currently exist, but could be implemented in a number of ways. The simplest way might be to install a new electric meter in close

proximity to where the PEV charging will take place. This electric meter would be linked to the existing utility account of the resident/PEV owner and the additional cost of electricity consumption from PEV charging would be reflected on the resident's existing monthly bill from the utility.

The third requirement of PEV charging is the charger itself. Chargers are available with a variety of specifications and capabilities from an array of manufacturers, but for the purpose of this examination, should be thought of as simply the device that ultimately transfers energy from the grid to batteries in a PEV. In the case of a renter with assigned parking, the charger is the most problematic element on account of its associated costs. The cost of the charger and installation is relatively high, ranging from \$1,000 to \$3,000 depending on the specific charger and the complexity of the installation<sup>73</sup>. In the case of a renter, the cost burden of a charger installation may be difficult to bear given the fact that the tenure of residence may be uncertain and the costs of installing a charger are nearly impossible to recoup if a resident chooses to move. From the property management entity's point of view, bearing the cost of charger installations is also fairly undesirable because of the inherent risk that a PEV owner may be a tenant one day and gone the next.

The issue of which stakeholder, the resident/PEV owner or the property management entity, should bear the cost burden of charger installation has to be resolved for urban PEV charging to flourish. There are a number of ways in which this could be done. First, the property management entity could bear the entirety of the charger costs. The basis of this would be that PEV charging availability adds

value to the property by creating a new source of revenue from existing tenants and potential sources by attracting new tenants. PEV charging could provide a potential source of revenue to the property management entity in that they would be able to charge a monthly fee for “PEV Parking Access.” A fee like this would cover the costs of the charger installation and could potentially include the electricity the tenants consume to charge PEVs. Either way, the capital costs of the charging equipment and installation could be recouped and after that the fee would represent added revenue for the property management entity.

Alternatively, the cost burden could be divided between the resident/PEV owner and the property management entity. This could be done in a manner where the resident/PEV owner pays for the charging equipment and the property management entity covers the installation cost. The understanding here would have to be that the resident/PEV owner will retain ownership of the charging equipment and the property management entity will retain the ability to accommodate PEV charging equipment in the future. This sharing of the cost would reduce the cost burden for each party but would also create a more complicated ownership arrangement that might not be desirable.

Because assigned parking implicitly allows for exclusive PEV parking spaces and the logistics of providing exclusive access to charging are straightforward, resolving the issues of which stakeholders will bear the costs of PEV charging equipment eliminates the most substantial hurdle in creating a “home” charging environment for renters with assigned parking. This demonstrates that while providing charging for renters in urban residences will involve a degree of

negotiation and compromise, it is very doable and should not be ignored on the basis that it cannot be made to work.

## **2. Residence & No Assigned Parking**

The considerations for establishing a method of home charging in a situation where there is not assigned or provided on or off-site parking are similar to those where parking is provided and assigned. The notable exception is that the building management entity is replaced by the parking entity. This complicates things mainly as a result of the disassociation between the resident's residence and their parking location. Practically, this means that whether the resident/PEV owner is a renter or an owner, from the parking entity's perspective, there is not necessarily the same level of apparent security of tenure as there would be if the parking were linked to an apartment or home.

The designated parking spot and exclusive charging access issues can be resolved by the same means as in the Rented Residence Assigned Parking case. Therefore, the primary concern in this case becomes facilitating a negotiation between the resident/PEV owner and the parking entity and establishing who will bear the costs of the charging equipment and installation. It seems that in some ways the parking entity would actually have more of an incentive to bear the total cost of the charger and installation than the building management entity would and less of an incentive in other ways. There would be more of an incentive in the sense that while the building management entity may find itself invested in charging equipment, without a tenant, and with a relatively small market to "sell" charging to,

a parking entity would have a much larger market to “sell” charging to. At the same time, the parking entity may have a smaller incentive to install charging equipment because they do not enjoy the certainty in clientele that the building management entity does. Although it would probably be preferable for the parking entity to lock in a tenant for charging, there would always be the opportunity to sell short-term, temporary charging in the same way that downtown parking spaces are sold.

