Bay Area Electrified Vehicle Charging Infrastructure: Options for Accelerating Consumer Access

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II. Glossary of Terms

ABAG – Association of Bay Area Governments
AFV – Alternative Fuel Vehicle
AVIP – Alternative Vehicle and Infrastructure Program
BAAQMD – Bay Area Air Quality Management District
BEV – Battery Electric Vehicle
CARB – California Air Resources Board
CEC – California Energy Commission
CO2e – Carbon Dioxide Equivalent
CPUC – California Public Utilities Commission
CV – Conventional Vehicle
DOE – United States Department of Energy
EV – Electrified Vehicles including: Battery Electric Vehicles, Gasoline-to-Electric Pathway Vehicles, and Plug-in Hybrid Electric Vehicles (PHEVs)
EVSE – Electric Vehicle Supply Equipment
GHG – Greenhouse Gases
HEV – Hybrid Electric Vehicle
ICE – Internal Combustion Engine
JPC – Joint Policy Committee
MTC – Metropolitan Transportation Commission
PACE – Property Assessed Clean Energy
PHEV – Plug-in Hybrid Electric Vehicles
REC – Renewable Energy Credits
TFCA – Transportation Fund for Clean Air
TOU - Time of Use
VMT – Vehicle Miles Traveled
V2G – Vehicle-To-Grid
ZEV – Zero Emissions Vehicle
$/kWh – Dollars per Kilowatt Hour
II. Executive Summary

Problem Statement
California’s transportation sector accounts for approximately 40 percent of statewide greenhouse gas (GHG) emissions, and more than 50 percent of all public health-related air pollution.\textsuperscript{1, 2} Given the anticipated environmental and energy security benefits of electrified vehicles (EVs), it is prudent for policymakers to encourage and accelerate the deployment of these technologies.\textsuperscript{3, 4} However, vehicle consumer preferences combined with Electric Vehicle Supply Equipment (EVSE) deployment barriers (e.g. equipment and installation costs, consumer knowledge, contractor service, and permitting procedures and expertise) may delay or prevent the societal benefits associated with EV technologies from being realized.

Environmental Policy Implementation & EVSE Deployment
The current "Bay Area EV Corridor" initiative recognizes the benefits of EV deployment.\textsuperscript{5} While there are several barriers to large-scale EV deployment (e.g. upfront costs, near-term EV supply constraints, limited travel range, consumer education, and electric grid preparedness), local governments can play an important role in accelerating consumer access to EVSE throughout the Bay Area.

Near-Term Bay Area EVSE Options
Near-term EV purchasers can use Level 1 EVSE technology (i.e. 120-volt, standard three prong outlet) to charge their vehicles. However, vehicle consumers are likely to prefer Level 2 EVSE technology (i.e. 240-volt, washer-dryer outlet) due to its faster charging time and standardized vehicle-to-charger connection. The barriers to Level 2 EVSE infrastructure installation (e.g. upfront costs, consumer knowledge, contractor service capability, and permitting procedures & expertise) will require special attention from both public and private sector entities.

Recommended Local Government Actions
Through a suite of existing mechanisms, innovative financing tools, and regulatory/process reforms, local Bay Area governments can help to facilitate EVSE deployment at the pace and scale needed to achieve California's current emissions mitigation mandates under the California Global Warming Solutions Act of 2006 (AB 32), the California Clean Air Act (CCAA), and National Ambient Air Quality Standards (NAAQS).

EVSE Deployment Options for Local Government

Formalized Strategy - Counties should begin with an accurate quantification of the local emissions mitigation benefits of operating Battery Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs) instead of Hybrid-Electric Vehicles (HEVs) and conventional internal combustion engine vehicles (CVs). An EV Impact Analysis & Transition Plan ties in well with existing Association of Bay Area Governments (ABAG) commitments and will help to implement the Bay Area EV Corridor deployment strategy.

Public Charging - Local governments may have a role in building public charging infrastructure to motivate EV demand because many private providers are reluctant to invest in and build charging stations before clear evidence of consumer demand. EV charging infrastructure
deployed at public places can increase public awareness of the growing electric vehicle presence in the Bay Area in the short run if placed at highly visible places.

*Multi-Dwelling Units (MDUs)/Apartment Buildings* - Municipalities should assist in the build-up of curbside charging stations near residential areas that do not have access to private or home charging stations.

*Planning Codes* - Local planning codes should be adapted to prepare and encourage the widespread use of EVs. This includes requirements that new residential and commercial buildings finalized after a certain point in time (e.g. 2012) feature wiring of electric lines which allow for easy connection of Level 2 chargers.

*Renewable Energy* - To realize the full air quality and climate change benefits offered by EV technologies, the electricity used to fuel EVs should be generated by low and/or zero emission energy technologies (e.g. wind and solar). This will ensure that transportation emissions are actually reduced rather than simply being displaced to the electricity generation sector.

*Educate EV Stakeholders* - EVSE installers and potential consumers should be aware of options and operations of EV technologies.

*Forge public-private partnerships* - Set the stage for private companies to take the lead in the future charging infrastructure market.

*Financing* - Obtain fiscal support from all federal, state, and regional funding sources, and establish alternative revenue streams (e.g. municipal bonds, sales tax surcharges, etc.).

*Lobby decision makers on the federal and state level* - Lobby decision makers for funding and policy support for alternative transportation fuels and vehicle deployment in the Bay Area.

*Property-Assessed Clean Energy (PACE) Financing for EVSE*  
PACE financing programs allow state and local governments to extend the use of land-secured financing districts to fund energy efficiency and renewable energy improvements on private property. This financing mechanism should be expanded to include residential and commercial EVSE projects. EVs and PHEVs save consumers money when compared to CVs and HEVs.

*Streamlining the EVSE Installation Process*  
This analysis offers the following four-step process for all Level 2 EVSE installation projects.

- **Step 1** - Consumer schedules an pre-purchase installation inspection with a licensed EVSE contractor to determine local grid preparedness, permitting needs, and project costs.
- **Step 2** - Consumer visits vehicle dealership to purchase EV, apply for electric utility time of use (TOU) rates (if necessary), and schedule EVSE installation appointment.
- **Step 3** - EVSE contractor works for consumer and utility to obtain permits and materials.
- **Step 4** - EVSE contractor installs charger and submits an installation inspection report to relevant public agencies and the electric utility.
Local Government’s Role in Accelerating EVSE Installation
There are several important areas within the accelerated process model that will require direct action by local governments. The following is a list of action areas that local governments can focus on to improve the efficiency of the EVSE installation process.

1) Consumer & Contractor Outreach – Establish inclusive outreach campaigns that educate vehicle consumers and EVSE contractors regarding the benefits of an accelerated process (e.g. time and financial consumer surplus).

2) EVSE Permitting & Reporting Standardization – Collaborate with intraregional governments to standardize and digitize the permitting and reporting process for EVSE installations throughout the region (e.g. through the Bay Area Joint Policy Committee (JPC)).

3) Lobbying for EVSE Deployment & Process Reform – Vehicle consumer education and outreach support, EVSE contractor education and licensing requirements, pre-purchase EVSE installation estimate and inspection promotion, EVSE time of use (TOU) metering, expedite EVSE installation permitting, and simplify EVSE installation reporting.

Conclusion
This paper makes the case that EVs will play an important role in reducing air pollution and GHG emissions from the transportation sector. It describes barriers to EV market penetration and argues that the public sector, including local governments, should act to reduce these barriers. The paper then focuses on EV charging infrastructure—describing available options, highlighting existing government financial and policy supports, and laying out the steps local governments can take to address this challenge.

Key Recommendations
1) Public charging stations
2) Curbside charging station deployment for multi-unit dwellings
3) Adaptation of urban planning codes
4) Stakeholder education
5) Public-private partnerships
6) Establishment of a financing mechanism for private charging stations
7) Streamlining the charging station installation process

This paper expands on the last two recommendations. It argues that PACE financing programs can reduce the upfront cost barrier to EV market penetration. Finally, the paper lays out a streamlined, consumer-friendly charging station installation process and the process reforms necessary to achieve it.

RAEL offers these recommendations in hopes that the San Francisco Bay Area will be able to establish a feasible, effective, and duplicable model for regional EVSE deployment that reflects the scope and urgency associated with California’s current environmental and energy challenges.
III. Introduction

This report is intended to provide guidance for Bay Area governments as they prepare to help increase and accelerate electrified vehicle (EV) market penetration.

Bay Area Transportation: Negative Impacts & Existing Policies

The transportation sector is responsible for significant negative contributions to air quality and anthropogenic greenhouse gas (GHG) emissions. Furthermore, dependence on the internal combustion engine drives national reliance on insecure, foreign energy sources. This section highlights the harmful environmental and security impacts of California’s transportation sector, as well as existing efforts to mitigate these impacts.

Air Pollution

Air pollution refers to criteria pollutants and toxic air contaminants (TACs)—for example, particulate matter (PM), reactive organic gasses (ROG), and nitrogen oxides (NOx). According to the World Health Organization (WHO), high ambient concentrations of fine PM (PM2.5) increase incidents of cardiopulmonary disease, lung inflammation, chronic respiratory disease, asthma, and other cardiovascular diseases. In California, mobile source emissions contribute 72% of smog precursors (i.e. combination of ROG and NOx emissions), and 20% of direct PM2.5 emissions. Relevant policies aimed at mitigating air pollution include the following:

- **Federal Clean Air Act**: Ratified in 1970, and amended in 1990, this act authorizes the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to regulate air pollution throughout the United States (U.S.). Air pollution in the Bay Area currently exceeds the NAAQS thresholds for 8-hour ozone and PM2.5. The Bay Area’s failure to achieve these standards has resulted in a “non-attainment” classification from the EPA. If the Bay Area does not reach NAAQS attainment levels, it will compromise the region’s ability to secure continued Congestion Mitigation and Air Quality (CMAQ) appropriations from the Federal government, which will exceed $68,000,000 region-wide in the 2010-2011 fiscal year.

- **California Clean Air Act**: Ratified in 1988, this act establishes California's air quality goals, planning mechanisms, regulatory strategies, and standards of progress. The California Clean Air Act (CCAA) provides the State with a comprehensive framework for air quality planning and regulation. Prior to its passage, there was no state-level clean air-planning framework. The act requires attainment of state ambient air quality standards by the earliest practicable date. For air districts in violation of the state ozone, carbon monoxide (CO), sulfur dioxide (SO2), or nitrogen dioxide (NO2) standards, attainment plans that detail efforts to reach attainment status are required.

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1 The 8-hour ozone limit requires that ozone pollutants remain present in breathable air for less than 8 hours. The PM2.5 standard sets a required maximum level of fine particulate matter in the air. The 2006 standards tightened the 24-hour fine particle standard from 65 micrograms per cubic meter (µg/m³) to 35 µg/m³, and retain the current annual fine particle standard at 15 µg/m³ (see Bay Area Air Quality Management District and EPA websites).

