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BEFORE THE STATE CORPORATION COMMISSION OF THE STATE OF KANSAS

DIRECT TESTIMONY OF

CHARLES A. CAISLEY

ON BEHALF OF KANSAS CITY POWER & LIGHT COMPANY

IN THE MATTER OF THE APPLICATION OF KANSAS CITY POWER & LIGHT COMPANY FOR APPROVAL OF ITS CLEAN CHARGE NETWORK PROJECT AND ELECTRIC VEHICLE CHARGING STATION TARIFF

DOCKET NO. 16-KCPE-160-MIS

Q: Please state your name and business address.

A: My name is Charles A. Caisley. My business address is 1200 Main, Kansas City, Missouri 64105.

Q: By whom and in what capacity are you employed?

A: I am employed by Kansas City Power & Light Company ("KCP&L" or "Company") as Vice President – Marketing and Public Affairs.

Q: On whose behalf are you testifying?

A: I am testifying on behalf of KCP&L.

Q: What are your responsibilities?

A: My responsibilities include the Company's small-scale distributed and renewable generation projects, energy products and services platforms, energy efficiency and demand response portfolio, community and customer strategy and communications, marketing, economic development, governmental affairs and public relations functions.

Q: Please describe your education, experience and employment history.

A: I graduated from the University of Illinois in Urbana-Champaign with a Bachelor's degree in political science. I earned a Juris Doctorate degree from Saint Louis University School of Law and a Master of Business Administration from Washington University in St. Louis. I joined KCP&L in 2007 as Director of Government Affairs. Prior to joining KCP&L, I was employed by the Missouri Energy Development Association (MEDA), the Missouri Industry Association for Missouri investor-owned utilities, as President. Prior to that I was employed as the Chief of Staff to the Speaker of the Missouri House. In both positions, I dealt extensively with utility law and energy policy.

Q: Have you previously testified in a proceeding before the State Corporation Commission of the State of Kansas ("Commission" or "KCC") or before any other utility regulatory agency?

A: I have not previously testified before the KCC; however, I recently testified before the Missouri Public Service Commission.

Q: What is the purpose of your testimony?

A: The purpose of my testimony is to (1) explain KCP&L's plans for its Electric Vehicle (or "EV") Clean Charge Network ("CCN") project, (2) give an overview of the status of similar projects around the country and the expectations for advancement of the industry in the near future, and (3) address certain general policy issues.

Q: What other witnesses are presenting testimony for KCP&L and what areas are they addressing?

A: Mr. Darrin Ives, Vice President – Regulatory Affairs, is presenting testimony on the regulatory aspects and policy issues related to the filing, including cost recovery, tariff language, and why the project is a function of providing regulated electric service to our customers.

Ms. Kristin Riggins, Sustainability Products Manager, presents testimony on the timeline and status of KCP&L's implementation of the CCN project. She also addresses the specifics of KCP&L's vendor contracts supporting the project.

Mr. Dan Bowermaster is the Program Manager, Electric Transportation at the Electric Power Research Institute ("EPRI"), a contractor hired by KCP&L to assist in evaluating the overall benefits of the CCN project. He is presenting testimony on the report prepared by EPRI regarding its study in that regard.

I. KCP&L'S EV CCN PROGRAM.

Q: What is the Clean Charge Network ("CCN")?

A: KCP&L has launched an initiative to install and operate just over 1,000 EV charging stations throughout the Greater Kansas City region and within the KCP&L and KCP&L Greater Missouri Operations Company ("GMO") service territories. Fifteen of these will be Level 3 charging stations and the remainder will be what is known as Level 2 charging stations. The Level 3 stations provide for quicker charging of vehicles. These stations will be located at 300-350 locations with the goal of creating a grid-integrated infrastructure to support the market penetration of EVs. This initiative, in furtherance of the Company's commitment to environmental sustainability, is capable of easily supporting more than 12,000 EVs with little or no waiting and as many as 25,000 EVs with moderate wait times. While the size of the capital investment as well as the overall scope of the project is relatively small, upon completion it will be the largest fully deployed utility-owned EV charging station installation in the United States. Currently, at least three other investor-owned utilities are engaged in EV charging station projects in California. Those projects, once fully deployed, will be five to fifteen times larger than KCP&L's.

The Level 3 charging stations were the first deployed by KCP&L and provide "fast charging", enabling a vehicle to charge from empty to 80% of full charge in about 20 minutes. The remaining sites will provide a 20-25 mile charge for every hour the vehicle charges. The stations will be located throughout the KCP&L and GMO service territories near where people live and work.

Q: How will the network be deployed?

A: Deployment is planned to occur between January 2015 and August 2016. KCP&L is partnering with organizations throughout our service territories who will host the charging station sites. Full deployment of the network is dependent upon sufficient voluntary agreements with host locations to provide property for the charging stations. Through these partnerships and a partnership with Nissan Motor Company, the Clean Charge Network will offer free charging on every station to all drivers through December 2016 or until a Commission-approved tariff covering charging station use is put in place. The host sites' charging station usage will be separately metered and electricity costs for charging station usage will be paid - through the partnership with Nissan for the Level 3 charging stations and by the host or EV driver for the remainder of the charging stations - under standard tariff rates. Additionally, through Company guidelines contained within the tariff and at the discretion of the host, a session fee may be applied. Space for the charging stations will be provided free-of-charge to the Company by the host site.

Q: Please explain how these host contracts work.

A: Company witness Ms. Kristin L Riggins explains the host contracts in more detail in her Direct Testimony; however, the standard host contract is for a term of ten years. The Company will install, own, and maintain the EV charging station infrastructure. Hosts may have Level 2 or Level 3 or both types of stations installed at their location. Those hosts who have Level 3 charging stations, must agree to provide one parking space for a dual port Level 3 charging station and 6-10 parking spots on average for 3-5 dual port Level 2 charging stations. As noted above, the host agrees to pay for the electricity used at the Level 2 charging stations, and Nissan is paying for the electricity used at the Level 3 charging stations through December 2016 or until a Commission-approved tariff covering charging station use is put in place.

Q: Please describe the facilities that KCP&L has constructed in connection with the CCN.

A: KCP&L has constructed the EV supply infrastructure and EV charging stations to deliver electricity to EVs. The facilities installed at each host site vary slightly depending on site requirements. In all cases a dedicated underground service drop is installed to feed the EV supply infrastructure. The EV supply infrastructure typically includes a prefabricated meter/service pedestal (incorporates, meter socket, load panel and breakers), electric meter, EV charging stations, and all required foundations, conduit, wire and connectors. Additionally, some host site locations require the installation of an overhead or underground distribution transformer and some require minor extensions or upgrades to the existing primary or secondary distribution facilities. As part of this project, KCP&L has worked with its Engineering and Standards departments to come up with standard designs and installation guidelines for EV charging stations as well as EV infrastructure. One purpose is to drive the cost of installations down and provide the framework for managing this infrastructure as an extension of the electrical distribution grid. An additional benefit of using standard designs and equipment is the ability to expand installations at installed locations as charging increases and more capacity is needed. Just as KCP&L plans and operates the electrical distribution system, the CCN is designed to operate as an extension of that system and be able to increase capacity quickly if rising demand in an area requires it. Finally, the vast majority of the CCN stations are being deployed on the distribution grid side of the meter at each host location as grid infrastructure.

Currently, every station in KCP&L's service territory that is not part of the CCN is installed on the customer's side of the meter. This presents a multitude of challenges. First, it can impact a customer's demand charge—which serves as a barrier to getting customers to deploy more stations. Second, it often requires a significant amount of additional electrical work to install the stations for the customers. This also serves as a disincentive to deploy the stations. Third, it is nearly impossible to see and evaluate the grid impact of deploying those stations. Deploying the EV charging stations in the same manner and to the same standards as we deploy grid infrastructure will allow KCP&L to maintain them in the same manner and will give billing and program flexibility.

Q: Please describe KCP&L's plan for establishing an EV charging network in Kansas.

A: KCP&L worked with a variety of entities to discuss and develop a unique strategy for establishing the CCN. We met with the Electric Power Research Institute ("EPRI"), the U.S. Department of Energy, Tesla, Nissan, ChargePoint and a number of other EV industry experts. In addition, we spoke with a variety of potential host sites with experience in this area in other parts of the country. Through these interactions, KCP&L learned best-practices for station deployment as well as the pitfalls to avoid.

As part of the deployment plan, KCP&L established some criteria to guide and inform station location and installation. Those criteria were:

1) Stations should be located in places that customers use every day. The goal is to have enough stations deployed in this manner that any customer would be able to access a station somewhere during their daily routine. The top list of targets included places where large populations work, tend to gather, and dwell for at least thirty minutes. For example, prime host locations include large workplaces—a significant opportunity for charging station networks; national brand retail chains such as Target, Whole Foods, Wal-mart and others; local grocery stores; community facilities such as parks, recreational areas and sports complexes; shopping malls and larger retail complexes.

2) Stations should be located in urban, sub-urban and rural areas. The whole point of the network is not to have any area within the KCP&L service territory where you cannot find a place to charge.

3) Stations should be located where public access is available.

4) Level 3 charging stations should be located in high traffic areas and at host companies where the average dwell time is less than thirty minutes or somewhere close off of an interstate.

Using these guidelines, KCP&L will distribute and deploy EV charging stations. Approximately one third of the overall network or around 100 of those locations will be in Kansas. In keeping with the guidelines established by the Company, high potential site locations will target educational institutions, healthcare facilities, hospitality centers, multi-family dwellings, municipal buildings, parks and recreation centers, retail outlets, workplaces and public parking sites. KCP&L will not just target high population areas, a number of sites will be deployed in outlying areas to ensure geographical coverage across our entire service territory.

Q: What are the costs for the CCN project?

A: The total budgeted capital cost for the project is approximately $16.6 million of which, based upon the service territory deployment plan, approximately $5.6 million would represent the budgeted investment in the Company's Kansas jurisdiction as the result of situs based allocators. In addition to these costs, KCP&L anticipates total Company annual operations and maintenance ("O&M") expense of roughly $250,000 which will be allocated to the Company's Kansas jurisdiction based on situs based allocators.

Q: How will billing and collection for the CCN be accomplished?

A: During the first two years of the CCN deployment, billing and collection will be conducted by KCP&L directly back to host companies. Every EV charging station installation has its own service drop, its own transformer and its own utility-grade metering. Total kilowatt-hour usage will be metered and recorded and billed back to the host company from the meter installed as part of the EV charging station installation on its property. To EV drivers, charging at CCN locations will be “free” until December 31, 2016. In reality, payment for electrical usage will be remitted to the Company by the host company for the Level 2 stations or by Nissan for the Level 3 stations.

Beginning on January 1, 2017, KCP&L hopes to have the necessary tariffs in place to provide flexibility around billing and collection allowing for variations depending on how each host company wants to tailor the charging experience for their customers. KCP&L envisions two scenarios for billing and collection. First, host companies that want to continue to pay for their customers to charge at the EV stations located on their property can choose to not charge the EV driver and just remit payment to KCP&L pursuant to monthly usage recorded on the utility meter.

In the second scenario, where host companies would prefer that EV drivers who charge at the stations located on their property pay for the electricity consumed during charging, KCP&L has contracted with a third party vendor called ChargePoint for the billing and collection functions related to energy provided at the EV charging stations. Under this scenario, individuals who charged their vehicles would be billed through the meters in the charging station they used. The charging station would be able to tell them the rate they were going to be charged as well as whether or not and when a session fee would be charged for charging at that station. The payment will be collected by ChargePoint, pursuant to an agreement between ChargePoint and the charging customer, and remitted to the utility. KCP&L will be able to compare usage recorded and paid for by all of the stations at an installation cumulatively, to the monthly usage recorded by the utility meter at the installation. KCP&L believes that each location needs to have flexibility, within guidelines established by tariff, to set up its own customer experience. The tariff proposed by KCP&L is discussed more fully in the Direct Testimony of Company witness Mr. Darrin R. Ives.

Q: Why does KCP&L believe there is a need for an EV charging station network in Kansas?

A: First, our customer research, coupled with a myriad of national studies conducted on the subject of EV's, shows significant customer interest in electric vehicles. In addition, in the first 36 months that EV's were commercially available, their sales outpaced the first 36 months of hybrid vehicle sales when the Toyota Prius was introduced nearly fifteen years ago. Finally, surface transportation is the last major sector of the economy that is not electrified. These facts, coupled with information that shows major auto manufacturers are committed to expanding their EV platforms, means that EV's are here to stay. It is just a matter of time before state policies will have to deal with a myriad of issues resulting from EV adoption.

The number of EVs in the U.S. is growing each year at a faster and faster pace and it is expected this trend will continue. The environmental benefits of EVs, the support for the industry by elected officials and policy makers, coupled with the decreasing costs of a growing number of EVs and plug-in hybrid electric vehicles (PHEVs) on the market as well as the economic savings to EV owners, all support a thriving industry over the next decade. However, the industry can only advance if there are adequate charging stations throughout the country, similar to what we now have for gasoline-powered vehicles. The lack of EV charging station infrastructure presents a barrier to market penetration at scale in the industry and the lack of a standardized financial transaction infrastructure also inhibits the industry's growth. KCP&L can help alleviate those barriers in its service territory.

The Kansas City region is the second largest automobile manufacturing center in the U.S., outside of Detroit. This makes KCP&L's service territory the perfect place to support the future of the industry and the more than 35,000 jobs associated with it. In addition, by invigorating EV adoption, there are a variety of customer benefits, both to EV drivers and non-EV drivers, that KCP&L will help accelerate in this region. Third, by deploying the CCN, KCP&L will get hard data on adoption, standards, customer experience and grid impacts. All of which can be used to inform state law and regulatory policy in Kansas, proactively rather than waiting until EV adoption increases and utilities and regulators have to react. Kansas is located in the middle of the country and is an important piece of the EV charging network nationwide that needs to be developed.

Specifically, the Clean Charge Network will help eliminate 'range anxiety' in the region, which is the number one roadblock to higher EV adoption. As more drivers adopt EVs, not only will overall transportation vehicle emissions be reduced but the cost of operating and maintaining the electrical grid will be spread over increased electricity usage.

Q: Why is it important that KCP&L be involved in this effort?

A: Utility companies are uniquely positioned to usher in this advancement because we can deploy an integrated EV infrastructure with standardized communication and billing platform across a defined territory, plan and optimize use of the grid to serve our customers where charging stations are needed, and use the stations as a platform that allows for further product and service solutions including demand-side management

("DSM") and dynamic pricing programs. In addition, this is a service our customers are requesting. KCP&L has an obligation to serve consumers of electricity in our service territory. Nowhere in Kansas statutes or in KCC rules does it restrict this obligation to stationary customers. In KCP&L's view, its customer pool includes mobile customers when they are located in our certificated service territory as well as our traditional stationary customers. We see the EV charging stations as part of our regulated local distribution network needed to provide efficient and sufficient electric service to EV operators in our territory.

Finally, KCP&L believes having the incumbent utility involved as a catalyst for EV infrastructure yields multiple benefits, including:

1) The development of standards for both design and installation so that charging infrastructure is as robust, reliable and cost-effective as other electrical infrastructure.
2) Using charging data to help develop this new infrastructure in a way that both meets customer demand as well as minimizes impact to the system.
3) Allows for customer demand response, time-of-use pricing and eventually battery storage to more efficiently manage the grid.
4) Driving cost out of the EV market for all parties interested in installing charging stations by increasing the EV market and driving costs lower.
5) By making sure that enough charging infrastructure is deployed to reduce or eliminate range anxiety.

Q: Can non-utility companies provide this service as well as KCP&L?

A: A private company may install charging stations, but there are legal restrictions on the resale of electric service to retail customers in Kansas. Concurrent with the filing of this testimony and our Application, KCP&L has filed a brief addressing those threshold legal issues and I will defer to that brief for a more in-depth analysis of those issues.

Second, given the nascent stage of EV adoption and the natural relationship between the level of EV adoption and the deployment of EV charging stations, it is unlikely that broad deployment of EV charging stations will occur unless it is accomplished as a part of the utility's regulated business. In my opinion, the California experience bears this out.

Currently, there is no business model under which non-utilities can install, operate and make a profit by deploying charging stations in a regulated state. If a non-utility company installs a charging station in the State of Kansas, it is prohibited from reselling the incumbent utility's electricity. A non-utility company might take the position that it could charge for the parking spot and bundle the electricity consumed into the price. However, this either proves too complicated for consumers to understand or too costly in comparison to the price of gasoline. In addition, it raises a host of potential regulatory issues. While these are covered in more depth in the legal brief on this issue, it should be noted that it would be next to impossible to lift the restriction on the reselling of electricity in one application without creating a slippery slope that would certainly threaten to undermine the entire regulatory system. Currently, in KCP&L's service territory, the only time EV charging is purchased and deployed is when a company or government entity installs charging facilities for non-financial reasons like customer service or environmental sustainability.

In fact, KCP&L considered a myriad of non-regulated business models to deploy EV charging stations prior to designing and deploying the CCN. All led to the same conclusion: there is no viable non-regulated business model for EV charging. In order to recover the investment in EV charging infrastructure a non-utility would either have to resell electricity at a much higher margin or charge more in parking fees than customers would be willing to pay. The only viable option is a utility infrastructure solution.

Yet, by deploying EV charging stations as utility infrastructure, all customers see significant benefits, as detailed later. And, the CCN will help drive down the cost of EV charging infrastructure all while serving as a catalyst to build demand for it

Q: Explain the benefit of implementing the CCN with 1,000 EV charging stations rather than a smaller pilot plan that could be used to evaluate the need for an expanded network.

A: Our project is large enough to be impactful, but is moderately sized from a capital expenditure perspective. We want to deploy enough charging stations to reduce or eliminate "range anxiety" which is the primary barrier to customers purchasing electric vehicles. It also is an extension of KCP&L's commitment to environmental sustainability. To have a meaningful impact on "range anxiety" EV charging stations need to be relatively numerous and situated across the entire service territory. Although I believe we have struck a reasonable balance between the desire to have numerous charging stations available and the level of associated cost we're asking other customers to bear, we do not yet have a solid estimate to what extent this will accelerate EV adoption in our service territory. Data shows that from January 2015, the beginning of the CCN implementation, to January 2016, we have seen the following increases: Number of charging sessions increased from 513 to 3,337 – a 550% increase; kWh usage from charging stations increased from 4,029 to 20,335 – a 405% increase; Number of unique EV drivers increased from 88 to 548 – a 523% increase. Once we are closer to fully deployed and have 18 months to evaluate the CCN's impact, we will develop a more sophisticated model to estimate EV adoption and the impact of the CCN.

