Errata to the
2010-2011 Alternative and Renewable Fuel and Vehicle Technology Committee Investment Plan
(Posted July 2, 2010)

The attached Battery Electric Drive Section is the only section of the Investment Plan with substantive changes.

Battery Electric Drive

Electric drive (EV) applications include hybrid-electric vehicles (HEV), plug-in hybrid-electric vehicles (PHEV), and battery electric vehicles (BEV) in light-, medium-, and heavy-duty applications.[42] (Plug-in electric vehicles [PEV], as used in this document, include both PHEVs and BEVs, but not HEVs.) In 2008, there were approximately 350,000 light-, medium- and heavy-duty electric drive vehicles registered in California for on-road use. The majority of these EV vehicles were HEVs. Currently, 10 automakers are producing light-duty HEVs, and as many as 110,000 of these vehicles are being added to the market in California each year. Department of Motor Vehicle (DMV) data for 2008 shows less than 15,000 of California's PEV vehicles were BEVs, of which approximately 10,000 were low-speed neighborhood electric vehicles (NEVs), a decrease from the more than 23,000 BEVs registered in 2004. There are less than 500 PHEV conversions in the current PEV vehicle population. Changes in the 2008 ZEV program encourage the production and deployment of PHEVs by adding a new vehicle category for compliance: Enhanced AT PZEVs, to meet up to 70 percent of the "pure" ZEV requirement in the near-term (2012 to 2014) and up to 50 percent in the medium-term (2015 to 2017).

~~ARB estimates up to 25,000 PHEVs per year will be deployed between 2012 and 2014.[43]~~

~~The number of PEVs in California over the next five years is expected to increase substantially, but projections vary significantly as evidenced in Table 4.~~

42 While fuel cell vehicles (FCVs) also use electric drive, they are not addressed in this section. Refer to the Hydrogen section instead.

~~43 *2008 Proposed Amendments to the California Zero-Emission Vehicle Program Regulations,* Staff Report, California Air Resources Board, February 8, 2008.~~

~~Table 4: Projections of PEV Deployments~~

On the forefront of the California BEV rollout, Nissan Motor Company has taken over 5,000 reservations for the Nissan Leaf BEV in California, and will likely see that number at least double by the end of the year.[44] By 2011 Nissan could deliver 5,000 to 10,000 electric drive vehicles to California. Tesla Motors will also continue sales of its Roadster and plans to begin production of its four-door Model S sedan at the former site of the New United Motor Manufacturing Inc. (NUMMI) plant in Fremont, California, in 2012. [45] Tesla has delivered over 1,200 Roadsters to customers worldwide, and plans to produce its Model S with an initial 20,000 vehicle production in 2012. Other original equipment manufacturers (OEMs) are preparing for commercial production and sales in California.[46]

Medium- and heavy-duty trucks, buses, and non-road vehicles can saturate market niches earlier than passenger vehicles at a much lower level of manufacturing (3,000 to 5,000 per year) to achieve cost-competitiveness with diesel vehicles. Hybrid electric designs are being offered for sale in limited volumes. Technology improvements and demonstrations will reduce costs and broaden market availability. Also, GHG emissions can be further reduced by introducing alternative and renewable fuels in hybrid-electric truck hybrid applications, demonstrating advanced hydraulic technology, electrifying on-board vehicle accessories, and demonstrating plug-in electric and battery electric trucks.

Installation of electric charge infrastructure will support the anticipated commercialization of electric drive vehicles. Both private and public charge points, along with potential upstream electrical system infrastructure upgrades, will support the widespread use of PEVs. Utilities are developing charging strategies, procedures and special rates that meet the needs of vehicle recharging and grid reliability. Infrastructure equipment will need to be standardized, on and off the vehicle.

Widespread use of electric drive technology may require:

- Consumer acceptance of commercially available light-duty vehicle models.
- Increased manufacturing scale and continued battery research, to bring down the cost per kilowatt hour (kWh) of electric vehicles' batteries.

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44 Source: Tracy Woodard, Nissan (number of reservations as of June 7, 2010.). The reservations are divided among four regions: San Francisco Bay Area (1,900), Los Angeles (1,800), San Diego (1,000), and Sacramento (250).

45 A total of 1,200 Roadsters were sold in 2009 (Source: Tesla CEO Elon. Musk November 8, 2009).

46 General Motors (GM) will deliver 100 Chevrolet Volt vehicles to utilities in 2010. (Source: GM at Los Angeles Auto Show in December 2009.) Fisker Automotive expects to have sales of up to 115,000 vehicles nationwide by 2015.

- Cost-competitive electric vehicles and electric vehicle components, absent subsidies, and accounting for the lower cost of electricity as a fuel.
- Adequate charging infrastructure including residential, workplace, and public access charging.
- Public familiarity with battery recharging and replacement, and vehicle performance.
- Smart charging capability to allow for better load management, reduced "on-peak" generation, and lower infrastructure costs.

Light-Duty Vehicles

Widespread usage of PEVs is an integral component to achieving California's low-carbon transportation goals. Using California's present electricity grid, the full fuel-cycle emissions of BEVs using today's California electricity grid are 65 percent to 70 percent lower than the emissions of conventional gasoline vehicles.[47] As California shifts to an increasingly renewable electricity generation system, BEVs will account for fewer GHG emissions on a full fuel-cycle basis. Full fuel cycle emissions of PHEVs are estimated to be 50 percent lower than conventional gasoline vehicles, depending on the proportion of miles driven in electric mode, which is a function of installed battery capacity and driver behavior.

The number of PEVs in California over the next five years is expected to increase substantially, but projections vary significantly as evidenced in Table 4.