2 The Bay Area Ozone Attainment Plan is a product of the Bay Area Air Quality Management District (BAAQMD).
Greenhouse Gas Emissions
Human-caused or anthropogenic GHG emissions are a significant contributor to climate change. Attempts to mitigate and adapt to climate change necessitate achieving atmospheric concentrations of 350 to 450 parts per million (ppm) of carbon-dioxide equivalent (CO$_2$e) by the year 2050. To achieve this goal, our civilization must drastically decrease GHG emissions over the next four decades. In the Bay Area, over one third of all GHG emissions come from the transportation sector, and over two-thirds of that is attributable directly to light-duty trucks and cars. It is clear that decreasing GHG emissions will require considerable reductions in transportation sector emissions, particularly from personal and fleet vehicles.

GHG Emissions in the Bay Area by Sector (Table 1.1)

Transportation GHG in the Bay Area Emissions by Vehicle Type (Table 1.2)

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iii Levels recommended by the Intergovernmental Panel on Climate Change (IPCC).
iv Emissions data and charts from BAAQMD emission inventory.
Relevant legislation aimed at mitigating GHG emissions includes the following:

- **Assembly Bill 1493 (Pavley):** Signed into law in 2002, AB 1493 mandates that the California Air Resources Board (CARB) adopt regulations requiring automakers to reduce GHG emissions for new passenger cars and light trucks beginning in 2009.\(^\text{10}\)

- **Assembly Bill 32 (Niñez):** The California Global Warming Solutions Act of 2006 mandates a return to 1990 GHG emissions levels by the year 2020. This is a reduction of 30% from today’s emissions level. AB 32 builds on Executive Order S-3-05, which mandates a reduction to 80% below 1990 levels by 2050. In 2008, Senate Bill 375 (Steinberg) was passed to support the regional land use and transportation planning necessary to implement AB32.\(^\text{11}\)

- **Corporate Average Fuel Economy (CAFE) Standards:** Last updated in 2010 by the U.S. Department of Transportation (DOT) in conjunction with EPA, CAFE standards currently require the average fuel economy for vehicles available for sale within the U.S. to reach 37.8 miles per gallon (mpg) for passenger cars and 28.8 mpg for light-duty trucks by 2016.\(^\text{12}\)

**Energy Security and Independence**

In June 2009, the U.S. House of Representatives passed the American Clean Energy and Security Act (H.R. 2454, Waxman-Markey), which was designed to reduce GHG emissions, and break America’s dependence on foreign oil.\(^\text{13}\) Unfortunately, the U.S. Senate has yet to produce a similar version of this legislation. While the Senate’s climate debate continues, and with new EVSE incentives on the Congressional agenda (H.R. 5442 and S. 3442), the Bay Area would be well advised to consider energy security as an important benefit for EVSE deployment.\(^\text{14}\) The Bay Area can reduce its dependence on insecure, petroleum-based transportation fuels by transitioning toward domestically produced, increasingly low and/or zero emission transportation fuel options like electricity. Additionally, the current oil spill in the Gulf of Mexico highlights the energy security and environmental dangers of even domestic petroleum production, and further justifies the need to deploy alternative transportation fuels.

**Reducing Transportation Emissions: Consumer Behavior & Alternative Fuel Vehicles**

*Changing Consumer Behavior: Mass Transit, Active Travel, and Sustainable Communities*

There are several methods for altering consumer transportation behavior and decreasing the negative environmental and national security impacts of transportation in the Bay Area. These include (1) expanding mass transit services and increasing consumer use of public transportation systems, (2) encouraging active travel such as biking or walking, and (3) establishing and supporting sustainable, compact communities. While these policies may meaningfully reduce vehicle miles traveled (VMT), they also require significant changes in consumer behavior as well as complex long-term planning. Furthermore, for the foreseeable future, passenger cars will likely remain on the road in large numbers. Thus, considering alternative options for reducing emissions from vehicles is necessary.
Alternative Fuel Vehicles: Hydrogen, Bio Fuel, and Electricity

Alternative fuel vehicles (AFVs)\(^{\text{V}}\) include those powered by hydrogen energy, bio fuels, and electricity, each of which has lower life-cycle emissions than conventional vehicles and hybrid-electric vehicles (HEV). Here again a multi-faceted approach is necessary—all three are worth pursuing. The focus of our research, and of the remainder of this report, is the electrified vehicle. There are two reasons for which electrified vehicles present a unique and valuable opportunity. First, several models of electrified vehicles are expected to become available, in large numbers, in the fall of 2010. Second, electrified vehicles have the distinctive feature of connection to the electricity grid—as the electricity grid gets cleaner so too, by implication, do the vehicles that rely on a cleaner grid. The next section elaborates on these two critical points.

Electrified Vehicles: Imminent Commercialization & Ties to Renewable Energy

Wide-Spread Availability in the Near Future

Electric vehicles can be divided into a few subcategories, all of which will soon be released to California’s vehicle market. These are displayed in Table 1.3 below.

Overview of Upcoming Electrified Vehicles in Mass Market (Table 1.3)

<table>
<thead>
<tr>
<th>Make / Model</th>
<th>Vehicle Type</th>
<th>Expected Release Date</th>
<th>Pending Contracts</th>
<th>Vehicle Mileage</th>
<th>Expected Manufacturer Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevrolet * Volt</td>
<td>Gasoline-to-Electric Pathway</td>
<td>Nov 2010</td>
<td>None.</td>
<td>40 miles per charge before gasoline backup re-charges battery</td>
<td>$35 - 40,000</td>
</tr>
<tr>
<td>Nissan * Leaf</td>
<td>Battery Electric Vehicle (BEV)</td>
<td>Dec 2010</td>
<td>Hertz Rental Cars pre-purchased fleet for SFO and OAK airports.</td>
<td>100 miles per charge</td>
<td>$37,280</td>
</tr>
<tr>
<td>Tesla * Roadster</td>
<td>Battery Electric Vehicle (BEV)</td>
<td>Already in Market</td>
<td>None.</td>
<td>237 miles per charge</td>
<td>$250,000 +</td>
</tr>
<tr>
<td>Toyota Prius</td>
<td>Plug-in Hybrid Electric (PHEV)</td>
<td>Already in Market in EU and China, US Market in Nov 2011</td>
<td>Regional “Smart Grid” partnership programs slated for California in 2011. Details unreleased.</td>
<td>13 miles per charge until gasoline engine begins to power vehicle</td>
<td>$26 – 30,000</td>
</tr>
</tbody>
</table>

* Modeled in economic analyses of financial incentives, Property Assessed Clean Energy, Appendix A.

\(^{\text{V}}\) Alternative Fuel Vehicles (AFVs) are defined as vehicles fueled exclusively by alternative fuels comprising: a) Mixtures containing 85 percent or more by volume of alcohol fuel, including methanol and denatured ethanol. b) Natural gas (compressed or liquefied). c) Liquefied petroleum gas (propane). d) Hydrogen. e) Fuels derived from biological materials. f) Electricity (including electricity from solar energy). g) 100 percent Biodiesel (B100) or Renewable Diesel meeting ASTM D-975. h) Blends of two or more alternative fuels, for example, natural gas and hydrogen. For more information see: [http://www.arb.ca.gov/fuels/altfuels/incentives/afip_att_c.pdf](http://www.arb.ca.gov/fuels/altfuels/incentives/afip_att_c.pdf)
Gasoline-to-Electric Pathway (e.g. Chevrolet Volt):
The gasoline-to-electric pathway vehicle is entirely battery powered. When the battery charge is depleted, a small gasoline engine starts up and recharges the battery while driving. The gasoline engine is not capable of powering the vehicle itself.

BEV (e.g. Nissan Leaf, Tesla Roadster):
Battery electric vehicles (BEV) are 100% battery-operated and must be charged entirely through connection to the electricity grid. Because there are no additional GHG or air-pollutant emissions attributable to the vehicle, the BEV is known as a “zero-emission” vehicle. The Tesla Roadster is a luxury electric vehicle and is not intended to compete directly with the Nissan Leaf.

PHEV (e.g. Toyota Prius Plug-In):
The plug-in hybrid electric vehicle (PHEV) contains both a battery and a traditional combustion engine. The PHEV is fully rechargeable through connection to the electricity grid. When the charge is fully used and the battery is out of power, the vehicle is powered by an internal combustion engine.

Connection to Energy Innovations through the Electricity Grid
A large and increasing amount of capital is flowing into renewable energy technologies in the state of California. These investments, ranging from local monies to American Recovery and Reinvestment Act (ARRA) dollars, are devoted to increasing the proportion of renewable power supplied to the California electricity grid. At present, Executive Order S-21-09 directs the California Public Utility Commission (CPUC) to achieve a 33% renewable energy portfolio by 2020.\textsuperscript{VI} However, Governor Schwarzenegger’s successor may rescind all previous executive orders. Current state legislative mandates, which are more politically stable, require that 20% of all California electricity be supplied by renewable sources, or attached to renewable energy credits (REC) by the year 2010.\textsuperscript{VII} California has not yet achieved this goal. Electrified vehicles take advantage of a unique opportunity to connect innovations in research and design across sectors. As grid emissions decrease so too will transportation emissions.

**Barriers to Electrified Vehicle Market Penetration**

The present generation of electrified vehicles does have some shortcomings.

*Upfront Costs: Batteries and Charging Stations*
EV batteries are expensive, as is the accompanying charging equipment known as electric vehicle supply equipment (EVSE). While this is an important barrier, it can be overcome. Economic analysis across a range of gas prices, battery costs and electricity prices reveals that when batteries are appropriately sized, electrified vehicles most often save money in comparison to CVs and HEVs.\textsuperscript{VIII}

\textsuperscript{VI} Executive Order S-21-09, Governor Arnold Schwarzenegger, State of California (2009).
\textsuperscript{VII} Senate Bill 107 codified a 20 percent by 2010 reduction (2006).
\textsuperscript{VIII} A comprehensive economic analysis follows in section 5 and appendix A of this paper.
Supply and Demand Discrepancies: Short Run Supply, Long Run Demand

A recent McKinsey and Company study, conducted for the City of New York, concludes that consumers who are prepared to purchase EVs at present (“early adopters”) outnumber available vehicles. In the long run, however, this is a problem that auto manufacturers will likely overcome and the real challenge will be increasing long-term consumer demand.

Stakeholder Education: Training Qualified Contractors, Encouraging New Buyers

Installation of EVSE equipment requires trained contractors. Charging an EV for daily use requires simple, though entirely new, consumer understanding. Taking advantage of tax rebates and subsidies to decrease costs requires thorough understanding of administrative processes. At present, communication between suppliers, consumers, manufacturers and contractors is minimal to non-existent. Increasing stakeholder cooperation and knowledge is necessary for timely EV deployment.