Along with KCP&L's environmental upgrades at several local power plants, renewable energy portfolio and energy efficiency programs, and KCP&L's recent announcement regarding cessation of burning coal at certain KCP&L and GMO generating units between 2016 and 2021, the KCP&L Clean Charge Network will reduce carbon emissions and help the Kansas City region attain Environmental Protection Agency ("EPA") regional ozone standards which is beneficial to the entire Kansas City region.

Q: What is the impact of the charging stations on KCP&L's distribution system?

A: This is a question that must be answered within the context of understanding the current state of the electric utility industry and how utilities currently approach operating the distribution system and what it is likely to look like in the near future.

We are at a critical point in the history of the electrical distribution system. For more than a century, utilities have seen consistently growing demand as nearly every major sector of the economy electrified. To address this growth, our solution as an industry has been simple – build more central generation and distribution to serve an increasingly diverse load. We have built to supply an ever increasing peak demand and to create reserves and redundancy to improve reliability. We build to meet a peak demand number, plus twelve percent reserves, that may only occur once in 20 years.

The unintended consequence of always building to accommodate peak demand is low system utilization. In fact, across the US, total system utilization averages 43 percent.

This provides for great reliability, but our assets are underutilized in comparison to most other industries.

With flat, or even declining overall demand, the shutdown of aging fossil-fired resources and increased environmental pressures, we are now faced with the same optimization, automation, and "lean" redesigns that most other industries have already been through. In addition, while load growth has been level or declining since 2008, the distribution grid is still faced with major constraints – whether it's from pockets of load growth on certain feeders, the addition of distributed generation, or simply due to age.

It is clear we cannot replace this infrastructure holistically. Cost pressures, third parties with alternative solutions like distributed renewable energy and automated energy efficiency devices and programs, environmental concerns and regulations as well as shifting customer expectations all point to an evolution in the way we approach maintaining and operating the electrical distribution grid. Optimizing our current and future investments with a focus on these new realities is crucial, as we, utilities and regulators will be responsible for managing a much more complex and distributed grid than ever before.

Just like energy efficiency and distributed renewable generation, KCP&L believes that EVs and EV charging is going to play a significant role in the distribution system's future. This presents a choice, to let that happen and react, or to proactively gain practical experience and information to incorporate this and things like it more effectively and efficiently.

Because KCP&L designed and is deploying the CCN unlike other parties, we designed it to minimize impact and cost to the distribution grid. In addition, we will take the information gleaned from its deployment to maximize value to the grid and to minimize future cost. The CCN is a smart system. This means that KCP&L can set it to reduce or eliminate charging in a peak demand situation. This can be done to the entire network or just to a feeder that is at a critical load level. Since it is a network, the CCN will eventually have time-of-use and demand response programs available system wide to minimize demand during peak load time periods. All of this helps minimize cost and improve reliability for the distribution grid. In addition, the CCN is set up so that we can pilot vehicle-to-grid discharge later in the project. This will provide information on the viability of EVs as distributed and cost-effective storage on the electrical grid.

As part of the CCN, we are defining standards and guidelines for EV charging station installation that will help ensure that future stations are not disruptive to the distribution system. Finally, with more than 1,000 stations deployed in our service territory, KCP&L will have the most robust set of charging data in the U.S. This will help KCP&L ensure that future deployment, whether as part of an expanded CCN or from third parties, is done in a manner that does not jeopardize reliability, minimizes cost and supports accessibility for all customers in our service territory.

Without the experience and real-world data derived from the CCN, EV charging stations present an unknown and potential threat to the distribution system. The CCN will help KCP&L turn that potential threat into an opportunity to improve the long-term cost and reliability of the electrical grid.

II. PROJECTS IN THE UNITED STATES AND FUTURE OF THE INDUSTRY.

Q: Can you provide some education about the status of CCN projects in other parts of the United States?

A: There are several states where regulators have allowed, or are considering allowing, utilities to install, own, operate and maintain EV charging stations or have passed legislation that allows for utilities to include EV charging station costs in rate base. In California, the California's Public Utilities Commission ("CPUC") Decision 14-12-079 rescinded the blanket prohibition against electric utility ownership of plug-in EV charging infrastructure adopted in Decision 11-07-029, stating [Decision 14-12-079] shall no longer be in effect, and shall be replaced by a case-specific approach. Subsequent to this order Southern California Edison ("SCE"), San Diego Gas & Electric ("SDG&E") and Pacific Gas & Electric ("PG&E") each filed applications (A.14-10-014, A.14-04-014 and A.15-02-009, respectively) with the CPUC for EV charging infrastructure deployment programs. While the program specifics of each application vary, each includes utility ownership of some portion of the EV charging infrastructure with the costs socialized across all customer rate classes.

In Decision 16-01-023, the CPUC approved a SCE 'Charge Ready Program' pilot with 1,500 EV charging stations. Under this pilot SCE will own, rate base and socialize the EV charging infrastructure. SCE will pay and expense EV charging station rebates that the host will own and operate. The host is the SCE customer of record and EV charge rates will be set by the host.

In the more recent Decision 16-01-045, the CPUC approved a SDG&E vehicle-grid integration ("VGI") Pilot Program consisting of 3,500 EV charging stations installed specifically at workplace and multi-dwelling unit host locations. SDG&E will own the EV charging infrastructure including the charging stations. Under the program, SDG&E will bill the SDG&E customer EV driver or host on a real-time pricing ("RTP") EV rate through their customer information system ("CIS"). Charging station usage by EV drivers that are not SDG&E customers will be billed to the host under the EV rate.

The proceeding for the PG&E application is ongoing. In the application, PG&E proposes to own the EV charging infrastructure including the charge stations. PG&E also proposes to contract with third parties to operate their charge station network. The third parties become the PG&E customer of record and set the EV charge rates.

In Indiana, Proceeding 44478 granted approval from the Indiana Utility Regulatory Commission ("IURC") to Indianapolis Power & Light Company for rate recovery related to distribution extensions and service lines to Blue Indy owned EV charging stations. They did not allow recovery of installation costs for Blue Indy owned charging locations and equipment. It should be noted however that the Blue Indy program was dramatically different from any of the other charging station projects mentioned in my testimony. Specifically, the Blue Indy program was also an electric vehicle ride-share program. The IURC denied recovery for the charging stations based predominantly on the fact that it did not like the ride-share program it effectuated. However, the CCN is not a ride-share program, it is open to the public and it is designed to leverage private capital to purchase electric vehicles. As previously noted, even the Blue Indy decision by the IURC allowed for recovery of electrical distribution grid costs.

In Washington, SHB 1571 designates that the Washington Utilities and Transportation Commission shall not regulate charging facilities provided by entities not regulated as utilities while at the same time indicating that utilities may offer EV charging as a regulated service. Additionally, in 2015, SHB 1853 provided clear policy directive and financial incentive to utilities for EV infrastructure build-out. This included the allowance of utilities to include EV charging station infrastructure in rate base when provided as a regulated service and established an incentive rate of return for EV charging station infrastructure at 2% above the utilities allowable return on equity ("ROE") on other investments.

Oregon's Public Utilities Commission opened up Investigative Docket UM1461 that led to addressing non-utility ownership of EV supply equipment and utility ownership of EV supply equipment with and without rate recovery. This led to Order 12-013 that allowed non-utility resale of electricity as a motor fuel; allowed utility ownership of EV charging station as a non-regulated, non-rate based venture; and permits utility operation as a regulated service. As a regulated service, rate base recovery is allowed, a separate EV rate class must be established and other need and benefit analysis is required.

The Arizona Public Service Company applied for approval of a proposed EV readiness demonstration project in proceeding E-01345A-10-0123. This was approved and allowed for approximately 50 EV charging stations and a public sale rate that included an infrastructure charge to cover costs. The approval also allowed for the demonstration infrastructure costs to be recovered through normal rate making in the event the pilot was discontinued.

Most recently, in pending Case #2015-00355 with the Kentucky Public Service Commission, Kentucky Utilities Company and Louisville Gas and Electric Company made application to install, own, operate and maintain EV charging stations. The application requested rates be established for EV charging stations provided by the utility to host-managed site locations. The station site host will have the option of assessing a fee to station users. The application also asks that a rate be adopted for EV charging services provided directly to EV drivers at utility-managed locations. As proposed, the full cost of EV charging stations, including maintenance, installation, and energy usage, will be borne by those who request the stations or who use the charging service and will be recovered through the proposed rate schedules.

Q: What does KCP&L see as the future of EVs?

A: Given the environmental benefits, I believe EV adoption will increase over time provided that a solution for "range anxiety" is developed. If that occurs, economies of scope and scale not previously present will emerge in the manufacture, distribution and sale of electric vehicles which will tend to reduce the price of electric vehicles and increase their functionality (*i.e.*, battery life). In just a few short years, we have seen the second generation of EVs nearly double their battery life and range. In addition, there are currently 18 major manufacturer models of EVs and PHEVs. By the end of 2017 that number is expected to nearly triple. We believe the future for EVs is very bright and that they will play an increasingly significant role in electricity consumption over the next ten years. Even with the current record low cost of oil, EVs are more cost-effective to drive and maintain than cars that run on gasoline.

III. GENERAL POLICY ISSUES

Q: What does KCP&L see as the prevailing policy in Kansas regarding electric vehicles and EV charging stations?

A: Candidly, I am not aware of a specific policy in Kansas regarding electric vehicles and EV charging stations; however, Governor Brownback commented on KCP&L's Clean Charge Network as an example of "the strong partnership to improve our communities and benefit our citizens." He also congratulated "KCP&L and their community partners on this effort that will help make our region more attractive to businesses."

Q: Do utility-provided EV charging stations such as the KCP&L's CCN serve the public interest?

A: Yes. The public interest is served in at least five significant ways through utility deployment of EV charging stations such as the CCN, including:

1. Beneficial Electrification: EVs increase electricity sales during off-peak times. Increased electricity sales help spread the costs of maintaining the grid over more kilowatt-hours, helping keep rates competitive for all customers. Off-peak usage also reduces the need for additional generation and grid upgrades to keep up with demand.
2. Environmental Benefits: EVs will reduce ozone-reducing pollutants and carbon dioxide from tailpipe emissions thereby providing environmental benefits. With KCP&L's fleet mix, EVs are equivalent to a 36 MPG conventional vehicle. The average fuel economy of new gas vehicles is 25.4 MPG.
3. Economic Benefits: A forward-thinking community attracts businesses and talent, especially in competitive categories. EV owners spending less on fuel and

maintenance spend more money on other products, and often do so locally. In addition, there is potential growth in the auto, EV, battery and charging industries within the Kansas City region. As a result there is direct and indirect job creation from charging station deployment, EV sales and servicing.

4. <u>Customer Programs</u>: The KCP&L Clean Charge Network provides vital data that helps us improve customer programs enabling new customer programs for DSM, time-of-use ("TOU") incentives and vehicle-to-grid battery storage/discharge.
5. <u>Cost and Installation Efficiency</u>: The Clean Charge Network is electrical infrastructure. Central design and smooth processes mean consistency, efficiency and easier expansion. Doing the work in a large deployment reduces equipment and installation costs. Charging station deployment can be factored into grid planning, reducing the cost of maintaining the grid.

Further benefit analysis has been conducted by the Electric Power Research Institute ("EPRI") and is presented in the Direct Testimony of Mr. Dan Bowermaster on behalf of KCP&L.

Q: What information did KCP&L rely on in determining that the CCN is in the public interest?

A: In addition to meetings with personnel at EPRI and participation on EV and EV infrastructure working groups and task forces through EPRI and the Edison Electric Institute ("EEI")**,** KCP&L reviewed and relied upon a number of EV-related reports and studies, including:

- California Transportation Electrification Assessment, Phase 1, Updated September 2014 (attached hereto as Schedule CAC-1);

- California Transportation Electrification Assessment, Phase 2, dated October 23, 2014 (attached hereto as Schedule CAC-2);
- Plug-in Electric Vehicle Deployment in California: An Economic Jobs Assessment (attached hereto as Schedule CAC-3);
- Economic Analysis, California Low Carbon Fuel Standard (attached hereto as Schedule CAC-4); and
- Introduction to ChargePoint, dated October 16, 2014 (attached hereto as Schedule CAC-5).

We also reviewed and relied upon KCP&L's own data from EV charging stations already deployed in KCP&L's service territory through federal grants and KCP&L's SmartGrid project. We also conducted extensive conversations and interviews with automobile manufacturers, our own large customers, national retailers, policymakers in both Missouri and Kansas, the Natural Resources Defense Council ("NRDC") as well as several EV and EV charging station industry associations.

Q: Will the status of KCP&L as a regulated public utility give your company any advantages over potential competitors?

A: In response to this question, I would reference my earlier answer regarding non-utilities' participation in this market in Kansas and Missouri. As a result of the economic and regulatory factors I referenced in my earlier answer, there are currently no companies that offer EV charging as a service. Currently, the only EV charging stations that exist for public charging have either been deployed by KCP&L, as part of a previous project in partnership with the Department of Energy (DOE), have been installed by government entities or have been installed by third party retailers as a service to their customers.

There is no business model or marketplace with which the CCN competes or could have an unfair advantage. Conversely, by serving as a catalyst for increased EV adoption the CCN is helping to develop a marketplace that ultimately other EV charging companies may choose to enter in the future.

Q: What are the benefits of the CCN to KCP&L's Kansas customers?

A: Beneficial Electrification: EVs increase electricity sales during off-peak times. Increased electricity sales help spread the costs of maintaining the grid over more kilowatt-hours, helping keep rates competitive for all customers. Off-peak usage also reduces the need for additional generation and grid upgrades to keep up with demand.

Environmental Benefits: EVs will reduce ozone-reducing pollutants and carbon dioxide from tailpipe emissions thereby providing environmental benefits. With KCP&L's fleet mix, EVs are equivalent to a 36 MPG conventional vehicle. The average fuel economy of new gas vehicles is 25.4 MPG.

Economic Benefits: A forward-thinking community attracts businesses and talent, especially in competitive categories. EV owners spending less on fuel and maintenance spend more money on other products, and often do so locally. In addition, there is potential growth in the auto, EV, battery and charging industries within the Kansas City region. As a result there is direct and indirect job creation from charging station deployment, EV sales and servicing.

Customer Programs: The KCP&L Clean Charge Network provides vital data that helps us improve customer programs enabling new customer programs for DSM, time-of-use ("TOU") incentives and vehicle-to-grid battery storage/discharge.

<u>Cost and Installation Efficiency</u>: The Clean Charge Network is electrical infrastructure. Central design and smooth processes mean consistency, efficiency and easier expansion. Doing the work in a large deployment reduces equipment and installation costs. Charging station deployment can be factored into grid planning, reducing the cost of maintaining the grid.

Further benefit analysis has been conducted by the Electric Power Research Institute ("EPRI") and is presented in the Direct Testimony of Mr. Dan Bowermaster on behalf of KCP&L.

Q: What are the benefits of the CCN to the state of Kansas?

A: In my opinion, the five areas of benefit that CCN provides to KCP&L Kansas customers discussed in the immediately preceding question are benefits that will be enjoyed by the state of Kansas as well.

Q: Does this fit into any broader strategy or perspective that KCP&L has regarding the future of the electrical distribution grid and how best to serve customers in the coming years?

A: Yes, it does. This is perhaps the most important aspect of the CCN. There's no question that the electric utility industry is entering a time of redefinition and change. Today is the beginning of a new era in grid modernization and a fundamental shift where customers and technology will push the limits of our historical business and regulatory models.

For more than one hundred years, investor-owned electric utilities that plan, build and run the distribution grid have operated under a straightforward regulated monopoly system. This model is predicated on reliability and cost efficiency. And it has worked well. The pricing model is simple: Investment plus cost of operations divided by customer usage. Regulators, stakeholders, customers, investors and utilities all understand it. The result of this system is one of the most reliable infrastructure systems in world history. Understandably, any system that has worked this well for more than a century should be circumspect about making wholesale changes.

However, we are entering a period of time where customer expectations of utilities and the regulatory system are changing. Now, modern information technology, a highly automated society, environmental concerns and increasingly effective forms of alternative and renewable generation are putting pressure on the traditional utility role and regulatory system. While customers still expect affordable and reliable electricity service, more and more their expectations are evolving and future success will be defined differently.

Over the last eight years, and for the first time in history, demand for electricity has significantly softened, we are seeing increased adoption of distributed generation and customers expect much more than just affordable and reliable electricity. Now customers are looking compensation for generating electricity, they expect much more communication and specialized rates that fit their lifestyle and the way they use electricity. They expect to be able to use data and new programs to reduce their consumption in a cost-effective manner. And they are no longer solitary electricity consumers. Personal electronic devices were the first mobile electricity consumers. Electric vehicles are the next logical step in that evolution. Just like the telephone companies and their regulators of twenty years ago had to adjust to incorporate mobile telephone and data service, to be successful in this new paradigm, our business and regulatory model must transition to meet new customer expectations. KCP&L believes smaller-sized projects that generate real data while meeting evolving customer expectations will produce useful information, available to all stakeholders and will help proactively, rather than reactively address this evolving ecosystem.

KCP&L believes that future success means embracing big data, automation and interactivity – especially on the demand-side, where customer-owned, edge-of-grid resources have made the distribution grid increasingly unpredictable. It also means adopting clean power and energy efficiency practices like never before – not only because policy is dictating it, but because our customers are too.

These changes lead to inevitable questions about who will pay, who will benefit, and, most importantly, how we will continue to ensure reliable and affordable energy during this evolution.

At KCP&L we believe that utilities and their regulators are best positioned to mold the grid of the future in ways that capture the most value and benefit all stakeholders. Unlike new entrants to the electric generation and distribution space, like renewable energy and technology companies, utilities do not optimize to one business model, solution or technology. Rather, we optimize in favor of our obligation to serve all customers fairly and reliably. This is an obligation that is supported by our regulators and the regulatory system. As such, we firmly believe that the utility is best suited to drive these changes to ensure the best societal outcomes in partnership with both our regulators and customers.

The CCN is part of our strategy that focuses on testing and proving customer programs via targeted projects and technologies that align with the philosophy of empowering customers and optimizing the grid. By embracing a vision of the future that chooses to think of integrating edge-of-grid resources as an opportunity, instead of a threat, and customers as partners, instead of obstacles, we can optimize grid utilization and continue to deliver affordable, clean, and reliable power for the long haul. Our ultimate goal is to proactively address regulatory policy to demonstrate that electric utilities and regulators are best positioned to maximize the total value of an optimized grid – from generation to consumption – and create the platform for implementing the grid of the future.

Q: Does that conclude your testimony?

A: Yes, it does.