47 ARB, "Low Carbon Fuel Standard Program," http://www.arb.ca.gov/fuels/lcfs/lcfs.htm.

Table 4: Projections of PEV Deployments

	2013	2015	2020
Morgan Stanley		250,000 PHEVs	
Southern California Edison			576,000 BEVs
Plug in America	47,455 BEVs		
California Electric Transportation Coalition		450,000 BEVs and PHEVs	

Source: ~~California Energy Commission~~Multiple sources

The benefits of high efficiency, reduced GHG and other criteria emissions, attractive vehicle attributes, and fuel diversity are among the primary motivations for pursuing PEV technology. In addition, state policy including the ZEV mandate is driving the timing of industry investments. The ZEV mandate currently applies only to the six largest automakers: Ford, General Motors (GM), Chrysler, Honda, Nissan, and Toyota. Several OEMs are testing PHEV models, and Toyota's goal is to have a Prius PHEV on sale for retail consumers by 2011.[48] In addition, 8 other existing automakers and 15 start-up companies plan to release PEVs during this time frame.

Under the ARRA, Ford received $5.9 billion in loans from the U.S. DOE to help it retool its plants to produce 13 fuel-efficient models, including as many as 10,000 PEVs per year beginning in 2011. Nissan received $1.6 billion in loans to retool its Tennessee plant to make PEVs.[49] In August 2009, Ford, GM, Chrysler, and others received $2.4 billion in federal grants to encourage the development of HEVs and PEVs. The grants include $1.5 billion for battery makers, $500 million for companies developing electric motors and drive components, and $400 million to test a recharging system for electric cars.

A main barrier to penetration of light-duty PEVs is vehicle purchase price, mostly due to high battery cost. Several California battery manufacturers are pursuing advances in battery technology to make them with lower costs, lighter in weight, and with higher energy densities that can provide longer range driving. Among other approaches, nanotechnology is being applied to develop high-energy-density lithium-ion batteries.[50] Charging costs are expected to

48 Jeffrey Ross, "Toyota Releases Details on Toyota Prius PHEV" http://www.autotropolis.com/autotropolis-columns/car-tech/toyota-releases-details-on-toyota-prius-phev.html.

49 The 1.3 million square foot battery manufacturing facility will be capable of producing 200,000 advanced-technology batteries annually. The adjacent vehicle assembly plant, which will produce the Nissan LEAF, will be capable of producing 150,000 cars annually. Source: www.nissanusa.com/leaf-electric-car.

50 The 2009 R&D 100 award given to Envia Systems and Argonne National Laboratory for highest energy and cycle life of all lithium-ion battery systems available in the market for electric vehicles.

be less in comparison to most internal combustion vehicles operating on gasoline. The cost of electricity as a fuel is typically 70 percent to 80 percent below the cost of gasoline per mile traveled.[51] However, battery replacement costs may offset some of these savings.

For consumers unfamiliar with BEV technology, the location of chargers, implications of limited driving range, and battery replacement cost will also be primary areas of concern. Accordingly, consumer education will be essential to familiarizing consumers with PEV technology.

The federal tax rebate of up to $7,500 and the AQIP rebate of up to $5,000 for PEVs will both help to encourage and accelerate the deployment of zero-emission vehicles in California.[52] Single-occupant access to the high-occupancy vehicle (HOV) lanes also provides a desirable incentive for BEVs.

The ARB, through its AQIP, is providing $4.1 million in its 2009-2010 funding plan as purchase incentives for PEVs on a "first-come, first-served" basis. The 2010-2011 funding plan provides up to $5 million for this category. Therefore, the Energy Commission is not proposing to provide incentives in this *2010-2011 Investment Plan*, but will continue to provide for vehicle charging infrastructure as described below.

Medium- and Heavy-Duty Vehicles

There are nearly 1 million medium- and heavy-duty vehicles registered in California on the road and a half-million registered in other states that are operating in California.[53] Hybrid-electric and hydraulic-hybrid technologies on medium- and heavy-duty vehicles can potentially reduce GHG emissions 60 percent on a full fuel-cycle basis compared to conventional diesel vehicles. Hybrid electric trucks use the engine to recharge the batteries, which assists the engine and auxiliary functions. Hydraulic-hybrids use a hydraulic pump and motor to capture regenerative braking and offer a power boost to the engine and auxiliary functions. Refuse trucks, drayage trucks, package delivery vans, utility trucks, transit and school buses, and harbor craft are the most practical applications due to their unique duty cycles. Deeper emissions and petroleum reductions can be achieved by combining PHEV technology with alternative and renewable fuel engines.

Presently, fewer than 600 commercial hybrid trucks are on the road today. However, at least 15 companies are developing hybrid-electric technologies, and at least four companies are

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51 *State Alternative Fuels Plan*, Final Adopted Report, CEC-600-2007-011-CMF, December 2007.

52 Source: http://www.arb.ca.gov/msprog/zevprog/zevprog.htm. A rebate of up to $5,000 is available on the Nissan Leaf and Tesla Roadster, however, rebates are not available to GM Volt customers. In order to qualify for the AQIP rebate, the vehicle must meet the AT-PZEV emissions requirements which requires a 10-year, 150,000-mile battery warranty. While GM has not yet applied for the AT-PZEV status, it plans to apply for the Volt's 2013 model year. The Volt currently has an 8-year or 100,000 mile warranty. http://blogs.edmunds.com/greencaradvisor/2010/07/chevy-volt-wont-get-californias-3000-phev-credit-or-10-year-battery-warranty.html

53 DMV data.

developing hydraulic-hybrid technologies. The primary obstacle facing this industry is the high incremental cost of the trucks. The incremental costs for medium- and heavy-duty HEV trucks in the ARB's Hybrid Truck and Bus Voucher Incentive Program (HVIP) range from $20,000 for trucks 8,500 to 10,000 lbs. to $70,000 for trucks over 38,000 lbs.[54] To facilitate commercial market introduction, next generation plug-in hybrid and battery electric trucks will benefit from continuing proof-of-concept demonstrations.