Limited Range vs. Conventional Vehicles: Consumer Range Anxiety

Range anxiety refers to the consumer fear of being stranded with no nearby charging option. Based on the 2001 National Household Travel Survey, the average consumer travels a total of 40 miles per day. In fact, most electrified vehicles will travel ample distances to cover the average miles-per-day traveled by a Bay Area consumer. However, easing this anxiety, which necessitates well-planned placement of charging stations throughout the region, will increase consumer demand.

Electric Grid Preparedness

Increased demand for electricity could overwhelm existing electric distribution infrastructure. While there is some threat of local disruption, overall grid stability is unlikely to be impacted. As electrified vehicle market penetration increases, a number of mitigating technologies exist to support and maintain grid-stability. Smart-charging, automated charging during off-peak, low-demand hours is one such option. Pacific Gas and Electric (PG&E) has set progressive goals to serve between 219,000 and 845,000 EVs by 2020, demonstrating their belief that overall grid-stability is not at risk.

Charging Infrastructure: Getting the Power to the People

A final barrier to electrified vehicle market penetration is the ease of access to EVSE infrastructure. Without simple, streamlined EVSE availability, consumers will be unable to easily transition from conventional vehicles to electrified vehicles. Increased access to EVSE infrastructure will increase consumer demand for electrified vehicles.

IX Studies indicate that the early EV adopters will not experience the same range anxiety that later EV consumers will face. Driven by the desire to have the latest technology, increase their social status or make an environmental statement, these early adopters are uninhibited by the costs of EVs or charging infrastructure and have even indicated that they would change their driving and parking behavior for these new vehicles. These early demanders are willing to make their purchases regardless of whether or not there is a robust network of charging stations. (See McKinsey PlaNYC et al).

X This assumption is carried throughout this report.
The negative externalities of the existing transportation sector necessitate the growth of electrified vehicles in the Bay Area. Further, in order to successfully grow the Bay Area electrified vehicles market, it is clear that purchase of EVs must move beyond early adopters to the marginal vehicle consumer. Initial EV consumers can serve as test-subjects for electrified vehicle policies, providing valuable insight into policy improvements and encouraging contractors and public agents to be fully prepared for future demand increase. As Bay Area drivers witness early adopter satisfaction with electrified vehicles and charging infrastructure, this new driving technology paradigm is shown to be consumer-friendly, and general consumer demand will increase. The public sector has the unique ability to facilitate consumer confidence and ease with this new product, thereby encouraging increased electrified vehicle market uptake and reducing environmental and political instability associated with the existing transportation sector.

Further, the public sector has a responsibility to intervene to help correct the market failures caused by internal combustion engine vehicles. These vehicles emit harmful pollutants into the atmosphere, which directly contribute to climate change, decrease air quality, and lead to many negative health and environmental outcomes. Since a clean atmosphere is a public good and currently has no monetary value in the marketplace, the price of internal combustion engine vehicles does not reflect their true societal costs. Both the California legislature and the federal government have intervened to correct this market failure and its associated negative externalities through several important mandates. While these mandates require major emissions reductions, they do not directly provide concrete tools for achieving these goals. Municipalities and regional actors can play a vital role in implementing these mandates through local policy decisions that motivate demand for low and zero emission vehicles. Municipalities can take decisive actions in jump-starting the construction of electrified vehicle charging infrastructure and paving the way for environmentally healthy vehicles of the future.

In short, the obstacles laid out above are important, though not impassable. With comprehensive, precisely targeted policies, the Bay Area governments can effectively break down most, if not all, of these barriers and become a national leaders in the charge for electrified vehicles.

This report focuses particularly on one barrier: the deployment of EVSE infrastructure. The next section of this report details existing EVSE infrastructure types and specifies public sector involvement options for increasing and accelerating access to EVSE infrastructure in the Bay Area.
IV. Bay Area Electric Vehicle Supply Equipment (EVSE) Options

Charging Infrastructure Options for Short-Distance Commuters

Level 1 (Slow Charging)
This charging station uses a 120-volt, three-prong outlet, which is the same power source as standard home appliances. Level 1 charging utilizes a portable EV supply equipment cord and plug set. To protect against overload, installation of a dedicated circuit is recommended. The total cost of a residential Level 1 charger is approximately $878. While this method is inexpensive, ubiquitous and does not require upgrades to a property’s existing electrical service, it may not be practical for the average electrified vehicle driver since recharging can take anywhere from 8 to 14 hours. Level 1 charging stations do, however, provide an immediate solution for electrified vehicle re-charging if a vehicle owner has not yet installed Level 2 charging infrastructure.

Level 2 (Medium Charging)
This charging alternative utilizes a 240-volt power supply, which is the equivalent of heavy-duty home appliances like washers and dryers. A residential Level 2 charger costs approximately $2146. Level 2 charging is often considered the “preferred” charging method for private homes, office parking lots, public facilities, and vehicle fleets because it is capable of recharging an electrified vehicle in approximately 4 to 6 hours. Furthermore, EVSE conductive power connector standards were recently approved by the Society of Automotive Engineers (SAE) (Document J1772), which sets the stage for Level 2 charging to be the predominant EVSE technology for electrified vehicles soon entering the market. Sections VI and VII of this policy brief focus on deployment, financing, and access to Level 2 EVSE infrastructure.

Charging Infrastructure Options for Longer-Distance Drivers

Level 3 (Fast charging)
This 480-volt charging technology is capable of recharging over half of an electrified vehicle’s battery capacity in 10 to 15 minutes, depending on the vehicle battery size. This is not a practical option for home use because it requires much more electricity than a domestic outlet can handle and it costs between $30,000 and $160,000. However, Level 3 charging will fill an important charging niche for long-distance travelers, and vehicle fleets that require frequent charging (e.g. taxis and emergency vehicles). As demand for electrified vehicles builds, Bay Area municipalities and their counterparts in other California regions can play an important role in coordinating Level 3 charging networks along the state’s major highways and transportation corridors.

Battery Swapping Charging Infrastructure
Battery swapping is an option for electric vehicle recharging in which electrified vehicle owners do not own the battery. Instead, consumers drive to swapping stations where an automated

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XI SAE J1772 (formally, “The Society of Automotive Engineers Surface Vehicle Recommended Practice J1772, SAE Electric Vehicle Conductive Charge Coupler”) establishes common operational, dimensional and performance standards requirements for EV conductive charging technology in North America as of 2010. This automotive power connector, produced by Yazaki, has a round connector and delivers 16.8 kilowatts of power at 120-240 volts.
service exchanges their depleted battery for a fully charged one in a matter of minutes. Better Place, based in Palo Alto, CA, is a well-known example of this model.

Several inherent difficulties exist within the battery swapping model that make it an impractical option for present and near-future use in the Bay Area. First, there is not yet sufficient investment capital for a Better Place demonstration project in the Bay Area. Second, consumers are likely to be reluctant to swap batteries with strangers especially because they will not have full knowledge about where the batteries have been and their current conditions. Third, vehicle owners may not actually demand this type of service. Instead, they may opt to charge their vehicles at home with Level 1 or 2 chargers. Auto manufacturers have expressed concerns about battery safety, warranties, and design homogenization. In fact, Nissan announced that it would not include a battery rental option for the Leaf in the U.S. because of lack of consumer confidence. Finally, battery compatibility is key to the battery-swapping concept, and there is currently no industry-wide standard for battery type, make, or model.

**Advanced Charging Scenarios**

*Vehicle to Grid (V2G)*

Vehicle-to-grid technology would allow electric vehicles to both draw electricity from and return electricity to the grid. This innovative technology capitalizes on the fact that electrified vehicle batteries store the same type of energy used to power homes and offices in the U.S. (60Hz AC). In fact, an electrified vehicle battery is capable of producing enough power to satisfy the electricity demand of 10 U.S. homes. Ideally, vehicle owners would recharge their vehicles during off-peak hours (overnight for example) when electricity is the least expensive. During peak hours, when electricity prices are highest, electricity stored in the battery would be sent back to the grid.

V2G provides a wide range of benefits to vehicle owners, utility companies and the general public. Vehicle owners may save more money by recharging when electricity is inexpensive and returning electricity to the grid when it is more expensive. Early estimates claim that EV owners could earn between $2000 and $3000 per year to feed electricity back into the grid. Utility companies may benefit because V2G would reinforce grid stability by reducing electricity production requirements during peak day-time hours when electricity demand is at its highest. Furthermore, V2G may allow utility companies to increase their use of intermittent renewable energy such as solar and wind. Increased reliance on renewable energy would decrease greenhouse gas emissions and air pollution from the electricity sector. The Marin Energy Authority has taken the lead in the Bay Area in exploring V2G feasibility. The county is in the process of applying for a Department of Energy (DOE) grant that would fund the integration of V2G and stationary batteries to store surplus wind energy.

*Inductive Electricity Charging*

This charging technology utilizes magnetic fields to transport electricity to recharge electrified vehicles. Since the plug and the receptor do not have to make physical contact, inductive charging makes it possible for vehicles to recharge through pavement based charging systems along roads or designated highways and in public and private parking spaces. Costs and practicality currently make inductive vehicle charging unrealistic.
V. EVSE Deployment Options for Local Governments

The nine counties in the Bay Area will have to play a crucial role to ensure a successful rollout of electrified vehicles. To ensure an optimal transition in the early phase of the technology’s adaption, relevant actors in the Bay Area will have to collaborate closely to exchange experiences and share best practice models. The Bay Area’s Joint Policy Committee (JPC) – which includes the Association of Bay Area Governments (ABAG), the Bay Area Air Quality Management District (BAAQMD), the Metropolitan Transportation Commission (MTC), and the San Francisco Bay Conservation & Development Commission (BCDC) – provides a strong organizational structure in this regard. Beyond such high level collaboration, direct contacts between the local experts on the municipal and county level are essential to identify optimal practices. Below, we outline tools at each local government’s disposal to facilitate charging infrastructure deployment.

A. Develop an informed strategy
Local governments should conduct an “EV Impact Analysis” that evaluates the costs and benefits of BEVs and PHEVs compared to HEVs and CVs in their communities. Such an analysis may tie in well with existing local climate plans. Subsequently, local actors should develop an “EV Transition Plan” which identifies local barriers and formulates a strategy for increasing demand for electrified vehicles. Our analysis of the concrete challenges of charging stations should be adapted to the specific hurdles within each city. Benchmarks for success should be considered as they can play an important role in incentivizing a critical review of current practices and identifying areas for improvement.