BEFORE THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS

In the Matter of the Application of Kansas City)
Power & Light Company For Approval of Its) Docket No.: 16-KCPE-160-MIS
Clean Charge Network Project and Electric)
Vehicle Charging Station Tariff)

AFFIDAVIT OF CHARLES A. CAISLEY

STATE OF MISSOURI)
) ss
COUNTY OF JACKSON)

Charles A. Caisley, being first duly sworn on his oath, states:

1. My name is Charles A. Caisley. I work in Kansas City, Missouri, and I am employed by Kansas City Power & Light Company as Vice President – Marketing and Public Affairs.

2. Attached hereto and made a part hereof for all purposes is my Direct Testimony on behalf of Kansas City Power & Light Company consisting of twenty-nine (29) pages, having been prepared in written form for introduction into evidence in the above-captioned docket.

3. I have knowledge of the matters set forth therein. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded, including any attachments thereto, are true and accurate to the best of my knowledge, information and belief.

CA Caisley
Charles A. Caisley

Subscribed and sworn before me this 16th day of February, 2016.

Nicole A.
Notary Public

My commission expires: Feb. 4, 2019

NICOLE A. WEHRY
Notary Public - Notary Seal
State of Missouri
Commissioned for Jackson County
My Commission Expires: February 04, 2019
Commission Number: 14391200

California Transportation Electrification Assessment

Phase 1: Final Report

August 2014; Updated September 2014

Prepared by
ICF International
620 Folsom St, Suite 200
San Francisco, CA 94107
415.677.7100

Energy+Enviromental Economics
101 Montgomery Street, Suite 1600
San Francisco, CA 94104
415.391.5100

Schedule CAC-1

Disclaimer. This Transportation Electrification Assessment Phase I report, prepared by ICF International with analytical support from E3, updates and expands upon previous work on the grid impacts, costs, and private and societal benefits of increased transportation electrification. Utility work groups made up of a cross section of investor owned utilities and municipally owned utilities provided input and consultation for critical aspects of the study. In addition, feedback and comments were solicited and received from the California Energy Commission and the California Air Resources Board. The report's findings and conclusions, however, are the work of ICF.

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Abbreviations and Acronyms

AEO	Annual Energy Outlook
ARB	California Air Resources Board
BEV	Battery Electric Vehicle
CARB	California Air Resources Board
CEC	California Energy Commission
CH4	Methane
CHE	Cargo Handling Equipment
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
CO2E	Carbon Dioxide Equivalent
CPI	Consumer Price Index
CPUC	California Public Utilities Commission
DER	Distributed Energy Resources
DGE	Diesel Gallon Equivalent
EER	Energy Equivalency Ratio
EIA	United States Energy Information Administration
EPA	US Environmental Protection Agency
EVSE	Electric Vehicle Supply Equipment
FCV	Fuel Cell Vehicle
GGE	Gasoline Gallon Equivalent
GHG	Greenhouse Gas
GSE	Ground Support Equipment
GWh	Gigawatt-hour
HOA	Home Owners Association
HP	Horsepower
HSR	High Speed Rail
IOU	Investor Owned Utility
ISOR	Initial Statement of Reasons
kW	Kilowatt
kWh	Kilowatt-hour
LCA	Lifecycle Analysis
LCFS	Low Carbon Fuel Standard
LEV	Low Emission Vehicle
MDU	Multi-Dwelling Unit
MT	Metric Ton
NMOG	Non-Methane Organic Gases
NOx	Oxides of Nitrogen
O&M	Operational and Maintenance

PEV	Plug-In Electric Vehicles
PHEV	Plug-In Hybrid Electric Vehicles
PHEV10	PHEV with 10 miles equivalent all electric range
PHEV20	PHEV with 20 miles equivalent all electric range
PHEV40	PHEV with 40 miles equivalent all electric range
PM	Particulate Matter
ROG	Reactive Organic Compounds
RTG	Rubber Tire Gantry
TE	Transportation Electrification
TEA	Transportation Electrification Assessment
TOU	Time of Use
TRU	Transport Refrigeration Unit
TSE	Truck Stop Electrification
TTW	Tank-To-Wheel
ULETRU	Ultra Low Emission TRU
VOC	Volatile Organic Compounds
WTT	Well-To-Tank
WTW	Well-To-Wheels
ZEV	Zero Emission Vehicle

Executive Summary

The key messages of this report are:

- Transportation electrification(TE) has the potential to provide significant benefits to society and utility customers
- The plug-in electric vehicle (PEV) segment shows particular promise, but increased utility involvement in the PEV market is necessary to accelerate adoption to achieve the maximum grid benefits of PEVs and the goals of the Governor's Zero Emission Vehicle (ZEV) Action Plan[1]
- The lack of a proven, sustainable third-party business model for owning and operating electric vehicle supply equipment (EVSE) is a significant market barrier to increased PEV adoption

Air quality and climate change concerns continue to be major drivers for transportation electrification in California. Electrified technologies have near-zero or zero tailpipe emissions of criteria pollutants, and electricity has much lower carbon intensity than fossil fuels like gasoline and diesel. Despite the environmental benefits of transportation electrification, the technologies still face many barriers. Most notably, electrified technologies often have higher upfront costs and/or require infrastructure investments, such as electric vehicle supply equipment, high load transformers and interconnections, and new recharging and electrical interconnections. In some cases, the barriers to adoption are attributable to misperceptions (e.g., that electrified technologies do not have the power needed to perform the required tasks).

This Transportation Electrification Assessment (TEA): (1) updates previous CalETC estimates of the market sizing, forecasts and societal benefits for each technology to 2030; (2) includes market sizing, forecasting and societal benefits for additional TE technologies; (3) performs a costing analysis of select TE technologies; (4) quantifies the grid benefits from PEVs; and (5) identifies the market gaps, barriers and potential solutions for PEV adoption to achieve the grid benefits.

The forecasting was done for three different cases: "In Line with Current Adoption", "In Between" and "Aggressive Adoption". The "In Line with Current Adoption" case is based on anticipated market growth, expected incentive programs, and compliance with existing regulations, and the "Aggressive Adoption" case is based on aggressive new incentive programs and/or regulations. The "In Between" case is in between the "In Line with Current Adoption" and "Aggressive Adoption" cases and varies by technology. For some technologies this is simply half-way in between and for other technologies this is a discretely separate case. The only exception is the plug-in vehicle (PEV) market penetrations. To avoid making market penetration the focus of the PEV grid benefit study, ICF and CalETC decided to use three different existing PEV penetration scenarios. The "In Line with Current Adoption", "In Between" and "Aggressive Adoption" cases were based on: California Zero Emission Vehicle (ZEV) compliance with a 50/50 split of PEVs and fuel cell vehicles (FCVs), ZEV "likely" compliance per the California Air Resources

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[1] 2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025, available online at: http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf

Board (CARB), and three times ZEV "likely" compliance, respectively. The detailed forecasting for each case and technology can be found in Appendix A and is summarized in Section 2. The detailed forecasting produced results that show the potential for significant increases in electricity consumption and societal benefits. Table 1 shows the potential electricity consumption and societal benefits in 2030 for the three cases and how these compare to statewide consumption and emission values.

Table 1. Electricity Consumption and Societal Benefits from the Detailed Forecasted Technologies in 2030

Case	Electricity Consumed (Mil kWh/yr)	Petroleum Displacement (Mil GGE/yr)	GHG Emissions Reduced (Mil MT/yr)	PM Emission Reduced (tons/day)	NOx+ROG Emissions Reduced (tons/day)
"In Line with Current Adoption" Case	6,230	558	4.92	0.44	24.8
"In Between" Case	14,300	1,330	11.5	0.73	43.5
"Aggressive Adoption" Case	33,200	3,310	28.9	1.29	71.9
California Statewide Consumption / Emissions	280,561 (Electricity – 2013)[2]	18,800 (Transportation – 2013)[3]	171 (Transportation – 2013)[4]	85 (Transportation – 2012)[5]	2,509 (Transportation – 2012)[6]
Percentage of California Statewide Values	2.2-11.8%	3.0-17.6%	2.9-16.9%	0.5-1.5%	1.0-2.9%

Transportation electrification has small projected criteria pollutant benefits compared to current emissions but significant potential for petroleum displacement and for helping California achieve its GHG emission reduction goals.

Many of these transportation electrification technologies, in addition to achieving significant societal benefits, have operational cost benefits including decreased fuel costs and lower operational and maintenance (O&M) costs. The costing analysis for PEVs, forklifts, truck stop electrification (TSE) and truck refrigeration units (TRUs) employed a benefit-cost ratio, which is the operational benefits (private benefits) and monetized societal benefits divided by the capital costs. A benefit-cost ratio greater than one indicates that the technology has overall lifecycle cost savings for the owner; societal benefit-cost ratio greater than one indicates there are monetized net benefits to society greater than the cost of the technology. The private benefits and cost effectiveness determined in this report are from both a consumer perspective and a TE technology owner and operator perspective.

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[2] http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-CMF.pdf

[3] California 2013 Weekly Fuels Watch Report http://energyalmanac.ca.gov/petroleum/fuels_watch/; all sectors

[4] http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_by_sector_00-12_sum_2014-03-24.pdf

[5] http://www.arb.ca.gov/aqd/almanac/almanac13/pdf/chap213.pdf

[6] California Almanac of Emissions and Air Quality 2013 Edition - Chapter 2 Current Emissions and Air Quality http://www.arb.ca.gov/aqd/almanac/almanac13/pdf/chap213.pdf

Figure 1 below shows that for TE technologies in 2013, TSE has the potential for extremely high total and private benefit-cost ratios but the overall magnitude of the societal benefits (in this case petroleum displacement in 2030) is significantly lower than for PEVs and forklifts, and lower than for TRUs. The dotted line represents a benefit-cost ratio of one.

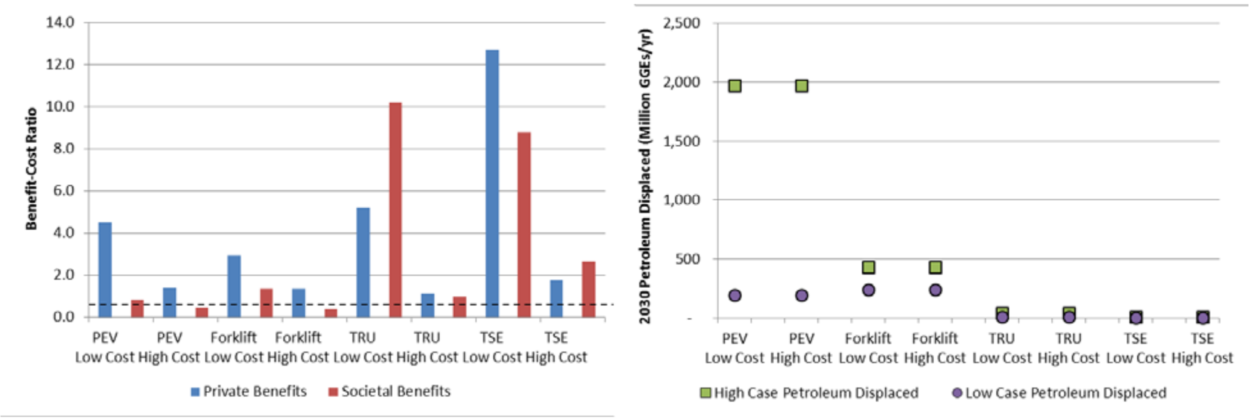

Figure 1. 2013 Benefit-Cost Ratio and 2030 Petroleum Displacement Potential of Select TE Technologies

In addition to the societal benefits from displacing conventional technologies, PEVs also have the potential for significant grid benefits to society and utility ratepayers. If utilities can serve PEV electricity demand with existing infrastructure, this increases the utilization of their existing assets, which could lower electricity rates for all ratepayers. The Phase 2 report will determine the cost effectiveness and value to the utility and ratepayer from PEVs.

To achieve the potential long-term grid benefits of PEVs, it is necessary to increase and maximize the market penetration of PEVs in the near term. ICF, with consultation from a utility stakeholder working group consisting of investor owned utilities and municipally owned utilities, identified the following major market gaps and barriers for PEV market penetration: consumer costs, charging infrastructure deployment, sustainability of third-party ownership of PEV charging equipment, consumer education and outreach, and vehicle features. Table 2 summarizes the major market gaps and barriers and potential solutions.

Table 2. Major Market Gaps and Barriers and Potential Solutions

Market Gaps and Barriers		Potential Solutions
Consumer Costs	• Upfront vehicle costs • Upfront charging infrastructure (EVSE) costs • Vehicle operating costs; need for competitive charging rates for PEVs and shift in traditional billing paradigm	• Increased publicity and continued availability of existing incentives • Creative use of utility LCFS credits or utility developed programs (e.g. battery second life) to reduce the upfront vehicle or EVSE costs • Improved PEV charging rate structures to increase the reduced fuel cost benefits for drivers
Charging Infrastructure	• Lack of information available to single family homeowners seeking to decide between Level 1 and Level 2 charging installation • Little to no progress made in deploying charging at multi-dwelling units; MDU installations are particularly challenging due to technical and logistical issues • Lack of investment in workplace charging infrastructure to date	• Engage MDUs/HOAs, employers and workplace parking providers as a trusted advisor regarding optimal and cost-effective EVSE solutions
Sustainability of Third-Party Ownership of EVSE Networks	• Sustainability of revenue model is frequently challenged and has not been convincingly demonstrated • Demand for non-home charging is unclear due to several factors: vehicle purchasing behavior, consumer willingness to pay for charging, and charging needs/behaviors	• Alternatives to additional public investment in charging infrastructure • Revisiting the CPUC ruling regarding utility investment in charging infrastructure • Improved evaluation of charging infrastructure deployment
Consumer Education and Outreach	• General lack of PEV awareness and knowledge • Total cost of vehicle ownership is poorly understood • Disparate efforts to improve PEV education	• The utility acting as a trusted advisor in the PEV market • Engage with PEV ecosystem partners
Vehicle Features	• Limited vehicle offerings in marketplace	• Modifications to the ZEV program to incentivize the development of PEVs outside of traditional market segments (e.g. subcompacts or midsize sedans)

The primary theme connecting the list of potential solutions is increased utility involvement to help accelerate PEV adoption. This includes increased consumer outreach, education, and incentives for charging infrastructure development, engaging customers by serving as a trusted advisor, and potential involvement in deployment and ownership of EVSE. Such increased utility involvement is an important catalyst for achieving the maximum grid benefits of PEVs. Similar activities could also be applied to other transportation electrification market segments.

1 Introduction

Regional air quality and climate change concerns and the associated federal and state policies continue to be major drivers for transportation electrification (TE) in California. Electrified transportation technologies have near-zero or zero tailpipe emissions and electricity has a much lower carbon intensity than fossil fuels such as gasoline and diesel. Furthermore, the transportation sector's petroleum dependency continues to be a national security concern while exposing consumers and businesses to price volatility. Despite the environmental benefits of transportation electrification, the technologies still face many barriers. Most notably, electrified technologies often have higher upfront costs and/or require significant infrastructure investments including electric vehicle supply equipment (EVSE), high load transformers and new electrical interconnections. Transportation electrification technologies include, but are not limited to on-road vehicles and off-road technologies such as forklifts, truck stop electrification (TSE), transport refrigeration units (TRUs), and cold-ironing at ports.

This Transportation Electrification Assessment (TEA) study (1) updates the market sizing, forecasts and societal benefits (e.g. petroleum displacement, GHG emission reductions and criteria pollutant emission reductions) of transportation electrification (TE) technologies from the previous CalETC Study[7], revising projections out to 2030; (2) includes new market sizing, forecasting and societal benefits for additional TE technologies such as medium and heavy-duty vehicles, high speed rail (HSR), commuter and light rail, and dual mode catenary trucks; (3) performs a costing analysis of select TE technologies; (4) quantifies the grid benefits from PEVs; and (5) identifies the market gaps, barriers and potential solutions for PEV adoption to achieve the grid benefits. Utility work groups made up of a cross section of investor owned utilities (IOUs) and municipally owned utilities (MOUs) were convened to provide input and consultation for critical aspects of the TEA study. In addition, feedback and comments were solicited and received from the California Energy Commission (CEC) and the California Air Resources Board (CARB).

The TEA has been split into two reports: Phase 1 and Phase 2. Phase 1 includes market sizing, forecasts and societal benefits, costing analysis of select TE technologies, a high level discussion of potential grid benefits from PEVs, and identification of market gaps and barriers and potential solutions for PEV adoption. The costing analysis in Phase 1 is from a TE technology consumer perspective and takes into account operational benefits and fuels savings in addition to societal benefits from decreased petroleum consumption, greenhouse gas (GHG), and criteria pollutant emissions. Phase 2 is the detailed modeling and quantification of the grid benefits from PEVs. Phase 2 focuses on the economic and cost effectiveness tests from a utility and overall ratepayer perspective including estimating increases in net revenue for the utilities from PEVs. The Phase 1 report is divided into the following sections:

- Section 1 – Introduction
- Section 2 – Market Sizing and Forecasting
- Section 3 – Costs and Benefits of Select TE Segments

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[7] "Electric Transportation and Goods Movement Technologies in California: Technical Brief," TIAX LLC report for CalETC, revised/updated September 2008.

- Section 4 – Transportation Electrification Grid Benefits
- Section 5 – Market Gaps and Barriers to PEV Market Penetration
- Section 6 – Conclusions

2 Market Sizing and Forecasting

An extensive literature review was undertaken from publicly available documents and documents supplied directly from the utilities, and from the previous CalETC Study[8]. Some of the utilities have performed internal analyses of transportation electrification technologies and those resources and assessments were utilized in the following market sizing. Table 3 below shows the technologies researched in the literature review. Detailed market sizing and forecasting was performed for the technologies in the first and second columns for 2013, 2020 and 2030. Costing analysis (Section 3) was done for the select technologies in the first column. These technologies were selected by ICF with input and agreement from the utility workgroups. For the technologies in the third column, the review did not provide enough additional information for a comprehensive update to the previous assessment. Therefore the market sizing for these technologies was done by utilizing the forecasts from the previous CalETC report (which covered the period from 2010 to 2020) to cover the period from 2013 to 2030. There is not enough information to determine if the original forecasts for these technologies were achieved. However the previous forecasts were done prior to the start of the recession in 2008, likely resulting in delayed implementation of these technologies.