ARRA funded 2,576 HEVs and 100 BEVs for demonstration in the medium- and heavy-duty vehicle classes nationwide. The funding will evaluate technical feasibility and build customer familiarity through a nationwide demonstration.

The Energy Commission and ARB are coordinating the use of their respective AB 118 funds for the development and deployment of advanced on-road medium- and heavy-duty vehicles. The ARB has allocated $20.4 million for FY 2009-2010 for a voucher program that will provide incentives for the purchase of commercially available medium- and heavy-duty vehicles. The ARB is also providing up to $25 million for this category for FY 2010-2011 in its AQIP Funding Plan.

The Energy Commission's funds will be used to demonstrate technology advancements in medium- and heavy-duty BEV and PHEV vehicles as well as hybrid-electric, hydraulic-hybrid and fuel cell applications. Under the FY 2008-2010 investment plan, program funds will match ARRA funding to provide a demonstration of 123 medium-duty PHEVs, primarily in Central and Southern California. Additionally, the Energy Commission, based on a solicitation from November 2009 (PON-09-004), will fund the following projects for advanced medium- and heavy- duty vehicle development and demonstration.

54 Joe Calavita, Air Resources Board, electronic communication, April 29, 2010. The HVIP will be administered and implemented by a partnership between ARB and CALSTART; updates on the HVIP implementation manual are available at http://www.arb.ca.gov/msprog/aqip/hvip.htm.

Table 5: Medium- and Heavy-Duty Hybrid and Electric Vehicle Projects Funded by the Program

Solicitation	Project Description	Proposed Award
PON-08-010	Medium-duty PHEV commercial fleet demonstration and evaluation	$5,000,000
PON-09-004	Commercial truck platform demonstration, incorporating a natural gas engine and hybrid electric drive	$2,100,000
PON-09-004	Hydraulic-hybrid drivetrain implementation in delivery trucks	$750,000
PON-09-004	Demonstration of a truck with a Class 8 hybrid electric system and intercooled recuperated 350 kW microturbine	$1,458,735
PON-09-004	Battery-electric bus demonstration	$888,595
PON-09-004	Class 4 electric vehicle demonstration	$1,345,552
PON-09-004	Hybridization of utility service vehicles demonstration	$494,678
PON-09-004	Design, develop and deploy a range-extended electric vehicle powertrain for medium-duty truck applications	$1,153,053
Total		**$13,190,613**

Source: California Energy Commission

In addition to these projects, the Energy Commission will fund up to $7 million for an advanced medium- and heavy-duty vehicle Center of Excellence. The center, in close partnership with the Energy Commission, will serve as a central entity to identify strategic opportunities to develop and demonstrate advanced technologies and fuels, as well as plan, and coordinate~~, evaluate, fund, and manage~~ projects in California to accelerate the introduction of a broad array of advanced vehicle technologies and fuels across all sectors of the medium- and heavy-duty market.

Electricity also has the potential to displace diesel fuel and reduce criteria and GHG emissions in a number of non-road markets including forklifts,[55] truck refrigeration and auxiliary power units, port cold ironing, and truck-stop electrification (TSE). Electrifying truck engines and non-road applications offers significant criteria pollutant and GHG emission reduction benefits, as well as fuel savings and other efficiency improvements.[56] However, the high upfront capital costs to purchase and install equipment inhibit the widespread adoption of these technologies.

55 The Energy Commission is using both indoor and outdoor BEV forklifts within this context.

56 California Energy Commission. *2009 Integrated Energy Policy Report.* CEC-100-2009-003-CMF. December 2009. http://www.energy.ca.gov/2009_energypolicy/index.html.

ARRA funding provided more than $22 million for 50 TSE projects outside California, expanding the network of TSE availability for the more than 76,000 long-haul trucks that travel into and throughout California. In 2006, California had seven truck stops that featured TSE infrastructure and services. However, California has more than 300 truck stop sites and 20,000 truck parking spots that are candidates to switch to TSE and use electricity instead of fuel burning auxiliary power units for cabin power. TSE costs about $10,000 per parking stall.

Technology improvements and demonstrations of on-road and non-road medium- and heavy-duty vehicles will reduce manufacturing costs, broaden market availability and significantly reduce GHG emissions. To provide for ongoing demonstrations of on-road and non-road medium- and heavy-duty vehicle technology advancements, the Energy Commission will allocate $14 million in grants and loans in this *2010-2011 Investment Plan*.[57]

Charging Infrastructure

Installation and upgrades of electric charging infrastructure will need to keep up with the expected roll-out of PEVs. California currently has 413 stations with 1,300 public access electric charge points.[58, 59, 60] A charging point consists of a single charge outlet, while a charging site (or station) may offer multiple charging points. While this existing network of public access charge points is important for the legacy fleet of PEVs, some of these stations will need to be upgraded to include Society of Automotive Engineers (SAE) J1772-compliant connectors to charge new PEVs. In addition, a larger, more strategic network of new electric charging stations will be needed to support the number of new PEVs expected to be introduced into the market over the next few years. This will include charging infrastructure for single- and multi-family residences, business and municipal fleets, commuter corridor locations, and charge points for medium-duty and heavy-duty electric trucks and transit buses.