B. Public Charging Infrastructure: maximize visibility & assuage consumer range anxiety
EV charging infrastructure deployed in highly visible public places can increase public awareness of the growing electric vehicle presence in the Bay Area. Municipalities should choose locations that will be very accessible and utilized by the greatest number of future EV owners. Optimal locations are heavily trafficked places where people park for long periods of time. Citing chargers near local governmental offices can serve a dual use; they can provide charging opportunities for local citizens during the day, and repower the electrified municipal fleet over night. Other strategic places include shopping malls, performing arts centers, parks, zoos, movie theaters, sports arenas, amusement parks, and other recreation centers. The same holds true for publically owned downtown garages, public transit hubs like airports, Bay Area Rapid Transit (BART) stations, Amtrak stations, university campuses, libraries, and hospitals.

Conveniently located public charging options can also boost consumer demand for EVs by reducing consumer range anxiety. Local governments should ensure that there are enough public charging stations available and accessible along commuter routes. Studies have indicated that just 10 to 30 percent of the total number of gas stations must be equipped with electric charging devices to sufficiently reduce range anxiety and boost consumer confidence for local, short-distance drivers. For long-distance drivers, charging stations should be located every 40 miles as a “safety net.”
C. Make chargers available for multi-unit dwellings without garages

Municipalities should assist in the development of curbside charging stations near residential areas that do not have access to private or home charging stations. This applies to residents living in multi-unit apartment buildings without garages or tenants in a rental property. Such curbside stations can be connected to existing infrastructure like streetlamps as deemed fit for grid stability. Local governments should facilitate neighborhood agreements and collaboration between tenants and landlords to find efficient cost-sharing ownership designs. Furthermore, they can ease the permitting steps required to access the publicly owned curbside. Since the financing tools for charging stations discussed later in this paper are targeted at commercial and single-family residential properties, a municipal focus on multi-unit dwellings addresses an important charging station access gap.

D. Adapt urban planning codes

Local planning codes should be adapted to prepare for and encourage the widespread use of electrified vehicles. This includes requiring new residential and commercial properties to be wired for Level 2 chargers. Likewise, newly constructed commercial garages should be required to feature electrical wiring suitable for charging infrastructure installation. Finally, local governments should require commercial project developers to reserve a certain percentage of parking spots for electric vehicles and equip these lots with chargers.

E. Use clean electricity for municipal chargers

To realize the full potential of cleaner air and climate change mitigation offered by electrified vehicles, electricity should come from clean sources. Otherwise, the pollution is only displaced and not eliminated. While increasingly strong renewable portfolio standard mandates will “green the grid” over time, municipalities should consider opting into contracts with their electricity providers to purchase clean electricity, or engage in carbon credit trading to offset parts of their environmental footprint.

Alternatively, municipalities may choose to couple the deployment of charging stations with the construction of renewable energy projects. For example, several companies offer a combination of solar photovoltaic (PV) systems integrated into the roof structure above parking lots, which either power connected EVs or supply electricity to the general grid. Studies have shown that integrating charging facilities from the very beginning with renewable energy sources is much more cost-effective than retrofitting them later on.

F. Educate all EV stakeholders about charging options and operations

Local government can play an important role in educating, training, and coordinating all EV stakeholders including consumers, car dealers, utility companies, contractors, and city and county transportation managers. It will be especially important for groups like the JPC to convene stakeholders in the coming months in order to best prepare the region as EV technologies come to local vehicle markets.

Municipalities can partner with local schools, businesses, and civic groups to facilitate training and/or evening and weekend workshops. Specific sessions could target electricians to teach them how to inspect, permit, and report for EVSE installation projects. Also, education can generate surplus demand and acceptance of electrified vehicles in the Bay Area by assuaging
consumer anxieties. These trainings should emphasize the environmental and health benefits of these vehicles, their cost savings compared to conventional vehicles, the available charging infrastructure and financing options, the best times to recharge vehicles to take advantage of the biggest cost savings, available subsidies and tax credits, and permitting procedures for charging infrastructure.

It is also crucial for local and county fleet and transportation managers in the Bay Area to develop a forum in which they can share ideas and best practices as well as coordinate regional policies.

G. Public-Private Partnerships: establishing viable charging infrastructure markets

The rollout of charging infrastructure for electric vehicles requires large-scale investments over the five to ten years. Meeting these needs with public expenditures alone will be impossible in these difficult economic times. In the long run, the private sector will be much better equipped than the public sector to cost-effectively finance and deploy charging infrastructure. However, to accelerate the initial deployment of charging stations, cooperation between both sectors is crucial. The public sector can support pioneering companies in their efforts to provide their employees with charging stations, or replace their conventional fleets with electrified vehicles.

For private charging station companies, local governments should provide infrastructure-siting access to public lands at the lowest feasible cost. The necessary paperwork to access this land should be simplified, and the development process should be streamlined and facilitated by the relevant public partners.

Public stakeholders have to encourage the development of an open and competitive market in the charging sector to ensure least-cost solutions, and to spur innovation and user friendliness. This has to be balanced with cooperation between the competitors in order to ensure general compatibility between the charging networks, so that consumers are not limited to the use of one particular company. Because these incompatibilities would have detrimental effects for consumers, the public sector should follow this market development closely and intervene when appropriate.

H. Lobby policymakers on the state and federal level

Local governments play an important role in informing state and federal decision-makers about needs and experiences on the ground. One issue that requires an interregional approach for charging infrastructure plans is the creation of long-distance EV corridors. In order to overcome the range limitations of BEVs, recharging stations have to be available along heavily frequented interregional transportation routes. These include for example the corridors between the Bay Area, Los Angeles, and San Diego, and also the route from San Francisco to Sacramento and Reno. State and federal funds can incentivize the private sector to deploy Level 3 chargers along these routes and state policies can ease administrative barriers.

Current monetary incentives are largely insufficient to initiate large-scale deployment of parking structures, which integrate renewable energy generators (primarily photovoltaic). Although the California Solar Initiative and federal renewable energy tax credits offer some assistance, the current charging stations favor infrastructure relying on the general electricity mix. Because
the environmental benefits of EVs are intrinsically linked to their fuel source, it is essential to promote integrated technologies as they reduce costs through learning-by-doing.

In addition to these infrastructure related measures, state level decision-makers can promote EVs with a range of other incentives. For example those purchasing EVs are eligible for Single Occupant Carpool Lane Stickers for the High Occupancy Vehicle (HOV) Lane Exception until the end of 2010.42 Since electric vehicles are expected hit the market in large numbers in late-2010 and early-2011, local governments should support SB 535 (Yee), which seeks to extend this incentive until 2014.43 Counties can also advocate for EV exemptions from vehicle registration fees and statewide tolls, which would require changes to the California Vehicle Code.

Finally, electrified vehicles would benefit from the introduction of a “feebate” program, which creates a schedule of both fees and rebates that reflects the amount of pollution that different vehicles emit.44 Although the Clean Vehicle Incentive Program (AB 1212, Ruskin) has remained in the California Assembly’s Transportation Committee since early 2009, counties should vocally support an empowerment of the Californian Air Resources Board (CARB) to create a self-financing mechanism promoting cleaner vehicles.45

I. Establish finance mechanisms for chargers
Cities can take several measures to finance public chargers. First, they can issue municipal bonds that are repaid with revenue generated from electricity sales at the charging stations. Since the profitability of these stations is unclear due to uncertain demand for public charging, local governments should negotiate for sufficient provisions with private operators (e.g. Coulomb Technologies) to preclude net-losses. There are several financing options for public charging stations currently available. For example, several cities in Contra-Costa County have levied a $0.005 surcharge on the local sales tax, which feeds into a local transportation fund. Nine chargers in three cities have already been financed with this tool.

For both public and private entities, there are a variety of tax credits, grants and funds available that aid the deployment of chargers. These subsidies are not sustainable, and we recommend making residential and commercial chargers eligible for Property Assessed Clean Energy (PACE) financing to reduce this upfront cost barrier (described in Section VI).

J. Streamline the infrastructure permitting processes
Local governments can streamline and accelerate the EVSE installation process. The current process is burdensome to the consumer and Section VII of this paper details an efficient process, and the reforms necessary to achieve it.

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XII Purchasers of new vehicles that emit larger amounts of emissions pay a one-time surcharge at the point of purchase. These surcharges are then used to provide rebates to buyers of new vehicles that emit less pollution.
VI. EVSE Financing Tools

Overview of Existing Subsidies and Tax Credits

To overcome some of the difficulties that EV manufacturers face, a variety of public support measures have been launched ranging from the federal to the local level. Some of these include mandatory shares of alternative fuel vehicles in public fleets, financial assistance in form of block and matching grants and soft incentives like preferential access to high occupancy vehicle (HOV) lanes. The American Recovery and Reinvestment Act (ARRA), alone, dedicated $2.4 billion to the promotion of EVs, mostly in the form of grant money to manufacturers of EVs and their components. The following section provides a brief overview of subsidies and tax credits available to consumers in the Bay Area who are interested purchasing an EV and the associated charging infrastructure.

Subsidies and Tax Credits for Electrified Vehicles

Federal Subsidies
On the national level, the Federal Tax Credit is the only subsidy available for regular consumers who purchase EVs. The subsidy is intended to compensate for the additional up-front costs incurred compared to the purchase of a traditional CV. Depending on the capacity of the battery, the total tax credit may range between $2,500 (minimum of a 5kWh battery) and $7,500 ($417 is awarded for every additional kWh thereafter). Currently, no vehicles have been certified to be eligible for this credit. Similar to the practices applied to HEVs in the past, the dollar amount of the tax credit will decrease after the threshold of 200,000 vehicle sales per manufacturer is surpassed. The credit is currently set to expire at the end of December 2014, although there is a chance that the tax credit will expire earlier if demand is high (as was the case with regular hybrid vehicles—originally set to last until December 2010, the tax credit expired well before due to popular demand).

California Subsidies
In October 2007, the Assembly Bill 118 (Núñez) was signed into law in California, laying the groundwork for the current state funding structure for alternative fuel vehicles. AB 118 created three primary programs. The first is the Alternative and Renewable Fuel and Vehicle Technology Program, which has an annual fund of $10 billion administered by the California Energy Commission (CEC). The second innovation was the Enhanced Fleet Modernization Program (EFMP), which is authorized $30 million per year to the Bureau of Automotive Repair (BAR) to accelerate turnover of California’s on-road, light-duty vehicle fleet. The third program established under AB 118 was the Air Quality Improvement Program (AQIP), overseen by the California Air Resource Board (CARB). The AQIP appropriation for the fiscal year 2009-2010 totaled $34.6 million for clean vehicle and equipment projects, research on biofuels production, the air quality impacts of alternative fuels, and workforce training.

A subprogram of AQIP is the Clean Vehicle Rebate Project (CVRP or The Zero-Emission and Plug-In Hybrid Light-Duty Vehicle Rebate Project), which is administered by the California Center for Sustainable Energy (CCSE). AQIP funded the program with $4.1 million for the fiscal year 2009-2010. The project is expected to expire in the year 2015. Light-duty zero-
emission vehicles (ZEVs) are eligible to receive a rebate up to $5,000, whereas PHEVs are eligible for only $3000. Heavy-duty vehicles for commercial use, or for public agencies are eligible for a $20,000 rebate. Receiving such subsidies for a purchase or lease binds the consumer to operate the vehicle in California for a minimum of 36 consecutive months.