Table 3. Electric Technologies in this Forecast

Detailed Forecasting Update and Cost Analysis	Detailed Forecasting Update	Previous Forecast of 2010 to 2020 used for 2013 to 2030
• Light-Duty PEVs (PHEVs and BEVs) • Forklifts • Truck Stop Electrification (TSE) • Transportation Refrigeration Units(TRUs)	• Shore Power at the Ports • Port Cargo Handling Equipment • Airport Ground Support Equipment (GSE) • High Speed Rail (HSR) • Light (including trolley buses) and Heavy Passenger Rail (e.g. SDMTS[9],BART, LA Metro) • Commuter Rail (Caltrain) • Dual Mode Catenary Trucks on I-710/SR60 • Medium- and Heavy-Duty PEVs	• Lawn and Garden • Sweepers/Scrubbers • Burnishers • Tow Tractors/Industrial Tugs • Personnel/Burden Carriers • Turf Trucks • Golf Carts

The detailed market sizing and forecasting, in addition to the extensive literature review, included contacting industry and government experts (CARB, CEC, and the US Environmental Protection Agency)

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[8] "Electric Transportation and Goods Movement Technologies in California: Technical Brief," TIAX LLC report for CalETC, revised/updated September 2008.

[9] http://www.sandag.org/index.asp?projectid=250&fuseaction=projects.detail: ten mile expansion of San Diego trolley system by 2018

to characterize current and future markets conditions and regulatory drivers for each technology. Utility work groups were convened to review the electrification forecasts prior to calculating electricity consumption and societal benefits and performing the cost analysis (Section 3).

The future populations and electricity consumption (and subsequent societal benefits) were estimated for three cases:

- The "In Line with Current Adoption" case is based on anticipated market growth, expected incentive programs, and compliance with existing regulations. For technology that could potentially not be built, like HSR and I710, build/no-build scenarios were considered.
- The "Aggressive Adoption" case is based on aggressive new incentive programs and/or regulations. "Aggressive Adoption" cases are not the hypothetical maximums, but are tangibly aggressive.
- The "In Between" case will fall somewhere in between the "In Line with Current Adoption" and "Aggressive Adoption" cases and will vary by technology. For some technologies it will simply be half-way between the two other cases, but for some technologies (e.g. large projects like high speed rail) a specific "In Between" case was developed. The "In Between" case in this study omits the technologies in the far right column of Table 3 since an "In Between" or medium case was not included in the previous 2007 study.[10]

The forecasts developed in Phase 1 of the study for PEVs will be used in Phase 2 to determine the grid benefits of light duty PEVs. To avoid making market penetration the focus of the PEV grid benefit study, ICF and CalETC decided to use three different existing PEV penetration scenarios: California Zero Emission Vehicle (ZEV) compliance with a 50/50 split of PEVs and fuel cell vehicles (FCVs) ("In Line with Current Adoption" case), likely California ZEV compliance as defined by CARB ("In Between" case) and three times the likely California ZEV compliance ("Aggressive Adoption" case).

While performing the market sizing and forecasting, conventional fuel consumption and criteria pollutant emission factors were gathered. These factors were used to determine GHG reductions, petroleum displacement and criteria pollutant emission reductions from the forecasted electrified technologies. GHG emissions and California based upstream criteria pollutant emission factors were used from California's State Alternative Fuels Plan (AB1007 analysis)[11], as shown in Table 32. However, the criteria pollutant emission factors for upstream emissions were conservative because they assumed that all of the electricity and refinery emissions occurred with the air basin where the electricity was consumed, when this is not the case in practice. The tables in the follow section detail the resulting market sizing and forecasting and resulting societal benefits (petroleum displacement, GHG emission reductions and criteria pollutant emission reductions). The detailed forecasting for each technology,

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[10] The previous CalETC study contained "Expected" and "Achievable" cases which were converted to low and high cases for this study.

[11] "Full Fuel Cycle Assessment: Well to Tank Energy Inputs, Emissions and Water Impact," Consultant Report for the California Energy Commission, February 2007. http://www.energy.ca.gov/2007publications/CEC-600-2007-002/CEC-600-2007-002-D.PDF

including regulatory assumptions and data sources and assumptions for calculating societal benefits, can be found in Appendix A.

2.1 “In Line with Current Adoption” Case

The “In Line with Current Adoption” case for many technologies maintains the current population of electrified technologies, includes minimal anticipated natural growth, or achieves minimum compliance with current state and/or federal regulations. Electrification was not assumed to be the only avenue for compliance for regulations where multiple compliance options are available (e.g. anti-idling, ocean going vessels at-berth, TRUs). Table 4 shows the California electric technology population forecasts in the “In Line with Current Adoption” case. TSE penetration is shown as the number of electrified spaces, cold-ironing as the number of electrified ship visits, electrified rail as passenger-miles, and fixed guideway as truck-miles.

The anticipated connected load and resulting annual electricity consumption for populations in the table were calculated for each type of equipment. The data sources and assumptions for electricity load and annual consumptions for each type of equipment can be found in Appendix A. Table 5 shows the resulting annual electricity consumption in 2013, 2020 and 2030.

Table 4. "In Line with Current Adoption" Case Electric Technology Populations in Thousands (Total, Not Incremental)

Electric Technology		Population (in 000s, Total, Not Incremental)		
		2013	2020	2030
PEVs (50/50 FCV/PEV)	BEV	13.6	27.4	60.4
	PHEV	29.9	168	544
Forklifts	Class 1 + 2	42.9	57.2	82.0
	Class 3	51.5	66.9	92.6
Truck Stop Electrification (Spaces)		0.262	0.262	0.262
Transport Refrigeration Units		3.63	5.88	9.31
Shore Power (Ship Visits)		1.94	4.17	6.34
Port Cargo Handling Equipment	Yard Tractors	0	0.318	0.503
	Forklifts	0	0.122	0.193
	Cranes	0	0.022	0.068
Airport GSE		1.26	2.23	2.78
High Speed Rail (Passenger-miles)		0	1,880,000	2,640,000
Light and Heavy Passenger Rail (Passenger-miles)	Light	899,000	1,042,000	1,094,000
	Heavy	1,620,000	1,802,000	1,802,000
Commuter Rail (Passenger-miles)		0	0	0
Dual Mode Catenary Trucks on I-710 / SR 60 (Truck Miles)	I-710	0	0	0
	SR-60	0	0	0
Medium-Duty Vehicles		0.5	4.2	96.5
Heavy-Duty Vehicles		0.5	0.08	8.8
	Subtotal	**145** **2,522,000 (pass miles)**	**336** **2,845,000 (pass miles)**	**904** **2,896,000 (pass miles)**
Lawn and Garden		8,000	8,500	9,000
Sweepers/Scrubbers		27-28	28-30	28-31
Burnishers		101-102	104-104	106-107
Tow Tractors/Industrial Tugs		9	10	12
Personnel/Burden Carriers		37	40	44
Turf Tractors		0	3	7
Golf Carts		74-82	80-92	85-103
	Subtotal	**248-258** **8,000 (L&G)**	**262-276** **8,500 (L&G)**	**275-297** **9,000 (L&G)**

Table 5. “In Line with Current Adoption” Case Electric Technology Electricity Consumption in Million kWh

Electric Technology		Electricity Consumption (Annual Million kWh)		
		2013	2020	2030
PEVs	BEV	40.9	81.2	170
	PHEV	70.5	385	1,195
Forklifts	Class 1 + 2	786	1,048	1,501
	Class 3	271	351	486
Truck Stop Electrification		0.897	1.595	1.91
Transport Refrigeration Units		8.92	14.4	22.8
Shore Power		102	218	330
Port Cargo Handling Equipment	Yard Tractors	0 (2010)	20.5	32.5
	Forklifts	0	0.496	0.785
	Cranes	0	2.36	7.49
Airport GSE		5.9	10.4	13.0
High Speed Rail		0	756	1,051
Light and Heavy Passenger Rail	Light	274	314	332
	Heavy	373	400	400
Commuter Rail		0	0	0
Dual Mode Catenary Trucks on I-710 / SR 60	I-710	0	0	0
	SR-60	0	0	0
Medium-Duty Vehicles		0	25	550
Heavy-Duty Vehicles		0	1	183
	Subtotal	**1,930**	**3,630**	**6,280**
	Percentage of CA Electricity Consumption – 250,561 GWh (2013)[12]	**0.7%**	**1.3%**	**2.2%**
Lawn and Garden		113	120	128
Sweepers/Scrubbers		9-30	10-31	10-33
Burnishers		57-79	58-81	60-83
Tow Tractors/Industrial Tugs		53-79	62-92	70-105
Personnel/Burden Carriers		75	82	90
Turf Tractors		0	9	20
Golf Carts		84-92	89-104	95-116
Subtotal		**391-468**	**421-510**	**453-555**

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[12] http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-CMF.pdf

Table 5 shows that even in the “In Line with Current Adoption” case, forklifts have significant electricity consumption. This is due to a relatively mature market with more than 40% market share of electric forklifts without additional incentives or drivers.

Table 6 shows the petroleum and GHG displacement for the “In Line with Current Adoption” case. Petroleum fuel displacement was calculated by determining the annual fuel consumption for the competing conventional fueled equipment combined with the population forecast. Increased use of certain rail systems would displace compressed natural gas (CNG) from transit buses rather than diesel. The quantity of displaced CNG is listed separately from the displaced diesel since CNG is not petroleum based. ICF calculated the GHG emissions displaced by combining petroleum displaced and electricity consumed, using the full fuel cycle GHG emission factors in Table 32.

Table 7 shows the criteria pollutant emission reductions in the “In Line with Current Adoption” case for 2013 2020, and 2030. ICF calculated reductions of criteria pollutant emissions (PM and NOx + ROG/NMOG) based on current regulations for criteria pollutant emissions (e.g. LEV III[13], ULETRU In-Use Performance Standard[14]) and current emission factors for conventional fuels. The California based upstream criteria pollutant emission factors used are shown in Table 32.

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[13] “Low-Emission Vehicle Program - LEV III,” http://www.arb.ca.gov/msprog/levprog/leviii/leviii.htm

[14] http://www.arb.ca.gov/diesel/tru/tru.htm

Table 6. "In Line with Current Adoption" Case Electric Technology Petroleum and GHG Displacement

Electric Technology	Petroleum Displacement (millions of GGE/year)			GHG Displacement (millions of tons/year)		
	2013	2020	2030	2013	2020	2030
BEVs	5.12	9.96	17.2	0.04	0.09	0.15
PHEVs	11.1	57.9	153	0.10	0.55	1.39
Forklifts	94.0	125	180	0.78	1.11	1.60
Truck Stop Electrification	0.15	0.27	0.33	0.001	0.003	0.003
Transport Refrigeration Units	1.04	1.69	2.67	0.009	0.015	0.024
Shore Power	8.78	18.8	28.5	0.064	0.15	0.23
Port Cargo Handling Equipment	0 (2010)	2.13	3.83	0	0.018	0.032
Airport GSE	0.47	0.83	1.04	0.003	0.007	0.008
High Speed Rail	0	32.8	45.9	0	0.15	0.21
Light and Heavy Passenger Rail	46.4 30.8 (CNG)	51.8 35.4 (CNG)	51.9 37.1 (CNG)	0.49	0.61	0.63
Commuter Rail	0	0	0	0	0	0
Dual Mode Catenary Trucks on I-710 / SR 60	0	0	0	0	0	0
Medium-Duty Vehicles	0	2.7	58.2	0	0	0.5
Heavy-Duty Vehicles	0	0.1	15.4	0	0	0.15
Subtotal	**167** **30.8 (CNG)**	**304** **35.4 (CNG)**	**558** **37.1 (CNG)**	**1.49**	**2.73**	**4.92**
Percentage of 2013 CA Consumption / Emissions 18.8 Billion GGE[15]/171 MMT[16]	**0.9%**	**1.6%**	**3.0%**	**0.9%**	**1.6%**	**2.9%**
Lawn and Garden	0	0	0	0	0	0
Sweepers/Scrubbers	2.9-3.0	3.0-3.2	3-3.3	0.04	0.04	0.04
Burnishers	0.7	0.7	0.7	0.01	0.01	0.01
Tow Tractors/Industrial Tugs	0.54	0.72	0.81	0.01	0.01	0.01
Personnel/Burden Carriers	0.5	0.58	0.64	0.01	0.01	0.01
Turf Tractors	0	2.1	4.5	0.00	0.02	0.05
Golf Carts	0.5	0.5	0.6	0.01	0.01	0.01
Subtotal	**5.1-5.2**	**7.5-7.8**	**10-11**	**0.08**	**0.10**	**0.13**

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[15] California 2013 Weekly Fuels Watch Report http://energyalmanac.ca.gov/petroleum/fuels_watch/; all sectors

[16] http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_by_sector_00-12_sum_2014-03-24.pdf

Table 7. “In Line with Current Adoption” Case Electric Technology PM and NOx + ROG/NMOG Displacement in California (Tons/Day)

Electric Technology	PM (Tons/Day)			NOX + ROG/NMOG (Tons/day)		
	2013	2020	2030	2013	2020	2030
BEVs	0.004	0.01	0.01	0.06	0.11	0.11
PHEVs	0.01	0.03	0.03	0.10	0.50	0.80
Forklifts	0.04	0.05	0.08	2.92	3.92	5.62
Truck Stop Electrification	0.000	0.000	0.001	0.03	0.05	0.06
Transport Refrigeration Units	0.002	0.003	0.005	0.33	0.53	0.87
Shore Power	0.075	0.162	0.246	4.39	9.40	14.3
Port Cargo Handling Equipment	0	0.001	0.002	0	0.05	0.09
Airport GSE	0.001	0.001	0.001	0.08	0.10	0.13
High Speed Rail	0	0.011	0.015	0	0.32	0.45
Light and Heavy Passenger Rail	0.020	0.023	0.024	0.47	0.55	0.56
Commuter Rail	0	0	0	0	0	0
Dual Mode Catenary Trucks on I-710 / SR 60	0	0	0	0	0	0
Medium-Duty Vehicles	0.0	0.0	0.0	0.0	0.1	0.6
Heavy-Duty Vehicles	0.0	0.0	0.03	0.0	0.02	1.33
Subtotal	**0.15**	**0.30**	**0.44**	**8.36**	**15.6**	**24.8**
Percentage of 2013 CA Emissions – 85 TPD PM[17]/ 2,509 TPD NOX +ROG[18]	**0.2%**	**0.4%**	**0.5%**	**0.3%**	**0.6%**	**1.0%**
Lawn and Garden	0	0	0	0	0	0
Sweepers/Scrubbers	0.03	0.022	0.02-0.03	0.58-0.61	0.53-0.57	0.55-0.60
Burnishers	0	0	0	0.04	0.04	0.04
Tow Tractors/Industrial Tugs	0	0	0	0.02	0.02	0.02
Personnel/Burden Carriers	0	0	0	0.07	0.08	0.09
Turf Tractors	0	0	0	0	0.12	0.25
Golf Carts	0	0	0	0.05-0.06	0.06-0.07	0.06-0.08
Subtotal	**0.03**	**0.022**	**0.02-0.03**	**0.76-0.80**	**0.85-0.90**	**1.0-1.1**

2.2 “In Between” Case

The “In Between” case for many technologies is halfway in between the “In Line with Current Adoption” and "Aggressive Adoption" cases except for PEVs, TRUs, cold-ironing, HSR, and fixed guideway. For these identified technologies, specific “In Between” cases were developed. These specific cases can be found in Appendix A. Table 8 shows the California electric technology population forecasts in the “In Between” case for 2013, 2020, and 2030 where TSE penetration is shown as the number of electrified spaces, cold-

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[17] http://www.arb.ca.gov/aqd/almanac/almanac13/pdf/chap213.pdf

[18] California Almanac of Emissions and Air Quality 2013 Edition - Chapter 2 Current Emissions and Air Quality http://www.arb.ca.gov/aqd/almanac/almanac13/pdf/chap213.pdf

ironing as the number of electrified ship visits, electrified rail as passenger-miles, and fixed guideway as truck-miles.

Table 8. "In Between" Case California Electric Technology Populations in Thousands (Total, Not Incremental)

Electric Technology		Population (in 000s, Total, Not Incremental)		
		2013	2020	2030
PEVs ZEV Likely Compliance	BEV	24.1	147	734
	PHEV	29.9	249	1,580
Forklifts	Class 1 + 2	42.9	62.9	101
	Class 3	51.5	66.9	92.6
Truck Stop Electrification (Spaces)		0.262	1.52	2.45
Transport Refrigeration Units		3.63	15.9	67.3
Shore Power (Ship Visits)		1.94	5.48	8.53
Port Cargo Handling Equipment	Yard Tractors	0	0.795	2.64
	Forklifts	0	0.304	0.866
	Cranes	0	0.097	0.308
Airport GSE		1.26	3.00	4.91
High Speed Rail (Passenger-miles)		0	1,880,000	5,900,000
Light and Heavy Passenger Rail (Passenger-miles)	Light	899,00	1,150,000	1,330,000
	Heavy	1,620,000	2,010,000	2,250,000
Commuter Rail (Passenger-miles)		0	386,000	418,000
Dual Mode Catenary Trucks on I-710 / SR 60 (Truck Miles)	I-710	0	30,700	194,000,000
	SR-60	0	0	0
Medium-Duty Vehicles		0.5	6.3	183.7
Heavy-Duty Vehicles		0.5	0.38	23.5
	Subtotal	**156 2,522,000 (pass miles)**	**559 3,580,000 (pass miles)**	**2,804 4,180,000 (pass miles)**

The anticipated connected load and resulting annual electricity consumption for populations in the table above were calculated for each type of equipment. The data sources and assumptions for electricity load and annual consumptions for each type of equipment can be found in Appendix A. Table 9 shows the resulting "In Between" case annual electricity consumption in 2013, 2020 and 2030.

Table 9. "In Between" Case Electric Technology Electricity Consumption in Million kWh

Electric Technology		Electricity Consumption (Annual Million kWh)		
		2013	2020	2030
PEVs	BEV	72	436	2,060
	PHEV	72	568	3,490
Forklifts	Class 1 + 2	786	1,180	1,940
	Class 3	271	351	486
Truck Stop Electrification		2.16	12.1	22.2
Transport Refrigeration Units		8.92	44.4	200
Shore Power		102	287	446
Port Cargo Handling Equipment	Yard Tractors	0	51.3	146
	Forklifts	0	1.24	3.53
	Cranes	0	10.6	33.7
Airport GSE		5.9	14.0	22.9
High Speed Rail		0	756	2,340
Light and Heavy Passenger Rail	Light	274	347	404
	Heavy	373	446	498
Commuter Rail		0	144	156
Dual Mode Catenary Trucks on I-710 / SR 60	I-710	0	82.9	525
	SR-60	0	0	0
Medium-Duty Vehicles		0	38	1,047
Heavy-Duty Vehicles		0	6	446
Subtotal		**1,970**	**4,770**	**14,300**
Percentage of CA Electricity Consumption – 250,561 GWh (2013)[19]		**0.7%**	**1.7%**	**5.1%**

Table 10 shows the petroleum and GHG displacement for the "In Between" case in 2013, 2020, and 2030. Petroleum fuel displacement was calculated by determining the annual fuel consumption for the competing conventional fueled equipment combined with the population forecast. Increased use of a certain rail systems would displace CNG from transit buses rather than diesel. The quantity of displaced CNG is listed separately from the displaced diesel since it does not come from petroleum. ICF calculated the GHG emissions displaced by combining petroleum displaced and electricity consumed, using the full fuel cycle GHG emission factors in Table 32.