There are three common levels for recharging PEVs: Level 1, Level 2 and Level 3. These levels are based on the output voltage and amperage of the charge, and can be provided through either alternating current (AC) or direct current (DC). The most common of these is Level 1 AC charging (120 volts, 15 or 20 amps), which is equivalent to the power provided by a household outlet. Level 2 AC charging requires 240 volts and up to 80 amps, which is equivalent to the power needed to operate heavy-duty appliances, such as a clothes dryer. In general, DC charging, which requires a converter and a separate connector on the vehicle, is faster than AC charging because it charges the vehicle's battery pack directly.

57 This includes vehicles that utilize the following technologies: battery electric, hydrogen fuel cell, hydrogen internal combustion and other advanced technologies.

58 These are operable charge points, however some may be temporarily down.

59 Alternative Fuels & Advanced Vehicle Data Center, *Electric Fueling Stations in California*, http://www.afdc.energy.gov/afdc/progs/ind_state.php/CA/ELEC.

60 *EV Charger News*, http://www.evchargernews.com.

The Society of Automotive Engineers (SAE), recently adopted J1772 which provides for a standard connector for both Level 1 and 2 AC chargers.[61] SAE has not yet developed charging standards for Level 1 DC charging (200-450 volts, up to 80 amps) or Level 2 DC charging (200-450 volts, up to 200 amps). Similarly, the SAE has not yet established a standard for Level 3 AC charging or DC charging.

Conventionally, "fast charging" or "rapid charging" typically refers to a quick charge that replenishes an average-sized PEV battery within 30 minutes, and, depending on the technology, may fall into a number of the latter categories.[62] The SAE standards committee is working on a DC fast charge connector standard and is expected to be approved in 2010 or 2011.

For a Nissan Leaf with a 100-mile range (24 kWh battery pack), recharging at Level 1 AC is estimated to provide 4 to 5 miles of range per hour of charging. Recharging at Level 2 AC can provide the Nissan Leaf with 12 to 15 miles of range per hour of charging. A high-voltage, high-amperage DC charging system can provide 80 miles of range to a Nissan Leaf within 30 minutes.[63]

~~There are three voltage levels for recharging PEVs: Level 1 is ordinary household current at 120 volts; Level 2, at 240 volts, is used in residences for washers and dryers, although some older homes do not have adequate Level 2 wiring; and Level 3 direct current (DC) charging, at 360 volts, is rarely found in residences, but is necessary for quick charges. For the Nissan Leaf with a 100-mile range (24 kWh battery pack), recharging at Level 1 (110 volts at 15 amperes [amps]) provides only 4 to 5 miles of range per hour of charging.[64] Level 2 (220 volts at 40-60 amps) recharging provides 12 to 15 miles of range per hour of charging. A Level 3 DC charging system (360 volts at 100 amps) recharge provides 80 miles of range with one hour of charging.[65]~~

The average cost for Level 2 residential infrastructure "smart charging" equipment is approximately $4,066[66] depending on a variety of cost drivers.[67] The total installed average cost

61 Society of Automotive Engineers. *SAE Standard on EV Charging Connector Approved.* http://www.sae.org/mags/AEI/7479.

62 Alternative Fuels & Advanced Vehicle Data Center. *Advanced Vehicle Testing Activity: Battery Chargers for Electric Vehicles.* http://www1.eere.energy.gov/vehiclesandfuels/avta/light_duty/fsev/fsev_battery_chargers.html.

63 Presentation to the Energy Commission staff by Nissan, June 3, 2010.

~~64 All Cars Electric. *2011 Nissan Leaf: Batteries*. http://www.allcarselectric.com/blog/1033848_2011-nissan-leaf-batteries~~

~~65 Presentation to the Energy Commission staff by Nissan, June 3, 2010.~~

66 Energy Commission estimate based on budget numbers in EV proposals from PON-08-10 and PON-09-06.

67 Cost drivers include panel upgrades, conduit length, panel size, attached vs. detached garage, indoor vs. outdoor installation, wall vs. pedestal mounted chargers, special work such as coring, boring and

of a residential charger is approximately $5,789, accounting for expenses such as charging equipment, installation labor, permits, materials, freight and taxes. [68] Certain cost drivers such as a new panel upgrade may increase the installation cost by an average of 50 percent.[69] Consumers who purchase residential charging equipment may receive a tax credit of up to $2,000 for charging equipment placed into service through December 31, 2010. The average cost for Level 2 commercial charging equipment is $4,066. The total average installed cost of Level 2 commercial charging infrastructure is about $7,112.[70] A federal tax credit of up to 50 percent of the cost of commercial charging equipment placed in service after January 1, 2009, (not to exceed $50,000) will also be available through the end of 2010. Credits may apply to each location for multiple sites. The primary installation cost drivers are panel upgrades, length of conduit, panel size, whether the location is detached or not, wall versus pedestal charger, extent of special work such as trenching and pouring, and time-of-use meter costs.[71] According to some OEMs an ideal residential consumer rebate would be $500 to $1,000 for installation.[72]

The charging of PEVs will necessarily increase statewide demand for electricity. By 2020, PEVs are expected to increase annual electricity demand on a statewide basis by roughly 4,400 gigawatt-hours (approximately 1.4 percent), and peak demand by roughly 190 megawatts (approximately .3 percent). The Energy Commission's electricity demand forecast accounts for these minor increases.[73] Overall, the introduction of these vehicles will not seriously impact statewide electricity generation or transmission. However, as more PEVs enter the market, grid impacts may become more apparent at the local distribution level. Minimizing these impacts will be an important aspect of promoting PEV deployment.