Regional/Local Subsidies
The Bay Area Air Quality Management District (BAAQMD) has instituted the Transportation Fund for Clean Air (TFCA), which receives $22 million annually GHG reduction program implementation. The TFCA funds are generated from an annual $4/vehicle fee charged to all vehicles registered in the Bay Area.\textsuperscript{53} TCFA has set aside $5 million for Alternative Fuel Vehicles (AFVs), for which purchased or leased EVs, and related infrastructure investments are eligible.\textsuperscript{XIII} In addition, $2 million is available for Vehicle-based advanced technology projects that test or demonstrate emission reduction technologies (up to $500,000 per project).\textsuperscript{54} Public education on ZEV benefits is an additional emphasis of the TFCA.

The Bay Area Metropolitan Transportation Commission (MTC) has instituted the Innovative Grants program as part of its Climate Initiatives Grants Initiative ($80 million total funding for the latter).\textsuperscript{55} EV purchases qualify as projects promoting lower GHG emissions, and are eligible for a share of the $31 million available from 2009-2012.\textsuperscript{56} Private entities partnering with a public agency are eligible for the funds as well.\textsuperscript{57}

\textit{Subsidies and Tax Credits for Charging Infrastructure}

\textit{Federal Subsidies}
A Federal Alternative Fuel Infrastructure Tax Credit is available for EVSE infrastructure projects. Commercial applicants are eligible for tax credits of 50\% of the incurred installation costs, although the refund is capped at $50,000. The tax credit is counted separately at each location, which enables an owner of multiple properties to receive multiple tax credits. Residential applicants are eligible for tax credits of 50\% of the installation costs with a cap at $2000.\textsuperscript{58} Both programs are currently set to end at December 31\textsuperscript{st} 2010, although an extension might be possible in Congress.

The federal EV Project received $99.8 million from the Department of Energy (DOE) and has attracted an additional $100 million in private funds. Through the fall of 2012, more than 10,950 Level 2 chargers and 260 Level 3 chargers will be installed in five participating states (one of them being California, specifically the city of San Diego).\textsuperscript{59} The Bay Area should try to join the program as soon as possible.

\textsuperscript{XIII} Alternative Fuel Vehicles (AFVs) are defined as vehicles fueled exclusively by alternative fuels comprising: a) Mixtures containing 85 percent or more by volume of alcohol fuel, including methanol and denatured ethanol. b) Natural gas (compressed or liquefied). c) Liquefied petroleum gas (propane). d) Hydrogen. e) Fuels derived from biological materials. f) Electricity (including electricity from solar energy). g) 100 percent Biodiesel (B100) or Renewable Diesel meeting ASTM D-975. h) Blends of two or more alternative fuels, for example, natural gas and hydrogen. For more information see: http://www.arb.ca.gov/fuels/altfuels/incentives/afip_att_c.pdf
Regional/Local Subsidies
As mentioned above the Transportation Fund for Clean Air (TFCA) offers $5 million for alternative fuel vehicles and infrastructure. Private homeowners can apply for a rebate of 50% of the installation costs capped at a total of $2000. Commercial applicants receive up to $20,000. Although the program ends officially on December 31st 2010, it will likely continue. From January to June 2011, additional incentive funding will be available for 1000 home charging stations.

The Alternative Vehicle and Infrastructure Project is another program by the BAAQMD, which has existed since November 2009 and has funds of $5 million for governmental and private entities. It is intended for medium-sized projects and provides a minimum of $10,000 in subsidies, which can be combined with other grants to recoup up to 100% of all costs.

Finally, BAAQMD has a Level 3 Charging Infrastructure Fund of a total of $2 million to support projects with individual grants ranging between $10,000 and $500,000.

The Bottom Line of EVSE Incentives

The average applicant interested in the installation of a residential EV charger can apply for tax credits and grants, which may cover 100% of the associated installation costs up to an amount of $4,000 (including cutting walls and new wiring). On average, this accounts for roughly 50% of the overall EVSE project costs.

Commercial applicants can receive a reimbursement of 100% of their installation costs up to $70,000, which accounts for 45% of the overall EVSE project costs on average.

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XIV The information pertaining BAAQMD funds is based on a telephone interview with BAAQMD grants manager for the strategic fund division, Karen Schkolnick on April 10, 2010.
Overview of funding sources available for EVs and EVSE (Table 1.4)

Funding sources available to residential and commercial EV consumers (Table 1.5)

<table>
<thead>
<tr>
<th>Level of Government</th>
<th>EV residential</th>
<th>EV commercial</th>
<th>EVSE Residential</th>
<th>EVSE Commercial</th>
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<tbody>
<tr>
<td>Federal</td>
<td>Tax credit: 2,500 + $417 * kWh &gt; 5</td>
<td>Tax credit: 2,500 + $417 * kWh &gt; 5</td>
<td>50% tax credit for installation costs capped at $2,000</td>
<td>50% tax credit for installation costs capped at $50,000</td>
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<tr>
<td>California</td>
<td>CVRP: $5,000 for BEVs $3,000 for PHEVs</td>
<td>CVRP: $20,000 for heavy duty BEVs</td>
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<tr>
<td>Bay Area</td>
<td>$5 million for AFVs by TFCA</td>
<td>$5 million for AFVs by TFCA</td>
<td>50% for installation costs capped at 2,000 by TFCA</td>
<td>50% for installation costs capped at 20,000 by TFCA</td>
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<td></td>
<td>$2 million for advanced technology by TFCA</td>
<td>$2 million for advanced technology by TFCA</td>
<td></td>
<td>AVIP: $10,000+ for midsize projects with public partner, by BAAQMD</td>
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<td></td>
<td>$31 million Innovative Grant by MTC</td>
<td>$31 million Innovative Grant by MTC</td>
<td></td>
<td>Level 3 charging: $10,000-500,000 grants by BAAQMD</td>
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</tbody>
</table>
As already highlighted, these are only short-term subsidies. To ensure a more sustainable financing, we advise making residential and commercial EVSE projects eligible for Property Assessed Clean Energy (PACE) financing programs.

**Property Assessed Clean Energy (PACE) and EVSE Deployment**

*Overview: Financing to Encourage Energy Efficiency and Mitigate Climate Change*

Property Assessed Clean Energy (PACE) is an innovative program intended to finance energy improvements that provide environmental, health, and energy independence benefits. PACE programs allow state and local governments, by amending existing state law, to extend the use of land-secured financing districts to fund energy efficiency and renewable energy improvements on private property. Property owners are then able to repay costs through property assessments secured by senior tax liens on their property, and paid as additions to their property tax bills. By extending payback periods and reducing a property owner’s up-front investment cost, PACE financing has been used to eliminate key financial barriers to investment in energy efficiency and renewable energy improvements.

One of the advantages of PACE financing is that the assessment is a debt of the property, not the property owner. This means that when property ownership transfers, the assessment stays with the property and the new owner is responsible for paying its balance. This characteristic eliminates a key disincentive to energy efficiency and renewable energy investing—payback periods that extend beyond the length of time a property owner plans to own a property. While new owners bear the burden of paying the balance of PACE assessments, they also benefit from the energy improvements for which the assessment was placed. As such, PACE financing is restricted to improvements that are permanently affixed to the property. This ensures that new property owners receive the benefits for which they are paying the assessment. PACE financing is, therefore, not likely to be an appropriate mechanism for directly financing electrified vehicles. If a property owner purchases an electrified vehicle with funds from a PACE assessment, that vehicle must stay with the property upon a property sale. This is impractical as it complicates real estate transactions and prospective property buyers are unlikely to be interested in purchasing used a vehicle in conjunction with their property purchase. PACE programs, however, do have the potential to reduce the up-front cost barrier to electric vehicle market penetration by financing the cost of electric vehicle charging stations.

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XV Energy improvements are typically energy efficiency retrofits and renewable energy installations.

XVI For more information on PACE programs, please visit: [http://www1.eere.energy.gov/wip/solutioncenter/financialproducts/PACE.html](http://www1.eere.energy.gov/wip/solutioncenter/financialproducts/PACE.html)

XVII Lien priority is a matter of state law. In California, PACE assessments are supported by senior tax liens.

XVIII PACE programs typically require that the expected useful life of energy improvements surpasses the length of the PACE assessment.
EVSE Charging Infrastructure: The Case For PACE Eligibility
The DOE’s Guidelines for Pilot PACE Financing Programs requires programs to limit funding to 
permanently-affixed packages of energy improvements that (1) are expected to pay for 
themselves over the life of the PACE assessment and (2) contribute to PACE’s public 
purpose.

PACE Eligibility Requirement One: Savings Exceed Costs
This first requirement, that the package of PACE-financed energy improvements delivers savings 
in excess of investment costs, was developed as a protection for mortgage holders and program 
participants as it increases the participant’s ability to repay PACE assessments and other debt. 
While electric vehicle charging stations do not directly lead to savings, they can still meet this 
requirement in two ways.

First, it is important to note that the cost of charging stations is small when compared to the 
average package of PACE-financed energy improvements. According to a 2008 DOE report, 
the total cost of purchase and installation of Level 2 residential charging stations is $2,146. 
Net of available subsidies and tax credits, this amount drops to just $850. The average residential 
PACE assessment is approximately $23,000, so charging infrastructure would account for just 5- 
10% of this total (depending on whether financing is net of subsidies and tax credits). 
This leaves significant room for property owners to finance both charging stations and other 
improvements and create an overall package of improvements that delivers savings in excess of 
investment costs. Furthermore, because most PACE programs require minimum assessment 
 sizes, it is unlikely that charging stations will be the only PACE-funded improvement in which a 
property owner invests. Importantly, there is already ample precedent for focus on overall 
energy improvements packages—allowing participants to fund specific improvements, such as 
high-performance windows, that do not deliver net savings.

Second, charging stations deliver indirect savings to property owners. It is reasonable to assume 
that charging stations will typically be installed in conjunction with electrified vehicle purchases. 
We analyzed the economics of PHEVs and BEVs compared to HEVs and CVs over a range of 
battery sizes, battery lifetimes, electricity prices, and gasoline prices. When infrastructure 
costs and all available subsidies and tax credits are taken into account, the economics of PHEVs 
and BEVs are generally superior to CVs when batteries are sized appropriately to a driver’s 
travel habits. While the economics of PHEVs and BEVs become more sensitive to model inputs 
when HEVs are used as a base case, low overall HEV market penetration may warrant placing 
greater emphasis on the CV comparison—in the Bay Area, just 1.74% of vehicles are HEVs and 
this is more than double California’s .77% HEV market penetration.