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[19] http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-CMF.pdf

Table 10. “In Between” Case Electric Technology Petroleum and GHG Displacement

Electric Technology	Petroleum Displacement (millions of GGE/year)			GHG Displacement (millions of tons/year)		
	2013	2020	2030	2013	2020	2030
BEVs	9.04	52.8	205	0.08	0.47	1.72
PHEVs	11.2	84.9	450	0.10	0.80	4.09
Forklifts	94.0	139	225	0.78	1.23	2.00
Truck Stop Electrification	0.37	2.07	3.78	0.003	0.020	0.037
Transport Refrigeration Units	1.04	5.26	23.9	0.009	0.048	0.22
Shore Power	8.78	24.8	34.138.6	0.064	0.20	0.31
Port Cargo Handling Equipment	0	5.90	17.2	0	0.050	0.14
Airport Ground Support Equipment	0.47	1.12	1.84	0.003	0.009	0.014
High Speed Rail	0	32.76	102.7	0	0.15	0.49
Light and Heavy Passenger Rail	46.4 30.8 (CNG)	64.1 38.4 (CNG)	71.4 44.0 (CNG)	0.49	0.67	0.76
Commuter Rail	0	6.40	6.93	0	0.031	0.033
Dual Mode Catenary Trucks on I-710 / SR 60	0	5.93	37.5	0	0.043	0.28
Medium-Duty Vehicles	0	4	111	0.0	0.0	1.0
Heavy-Duty Vehicles	0	0	38	0.0	0.01	0.44
Subtotal	**195** **30.8 (CNG)**	**478** **38.4 (CNG)**	**1,430** **44.0 (CNG)**	**1.53**	**3.77**	**11.5**
Percentage of 2013 CA Consumption / Emissions 18.8 Billion GGE[20]/171 MMT[21]	**0.9%**	**2.3%**	**7.1%**	**0.9%**	**2.2%**	**6.7%**

Table 11 shows the criteria pollutant emission reductions in the “In Between” case for 2013 2020, and 2030. ICF calculated reductions of criteria pollutant emissions (PM and NOx + ROG/NMOG) based on current regulations for criteria pollutant emissions (e.g. LEV III[22], ULETRU In-Use Performance Standard[23]) and current emission factors for conventional fuels. The California based upstream criteria pollutant emission factors used are shown in Table 32.

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[20] California 2013 Weekly Fuels Watch Report http://energyalmanac.ca.gov/petroleum/fuels_watch/; all sectors

[21] http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_by_sector_00-12_sum_2014-03-24.pdf

[22] “Low-Emission Vehicle Program - LEV III,” http://www.arb.ca.gov/msprog/levprog/leviii/leviii.htm

[23] http://www.arb.ca.gov/diesel/tru/tru.htm

Table 11. "In Between" Case Electric Technology PM and NOx + ROG/NMOG Displacement in California (Tons/Day)

Electric Technology	PM (Tons/Day)			NOX + ROG/NMOG (Tons/day)		
	2013	2020	2030	2013	2020	2030
BEVs	0.01	0.03	0.04	0.10	0.51	1.15
PHEVs	0.01	0.05	0.06	0.10	0.70	2.02
Forklifts	0.04	0.06	0.09	2.92	4.31	6.93
Truck Stop Electrification	0.000	0.003	0.005	0.03	0.36	0.67
Transport Refrigeration Units	0.002	0.006	0.019	0.33	1.4	5.6
Shore Power	0.075	0.21	0.33	04.30	12.4	19.3
Port Cargo Handling Equipment	0	0.003	0.009	0	0.14	0.39
Airport Ground Support Equipment	0.001	0.002	0.002	0.08	0.14	0.23
High Speed Rail	0	0.011	0.041	0	0.32	1.1
Light and Heavy Passenger Rail	0.019	0.026	0.029	0.47	0.61	0.69
Commuter Rail	0	0.002	0.003	0	0.07	0.07
Dual Mode Catenary Trucks on I-710 / SR 60	0	0.003	0.003	0	0.14	0.71
Medium-Duty Vehicles	0.0	0.0	0.0	0.0	0.1	1.2
Heavy-Duty Vehicles	0.0	0.0	0.09	0.0	0.09	3.54
Subtotal	**0.15**	**0.41**	**0.73**	**8.6**	**22.0**	**45.1**
Percentage of 2013 CA Emissions – 85 TPD PM[24]/ 2,509 TPD NOX +ROG[25]	**0.2%**	**0.5%**	**0.9%**	**0.3%**	**0.8%**	**1.7%**

2.3 "Aggressive Adoption" Case

The "Aggressive Adoption" case for many technologies includes aggressive new incentive programs and/or regulations, especially regulations similar to the mandate at the ports. "Aggressive adoption" cases are not simply the hypothetical maximums, but are tangibly aggressive and anticipate achieving compliance with regulations where electrification is not the only avenue for compliance (e.g. anti-idling, ocean going vessels at-berth, TRUs) solely through electrification. Table 12 shows the California electric technology population forecasts in the "Aggressive Adoption" case where TSE penetration is shown as the number of electrified spaces, cold-ironing as the number of electrified ship visits, electrified rail as passenger-miles, and fixed guideway as truck-miles.

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[24] http://www.arb.ca.gov/aqd/almanac/almanac13/pdf/chap213.pdf

[25] California Almanac of Emissions and Air Quality 2013 Edition - Chapter 2 Current Emissions and Air Quality http://www.arb.ca.gov/aqd/almanac/almanac13/pdf/chap213.pdf

Table 12. “Aggressive Adoption” Case California Electric Technology Populations in Thousands (Total, Not Incremental)

Electric Technology		Population (in 000s, Total, Not Incremental)		
		2013	2020	2030
PEVs 3x ZEV Likely Compliance	BEV	24.1	441	2,200
	PHEV	29.9	745	4,750
Forklifts	Class 1 + 2	42.9	68.7	120
	Class 3	51.5	66.9	92.6
Truck Stop Electrification (Spaces)		0.262	2,790	4,640
Transport Refrigeration Units		3.63	46.1	263
Shore Power (Ship Visits)		1.94	7.58	11.3
Port Cargo Handling Equipment	Yard Tractors	0	1.270	4.030
	Forklifts	0	0.486	1.540
	Cranes	0	0.173	0.547
Airport GSE		1.26	3.77	7.04
High Speed Rail (Passenger-miles)		0	1,880,000	8,330,000
Light and Heavy Passenger Rail (Passenger-miles)	Light	899,000	1,250,000	1,560,000
	Heavy	1,620,000	2,210,000	2,810,000
Commuter Rail (Passenger-miles)		0	422,000	633,000
Dual Mode Catenary Trucks on I-710 / SR 60 (Truck Miles)	I-710	0	76,031	241,000
	SR-60	0	0	315,000
Medium-Duty Vehicles		0.5	16.4	834
Heavy-Duty Vehicles		0.5	0.795	65.8
	Subtotal	**155** **2,520,000 (pass miles)**	**1,400** **3,960,000 (pass miles)**	**8,360** **5,560,000 (pass miles)**
Lawn and Garden		9,300	11,000	14,100
Sweepers/Scrubbers		29	32	35
Burnishers		103	106	109
Tow Tractors/Industrial Tugs		14	16	19
Personnel/Burden Carriers		51	54	57
Turf Tractors		9	18	27
Golf Carts		89	103	117
	Subtotal	**295** **9,300 (L&G)**	**329** **11,000 (L&G)**	**364** **14,100 (L&G)**

The anticipated connected load and resulting annual electricity consumption for populations in the table above were calculated for each type of equipment. The data sources and assumptions for electricity load and annual consumptions for each type of equipment can be found in Appendix A.

Table 13 shows the resulting "Aggressive Adoption" case annual electricity consumption in 2013, 2020 and 2030.

Table 14 shows the petroleum and GHG displacement for the "Aggressive Adoption" case in 2013, 2020, and 2030. Petroleum fuel displacement was calculated by determining the annual fuel consumption for the competing conventional fueled equipment combined with the population forecast. Increased use of a certain rail systems would displace CNG from transit buses rather than diesel. The quantity of displaced CNG is listed separately from the displaced diesel since it does not come from petroleum. ICF calculated the GHG emissions displaced by combining petroleum displaced and electricity consumed, using the full fuel cycle GHG emission factors in Table 32.

Table 13. "Aggressive Adoption" Case Electric Technology Electricity Consumption in Million kWh

Electric Technology		Electricity Consumption (Annual Million kWh)		
		2013	2020	2030
PEVs	BEV	72	1,310	6,170
	PHEV	72.0	1,700	10,500
Forklifts	Class 1 + 2	786	1,310	2,380
	Class 3	271	351	486
Truck Stop Electrification		3.43	22.6	42.4
Transport Refrigeration Units		8.92	14.4	22.8
Shore Power		102	362	551
Port Cargo Handling Equipment	Yard Tractors	0	82.2	260
	Forklifts	0	1.98	6.28
	Cranes	0	18.9	59.9
Airport GSE		5.9	17.6	32.9
High Speed Rail		0	756	3,490
Light and Heavy Passenger Rail	Light	274	380	477
	Heavy	373	494	628
Commuter Rail		0	157	236
Dual Mode Catenary Trucks on I-710 / SR 60	I-710	0	160	722
	SR-60	0	0	945
Medium-Duty Vehicles		0	98	4,753
Heavy-Duty Vehicles		0	12	1,235
	Subtotal	**1,970**	**7,300**	**33,200**
	Percentage of CA Electricity Consumption – 250,561 GWh (2013)[26]	**0.7%**	**2.6%**	**11.8%**
Lawn and Garden		185	197	209
Sweepers/Scrubbers		10-30	11-34	12-37
Burnishers		58-80	60-82	61-85
Tow Tractors/Industrial Tugs		84-125	97-146	111-167
Personnel/Burden Carriers		104	110	116
Turf Tractors		27	54	81
Golf Carts		100	116	132
Subtotal		**568-651**	**645-739**	**722-827**

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[26] http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-CMF.pdf

Table 14. "Aggressive Adoption" Case Electric Technology Petroleum and GHG Displacement

Electric Technology	**Petroleum Displacement (millions of GGE/year)**			**GHG Displacement (millions of tons/year)**		
	2013	2020	2030	2013	2020	2030
BEVs	9.04	159	614	0.08	1.42	5.15
PHEVs	11.2	255	1,350	0.10	2.40	12.3
Forklifts	94.0	153	273	0.78	1.35	2.40
Truck Stop Electrification	0.59	3.86	7.24	0.006	0.038	0.071
Transport Refrigeration Units	1.04	7.09	35.7	0.009	0.064	0.33
Shore Power	8.78	31.2	47.7	0.064	0.25	0.39
Port Cargo Handling Equipment	0	9.67	30.6	0	0.081	0.26
Airport GSE	0.47	1.41	2.63	0.003	0.011	0.020
High Speed Rail	0	32.8	145	0	0.15	0.63
Light and Heavy Passenger Rail	46.4 30.8 (CNG)	62.8 42.2 (CNG)	79.2 52.2 (CNG)	0.49	0.74	0.91
Commuter Rail	0	7.00	10.51	0	0.034	0.051
Dual Mode Catenary Trucks on I-710 / SR 60	0	14.7	107	0	0.12	0.74
Medium-Duty Vehicles	0	10	503	0	0.1	4.3
Heavy-Duty Vehicles	0	1	104	0	0.01	1.31
Subtotal	**171 30.8 (CNG)**	**749 42.2(CNG)**	**3,310 52.2 (CNG)**	**1.53**	**6.76**	**28.9**
Percentage of 2013 CA Consumption / Emissions 18.8 Billion GGE[27]/171 MMT[28]	**0.9%**	**4.0%**	**18%**	**0.9%**	**4.0%**	**17%**
Lawn and Garden	5-16	10-29	18-50	0.06-0.09	0.11-0.33	0.20-0.58
Sweepers/Scrubbers	6.0	12	17	0.07	0.14	0.21
Burnishers	3	2.8	2.6	0.04	0.03	0.03
Tow Tractors/Industrial Tugs	20	22.9	26	0.22-0.23	0.26-0.27	0.03-0.31
Personnel/Burden Carriers	21	20	20	0.25	0.24	0.23
Turf Tractors	6.0	12	18	0.06	0.13	0.19
Golf Carts	9.6	14	19	0.12	0.17	0.23
Subtotal	**71-82**	**94-113**	**120-152**	**0.82-0.86**	**1.1-1.3**	**1.4-1.8**

Table 15 shows the criteria pollutant emission reductions in the "Aggressive Adoption" case for 2013 2020, and 2030. ICF calculated reductions of criteria pollutant emissions (PM and NOx + ROG/NMOG) based on current regulations for criteria pollutant emissions (e.g. LEV III[29], ULETRU In-Use Performance

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[27] California 2013 Weekly Fuels Watch Report http://energyalmanac.ca.gov/petroleum/fuels_watch/; all sectors

[28] http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_by_sector_00-12_sum_2014-03-24.pdf

[29] "Low-Emission Vehicle Program - LEV III," http://www.arb.ca.gov/msprog/levprog/leviii/leviii.htm

Standard[30]) and current emission factors for conventional fuels. The California based upstream criteria pollutant emission factors used are shown in Table 32.

Table 15. "Aggressive Adoption" Case Electric Technology PM and NOx + ROG/NMOG Displacement in California (Tons/Day)

Electric Technology	PM (Tons/Day)			NOX + ROG/NMOG (Tons/day)		
	2013	2020	2030	2013	2020	2030
BEVs	0.01	0.10	0.12	0.10	1.54	3.47
PHEVs	0.01	0.14	0.18	0.10	2.09	6.07
Forklifts	0.04	0.06	0.11	2.92	4.70	8.24
Truck Stop Electrification	0.000	0.000	0.001	0.03	0.05	0.06
Transport Refrigeration Units	0.002	0.003	0.005	0.33	0.53	0.87
Shore Power	0.075	0.27	0.41	4.39	15.6	23.8
Port Cargo Handling Equipment	0	0.001	0.002	0	0.05	0.09
Airport GSE	0.003	0.003	0.004	0.08	0.11	0.14
High Speed Rail	0	0.011	0.015	0	0.32	0.45
Light and Heavy Passenger Rail	0.019	0.028	0.036	0.47	0.67	0.85
Commuter Rail	0	0.003	0.004	0	0.07	0.11
Dual Mode Catenary Trucks on I-710 / SR 60	0	0	0	0	0	0
Medium-Duty Vehicles	0.0	0.0	0.0	0.0	0.2	5.4
Heavy-Duty Vehicles	0.0	0.0	0.25	0.0	0.19	9.9
Subtotal	**0.15**	**0.66**	**1.29**	**8.41**	**28.8**	**71.9**
Percentage of 2013 CA Emissions – 85 TPD PM[31]/ 2,509 TPD NOX +ROG[32]	**0.2%**	**0.8%**	**1.5%**	**0.3%**	**1.2%**	**2.9%**
Lawn and Garden	0.07-0.12	0.77-0.87	1.8-2.0	6.7-8.2	10-13	14-20
Sweepers/Scrubbers	0.06	0.09	0.13	1.2	2.1	3.1
Burnishers	0.01	0.01	0.01	0.17	0.17	0.16
Tow Tractors/Industrial Tugs	0.01	0.01	0.01	0.75	0.87	1.0
Personnel/Burden Carriers	0.12	0.11	0.11	2.9	2.7	2.6
Turf Tractors	0.03	0.06	0.09	1.3	2.6	3.9
Golf Carts	0.03	0.04	0.06	1.1	1.7	2.2
Subtotal	**0.33-0.38**	**1.1-1.2**	**2.2-2.4**	**14-16**	**20-23**	**27-33**

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[30] http://www.arb.ca.gov/diesel/tru/tru.htm

[31] http://www.arb.ca.gov/aqd/almanac/almanac13/pdf/chap213.pdf

[32] California Almanac of Emissions and Air Quality 2013 Edition - Chapter 2 Current Emissions and Air Quality http://www.arb.ca.gov/aqd/almanac/almanac13/pdf/chap213.pdf

3 Costs and Benefits of Select TE Segments

The following cost and benefit analysis includes both traditional elements (e.g. incremental capital cost, operational cost/savings, and fuel cost/savings) and non-traditional ratepayer benefits including GHG emission reduction, petroleum displacement and criteria pollutant reduction. The methodologies utilized in this section are consistent with those employed by agencies such as the California Energy Commission (CEC), Air Resources Board (ARB) and local air quality agencies to understand the costs and benefits of alternative fuels and emission reduction technologies and programs. Phase 2 will perform a more thorough analysis of the grid benefits from PEVs using CPUC consistent benefit and cost methodologies and considerations including analysis from both a ratepayer and utility perspective. The methodologies employed in Phase 2 will include the avoided cost methodology which has been adopted by the CPUC for evaluating distributed energy resources such as energy efficiency, demand response and distributed generation.

Public Utilities Commission (PUC) Code 740.8 calls for the inclusion of “interests” to ratepayers including activities “that promote energy efficiency, reduction of health and environmental impacts from air pollution, and greenhouse gas emissions related to electricity and natural gas production and use, and increased use of alternative fuels.” [33] In addition, agencies such as the California Energy Commission (CEC) and Air Resources Board (ARB) are shifting to a more comprehensive approach when considering costs and multiple benefits (e.g. State Alt Fuels Plan (AB1007), Vision for Clean Air).Grant programs such as Carl Moyer look to monetize and provide incentives for criteria pollutant emission reductions (e.g. NOx, ROG, PM) and AB118 looks to monetize and reduce GHG emissions and petroleum consumption. Due to transportation electrification’s higher capital costs and lack of a singular focus on one type of reduction, these programs do not reward the comprehensive benefits and operational cost savings of transportation electrification. The benefit-cost ratio was developed to incorporate the full range of societal benefits and operational cost savings. The cost analysis in this section is from the perspective of TE technology consumers.

The benefit-cost ratio categorizes cost elements as either costs or benefits (i.e., savings). Cost savings are characterized as a benefit and incorporated into the numerator. However, there are several trade-offs in this metric as well. For instance, a benefit-cost ratio requires that emission reductions (e.g., tons of GHG reductions) be monetized so that they can be included in the calculation. Monetized health and environmental benefits or damage costs can be controversial and also have their detractors. Both the cost-effectiveness metric and benefit-cost ratio can oversimplify the analysis of technologies. It is also important to consider the magnitude of the benefits.