Residential charging has the significant benefit of encouraging charging during periods of off-peak electrical demand. However, a complete charging network will require access to both residential and non-residential charging. Level 2 public access and commercial sites would provide vehicle owners the opportunity to extend their range by charging while the vehicle is

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trenching, and time-of-use meter. (Clean Fuel Connection, Presentation at Plug-In 2010 Conference 7/28/10)

68 Enid Joffe, Clean Fuel Connections, (Presentation at Plug-In 2010 Conference 7/28/10). Clean Fuel Connection's 2009 survey data indicates an average residential installation cost of $1,723 ($964 for labor, $550 for materials, $155 for permits and $54 for tax on materials).

69 Average cost of an installation requiring a new panel is $2,685 compared to $1,793. (Clean Fuel Connection, Presentation at Plug-In 2010 Conference 7/28/10)

70 Energy Commission estimate based on EV proposal budgets from PON-08-10 and PON-09-06. The average cost for installation for commercial chargers is $3,046.

71 Cal ETC, submitted to docket 09-ALT-1, May 25, 2010.

72 Alex Keros, General Motors, CPUC/CEC/ARB Joint Agency Workshop on Alternative-Fueled Vehicle Rulemaking 3/16/10.

[73] Kavalec, Chris and Tom Gorin, 2009. [*California Energy Demand 2010-2020, Adopted Forecast*]. California Energy Commission. CEC-200-2009-012-CMF

parked at work or commercial lots. Fast~~Level 3~~ charging sites can relieve drivers of range anxiety on longer trips and provide quick charging capability on freeway corridors between major metropolitan areas.

Public access and commercial charging, however, will increase the demand for electricity during peak periods. The addition of "smart" components to the charging equipment will coordinate the vehicle's charging and user preferences with the needs of the power grid. Smart chargers will ensure utilities can measure and control charging and optimize electricity transmission and distribution. Users may receive a lower rate for charging if the utility is allowed to control the timing of the charging to maximize benefits to the grid.[74] Additionally, impacts to the grid can be mitigated by offsetting the increased demand for electricity by improving local energy efficiency and/or installing photovoltaic systems.

The CPUC is required to evaluate and implement policies relating to PEVs and adopt rules by January 1, 2011.[75] On August 20, 2009, the CPUC filed an Order Instituting Rulemaking. The rulemaking will "consider tariffs, infrastructure and policies needed for California investor-owned electric utilities to ready the electricity system in a consistent, near-term manner for the projected statewide market growth of light-duty electric vehicles throughout California."[76] Similarly, electrical utilities have already begun to anticipate the needs and impacts of PEVs on the grid. Each investor-owned electric utility and some municipal electric utilities already offer special time-of-use rates for customers who purchase a PEV. This reduced off-peak rate incentivizes customers to recharge during off-peak hours, when excess generation and transmission capacity (and renewable wind capacity in particular) is available.[77]

Beyond potential electrical grid issues, the permitting, installation, and inspection of residential charging stations need to be seamless. This process will vary for each community and for each installation, but on the whole, it is complex, costly, and protracted. For example, the average residential installation time between ordering and installing charging equipment is over four weeks.[78] Although the actual charging panels may take a few hours to install, the entire process depends on a series of site visits including the utility company, licensed electrician, city permitting office, and city building inspector. It is common for delays to occur between steps, increasing installation time from a few days to several weeks. Other states and cities are adopting strategies to minimize the time needed for permitting. For example, New York City

74 For more information on metering issues, see the CPUC's Alternative Fuel Vehicle Proceeding (R.09-08-009) at: http://www.cpuc.ca.gov/PUC/hottopics/1Energy/090814_ev.htm

75 SB 626 (Kehoe, Chapter 355, Statutes of 2009)

76 CPUC, Order Instituting Rulemaking to Consider Alternative-Fueled Vehicle Tariffs, Infrastructure and Policies to Support California's Greenhouse Gas Emissions Reductions Goals. http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/106042.pdf.

77 E-mail from Matthew Crosby, CPUC, June 15, 2010.

78 Enid Joffe. Clean Fuel Connection, CPUC/CEC/ARB Joint Agency Workshop on Alternative-Fueled Vehicle Rulemaking, March 16, 2010.

does not require inspections under its electrical code, which uses a "permit for minor electrical work" for the installation of electrical circuits for residential charging.[79]

The OEMs are very interested in simplifying and streamlining this process and recommend a national installation process.[80] Local government jurisdictions often lack knowledge about the permitting process for vehicle charging, and many permit and inspection offices face workforce reductions due to declining budgets, thus exasperating the problem of timely permitting.[81] Additionally, potential PEV owners will need assistance in determining the electrical suitability of their residence or commercial structure to accommodate the installation of a charging system. To facilitate the rollout of electric vehicles in the next few years, these complex installation challenges must be addressed.

Another option to accommodate charging needs is the battery switch station (BSS), where a discharged battery pack is replaced with a fully charged battery pack. BSS enables third-party battery ownership, ease of battery replacement for servicing, and use in secondary applications. Since most charging will be done at home, work, and in public spaces, BSS deployment is not required on the same scale as the current gasoline infrastructure. High-mileage fleets such as taxicabs could use BSS within and between cities. BSS deployment, similar to natural gas station deployment, could initially follow major freeway corridors. At this time, however, the Energy Commission does not propose funding for battery swap stations due to a lack of vehicle manufacturer support.

Determining the number of charging sites needed to accommodate even the initial roll out of PEVs requires an understanding of both the number of vehicles expected over the coming years and the appropriate balance between residential charging and public charging requirements. In the case of the PEV market, estimating either these parameters is inherently uncertain and speculative. However, some initial work on these issues is already underway.