XIX For more information on DOE’s Guidelines for Pilot PACE Financing Program, please visit: 
http://www1.eere.energy.gov/wip/pdfs/arra_guidelines_for_pilot_pace_programs.pdf

XX While both residential and commercial property owners are typically eligible for PACE financing, this analysis 
focuses on residential electric vehicle charging stations.

XXI Lawrence Berkeley National Laboratory is currently collecting more detailed data on the precise number of 
assessments, dollar value, and types of improvements made.

XXII Because of high administrative costs, assessment sizes are typically mandated to be at least $3,000-$5,000.

XXIII Please see Appendix for this economic analysis. All modeling assumptions are described therein.
PACE Eligibility Requirement Two: Public Purpose Relevance
Discrete improvements must contribute to the stated public purpose of PACE programs—typically mitigating climate change or achieving energy independence—to be PACE-eligible. Charging stations will play an important role in increasing electric vehicle market penetration and reducing the transportation sector’s contribution to air pollution, climate change, and energy independence.

Ancillary Benefits of Charging Station Financing
Those property owners considering PACE financing for energy efficiency and/or renewable energy improvements may see electric vehicle charging stations listed as PACE-eligible measures and be drawn to a PHEV or EV purchase. Likewise, those property owners considering PACE to finance a charging station may decide to couple this investment with additional eligible energy improvements.

PACE Commercial Charging Station Applicability
As tax credits and subsidies expire in the coming years, PACE financing will become increasingly necessary to overcome the up-front cost of charging stations in the residential sector. In the commercial sector, where up-front capital costs are significant for large charging station projects even with tax credits and subsidies, PACE financing can play an important role in enabling these investments. While our economic analysis focused on residential vehicles and infrastructure, it is reasonable to conclude that the economics of commercial fleets are similar. In addition, commercial charging station owners can enhance the economics of their charging station investments by making the stations available, at a cost, to private consumers for re-charging.

PACE as a Tool to Eliminate Time Lags
There exists a significant time lag from EV purchase to EVSE installation. This gap poses a strong disincentive to marginal consumers considering the purchase of PHEVs and EVs. If charging stations are installed as part of a package of energy improvements before an electrified vehicle purchase, PACE may ease this particular barrier. The following section explores the administrative barriers to EVSE deployment, and provides comprehensive recommendations intended to streamline and accelerate the EVSE installation process.
VII. Streamlining the EVSE Installation Process

Consumers generally prefer immediate gratification when making purchases, and the 35-45 day waiting period imposed by the administrative hurdles of the EVSE installation process may discourage consumers from purchasing EVs.\textsuperscript{64, 65} In fact, a recent study by Accenture\textsuperscript{5} concluded that 60% of vehicle consumers are more likely to buy an EV only when it is superior to a gasoline-only model in every way.\textsuperscript{66} This survey finding implies that the inconvenience of waiting for EVSE installation may inhibit the majority of vehicle purchasers from adopting EV technologies.

The divergence between the current EVSE installation process and consumer preferences may inhibit the achievement of the Bay Area’s stated light-duty EV deployment goals of 20% by 2020, 50% by 2030, and 70% by 2040.\textsuperscript{67} In effect, consumer disillusionment with the EVSE installation process may delay the realization of the prospective environmental benefits of large-scale electrified vehicle deployment unless reforms are implemented that minimize consumer transaction costs by increasing process efficiency. Overcoming specific barriers to EVSE installation through targeted regulatory and/or legislative reforms may alleviate these concerns.

Bars to EVSE Installation

While the development of the SAE J1772 standard for Level 2 EVSE technology has simplified charger procurement choices for prospective EV consumers throughout North America, significant barriers to the timely installation of EVSE infrastructure remain.\textsuperscript{68}

1) *Upfront Equipment & Installation Costs* - Costs for residential garage, apartment complex, and commercial charging stations are significantly driven by the siting requirements for each environment.\textsuperscript{69}

   a) Residential Garage - Issues to consider include where the vehicle typically parks, where the charge inlet is located on the vehicle, and the length of the electric vehicle’s charge cord. The EVSE location should balance safety with convenience and location relative to the power supply to minimize cost.

   b) Apartment Complex/Multi-Dwelling Unit (MDU) - Installations are complicated by the need to install a circuit protection device to protect the charging circuit. As the breaker panel for each apartment is typically in the apartment, this panel cannot be used to source a new branch circuit as is possible in residential installations.

   c) Commercial Facility – This type of facility typically has a single utility service entrance, with power distributed to several subpanels throughout the building. The simplest installation occurs when the charger location is adjacent to a distribution panel. An alternative approach is to establish a new meter service account with the electric utility. The disadvantage of this approach is that the local utility will require the customer to contribute to the cost of connecting the new meter and to pay a separate bill for the additional meter and account fees.
2) Consumer Knowledge - Additional support is needed for coordinated and consistent electrified vehicle customer education and outreach efforts with manufacturers, government agencies, and equipment vendors.\textsuperscript{70}

   a) Current Electrical Status – Uncertainty regarding the electrical distribution panel capacity in the proposed project area.

   b) Service Bundling Options – Uninformed about energy efficiency and/or renewable energy investments that can be made in conjunction with EVSE installation.

   c) EV Time of Use (TOU) Rates – EV TOU rates provide electricity consumers with the option to save money by shifting their energy usage to off-peak, lower demand times with lower billing rates (e.g. $0.05-$0.064/kWh from 12:00AM-7:00AM).\textsuperscript{71} However, many eligible consumers are unaware of new metering technologies and utility rate benefits for off-peak energy consumption.\textsuperscript{72}

3) Contractor Role

   a) Service Capability – Electrical contractors currently have limited capability to serve consumers and utilities throughout the EVSE installation process (e.g. metering, panel upgrades, and permitting).\textsuperscript{73}

4) Permitting Procedures & Expertise

   a) No EVSE-Specific Permits – Many counties use a basic electrical permit for EVSE installations.\textsuperscript{74}

   b) Limited Expertise – Many local permitting offices are unfamiliar with EVSE technology. Therefore, these offices provide unclear guidance for EVSE permit applicants.\textsuperscript{75}

   \textit{Installation Streamlining: EVSE Contractors as Primary Consumer Contact}

The EV charging station installation process must be simplified and shortened in order maximize the effectiveness of the financing and incentive mechanisms outlined in the previous sections of this analysis. Policymakers, vehicle dealers, and electric utilities should establish an EVSE installation process that places EVSE contractors as the primary point of contact for consumers. This will help to better align the EVSE installation process with consumer preferences by reducing the time delay between vehicle purchase and charger installation.

   \textit{Recommended EVSE Installation Process Reforms}

It is important to acknowledge that vehicle dealers and electric utilities plan to offer specialized package services to electrified vehicle consumers that will prepare them for the operation and maintenance requirements associated with owning an EV.\textsuperscript{76} These services will go a long way toward improving the electrified vehicle purchasing experience. However, given the significance of EV technologies to existing environmental policy goals, it is prudent for policymakers to consider process reforms that complement ongoing private sector efforts to encourage the large-scale adoption of EV technologies.
1) **Consumer Education & Outreach** – Public agencies should provide consumer education and outreach assistance to help ensure timely EVSE deployment.

   a) Rate Calculator - Utilities should provide rate calculators that will help consumers make the best decisions related to electricity usage before visiting the vehicle dealership.

   b) Service Bundling - Combine EVSE installation with TOU rate discounts/incentives and efficiency improvements.

   c) Transparency – Informational materials should be easily comprehensible in order to support rational consumer decision-making.

   d) **Implementing Entities** – California Public Utilities Commission (CPUC), electric utility, vehicle dealer, and local agencies.

2) **EVSE Contractor Education & Licensing**

   a) Education – Public agencies, vehicle dealers, and utilities should work collectively to educate the EVSE contracting community on their central role in the EVSE deployment process.

   b) Licensing – EVSE installers should be authorized to represent client consumers as a permitting and procurement agent with the relevant utilities, vehicle dealers, vendors, and government agencies.

   c) **Implementing Entities** – California Building Standards Commission, CPUC, Contractors State License Board, electric utility, vehicle dealer, and local agencies.

3) **Pre-Purchase EVSE Installation Estimate & Inspection**

   a) Free Project Assessment - Prospective EV buyers should receive a free pre-purchase EVSE estimate and inspection from any licensed EVSE installer.

      i) **EVSE Inspection Components:**

         (1) Report to relevant utility on project area grid readiness and consumer interest in EVSE purchase;

         (2) Report to relevant vehicle dealer on consumer interest in BEV, PHEV, and/or EVSE purchase;

         (3) Assessment of project material and permitting needs; and,

         (4) Total project cost estimate.
b) Seamlessness – Due to contractor pre-inspection, EVSE installation should appear seamless to the consumer from EV sale to final, post EVSE installation inspection. The EVSE contractor should handle all tasks associated with EVSE installation after the consumer purchases the EV and schedules his/her charger installation appointment.

c) Implementing Entities – Consumer, EVSE contractor, and vehicle dealer.

4) **EVSE Time of Use (TOU) Metering**

   a) Require an EVSE TOU meter when a separate meter is needed to accommodate an EV at the proposed project site.

   b) Implementing Entities – CPUC and electric utility.

5) **Expedite EVSE Installation Permitting**

   a) On-line Permitting - Vehicle dealers and EVSE contractors should be able to submit all necessary permit application materials via the internet to the relevant utility and agencies;

   b) Standardization within Utility Service Area – Uniform installation permitting and reporting requirements within utility service territory; and,

   c) Bulk Permitting - High volume EVSE installers should be able to obtain multiple installation permits at a time in order to ensure timely installation.

   d) Implementing Entities – CPUC, electric utility, and local agencies.

6) **Simplify EVSE Installation Reporting**

   a) Self-inspection and reporting for licensed EVSE contractors;

      i) On-line Reporting – An online, uniform report with pictures and test data submitted to the relevant utility and agencies should be sufficient for regulatory compliance in 90% of EVSE installations;\(^78\)

      ii) Random Audits – Random post-installation inspections by the relevant utility and agencies for 10% of EVSE installations (i.e. 1 out of 10 EVSE installations is randomly audited to verify the contractor’s installation report).\(^79\)

   b) Implementing Entities – CPUC, electric utility, and local agencies.
**Accelerated EVSE Installation Process**

The following EVSE installation process scenario assumes that the EV consumer’s electric service distribution panel has adequate capacity for a Level 2 charging station, and that the entire process should take no more than 30 calendar days (with the exception of unrelated consumer scheduling conflicts). If additional electric capacity were required at the proposed EVSE project site, this would drastically increase this process time estimate. Conversely, if the consumer opts for Level 1 charging, then this would obviate, or significantly reduce the time needed for EVSE installation.