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[33] PUC Code § 740.8 - “As used in Section 740.3, ‘interests’ of ratepayers, short- or long-term, mean direct benefits that are specific to ratepayers in the form of safer, more reliable, or less costly gas or electrical service, consistent with Section 451, and activities that benefit ratepayers and that promote energy efficiency, reduction of health and environmental impacts from air pollution, and greenhouse gas emissions related to electricity and natural gas production and use, and increased use of alternative fuels.” http://www.leginfo.ca.gov/cgi-bin/displaycode?section=puc&group=00001-01000&file=727-758

The analysis in the following section looks at the benefit-cost ratio for the selected technologies (PEVs, forklifts, TSE and TRUs) and compares them with the magnitude of potential benefits using the 2030 “Aggressive Adoption" case. The cost elements in the analysis include incremental costs (both vehicles and infrastructure), operational and maintenance (O&M) and fuel costs, and monetized societal benefits. Table 16 below shows the factors for monetizing the societal benefits. For each of the emission reduction benefits, the most conservative values (the highest discount rate) were selected for the analysis. The values for 2020 were escalated to 2030 using the consumer price index (CPI)[34] from the U.S. Bureau of Labor Statistics.

Table 16. Factors for Monetizing Societal Benefits

Societal Benefit	Unit	Discount Rate	2013	2020	2030
Displaced Petroleum[35,36]	$/GGE		$0.44	$0.43	$0.42
GHG [37,38]	$/MT	5%	$11	$12	$16
NOx[39,40]	$/ton	7%	$4,675	$5,082	$6,098
PM [41,42]	$/ton	7%	$1,450,038	$1,650,681	$1,977,357
VOC [41,42]	$/ton	7%	$1,118	$1,20	$1,423

For each of the following technologies analyzed, summary tables and figures are presented in the following section for annualized costs, private benefits and monetized societal benefits. The detailed analysis, data sources and assumptions can be found in Appendix B for all technologies.

3.1 Plug-In Electric Vehicles (PEVs)

The analysis for PEVs has been divided into two classes: passenger cars and light trucks. This is due to differences in incremental capital costs and fuel economies between the two classes of vehicles. For each class the analysis includes PHEV10, PHEV20, PHEV40 and BEV for 2013, 2020 and 2030 to account for the differences in gasoline and electricity consumption and cost, and incremental costs between

[34] http://www.bls.gov/cpi/

[35] Leiby, P. Estimating the Energy Security Benefits of Reduced U.S. Oil Imports, ORNL/TM-2007/028, March 2008

[36] EPA RFS Annual Rulemaking, Updated Energy Security Benefits, 2012. EPA-HQ-OAR-2010-0133-0252, Available online at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2010-0133-0252

[37] Interagency Working Group on Social Cost of Carbon. 2010. Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. February. United States Government. http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf

[38] Interagency Working Group on Social Cost of Carbon. Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, United States Government, May 2013.

[39] Diesel Emissions Quantifier Health Benefits Methodology, EPA, EPA-420-B-10-034, August 2010.

Available online: http://www.epa.gov/cleandiesel/documents/420b10034.pdf

[40] EPA/HNTSA, Draft Joint Technical Support Document: Proposed Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, EPA-420-D-11-901, November 2011.

each type of vehicle in each year. The detailed costing analysis, data sources and assumptions can be found in Appendix B.

3.1.1 Passenger Cars

Table 17 and Table 18 below show the resulting private and societal benefit-cost ratios. The private benefit from both a time of use (TOU) rate and a domestic rate are shown separately in the tables below and in Figure 2 and Figure 3. A domestic rate structure is a traditional tiered residential rate structure where the more electricity a household consumes from charging a PEV, the higher the marginal electricity rate no matter when the charging occurs. A TOU rate structure rewards off-peak electricity consumption (e.g. PEV charging) by applying a lower rate than is used during other time periods. The use of a domestic rate reduces the private benefit 7 to13% in 2013 and 16 to41% in 2030. To develop the benefit-cost ratio shown in Figure 2 and Figure 3 for passenger cars, the annual private benefits and monetized societal benefits are divided by the annualized private costs. A private benefit-cost ratio exceeding one means the technology has lifecycle savings. The red line in Figure 2 and Figure 3 delineate a benefit-cost ratio of one (1).

Table 17. TOU Rate Private and Societal Benefit-Cost Ratios

Passenger Cars	PHEV10			PHEV20			PHEV40			BEV		
	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030
Private Benefit-Cost Ratio												
Operational Savings	4.47	7.82	12.53	1.63	3.01	7.49	1.76	3.59	3.84	1.57	3.67	8.89
Societal Benefit-Cost Ratios												
Petroleum Displacement	0.48	0.78	1.10	0.19	0.35	0.82	0.22	0.47	0.50	0.17	0.41	0.96
GHG Emission	0.12	0.22	0.41	0.04	0.09	0.28	0.05	0.12	0.16	0.04	0.10	0.30
NOx	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
PM	0.22	0.24	0.02	0.13	0.16	0.01	0.18	0.25	0.01	0.16	0.24	0.01
VOC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Societal	**0.82**	**1.25**	**1.54**	**0.37**	**0.61**	**1.13**	**0.46**	**0.85**	**0.67**	**0.37**	**0.76**	**1.28**

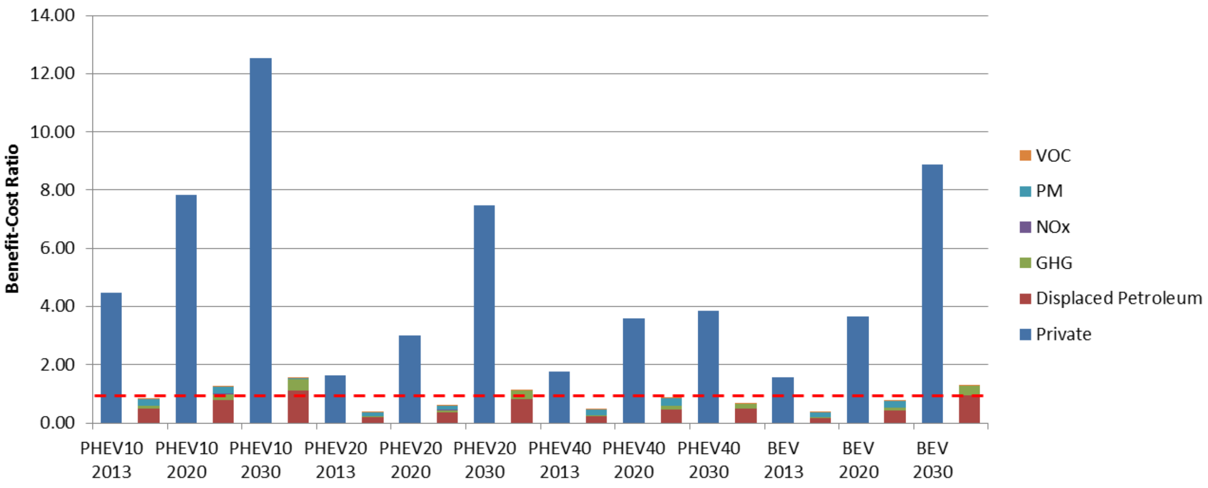

Figure 2. Benefit-Cost Ratio for Passenger Cars - TOU Rate

Table 18. Domestic Rate Private and Societal Benefit-Cost Ratios

Passenger Cars	PHEV10			PHEV20			PHEV40			BEV		
	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030
Private Benefit-Cost Ratio												
Operational Savings	4.19	6.97	10.54	1.46	2.43	5.29	1.52	2.67	2.25	1.37	2.78	5.49
Societal Benefit-Cost Ratios												
Petroleum Displacement	0.48	0.78	1.10	0.19	0.35	0.82	0.22	0.47	0.50	0.17	0.41	0.96
GHG Emission	0.12	0.22	0.41	0.04	0.09	0.28	0.05	0.12	0.16	0.04	0.10	0.30
NOx	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
PM	0.22	0.24	0.02	0.13	0.16	0.01	0.18	0.25	0.01	0.16	0.24	0.01
VOC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Societal	**0.82**	**1.25**	**1.54**	**0.37**	**0.61**	**1.13**	**0.46**	**0.85**	**0.67**	**0.37**	**0.76**	**1.28**

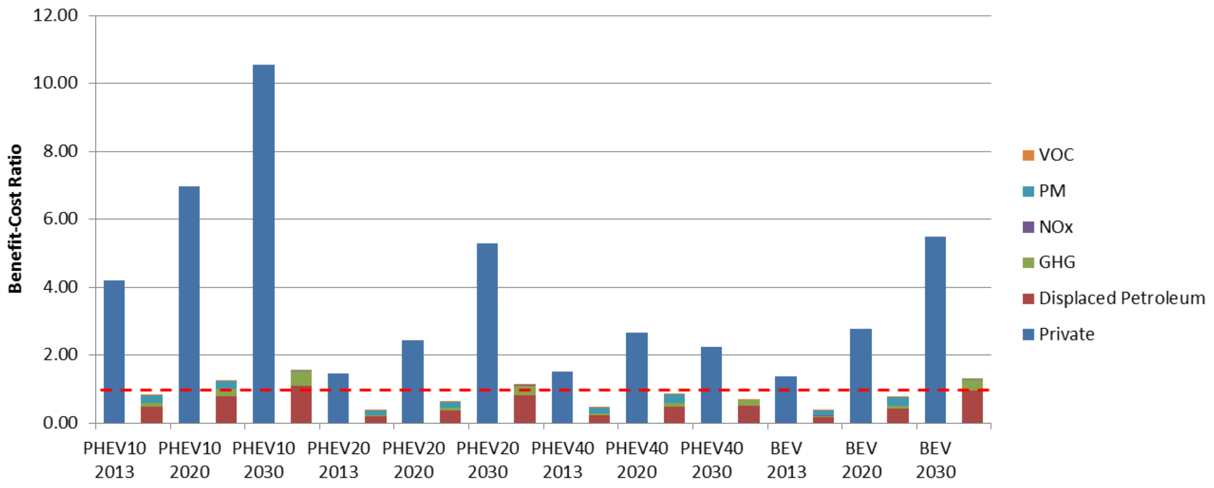

Figure 3. Benefit-Cost Ratio for Passenger Cars - Domestic Rate

Figure 2 and Figure 3 show the private and total benefit-cost ratios for all technologies and classes are above one (the dotted red line) and significantly above one for 2020 and 2030. Figure 2 and Figure 3 also show that for 2013, differences between the benefit-cost ratio from the TOU and domestic rates are much smaller than in 2030. This is due to rate differences of only $0.065 per kWh in 2010 and $0.14 in 2030. The ratio differences are also accentuated by the dramatic reduction of the incremental cost (denominator of the ratio) between 2013 and 2030. We can also see that due to increasingly more stringent tailpipe emission standards the 2030 NOx, PM and VOC reductions, and hence their resulting societal benefits, are almost zero.

3.1.2 Light Trucks

Table 19 and Table 20 below show the resulting private and societal benefit-cost ratios. The private benefit of both a TOU rate and a domestic rate are shown separately in the tables below and in Figure 4 and Figure 5. The use of a domestic rate reduces the private benefit 6 to 14% in 2010 and 13 to 33% in 2030. To develop the benefit-cost ratio shown in Figure 4 and Figure 5 for passenger cars, the annual private benefits and monetized societal benefits are divided by the annualized costs. A private benefit-cost ratio exceeding one means the technology has lifecycle savings. The red line in Figure 4 and Figure 5 delineate a benefit-cost ratio of one.