Projections of how many PEVs will be on the road even in the near term is limited. Nissan estimates the number of their PEV deployments to be 1,000 in Los Angeles, 1,000 in San Diego, 1,300 in the Bay Area and 250 in Sacramento by 2011. GM expects over 1,000 Chevy Volt extended range PEVs in the Bay Area by the end of 2011. ~~In addition, Toyota, Chrysler, Mitsubishi, Fisker, Ford, and Tesla~~ Other automakers will be entering the market in the following years with PEV models, but no public estimates are available.

Charging infrastructure deployment also needs to consider an "appropriate" number of public and workplace charging stations to encourage public adoption of PEVs and support the

79 Title 27, Chapter 3 Electrical Code of the New York City Electrical Code, Electrical Permit Application ED-16A.

80 Alex Keros, General Motors, CPUC/CEC/ARB Joint Agency Workshop on Alternative-Fueled Vehicle Rulemaking, March 16, 2010.

81 Bob Hayden, City of San Francisco, CPUC/CEC/ARB Joint Agency Workshop on Alternative-Fueled Vehicle Rulemaking, March 16, 2010.

development of a competitive market for public charging services. ~~Until PEVs gain some level of market share, private sector investments in public charging will be quite limited due to the uncertainties of utilization and revenue potential.~~ For example, the CPUC estimates that one home charging and 0.5 public charging capacity is needed for each vehicle. ~~However, with 75 percent to 90 percent of the charging occurring at home, each public charger will average only 30 to 72 minutes of use per day. These charging levels are unlikely to be profitable for private financing.~~[82] Nissan, Ford, GM and Chrysler similarly estimate that there is a need for one home charger and 0.3 public chargers per vehicle. However, these ratios are very speculative and without strong empirical foundation. Recent studies in Germany and Japan suggest that range anxiety may not be as significant an issue for new PEV drivers and that public charging infrastructure may experience only moderate use.[83] More analysis is needed to better understand PEV owner driving and charging patterns as the vehicles enter the market.

Further, until PEVs gain some level of market share, private sector investments in public charging will be quite limited due to the uncertainties of utilization and revenue potential. If 75 percent to 90 percent of the charging occurs at home, each public charger will average only 30 to 72 minutes of use per day. This is unlikely to be profitable for private financing on the basis of revenue from charging only.[84] And yet, ~~I~~if the projections of PEV deployment shown in Table 4 are realized~~, however,~~ the investment needed to keep pace with infrastructure demand will far exceed the Energy Commission's available funds. Consideration will need to be given for a business case for PEV charging infrastructure, especially for public charging.

Significant regional planning efforts for PEV infrastructure have been under way over the past several years in preparation for proposed PEV rollouts. These regions include San Diego, Los Angeles, the San Francisco Bay Area and Sacramento. These efforts have included regional and local government, OEM's, utilities and PEV consortia.

To facilitate the development of PEV infrastructure throughout the state, organizations such as "Ready, Set, Charge!" are beginning to coordinate efforts between PEV regional areas. "Ready, Set, Charge!" is convening representatives of utilities, auto and electric vehicle supply equipment (EVSE), OEM's, regional and local governments, and PEV organizations to develop statewide solutions to PEV infrastructure challenges such as installation process streamlining and consumer awareness.[85] This will link PEV infrastructure development efforts in the

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~~82 CPUC, Preliminary Staff response to PEV charging criteria questions, June 14 2010~~

83 2010 Plug-In Conference, July 27, 2010, San Jose, Presentation by CHAdeMO Association TEPCO. BMW Mini-E Berlin Study, presented July 16, 2010, http://www.energy.ca.gov/2009-ALT-1/documents/2010-07-16_meeting/2010-07-16_CEC_Infrastructure.pdf.

84 CPUC, Preliminary ~~s~~Staff response to PEV charging criteria questions, June 14, 2010

85 "Ready, Set, Charge California!" A Statewide Action Plan to Support Regional EV Readiness, May 11, 2010, Co-Sponsors: Electric Power Research Institute (EPRI), Clean Fuel Connections, EV Communities Alliance, GM.

metropolitan regions of Los Angeles, San Diego, ~~the Central Coast,~~ the Bay Area, and the Sacramento area.

The Energy Commission also funds the PHEV and BEV Research Center at the UC Davis Institute of Transportation Studies. The center will study consumer behavior and grid-connected vehicles, ways to restructure the cost of automotive batteries, and the optimal interaction between plug-in vehicles and smart grid systems.[86] The Center, in conjunction with the Energy Commission and other public and private stakeholders, has formed the PEV Collaborative Council. Its purpose is to bring together California leaders to create a strategic plan for PEV success in California in the near-term and beyond early adopters. The Council will conduct public meetings between July and November 2010 with the goal of preparing a draft strategic plan by December 2010.

Although considerable ~~some~~ challenges and uncertainties remain, charging infrastructure is needed as PEVs are expected to begin market introduction in the 2010 ~~and~~ 2011 timeframe. Based on public announcements by automakers, the Energy Commission expects that 5,000 PEVs could be introduced into the California market in the 2010-2011 timeframe. The Energy Commission has awarded approximately $15.3 million for electric charging infrastructure projects that was allocated in the first investment plan. This funding will allow the upgrade of existing charging sites and installation of electric charging stations in all major metropolitan areas where PEVs are expected to be initially introduced by the automakers. Table 6 provides a summary description of these projects.