- **Step 1** - Consumer schedules an installation estimate and inspection with a licensed EVSE contractor. Pre-purchase EVSE inspection should include:
  
  a) Confirm project area grid distribution readiness for the utility;  
  b) Report to relevant vehicle dealer on consumer interest in EV/EVSE purchase;  
  c) Assessment of project material and permitting needs; and,  
  d) Total project cost estimate.

- **Step 2** - Consumer visits vehicle dealership:
  
  a) Consumer purchases electrified vehicle & EVSE package (if a charging station is desired and feasible);  
  b) EV salesperson helps the consumer complete an on-line electric utility application for EV TOU rates (if necessary); and,  
  c) EV salesperson helps the consumer schedule an EVSE contractor installation appointment.

- **Step 3** - EVSE Contractor Works for Consumer & Utility:
  
  a) EVSE contractor applies for all necessary project permits online; and,  
  b) EVSE contractor procures all necessary material and equipment for the specified installation project.

- **Step 4** - EVSE Contractor Installation Appointment:
  
  a) EVSE contractor installs charging station and TOU meter (if necessary);  
  b) EVSE contractor self-inspects and documents installation; and,  
  c) EVSE contractor submits an on-line, uniform inspection report to the relevant utility and agencies.
Local Government’s Role in Accelerating EVSE Installation

The implementation of the accelerated EVSE installation process outlined above will require action and/or reform by multiple public and private sector entities with varying levels of authority and resources. Regardless, there are several important areas within the accelerated process model that will require direct action by local governments. The following is a list of action areas that local governments can focus on to improve the efficiency of the EVSE installation process.

1) Stakeholder Outreach – Establish inclusive outreach campaigns that educate consumers on the need to assess their EVSE needs, options, and potential benefits prior to purchasing an electrified vehicle. Inform contractors of the special permitting and reporting procedures required for EVSE installations as opposed to other electrical projects.

2) EVSE Permitting & Reporting Standardization – Collaborate with other counties and/or municipalities within the same utility service area (i.e. intraregional governments) in order to standardize and digitize the permitting and reporting process for EVSE installations throughout the region (e.g. through the Association of Bay Area Governments).

3) Lobbying for EVSE Deployment & Process Reform – Advocate for the timely deployment of EVSE infrastructure and the policy reforms needed in order to implement an accelerated process for EVSE installation. The following is a list of potential EVSE advocacy areas for local governments, as well as the related decision making entities for each topic area (see detailed process reform list above):

   a) Consumer Education & Outreach - CPUC, electric utility, and vehicle dealer.

   b) EVSE Contractor Education & Licensing - California Building Standards Commission, CPUC, Contractors State License Board, electric utility, and vehicle dealer.

   c) Pre-Purchase EVSE Installation Estimate & Inspection - Consumer, EVSE contractor, and vehicle dealer.

   d) EVSE TOU Metering - CPUC and electric utility.

   e) Expedite EVSE Installation Permitting – Intraregional counties & municipalities, CPUC, and electric utility.

   f) Simplify EVSE Installation Reporting – Intraregional counties & municipalities, CPUC and electric utility.
While local governments do not possess the authority or resources necessary to unilaterally implement the entire process model for accelerated EVSE installation recommended here, the action areas above highlight the importance of local governments in ensuring timely EVSE deployment. We recognize that the organizational culture and inertia of relevant local government institutions may inhibit the implementation of the process reforms recommended above. However, given the societal imperatives associated with the deployment of electrified vehicle technologies, Bay Area municipalities should seek to overcome institutional hurdles, and establish an EVSE installation process that contributes to environmental protection and energy independence by accelerating consumer acceptance of EV technologies.

VIII. Conclusion & Recommendations

This paper makes the case that EVs will play an important role in reducing air pollution and GHG emissions from the transportation sector. It describes barriers to EV market penetration and argues that the public sector, including local governments, should act to reduce these barriers. The paper then focuses on EVSE infrastructure deployment—describing available options, highlighting existing government financial and policy supports, and laying out the steps local governments can take to address the EVSE deployment challenge.

Key Recommendations
1) Public charging stations
2) Curbside charging station deployment for multi-unit dwellings
3) Adaptation of urban planning codes
4) Stakeholder education
5) Public-private partnerships
6) Establishment of a financing mechanism for private charging stations
7) Streamlining the charging station installation process

This paper expands on the last two recommendations. It argues that PACE financing programs can reduce the upfront cost barrier to EV market penetration. Finally, the paper lays out a streamlined, consumer-friendly charging station installation process and the process reforms necessary to achieve it.

RAEL offers these recommendations in hopes that the San Francisco Bay Area will be able to establish a feasible, effective, and duplicable model for regional EVSE deployment that reflects the scope and urgency associated with California’s current environmental and energy challenges.
IX. Appendix: Assessing the Economics of PHEVs and EVs Relative to HEVs and CVs

Two recent studies model the economic impact of PHEV and BEV usage.\textsuperscript{81, 82} The studies find that unless battery prices fall or long-term gasoline prices rise, the expected fuel savings from PHEVs and BEVs will not compensate vehicle purchasers for the additional battery cost relative to the current generation of HEVs and CVs. However, these studies ignore available Federal and state subsidies and tax credits for PHEVs and BEVs, as well as the cost of charging infrastructure. We build upon these models by including these parameters to reflect a more realistic measurement of the economic impact of PHEVs and BEVs on residential purchasers.

Our analysis includes a shorter range of expected battery lifetimes than the previous studies—3, 5, and 10 years instead of 12 years—to reflect current battery life expectations and the uncertainty of battery performance.\textsuperscript{XXIV} We include a 10-year battery lifetime because the Chevrolet Volt is expected to come with a 10-year, 150 thousand mile battery warranty.\textsuperscript{XXV} In addition, we have examined a range of battery sizes that approximate 3 vehicles that are likely to come to market over the next 12 months—the Chevrolet Volt, the Nissan Leaf, and the Tesla Roadster.\textsuperscript{XXVI, XXVII} We use a 16 kWh PHEV to model the Chevrolet Volt, a 24 kWh EV to model the Nissan Leaf, and a 53 kWh EV to model the Tesla Roadster.\textsuperscript{XXVIII} We maintain the assumption that additional battery cost is equal to marginal vehicle cost, but in reality BEVs should also realize savings from not needing a gasoline engine at all. Finally, we have expanded the range of gasoline prices to include $5 based on a 2009 Deutsche Bank study that suggested oil prices could reach $175 per barrel by 2016, implying a $4.75 per gallon U.S. gasoline price.\textsuperscript{83} Current Energy Information Agency (EIA) forecasts call for $2.84 per gallon in 2010 and $2.96 in 2011. These average U.S. prices are likely to exceed $3 per gallon at times during the driving season and already exceed $3 per gallon in California.\textsuperscript{XXIX}

**Battery Cost Uncertainty**

The uncertainty of future battery costs in terms of dollars per kilowatt-hour storage capacity ($/kwh) remains a major challenge in establishing the economic rationale for PHEVs and BEVs as the battery pack is the most expensive part of the vehicle. At the end of this Appendix, we list a range of battery cost projections. These estimates range from $260/kWh to $1,750/kWh. While acknowledging the variance in cost estimates, we believe $500/kWh is an appropriate battery cost projection for the next 2-3 years and expect battery costs to continue to decline as technology advances, production scale increases, and manufacturers advance along learning curves.

\textsuperscript{XXIV} As with cited studies, we ignore potential end-of-life battery applications and grid support services, which could be a source of additional battery value.
\textsuperscript{XXV} More information on the Chevrolet Volt can be found here: http://www.chevrolet.com/pages/open/default/future/volt.do
\textsuperscript{XXVI} More information on the Nissan Leaf can be found here: http://www.nissanusa.com/leaf-electric-car/index#/leaf-electric-car/index
\textsuperscript{XXVII} More information on the Tesla Roadster can be found here: http://www.teslamotors.com/
\textsuperscript{XXVIII} While the Chevrolet Volt is technically a PHEV as its gasoline engine is used to charge the vehicle’s battery not to directly power the car, for modeling purposes there is no significant difference in vehicle costs.
\textsuperscript{XXIX} For more information on EIA forecasts, please visit: http://www.eia.doe.gov/steo
Economic Conclusions

The high degree of uncertainty about battery prices and lifetimes makes unqualified conclusions about the economics of PHEVs and BEVs relative to HEVs and CVs challenging. While battery cost reductions are widely expected, both current costs and the trajectory of this cost decline remain in dispute. In the Bay Area, 1.74% of vehicles are HEVs. This low HEV market penetration may warrant comparing the economics of PHEVs and BEVs to CVs, yielding more favorable economic results.

Our analysis punishes both the 24 kWh and 53 kWh battery vehicles because of driving habit assumptions. Greater all-electric ranges make it more likely that many PHEV and EV owners will not drive enough to use their entire all-electric range each day. The economics of these vehicles suffers because owners must still pay for unutilized battery capacity. We find that the Chevrolet Volt—with an expected 40-mile all-electric range—is best-suited to our 40-mile daily vehicle travel assumption (20 miles roundtrip). The 16kWh PHEV is economically attractive versus both HEVs and CVs regardless of battery lifetime, fuel, and electricity prices. The 24 kWh EV is more sensitive to battery lifetime and input prices, but we still find that its economics are attractive using mid-range gasoline and battery lifetime assumptions. Finally, the Tesla Roadster is not economically viable when compared to HEVs or CVs in any case as our vehicle miles travelled (VMT) assumption leaves owners paying too much for extra battery capacity to make the economics attractive at current battery prices.

Ultimately, our analysis demonstrates that if manufacturers are able to produce batteries at a cost in the range of $500/kWh, the economics of “right-sized” PHEVs and BEVs with battery packs designed to meet average consumer VMT will generally be superior to HEVs and CVs.

Model Description

We model annual PHEV or EV fuel savings relative to HEVs and CVs at various electricity and gasoline prices. We then use battery lifetime assumptions to calculate the discounted value of these savings over a vehicle’s lifetime. Next, we put these savings in terms of dollars per kilowatt-hour of PHEV or EV battery capacity to get breakeven costs. Finally, we add the cost of private charging stations and available Federal and California subsidies to find the net breakeven battery costs that California residential PHEV and BEV purchasers currently face. Breakeven battery cost is defined as the battery price at which the vehicle’s battery capacity exactly pays for itself in expected fuel savings. Those boxes highlighted in green indicate a battery breakeven cost at or above our $500/kWh estimate. Conversely, those boxes highlighted in red indicate a battery breakeven cost below our $500/kWh estimate.
Figure A.1 - Pacific Gas & Electric (PG&E) Time of Use (TOU) EV Rate Structure

Table A.1

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### Table A.4 - 16 kWh 3-Year Battery Lifetime

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### Table A.5 - 16 kWh 5-Year Battery Lifetime

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### Table A.6: Breakeven battery costs for a 16 kWh PHEV (e.g. Chevy Volt) relative to comparable HEVs and CVs for 3, 5, and 10 year expected battery lifetimes. These tables are adapt from Farrell, A.E. et al (2008).
Table A.6 - 16 kWh 10-Year Battery Lifetime

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<th>Gasoline price ($/kWh)</th>
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**PHEV/Chevy Volt Model Assumptions**

1) EV efficiency is 5 miles/kWh based on manufacturer 40 mile/charge claims and usable battery capacity of 8 kWh. We have used 8 kWh to reflect assumptions about battery performance. As the battery deteriorates, additional battery capacity will be engaged to maintain vehicle performance.