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

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

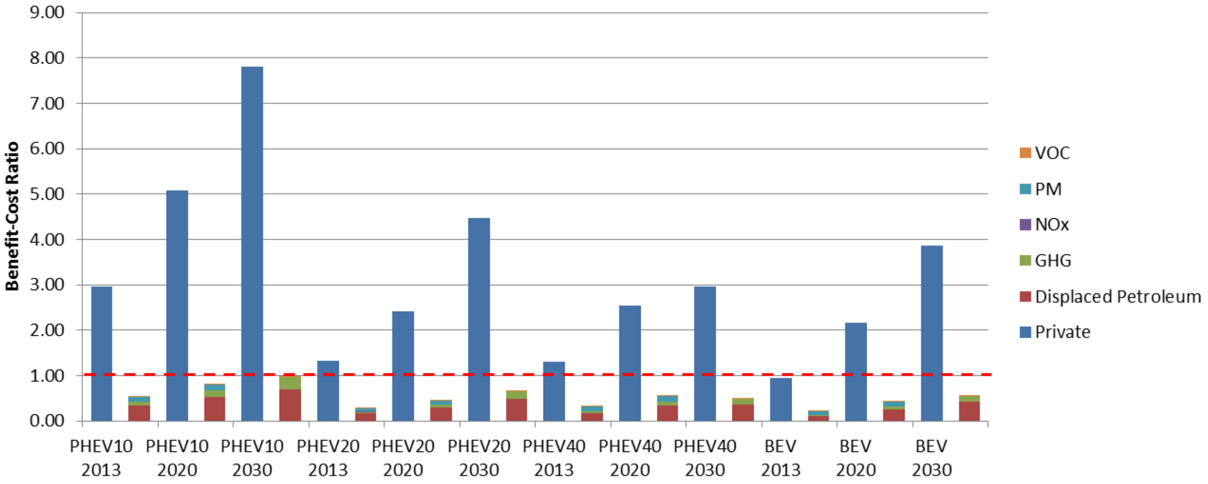

Figure 4. Benefit-Cost Ratio for Light Trucks - TOU Rate

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

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

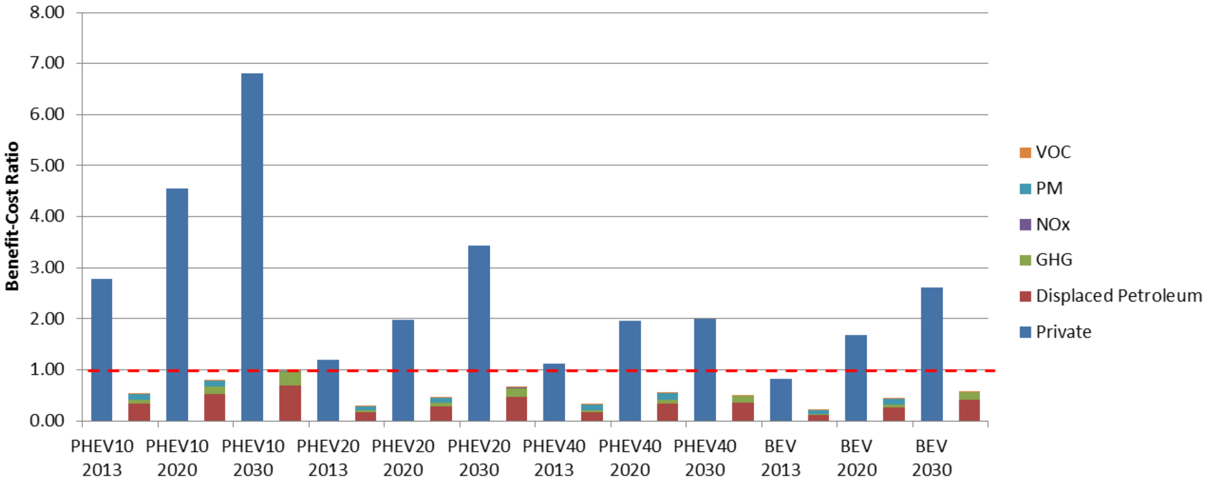

Figure 5. Benefit-Cost Ratio for Light Trucks - Domestic Rate

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

3.1.3 Summary

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

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

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

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

3.2 Forklifts

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

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

Table 22. Forklift Private and Societal Benefit-Cost Ratios

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

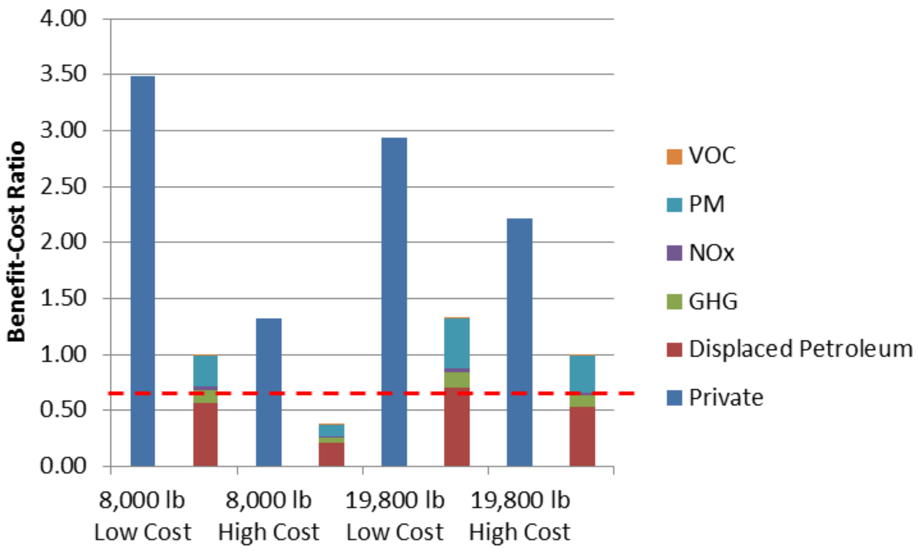

Figure 6. Benefit-Cost Ratio for Forklifts

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

3.2.1 Summary

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

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

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

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

3.3 Truck Stop Electrification (TSE)

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

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

Table 24. TSE Private and Societal Benefit-Cost Ratios

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

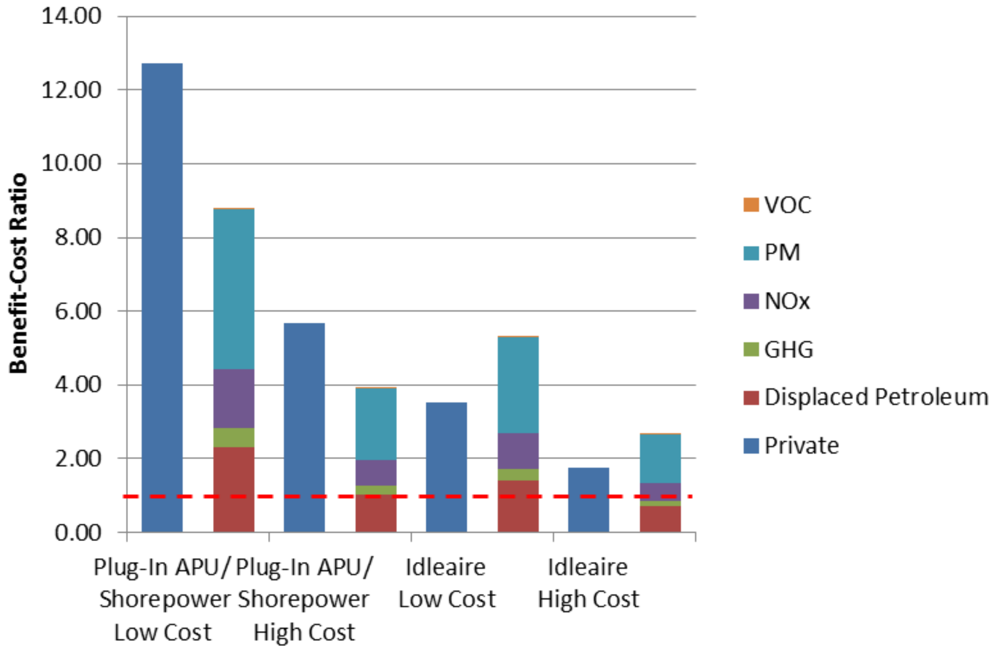

Figure 7. Benefit-Cost Ratio for TSE

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

3.3.1 Summary

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

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

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

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

3.4 Transport Refrigeration Units

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

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

Table 26. TRU Private and Societal Benefit-Cost Ratios

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

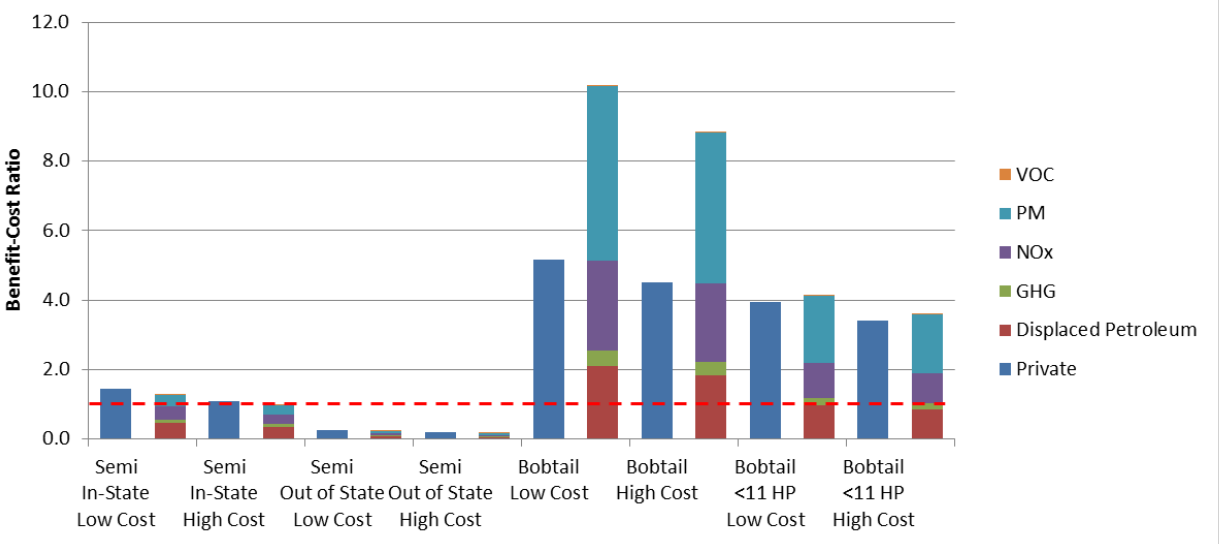

Figure 8. Benefit-Cost Ratio for TRUs

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

3.4.1 Summary

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

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

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

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

4 Transportation Electrification Grid Benefits

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

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

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

4.1 Objectives

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

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

4.1.1 Grid impacts

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

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

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

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

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

4.1.2 Ratepayer Benefits

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

4.1.3 Utility Managed Charging

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

4.1.4 Environmental Benefits

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

4.1.5 Vehicle Grid Integration

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.1 Consumer Costs

5.1.1 Identification of the Gaps and Barriers

Upfront Vehicle Costs

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

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

[46] Ibid.

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

Upfront EVSE Costs

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

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

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

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

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

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

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

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

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

Vehicle Operating Costs

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

5.1.2 Potential Solutions

Ensure availability of incentives

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

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

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

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

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

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

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

Creative use of LCFS credits

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

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

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

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

Battery second life

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

Improve PEV charging rates

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

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

5.2 PEV Charging Infrastructure Deployment

5.2.1 Identification of the Gaps and Barriers

Charging at single family homes

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

Charging infrastructure at multi-dwelling units

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

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

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

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

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

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

Workplace charging

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

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

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

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

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

Other away-from-home charging

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

Table 29. Example of Charging Type based on Purpose

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

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

5.2.2 Potential Solutions

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

Engage MDUs/HOAs, employers, and workplace parking providers

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

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

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

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

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

5.3 Third-Party Ownership of Charging Infrastructure

5.3.1 Identification of the Gaps and Barriers

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

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

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

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

Table 30. Services Provided by PEV Charging Industry Participants

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

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

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

Sustainability of revenue model

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

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

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

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

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

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

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

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

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

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

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

The demand for non-home charging is unclear

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

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

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

Vehicle purchasing behavior

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

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

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

Consumer willingness to pay for charging

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

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

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

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

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

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

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

Charging needs and behavior

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

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

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

5.3.2 Potential Solutions

Alternatives to additional public investment in charging infrastructure deployment

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

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

Revisit ruling regarding utility investment in charging infrastructure

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

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

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

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

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

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

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

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

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

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

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

Improved evaluation of charging infrastructure deployment

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

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

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

5.4 Consumer Education and Outreach

5.4.1 Identification of the Gaps and Barriers

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

Lack of PEV Awareness and Knowledge

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

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

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

Total Cost of Ownership

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

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

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

Improved PEV Education

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

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

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

aggregators that have started to emerge and assume a leading role (e.g., goelectricdrive.com); however, as previously stated, awareness about PEVs remains low, an indication that content and traffic to these sites could be improved.

5.4.2 Potential Solutions

Utility as trusted advisor in the PEV market

Utilities have a critical role to play when communicating with consumers about the benefits of PEVs. As PEVs can be part of greater customer engagement about their energy consumption, utilities should expand their advisory role in this area. Utilities have a 30-plus year history of serving as trusted advisors with other end-users, including in the deployment of energy efficient technologies (e.g., air conditioners, lighting, refrigerators, etc.). Furthermore, the Electric Power Research Institute (EPRI) reports that a synthesis of multiple surveys of potential PEV drivers indicates that there is a strong belief that it is the utility's role to develop charging infrastructure and educate consumers.[74]

Most utilities in California are already engaged in initiatives related to PEV deployment – including through coordination with Clean Cities groups, involvement with the California Plug-in Electric Vehicle Collaborative, or with other local/regional efforts. Continuing engagement in these types of initiatives is critical to the success of PEV adoption. Furthermore, it helps bolster the case for utilities to serve as a trusted advisor. Utilities should continue involvement with existing initiatives and identify new opportunities where available. Of particular note, the Bay Area's MTC recently launched the EV Outreach Program under the Climate Initiatives Program with the intent to encourage Bay Area residents to experience PEVs first-hand via two dozen ride-and-drive events while integrating with social media.

While many utilities[75] are educating customers about PEVs, the previously mentioned CPUC ruling limits the scope of education and outreach activities by IOUs with a prohibition of "mass marketing" and a requirement "to target customers with an interest in Electric Vehicle" (rather than the broader segment of automobile intenders). This ruling effectively prevents IOUs from engaging in broader educational initiatives aimed at the general public regarding PEVs and the benefits of fueling vehicles from the grid.

In addition to the information utilities already provide (e.g., PEV rates, environmental and societal benefits), utilities could provide critical and reliable tools about PEVs (e.g., to help customers

[74] Multiple EPRI reports including: a) Characterizing Consumers' Interest in and Infrastructure Expectations for Electric Vehicles: Research Design and Survey Results (2010), b) Southern Company Electric Vehicle Survey: Consumer Expectations for Electric Vehicles (2011), c) TVA Electric Vehicle Survey: Consumer Expectations for Electric Vehicles (2011), and d) Texas Plugs In: Houston and San Antonio Residents' Expectations of and Purchase Intentions for Plug-In Electric Vehicles (2012).

[75] It is worth noting that as part of the requirements for utilities earning credits under California's LCFS (participation in the LCFS program is voluntary), utilities must commit to educating the "public on the benefits of EV transportation (including environmental benefits and costs of EV charging as compared to gasoline)." The regulation suggests public meetings, EV dealership flyers, utility customer bill inserts, radio and/or television advertisements, and webpage content.

understand the total cost of ownership or choose the charging level needed based on their driving behavior). As noted in the Ernst & Young report, when utilities decide where they want to sit in the emerging ecosystem (and in the case of IOUs, where they are *allowed* to sit), a stable value chain is likely to emerge. As such, the long-term success of (light-duty) vehicle electrification depends on meaningful utility engagement. Plus, considering that a typical call to a utility's call center about PEVs may lead to a conversation about rates, metering, billing, information resources, PEVs at homes with solar energy and other related topics, the utility is ideally suited as the "first stop" for a PEV inquiry.

Engage with PEV ecosystem partners

Outside of existing initiatives, utilities should continue to seek opportunities to engage with PEV ecosystem partners to educate consumers about the benefits of PEV ownership. These include engagement with automobile manufacturers (OEMs), dealers, and private and public fleets, government agencies, and PEV charging industry market participants.

5.5 Vehicle Features

5.5.1 Identification of the Gaps and Barriers

Limited offerings

Over the last several years, about 63% of Californians' new light duty vehicle purchases have been automobiles, with the balance characterized as light trucks. In 2013, the top ten selling vehicles in California were the Toyota Prius, Honda Civic, Honda Accord, Toyota Camry, Toyota Corolla, Ford F-Series, Honda CRV, Nissan Altima, Toyota Tacoma, and the BMW 3-Series.[76] The PEVs available today are in somewhat similar vehicle classes as these top-ten sellers, with a focus on the subcompact segment (e.g., the Toyota Prius) and the standard midsize (e.g., Honda Accord). There are fewer offerings in the larger vehicle classes, including sedans, vans, pickup trucks and SUVs, with the Toyota RAV4 PEV the only offering outside of the light-duty automobile category.

These types of limitations on PEV options, such as vehicle size and payload capacity, restrict potential purchasing opportunities. Consumers tend to purchase new vehicles that are similar to those that they are replacing and PEV equivalents are limited across many market segments.

5.5.2 Potential Solutions

Modify Zero Emission Vehicle Program

CARB's ZEV Program (as of 2018) uses a system of credits generated by OEMs based on the range of the vehicle. The number of credits are awarded based on the zero emission miles that can be traveled – with a minimum of 50 miles (on Urban Dynamometer Driving Schedule, UDDS) earning 1 credit and 350 miles (UDDS) earning 4 credits. Transitional ZEVs, like PHEVs, can earn up to 1.25 credits, depending on the zero emission VMT potential of the vehicle.

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[76] CNCDA, California Auto Outlook, Vol 10, Number 1, February 2014.

Although the success of the ZEV program is ultimately driven by VMT with no tailpipe emissions, basing the program's accounting system exclusively on vehicle range may preclude the development of PEVs in some vehicle classes. The market reality is that consumers do not buy vehicles because of their range – they buy vehicles because of their attributes. To incentivize OEMs to produce vehicles outside of the traditional PEV market segments (e.g., subcompact or midsize sedans), CARB might consider a multiplier for ZEV credits in market segments that are underrepresented in various vehicle offerings. CARB has taken significant measures in the updated regulatory proceedings to simplify the ZEV program; as a result, a simple multiplier based on a multi-year (e.g., 3 years) market assessment of vehicle segments may be advisable. Additionally CARB might consider encouraging PHEVs with substantial electric VMT capability as a way to expand ZEV offerings.

Appendix A: Calculation Methodology and Assumptions for Detailed Forecasting, Fuel Consumption and Emissions of TEA Segments

The first step in calculating the electricity consumption societal benefits is to estimate the future populations of each electric drive technology. The population forecasting included an extensive literature review of current and future market conditions, contacting industry and government experts (including CARB, CEC and EPA) and using a utility work group to review the electrification forecasts prior to calculation of benefits and costs. As discussed in Section 2, the future populations and electricity consumption were estimated for three cases, described as:

- "In Line with Current Adoption" is a low case based on anticipated market growth, expected incentive programs, and compliance with existing regulations. For technology that could potentially not be built, like HSR and I710, build/no-build scenarios were considered.
- "Aggressive Adoption" is a high case based on aggressive new incentive programs and/or regulations. "Aggressive adoption" cases are not simply the hypothetical maximum, but are tangibly aggressive.
- "In Between" is a medium case that will fall somewhere in the middle of the low and high cases and will vary by technology. For some technologies it will simply be half-way while for some technologies while other technologies have more direct medium cases.

After developing population forecasts, it is necessary to determine consumption levels for electricity and conventional fuels displaced. These consumption levels are used to determine GHG and criteria pollutant emission reductions. For gasoline, diesel, CNG and electricity, it is necessary to also take into account the upstream criteria pollutant emissions from electricity and petroleum production and refining. Each technology has specific criteria pollutant combustion emission factors but the upstream factors are constant for each type of fuel. Table 32 below shows the upstream criteria pollutant emission factors for conventional fuels (AB 1007)[77] and electricity. The electricity emission factors are based on 78.7%[78] natural gas combined cycle in 2013 and 67%[79] in 2020 and 2030, with the balance being renewable electricity. GHG emission factors are from the Low Carbon Fuel Standard for each fuel except for the 2020/2030 electricity pathway which is based on 67% natural gas combined cycle and 33% renewables. These factors include the full fuel cycle and do not include emissions associated with vehicle or battery manufacturing. Electricity production outside of urban areas has much less significant impact on human health (e.g. criteria air pollutants).

[77] "Full Fuel Cycle Assessment: Well to Tank Energy Inputs, Emissions, and Water Impact", Consultant Report for the California Energy Commission, February 2007. http://www.energy.ca.gov/2007publications/CEC-600-2007-002/CEC-600-2007-002-D.PDF

[78] 78.7% based on LCFS marginal electricity pathway

[79] 67% based on RPS requirement for 33% renewables

Table 32. Upstream Emission Criteria Pollutant and GHG Emission Factors

Fuel, Unit	NOx (g/unit fuel)	ROG (g/unit fuel)	PM (g/unit fuel)	GHG (g/unit fuel)
RFG3 (E10), gallon	0.116	0.509	0.0046	11,442
Diesel, Gallon	0.188	0.471	0.0081	13,182
Natural Gas, DGE	0.094	0.027	0.017	9,144
Electricity (2013), kWh	0.041	0.0087	0.0049	377
Electricity (2020/2030), kWh	0.035	0.0074	0.0042	305

In general, emission reductions are calculated by determining the displaced emissions from the reduced petroleum consumption and subtracting the emissions from electricity production. The specific methodologies for determining the populations, electricity consumed and societal benefits for each technology are provided below.

Each type of vehicle and electrification technology has a different level of electricity consumption and efficiency compared to conventional technologies. Table 33 below shows the annual kWh consumption per unit for each technology (except for rail) analyzed in this section and the corresponding energy equivalency ratio (EER). The EER is the ratio of conventional fuel energy to electricity energy for the same work.

Table 33. Annual Electricity Consumption and EER for Each Technology

Electrification Technology	Annual Electricity Consumption (kWh/yr)	EER
PHEV10 (PC/LT)	1,006 / 1,326 (2013)	4.05 - electric; 1.5 – gasoline (2013) 3.4 - electric; 1.5 – gasoline (2020) 3.0 - electric; 1.4 – gasoline (2030)
PHEV20 (PC/LT)	2,012 / 2,652	4.05 - electric; 1.5 – gasoline (2013) 3.4 - electric; 1.5 – gasoline (2020) 3.0 - electric; 1.4 – gasoline (2030)
PHEV40 (PC/LT)	3,079 / 4,058	4.05 - electric; 1.5 – gasoline (2013) 3.4 - electric; 1.5 – gasoline (2020) 3.0 - electric; 1.4 – gasoline (2030)
BEV (PC/LT)	2,968 / 3,912	4.05 (2013) 3.4 (2020) 3.0 (2030)
Forklift (8,000lb / 19,000 lb)	18,312 / 52,080	3.8 / 2.5
TSE (per space)	3,423	5.64
e-TRUs (Semi / bobtail / 11hp bobtail) (per TRU)	3,180 / 2,448 / 938	3.9
Shore Power – Container (per berth)*	6,136,000	2.86
Shore Power – Reefer (per berth)*	3,311,000	2.86
Shore Power – Cruise (per berth)*	28,620,000	2.86
Shore Power – Tanker (per berth)*	3,570,000	2.86
CHE – Yard Tractor	64,600	2.9
CHE – Forklift	4,075	4.5
CHE – RTG Crane	109,000	4.0
Airport GSE	4,670	2.65
Dual Mode Catenary Trucks	17,000-20,000	2.1-2.4
MD PHEV	5,500 – 6,800	3.4
MD BEV	8,200 – 11,000	3.4
HD PHEV	12,000 – 17,000	2.7
HD BEV	22,000 – 131,000	2.7
* - Assumed 60% berth occupancy		

Plug-In Electric Vehicles (PEVs). To avoid making market penetration the focus of the PEV grid benefit study, ICF and CalETC decided to choose three different existing PEV penetration scenarios: California Zero Emission Vehicle (ZEV) compliance with a 50/50 split of PEVs and fuel cell vehicles (FCV), California

ZEV program “likely” compliance as defined by CARB, and three times the California ZEV “likely” compliance.[80] The population projections include a breakdown of PHEVs/BEVs, but ICF and CalETC further developed a breakdown of the PHEVs among PHEV10, PHEV20 and PHEV40. In addition each technology was divided between passenger cars (PCs) and light-trucks (LTs). Table 34 below shows the population percentage breakdown for PHEV and BEV between technology and class. The percentages for PHEVs and BEVs separately total 100%.