86 For more information, refer to the center's website, http://phev.its.ucdavis.edu/.

~~87 For more information, refer to the center's website, http://phev.its.ucdavis.edu/.~~

Table 6: PEV Infrastructure Projects Funded by the Program

Solicitation	Project Description	Proposed Award
PON-08-010	Nissan and Electric Transportation Engineering Corporation will deploy 1,000 BEVs in San Diego and install up to 1,000 Level 2 residential chargers, up to 1,300 Level 2 commercial chargers, and up to 60 Level 3 fast chargers in San Diego and the adjacent transportation corridor.	$8,000,000
PON-08-010	Coulomb Technologies, Clean Fuel Connection, and California Car Initiative will install 1,290 networked PEV charging stations in San Francisco, Sacramento, and Los Angeles. Coulomb's chargers will have smart grid capabilities, as well as Web services to enable drivers to find available stations.	$3,417,000
PON-08-010	The Sacramento Municipal Utility District will demonstrate and test 34 Chevrolet Volt PHEVs in their fleet applications and install Level 3 DC chargers at SMUD's facility. The chargers will be integrated with SMUD's Advanced Metering Infrastructure system to collect data on electrical grid impacts and charging time.	$553,000
PON-08-010	The Sacramento Municipal Utility District will demonstrate and test 20 Chrysler PHEVs in their fleet applications and install Level 3 DC chargers at SMUD's facility. The chargers will be integrated with SMUD's Advanced Metering Infrastructure system to collect data on electrical grid impacts and charging time.	$100,000
PON-09-006	Clipper Creek will update 635 existing chargers statewide to the SAE-J1772 standard and install meters, as directed by the local utility, so that usage can be monitored and eventually coordinated with the local utility.	$1,900,000

PON-09-006	Foothill Transit will build two quick-charge stations for up to 12 electric buses that will have the capacity to recharge a battery from 10 percent to 95 percent in 10 minutes or less. The project will provide information on battery life and performance.	$200,000
PON-09-006	Los Angeles County Metropolitan Transportation Authority will install 15 new chargers and upgrade 5 existing chargers at end-of-the-line parking lots.	$415,185
PON-09-006	City of Reedley will install three charging stations as part of a Central Valley Transportation Center. The center will include a learning center and education center component to train current and future vehicle technicians on the latest technologies.	$180,400
PON-09-006	The Association of Bay Area Governments will install 135 charging stations as part of the Bay Area EV Corridor Project.	$504,415
Total		**$15,270,000**

Source: California Energy Commission

California currently has 1,300 public charge points. In the above projects, the Energy Commission is funding more than 4,000 residential charging installations and public charge points. The deployment of new charging stations funded by the Energy Commission is being done in coordination with regionally based plans and will include advanced smart grid technologies.

~~The Energy Commission also funds the PHEV and BEV Research Center at the UC Davis Institute of Transportation Studies. The center will study consumer behavior and grid-connected vehicles, ways to restructure the cost of automotive batteries, and the optimal interaction between plug-in vehicles and smart grid systems.[87] The Energy Commission also will engage stakeholders in a broader effort to prepare a statewide plan to ensure that charging infrastructure issues are addressed in a consistent manner from region to region and to guide the magnitude and geographic distribution of program funds.~~

Given an estimated initial deployment of 5,000 PHEVs and BEVs, the total cost of residential chargers for each of these vehicles would be about $18.8 million.[88] Assuming a need for 0.3

~~87 For more information, refer to the center's website, http://phev.its.ucdavis.edu/.~~

~~88 After a federal tax credit, the cost of a residential charger (including installation and related costs) is roughly $3,756 ($3,756 x 5,000 =$18,780,000).~~

public chargers per BEV and an estimated deployment of 3,550 BEVs, the total cost for these chargers and installations would be about $5.4 million.[89] The combined costs of residential and commercial chargers would be $24.2 million.

To meet the continued need for EV infrastructure, the Energy Commission proposes $3 million in grants in this investment plan to fund residential charging, public charging, and a range of issues related to electric vehicle community readiness including education, workforce training and staffing of local government entities, and strategic planning for the establishment of electric vehicle infrastructure in California.

The Energy Commission will encourage a phased deployment of public charging infrastructure given the uncertain need for an extensive rollout of public chargers. Although it is important to support early adopters of BEVs, it is equally important to minimize stranded investments and maximize the benefit of public funds. The Energy Commission will be working with its awardees to implement a measured approach to infrastructure deployment plans, and will assess data on BEV public charging as it becomes available.

~~The Energy Commission proposes $3 million in grants and loans in this investment plan to fund home charging, public charging, and a range of issues related to electric vehicle community readiness including education, workforce training and staffing of local government entities, and strategic planning for the establishment of electric vehicle infrastructure in California. Given a ratio of 1 home charger and 0.3 public chargers for each PEV, this amount will be expected to provide the necessary charging support for 1,136 new PEVs.[90] This allocation is very conservative in comparison to anticipated vehicle deployments, and may need to be adjusted in the future.~~

Battery Reuse

Battery reuse occurs when an electric vehicle's battery is removed and repurposed for a second application after its retirement from the vehicle. To accelerate the implementation of PHEVs or PBEVs, and to promote the growth of the battery market, the Energy Commission~~'s Public Interest Energy Research (PIER) Transportation Program Area~~ is identifying and evaluating potential reuse strategies for vehicle traction batteries, known as "Battery Second Use."

89 After a federal tax credit the cost of a public charger (including installation and related costs) is $5,079 (3,550 x $5,079 x .3= $5,409,135).