Working off of this model, the relationship between the resident/PEV owner and parking entity could potentially be a non-exclusive one where agreed-upon terms of use could reserve the right to charging for the primary tenant during certain times and sell this same right on an ad hoc basis during non-reserved times. The most straightforward arrangement might be a situation where there is a reserved charging period starting in the evening and ending the following morning and then saleable charging all day during the week and an alternative arrangement on weekends. This type of relationship or contract could be structured to facilitate a daily commute or whatever other, regular schedule the resident/PEV owner might have. By functioning as a hedge against fickle tenants, the ability of the parking entity to generate revenue by selling charging greatly increases the possibility that a parking entity would be willing to bear the burden of charger costs and enable off-site, assigned parking for PEV owners that closely mimics a “home” charging scenario.

### **3. Third-Party Subscription Charging**

In addition to the use cases described above, a possible scenario for providing PEV charging to downtown residents could take the form of third-party

ownership of charging equipment and a subscription service for charging that the resident/PEV owner would pay for. Although an exact model for this does not exist yet, Coulomb Technologies, a manufacturer of PEV charging stations, offers a similar service for its network of public chargers<sup>74</sup>. Under the Coulomb model, customers who sign up receive a “Charge Card” that uniquely identifies them to any Coulomb charging station. Customers can opt to pay for a monthly charging plan similar to cell phone service plans that includes a fixed number or unlimited number of charges depending on the plan. Customers can also choose to simply pay per charge. Although Coulomb’s model is geared towards public charging, it seems as though the model could be tweaked to accommodate residential charging. Under this new residential model Coulomb or another charging service provider would own the charging equipment and pay for the installation. Residential subscribers would pay a monthly fee that grants them the right to exclusive access to the charger and potentially a certain number of charges per month.

The benefit of a third-party subscription case is that the resident/PEV owner could gain secure access to PEV charging with little upfront cost to them or to the building management or parking entities. This is important because it makes the negotiations between the resident, third-party charging provider, and the building management or parking entity much easier since there is virtually no risk for anyone but the third-party charging provider. Because it transfers the risk away from all the parties except the charging provider, third-party subscription charging could end up being the most palatable and convenient scenario in the short term until there is a significant number of PEVs in the market.

## **Conclusion**

By demonstrating the numerous and significant benefits of mainstream PEV adoption, the current ability of the California electric grid to handle PEVs, and the demographic similarities between hybrid owners and the residents of downtown Los Angeles, this paper argues that PEVs should and will be embraced by consumers whether they live in single-family homes with private garages or high-rise apartment buildings with no assigned parking. Concurrently, this paper argues that barriers to PEV charging and thus PEV ownership must be removed. As Chapter 2 demonstrates, the barriers to PEV charging are not rooted in the inability of California's grid assets to handle a large influx of PEVs. Smart charging, responsive electricity pricing mechanisms, and the relatively small number of PEVs expected to end up on California's roads by 2020 all promise to minimize any generation and load impacts that PEVs will have.

The real barriers to PEV charging and ownership are presented in the second half of the paper, which argues that the people most likely to purchase PEVs do not live exclusively in single-family homes. In addition, the second section of this paper shows that while the provision of "home" charging is necessary to assuage



consumer reservations about PEVs, the definition of home does not have to and should not be limited to the single-family home. By illustrating the relatively inhospitable environment that downtown Los Angeles currently offers for PEV charging, this paper demonstrates how limiting the discussion of home charging to single-family homes limits the adoption of PEVs by writing them off in certain areas from the beginning. In concluding with three potential use cases of urban PEV charging and the ways in which it *can* be made to work to the benefit of all those involved, this paper illustrates what can and must be done to make practical PEV charging and ownership a reality.

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