2) HEV efficiency is 37.1 miles/gallon, and CV efficiency is 24.1 miles/gallon. Each vehicle travels 11,000 miles/year.

3) Discount rates of 39%, 25%, and 16% to correct for vehicle depreciation and declining vehicle usage over a 3, 5, and 10 year vehicle lifetime, respectively. These discount rates are based on an interest rate of 6%.

4) Accounting for an 80% depth-of-discharge limitation, the HEV battery pack size is 2.2 kWh. The total EV battery pack size is 16 kWh. We take the additional battery cost to represent the entire marginal vehicle cost (which is less defensible for BEVs), we do not include battery replacement or new business models, we treat future fuel prices as constant and certain, and we assume that the purchase of an EV does not change the cost of other household electricity consumption.

5) A Federal tax credit of between $2,500 and $7,500 is available per plug-in vehicle purchased based on the size of the battery. Batteries with capacity of 16 kWh qualify for the full $7500 credit. This tax credit will decrease in dollar amount after 200,000 plug-in vehicles per automaker are sold and the credit expires at the end of 2014.

6) A Federal tax credit of up to 50% of the installation costs, with a cap of up to $2,000 per site is effective for equipment put into service between December 31st 2005 and January 1st, 2011. We assume that this tax credit will be extended.

7) Level 2 residential charging stations cost $2,146. Of this cost, $1,296 is eligible for the federal installation tax credit, leaving a net infrastructure cost to consumers of $850.

8) A California state subsidy of $3,000 for plug-in hybrids and $5,000 for electric vehicles launched on March 15, 2010.
Tables A.6 – A.8: Breakeven battery costs for a 24 kWh EV (e.g. Nissan Leaf) relative to comparable HEVs and CVs for 3, 5, and 10 year expected battery lifetimes. These tables are adapt from Farrell, A.E. et al (2008).^90^  

**Table A.6 - 24 kWh 3-Year Battery Lifetime**

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**Table A.7 - 24 kWh 5-Year Battery Lifetime**

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<tbody>
<tr>
<td>$0.05</td>
<td>HEV</td>
<td>CV</td>
<td>HEV</td>
<td>CV</td>
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<tr>
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<tr>
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<td>$399</td>
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**Table A.8 - 24 kWh 10-Year Battery Lifetime**

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<td>$0.05</td>
<td>HEV</td>
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<td>HEV</td>
<td>CV</td>
</tr>
<tr>
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<td>$502</td>
<td>$657</td>
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<tr>
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<td>$543</td>
<td>$478</td>
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<tr>
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<td>$389</td>
<td>$522</td>
<td>$455</td>
<td>$614</td>
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<td>$0.25</td>
<td>$366</td>
<td>$501</td>
<td>$432</td>
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<td>$0.30</td>
<td>$342</td>
<td>$480</td>
<td>$408</td>
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**BEV/Nissan Leaf Model Assumptions**

1) BEV efficiency is 5.21 miles/kWh based on manufacturer claims of 100 mile/charge range and 19.2 kWh usable battery capacity assumption. We have used 19.2 kWh to reflect 80% depth of discharge limitation.

2) HEV efficiency is 37.1 miles/gallon, and CV efficiency is 24.1 miles/gallon.^91^ Each vehicle travels 11,000 miles a year.^92^

3) Discount rates of 39%, 25%, and 16% to correct for vehicle depreciation and declining vehicle usage over a 3, 5, and 10 year vehicle lifetime respectively. These discount rates are based on an interest rate of 6%.^93^
4) Accounting for an 80% depth-of-discharge limitation, the HEV battery pack size is 2.2 kWh. The total EV battery pack size is 24 kWh. We take the additional battery cost to represent the entire marginal vehicle cost (which is less defensible for BEVs), we do not include battery replacement or new business models, we treat future fuel prices as constant and certain, and we assume that the purchase of an EV does not change the cost of other household electricity consumption.

5) A Federal tax credit of between $2,500 and $7,500 is available per plug-in vehicle purchased based on the size of the battery. Batteries with capacity of 24 kWh qualify for the full $7500 credit. This tax credit will decrease in dollar amount after 200,000 plug-in vehicles per automaker are sold and the credit expires at the end of 2014.

6) A Federal tax credit of up to 50% of the installation costs, with a cap of up to $2,000 per site is effective for equipment put into service between December 31st 2005 and January 1st, 2011. We assume that this tax credit will be extended.

7) Level 2 residential charging stations cost $2,146. Of this cost, $1,296 is eligible for the federal installation tax credit, leaving a net infrastructure cost to consumers of $850.


Table A.9-A.X - Breakeven battery costs for a 53 kWh EV (e.g. Tesla Roadster) relative to comparable HEVs and CVs for 3, 5, and 10 year expected battery lifetimes. These tables are adapt from Farrell, A.E. et al (2008).

<table>
<thead>
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<th>Table A.9 - 53 kWh 3-year Battery Lifetime</th>
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<td>Break-even battery cost ($/kWh) Including Subsidies and Infrastructure Costs</td>
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<td>Gasoline price</td>
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<td>Electricity price ($/kWh)</td>
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<td>$0.05</td>
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<tr>
<td>$0.10</td>
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<td>$0.20</td>
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<table>
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<th>Table A.10 - 53 kWh 5-year Battery Lifetime</th>
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<td>Break-even battery cost ($/kWh) Including Subsidies and Infrastructure Costs</td>
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<td>Gasoline price</td>
</tr>
<tr>
<td>Electricity price ($/kWh)</td>
</tr>
<tr>
<td>$0.05</td>
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<tr>
<td>$0.10</td>
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</tr>
<tr>
<td>$0.20</td>
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<tr>
<td>$0.25</td>
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</table>
### Table A.11 - 53 kWh 10-year Battery Lifetime

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</thead>
<tbody>
<tr>
<td><strong>Gasoline price ($/kWh)</strong></td>
<td><strong>HEV</strong></td>
<td><strong>CV</strong></td>
<td><strong>HEV</strong></td>
<td><strong>CV</strong></td>
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<td>$165</td>
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<td>$179</td>
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<td>$174</td>
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<td>$197</td>
<td>$155</td>
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#### BEV Sport Car/Tesla Roadster Model Assumptions

1) BEV sports car efficiency is 5.57 miles/kWh based on manufacturer 237 mile/charge claims and usable battery capacity of 42.4 kWh. The total EV battery pack size is 53 kWh. We have used 42.4 kWh of actual capacity to reflect an 80% depth-of-discharge limitation.

2) HEV efficiency is 37.1 miles/gallon, and CV efficiency is 24.1 miles/gallon. Each vehicle travels 11,000 miles/yr.

3) Discount rates of 39%, 25%, and 16% to correct for vehicle depreciation and declining vehicle usage over a 3, 5, and 10 year vehicle lifetime, respectively. These discount rates are based on an interest rate of 6%.

4) Accounting for an 80% depth-of-discharge limitation, the HEV battery pack size is 2.2 kWh. We take the additional battery cost to represent the entire marginal vehicle cost (which is less defensible for BEVs), we do not include battery replacement or new business models, we treat future fuel prices as constant and certain, and we assume that the purchase of an EV does not change the cost of other household electricity consumption.

5) A Federal tax credit of between $2,500 and $7,500 is available per plug-in vehicle purchased based on the size of the battery. Batteries with capacity of 53 kWh qualify for the full $7,500 credit. This tax credit will decrease in dollar amount after 200,000 plug-in vehicles per automaker are sold and the credit expires at the end of 2014.

6) A Federal tax credit of up to 50% of the installation costs, with a cap of up to $2,000 per site is effective for equipment put into service between December 31st 2005 and January 1st 2011. We assume that this tax credit will be extended.

7) Level 2 residential charging stations cost $2,146. Of this cost, $1,296 is eligible for the federal installation tax credit, leaving a net infrastructure cost to consumers of $850.

8) A California state subsidy of $3,000 for plug-in hybrids and $5,000 for electric vehicles launched on March 15, 2010.
<table>
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<th>Reference</th>
<th>Battery Application</th>
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<tbody>
<tr>
<td>A123 Systems</td>
<td>Li-Ion Battery</td>
<td>2013</td>
<td>$500/kwh</td>
</tr>
<tr>
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<td></td>
<td>2016</td>
<td>$350/kwh</td>
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<tr>
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<td>2016</td>
<td>$300/kWh, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>only</td>
<td>$1,700</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>$200/kWh, or</td>
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<tr>
<td></td>
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<td></td>
<td>$3,400</td>
</tr>
<tr>
<td>Pesaran et al 2007 (NREL)^4</td>
<td>High energy batteries</td>
<td>2007</td>
<td>$800-1,000/kWh</td>
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<tr>
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<td>$550/kWh, or $1700</td>
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<tr>
<td></td>
<td></td>
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<td>$575/kWh, or</td>
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<td>For PHEV40</td>
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<td>$3,300</td>
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<td></td>
<td></td>
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<td>$2,200</td>
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<td></td>
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<td>$380/kWh, or</td>
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<td></td>
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<td>$7,100</td>
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<td>Ton et al 2008 (Sandia)</td>
<td>Li-ion battery</td>
<td>2008</td>
<td>$1,333/kWh</td>
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<td>CARB 20095</td>
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<td>2018</td>
<td>$780/kWh</td>
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<td>$480-600/kWh</td>
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<td>$450-560/kWh</td>
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<td>For PHEV10</td>
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<td>$260-700/kWh</td>
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<td>2010</td>
<td>$1,650/kWh</td>
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<tr>
<td></td>
<td>For PHEV40</td>
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<td>$1,050/kWh</td>
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<td>2010</td>
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<td>For PHEVs</td>
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<td>2012 (High Volumes)</td>
<td>$400/kwh</td>
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Battery Cost Expectations ($/kWh)^102, 103, 104
X. End Notes

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Renewable & Appropriate Energy Laboratory (RAEL)

RAEL is a unique research, development, project implementation, and community outreach facility based at the University of California, Berkeley in the Energy and Resources Group and the Department of Nuclear Engineering. RAEL focuses on designing, testing, and disseminating renewable and appropriate energy systems. The laboratory's mission is to help these technologies realize their full potential to contribute to environmentally sustainable development in both industrialized and developing nations while also addressing the cultural context and range of potential social impacts of any new technology or resource management system.

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