~~90 These estimates are based on an estimated cost of $5,789 per residential charger and $7,112 per public charger. They also assume a federal tax credit of 50 percent, and Energy Commission coverage of 50 percent of the remaining cost.~~

Several strategies discussed in a recent Energy Commission ~~PIER~~ paper could hasten the early commercialization of electric vehicles in California.[91] They include: battery downsizing, standardization, and leasing, with shortened initial vehicle deployment and repurposing/downcycling into stationary use for grid-support services. These strategies, based on minimizing the battery size and cost by re-defining "battery life," combined with strategies for capturing later-stage battery value in stationary applications, can help to reduce the estimated initial lease prices of new plug-in vehicle batteries. Electric utilities may value repurposed vehicle batteries as storage devices for nighttime power from renewables and delivery devices for peak needs, especially if such devices help to avoid building new power plants. Post-vehicle, stationary "battery-to-grid" (B2G) applications can also provide meter benefits for customers, offer demand-response services, improve utility operation, help defer costly grid upgrades, and support the profitability and penetration of wind power and other carbon-reduction measures.

The Energy Commission~~PIER Transportation~~, working with the UC Davis Plug-In Hybrid and Electric Vehicle Research Center, is advancing battery recycling within the Second Life Applications and Value of "Traction" Lithium Batteries request for proposals (RFP), which will include actual and simulated transactions between a household energy storage appliance (HESA) and the electricity system using real or proposed smart grid protocols. The center recently solicited the RFP to research possible second use applications and requirements for used automotive lithium-ion batteries. Applications that can use transportation batteries in complementary or secondary applications may help to build the market for automotive lithium batteries and extend the usable life and value of the batteries.

Manufacturing

Encouraging manufacturers of PEVs and their components to locate or expand their operations in California has the potential to create several thousand green jobs and substantial benefits to the state's economy. For example, at its peak production before it closed the NUMMI plant in Fremont, California, employed 4,500 high-skilled laborers and up to 35,000 supply chain workers in a joint venture between GM and Toyota. In a recent announcement, Toyota said it will partner with Tesla Motors Inc. to develop and build electric cars at the plant in Fremont. The long-term job growth potential is up to 10,000 jobs between suppliers and factory workers.[92]

Several California manufacturers produce batteries and component parts for automakers, components for the electronics industry, and stationary power storage systems for military and industrial customers. In addition, several start-up vehicle manufacturers have emerged in California and begun developing prototype and early market PEVs. However, difficulties in raising upfront capital can impede these manufacturers from developing and expanding the

91 Williams, Brett D, and Timothy E. Lipman. 2010. *Strategies for Transportation Electric Fuel Implementation in California: Overcoming Battery First-Cost Hurdles*. California Energy Commission, PIER Transportation Program Area. CEC-500-2009-091.

92 "Toyota to Invest $50 million in Tesla Electric Car Plant," *Sacramento Bee*, May 20, 2010.

plants and assembly lines to make advanced PEV components and produce electric and alternative fuel vehicles for commercial sales.[93]

Under the FY 2008-2010 program funding, the Energy Commission will award $19 million for a combination of grants for pre-development stages of manufacturing plants and loans to help finance assembly and production plants that make vehicles, batteries, electric propulsion systems, and other components in California. This solicitation would encourage investment in California-based manufacturing and assembly plants that produce alternative fuel vehicles and components that help the state meet its GHG emissions and petroleum fuel demand reduction targets. The Energy Commission will collaborate with the CAEATFA to establish loan mechanisms and facilitate sales tax exemptions for the purchase of equipment to manufacture ZEVs. The Energy Commission is reviewing proposals to cost-share the development and expansion of manufacturing and assembly plants in California that produce electric vehicles, alternative fuel vehicles, and batteries and component parts for electric vehicles, including other alternative fuel vehicles.[94]

California utilities estimate that California will represent 25 percent of the national purchases of light-, medium-, and heavy-duty PEVs. As a result of the ARRA solicitation process and follow up interviews with stakeholders, the Energy Commission intends to provide manufacturing incentives of $7.5 million in the form of grants and loans. This will ensure that California manufacturers are established to fulfill demand from California customers seeking electric drive vehicles. California will benefit economically from the local production of vehicles and components. This funding will likely result in 20,000 to 30,000 California-manufactured PEVs sold per year within five years. Additionally, by 2014 battery sales will likely reach 100,000 per year within California primarily for medium-duty and heavy-duty auxiliary power units. At these levels it is expected that battery cost will drop by up to 50 percent from current market rates, thereby increasing the competitiveness of PEVs compared to conventional vehicles. Repayments from revolving loans could reduce the need for annual allocations, and within five years, the need for manufacturing incentives could be eliminated, reduced, or based only on loans and loan guarantees. Conversely, if California incentives are not provided in the near term, customer demand will be met by products manufactured primarily outside California.[95]

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93 Although the U.S. DOE awarded nearly $1.7 billion nationwide for vehicle and battery manufacturing incentives, no California firm was selected for federal ARRA economic stimulus funding during 2009. However, the ARRA funds that were awarded nationwide will still have a large impact on the nation's ability to manufacture electric vehicles and components and will in turn impact California's market for electric drive vehicles.

94 As part of its earlier ARRA cost-sharing solicitation, the Energy Commission is providing $1 million toward a project to develop advanced anodes and cathodes that will increase the energy density of lithium-ion batteries.

95 All data in this paragraph was taken from the Energy Commission Electric Drive Workshop, and debriefing meetings with applicants after the ARRA solicitations. The Energy Commission staff hosted all meetings.

Table 7: Battery Electric Drive Funding Summary for FY 2010-2011

Develop and demonstrate advanced on-road and non-road medium- and heavy-duty vehicles	$14 Million
Infrastructure and related activities	$3 Million
Manufacturing facilities and equipment	$7.5 Million
Total	$24.5 Million

Source: California Energy Commission