Table 34. PEV Fleet Breakdown by Technology and Class

Vehicle Class	2013	2020	2030
PHEV 10 – PC	25%	22%	16%
PHEV10 – LT	0%	4%	12%
PHEV20 – PC	25%	22%	16%
PHEV20 – LT	0%	4%	12%
PHEV40 – PC	50%	43%	31%
PHEV40 – LT	0%	5%	14%
BEV – PC	100%	93%	77%
BEV – LT	0%	7%	23%

The forecasts used for the analysis are for populations of PEVs. ICF used retirement factors from the Argonne National Laboratory VISION Model[81] for the AEO 2013 reference case to develop a fleet turnover model and determine the annual sales required by year from 2012 – 2030 to achieve the vehicle population forecasts. The combination of VISION annual fuel economy of auto ICE and LT ICE for conventional vehicles and auto HEV, LT HEV, auto EV and LT EV (PHEV gasoline VMT is assumed to be at HEV fuel economy) for each model year and population turnover model were used with the annual VMT in Table 35 to determine petroleum displaced and electricity consumed. The factors from Table 32 were combined with the vehicle fuel economies shown in Table 36 to determine fuel consumed and GHG emission reductions.

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[80] The ZEV regulation does not require a certain number of ZEVs by 2030; it requires about 4,200,000 ZEV credits. ZEV credits earned per vehicle in 2030 can vary tremendously (e.g. 0.5 for some types of PHEVs and 4.0 for fuel cell EVs). This can result in many compliance pathways from fewer than 1 million cumulative PEVs in 2030 to more than 3 million.

[81] ANL VISION Model http://www.transportation.anl.gov/modeling_simulation/VISION/index.html

Table 35. Gasoline and Electric VMT and Energy Consumption

Vehicle Type	VMT		eVMT		Energy Consumption (kWh)					
	Daily	Annual	Daily	Annual	Daily			Annual		
					Res	NonRes	Total	Res	NonRes	Total
PHEV10	41	14,965	10	3,650	2.8	0.7	3.5	1,022	256	1,278
PHEV20			20	7,300	5.6	1.4	7	2,044	511	2,555
PHEV40			30.6	11,169	8.6	2.1	10.7	3,127	782	3,909
BEV	29.5	10,768	29.5	10,768	8.3	2.1	10.3	3,016	754	3,770

The VISION fuel economies are based on the fuel economies from AEO and apply an on-road loss factor for each vehicle and technology category. For example, Table 36 below shows the ICE, HEV and EV fuel economy for 2013, 2020 and 2030. The analysis for electricity and petroleum consumption utilized the fuel economies for all years from 2011 to 2030. The vehicle fuel economies in the table below combined with the annual VMT above result in slightly different annual electricity consumption, shown in the table above.

Table 36. Vehicle Fuel Economies

Fuel Economy (mi/GGE)	2013	2020	2030
Auto ICE	28.8	34.7	42.8
Auto HEV	43.0	50.9	62.0
Auto EV	117	117	129
LT ICE	21.8	25.2	31.8
LT HEV	33.6	36.7	48.9
LT EV	88.4	94.4	113

Criteria pollutant emission reductions were calculated by determining the gasoline VMT from Table 35 and vehicle population, and using LEV III emission regulations to produce grams per mile emission factors for NMOG+NOx and PM. Table 37 below shows the selected emission factors for vehicles purchased in 2013, 2020, and 2030. Emission factors were calculated for each sales year from 2011 to 2030.

Table 37. Gasoline VMT Criteria Pollutant Emission Factors

Emissions (g/mi)	2013	2020	2030
PM	0.01	0.0051	0.001
NMOG+NOx	0.119	0.074	0.03

Forklifts. The forklift forecast is based on the ITA Market Intelligence report[82] which includes annual sales from 1988 to 2012 of electric rider (Class 1 and 2), motorized hand (Class 3), and internal combustion engine (Class 4 and 5) forklifts. Based on an estimate of 3,159 operating hours per year per forklift and an estimated lifetime of 24,000 hours for electric forklifts and 21,000 hours for conventional forklifts, forklift lifetimes of 8 and 7 years were estimated for electric and conventional forklifts, respectively. Using the sales data and the estimated lifetimes, US populations were estimated for 1997 to 2012. Based on US Census population data, California is approximately 12.12% of the United States and it is assumed that a similar percentage of US forklifts are in California. This is the same methodology used by CARB in the Low Carbon Fuel Standard to determine the quantity of electric forklifts when determining LCFS credits.

Pre-recession (1997 to 2007) annual increases in forklift (Class 1, 2, 4, and 5) sales were used to project total forklift populations from 2012 to 2020 and 2030. For the “In Line with Current Adoption” case the annual growth rate from 1997-2012 of electric rider populations was used to determine populations of electric riders in 2020 and 2030. It is also assumed that all electric forklifts are within the <120 horsepower (hp) category. For the "Aggressive Adoption" case, it was assumed that a similar mandate for shore power at the ports was instituted and 60% of Class 1, 2, 4, and 5 forklifts by 2020 and 80% by 2030 would be electric. It is assumed in the "Aggressive Adoption" case that <120 and 120 to 175 horsepower forklifts would be replaced with electric. Based on CARB 2009 forklift populations by horsepower category, the incremental populations of electric forklifts were divided between <120 hp (86.1%) and 120 to 175 hp (13.9%) where electric forklifts designated as <120 hp displaced gasoline and LPG forklifts and 120-175 hp displaced diesel forklifts. The medium case forecast was chosen as halfway in between the “In Line with Current Adoption” and "Aggressive Adoption" cases for total incremental populations and <120 hp and 120 to 175 hp populations.

Based on research into electric and conventional fueled forklifts from Nissan, CAT and Kalmar, 6,000 to 8,000 lb forklifts were chose as representative of <120 hp and 19,800 lb forklifts were chose as representative of 120 to175 hp. The 6,000 to 8,000 lb lifts had an average battery pack size of 43.6 kWh (Nissan and Crown Spec sheets) and the 19,800 lb lifts had an average battery pack size of 124 kWh (Kalmar spec sheets). In addition, Class 3 forklifts had an average battery pack size of 12.5 kWh. ICF used previous CalETC assumptions of 3,150 hours of operation (525 6 hr shifts) per year which were based on

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[82] http://www.indtrk.org/wp-content/uploads/2013/04/US-Factory-Shipments-Through-2012.pdf

a 50/25/25 breakdown of single, double and triple shift forklift operation. It is assumed that each shift is 6 hours and that each battery uses 80% of its charge per shift. This resulted in 18,312 kWh per year for the 6,000 to 8,000 lb lift and 52,808 kWh per year for the 19,800 lb lifts. Displaced petroleum was calculated by taking the electricity consumed and converting it to gasoline and diesel using CARB fuel consumption factors in pounds per brake horsepower-hour (lb/bhp-hr) and the energy density of gasoline and diesel.

GHG emission reductions were calculated using the values in Table 32 and electricity consumed and gasoline and diesel displaced. Propane powers a substantial portion of the smaller forklifts and over 50% of all Class 4 and 5 forklifts, which includes all internal combustion forklifts.[83] GHG emissions for propane are assumed to be similar to gasoline since most propane consumed in California is petroleum based and requires the same crude production and refining processes. Criteria pollutant emission factors for gasoline and LPG lifts are based on the EPRI report 1007455 (consistent with the previous CalETC report) and diesel emission factors from OFFROAD 2011. The criteria pollutant emission factors are shown in Table 38 below. Electric consumed was converted to bhp and multiplied by the factors noted below to determine criteria pollutants reduced.

Table 38. Forklift Criteria Pollutant Emission Factors

	NOx (g/bhp-hr)	ROG (g/bhp-hr)	PM (g/bhp-hr)
Gasoline/LPG	0.6	0.3	0.015
Diesel – 2010	2.45	0.1	0.14
Diesel – 2020	0.27	0.05	0.01
Diesel – 2030	0.27	0.05	0.01

Truck Stop Electrification (TSE). Currently in California there are an estimated 262 electrified parking spaced as identified by the DOE Alternative Fuels Database and shorepower documentation under the DOE Shorepower Project that was funded by ARRA. Based on an SCE inventory, there are 9,282 truck parking spaces in California. The “In Line with Current Adoption” case assumes that there are still only 262 electrified parking spaces in 2020 and 2030 and also assumes that the capacity factor for each space increases from the current value of 0.28 to 0.5 in 2020 and 0.6 in 2030. The "Aggressive Adoption" case assumes a port-like mandate with 30% of spaces electrified in 2020 and 50% in 2030, and increases in the capacity factor to 0.67 in 2020 and 0.75 in 2030. The medium case is assumed to be halfway in between the “In Line with Current Adoption” and "Aggressive Adoption" cases.

The average load of 1.39 kW while plugging in (from the previous CalETC study) was combined with the value of 0.21 gallons of diesel per hour from the CARB Anti-Idling Regulation Initial Statement of Reasons (ISOR) and the number of spaces and capacity factors to determine electricity consumed and

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[83] http://www.afdc.energy.gov/uploads/publication/2013_Propane_Market_Outlook_1_.pdf

fuel displaced. Based on the CARB HDV Idling Regulation ISOR combined with new LEV III regulations for PM, the following emissions factors in Table 39 were used. The factors in the ISOR for NOx+NMHC were assumed to be 95% NOx and 5% NMHC based on data from the Bay Area Air Quality Management District (BAAQMD).[84]

Table 39. TSE Criteria Pollutant Emission Factors

	NOx (g/hr)	ROG (g/hr)	PM (g/ hr)
2013	14.3	0.76	0.87
2020	14.3	0.76	0.048
2030	14.3	0.76	0.048

Transport Refrigeration Units (TRUs). The TRU forecasts are based on the CARB TRU ISOR.[85] The ISOR has projected 2013 populations of eTRUs and based on conversations with CARB staff only 1% are semis (25 to 50 hp) and the remaining are bobtails (11 to 25 hp). The ISOR also contains California-based and out-of-state TRUs. Forecasts of TEU (truck equivalent unit) from the San Pedro Bay Container Forecast[86] were used to project 2020 and 2030 TRUs. The "In Line with Current Adoption" case maintains a consistent 11% market share of eTRUs and a 99/1 ratio of bobtails to semis. The "In Between" case assumes a port-like mandate for California-based TRUs with 30% and 80% electric in 2020 and 2030. The forecast projects that 75% and 100% of bobtails will be all electric in 2020 and 2030 respectively, <11 hp TRUs will be 25% and 80% electric, and semis will be 18% and 75% electric in 2020 and 2030. The "Aggressive Adoption" case includes the same projections for California-based TRUs and adds the out-of-state TRUs which are all semis. The same percent penetrations of 18% and 75% in 2020 and 2030 as the California-based were used.

Electricity consumption calculations included average electricity loads from the previous CalETC study of 8, 6 and 2.3 kW for the 25 to 50, 11 to 25 and <11 hp categories. The annual hours of operation are based on the CARB TRU ISOR and only 30% of the hours are at the facility and have the potential for e-standby. The fuel consumption values of 0.21, 0.62 and 0.85 gal/hr for <11 hp, 11 to 25 hp and 25 to 50 hp are based on the previous CalETC study. Criteria pollutant emission factors are based on the CARB TRU database with the only adjustments made for PM emission factors to comply with LEV III and are either 0.01g/bhp-hr or 85% emission reductions, whichever is higher. The criteria pollutant emission factors are shown in Table 40.

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[84] http://www.baaqmd.gov/~/media/Files/Engineering/policy_and_procedures/Engines/EmissionFactorsforDieselEngines.ashx

[85] http://www.arb.ca.gov/regact/2011/tru2011/truisor.pdf

[86] "San Pedro Bay Container Forecast Update," The Tioga Group, Inc – HIS Global Insight, July 2009. http://www.portoflosangeles.org/pdf/SPB_Container_Forecast_Update_073109.pdf

Table 40. TRU Criteria Pollutant Emission Factors

	NOx (g/bhp-hr)			PM (g/bhp-hr)			ROG (g/bhp-hr)		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
25-50 hp	4.8	2.9	2.9	0.16	0.01	0.01	0.1	0.1	0.1
11-25 hp	4.8	4.37	4.37	0.19	0.029	0.029	0.1	0.1	0.1
<11 hp	4.37	4.37	4.37	0.19	0.029	0.029	0.1	0.1	0.1

Shore Power. The overall “In Line with Current Adoption”, “In Between” and "Aggressive Adoption" forecasts contain individual forecasts for each type of ship that could use alternative marine power: container, reefer, cruise ships and tanker ships. Tanker ships are included in the analysis even though the only fleets affected by the regulation include those composed of container vessels, passenger vessels, or refrigerated cargo vessels. Electrification of tanker ships is only included in the "Aggressive Adoption" case. The container, reefer and cruise ship visits forecasted are consistent with CEC forecasts in the *California Energy Demand 2014-2024 Revised Forecast*[87].

The container ship forecasts are based on Wharfinger data[88] for container visits at the ports of Los Angeles/Long Beach, Oakland, and San Diego, using the San Pedro Bay Container Forecast Update to project future container ship visits out to 2020 and 2030.[89] Two current regulations and requirements are in place for shore power. The At-Berth Regulation requires fleets to meet 50% shorepower visit requirement starting 2014, 70% by 2017, and 80% by 2020. Any berths that received Prop 1b funding must exceed the At-Berth Regulation requirements and have 50% of total visits electrified in 2013, 60% by 2014, 80% by 2017 and 90% by 2020. The “In Line with Current Adoption” case assumes minimum compliance with 50%, 80% and 80% of fleet visits (approximately 74% of total visits from 2004 CARB data electrified in 2013, 2020, and 2030. The “In Between" case assumes 50%, 80% and 80% of total visits are electrified in 2013, 2020 and 2030 and the "Aggressive Adoption" case assumes 50%, 90% and 90% of total visits in 2013, 2020, and 2030 which matches the Proposition 1B funding requirements for all berths and visits..

The reefer ship visit forecasts are for Port Hueneme. Reefer ships are refrigerated cargo ships typically used to transport perishable commodities. For all three cases it is assumed that 50%, 80% and 80% of all visits will be electrified since three of the five berths at Port Hueneme have received Proposition 1B funding and have the additional requirements stated above.

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[87] “California Energy Demand 2014-2024 Revised Forecast: Volume 1,” CEC, September 2013. CEC-200-2013-004-SD-V1-REV

[88] Wharfinger data utilized for this study is data collected by keepers and owners of each of the wharfs identified and supplied to CARB as part of the shore power regulation. CARB supplied the data to ICF via email communication.

[89] http://www.portoflosangeles.org/pdf/SPB_Container_Forecast_Update_073109.pdf

For cruise ships at the ports of Los Angeles (LA), Long Beach (LB), San Diego (SD) and San Francisco (SF), CEC estimates for total visits and electrification in 2013 were utilized and an estimated 5% annual increase was applied until 2030 for total cruise ship visits. In the "In Line with Current Adoption" case, it is assumed that number of electrified visits in 2013 stays the same in 2020 and 2030 for the ports of LA, LB and SD. In the "Aggressive Adoption" case, it is assumed that the number of electrified visits is increased by an annual rate of 5% from 2013 to 2020 and 2030. The "In Between" cases is halfway between the "In Line with Current Adoption" and "Aggressive Adoption" cases. For the Port of SF, it is assumed for all cases that 0, 80, and 80 electrified visits occur in 2013, 2020 and 2030 respectively based on projections made by the port staff.

For tanker ships, total visits reported in the CARB Evaluation of Cold-Ironing Vessels at California Ports[90] were escalated to 2020 and 2030 based on petroleum fuel consumption from the CEC Fuels Forecast. Electrification of tanker visits is assumed to be zero in the "In Line with Current Adoption" and "In Between" cases. In the "Aggressive Adoption" case, it is assumed that tanker ships comply with the regulation and 80% of all visits will be electrified in 2020 and 2030.

Data from the Port of Long Beach 2011 emissions inventory[91] was used to determine electrical load and berthing time for each type of ship visit. The weighted average total berth time, hoteling time and load shown in Table 41 below were used to calculate the total electricity consumption in 2013, 2020 and 2030.

Table 41. Shore Power Berth Time, Hoteling Time and Electric Load

Vessel	Total Berth Time (hrs)	Hoteling Time (hrs)	Electric Load (MW)
Container Ships	47	45	1.168
Reefer	60	58	0.630
Cruise/Passenger	14.8	12.8	5.445
Tanker	42.6	40.6	0.679

Diesel fuel consumption reductions are calculated by converting electricity consumed to diesel based on the assumption of displacing 35% efficient diesel auxiliary engines. GHG emission reductions are based on factors in Table 32. Criteria pollutant emissions are calculated based on factors from the CARB Evaluation of Cold-Ironing Vessels at California Ports[92] shown in Table 42 below.

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[90] "CARB Evaluation of Cold-Ironing Vessels at California Ports (Draft Report): Appendix C," http://www.arb.ca.gov/ports/marinevess/documents/coldironing0306/execsum.pdf

[91] http://www.polb.com/civica/filebank/blobdload.asp?BlobID=10194

[92] "CARB Evaluation of Cold-Ironing Vessels at California Ports (Draft Report): Appendix C," http://www.arb.ca.gov/ports/marinevess/documents/coldironing0306/execsum.pdf

Table 42. Cold-Ironing Criteria Pollutant Emission Factors

Pollutant	Diesel Engine Emission Factor (g/kW-hr)
NOx	13.6
PM	0.25
HC (VOC)	0.4

Port Cargo Handling Equipment. Forecasts for port cargo handling equipment (CHE) were made based on three different technologies that could be electrified: yard tractors, forklifts and RTG cranes. The baseline population for these technologies for 2010 is from the 2011 cargo handling equipment information in Appendix B[93]. Forecasts for total populations in 2020 and 2030 for each of the three technologies were made using the San Pedro Bay Container Forecast Update similar to TRUs. The “In Line with Current Adoption” case assumes a 10% electric technology market penetration in 2020 and 2030 for yard tractors and forklifts and 5% in 2020 and 10% in 2030 for RTG cranes. The lower 2020 electric penetration for RTG cranes is due to increased issues around RTG expansion and planning required for their acceptance. The "Aggressive Adoption" case uses a port like mandate with 40% market penetration in 2020 and 80% in 2030. The "In Between" case is in the middle of the “In Line with Current Adoption” and "Aggressive Adoption" cases.

Fuel consumption of both conventional and electric yard hostlers (192 kWh/shift) and RTG cranes (417 kWh/shift) is based on a 2012 TIAX study[94]. The fuel consumption for forklifts is based on the forklift analysis and assumes an 8,000 lb capacity for each lift. GHG emission reductions are based on factors in Table 32. Criteria pollutant emission factors are based on the CARB cargo handling equipment inventory model (2011) and the TIAX report for average horsepower of the conventional technologies. Criteria pollutant emission factors for CHE can be found in Table 43 below.

Table 43. Port CHE Criteria Pollutant Emission Factors

	NOx (g/bhp-hr)			PM (g/bhp-hr)			ROG (g/bhp-hr)		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
Yard Tractors	2.45	0.27	0.27	0.11	0.01	0.01	0.1	0.05	0.05
Forklifts	2.45	0.27	0.27	0.14	0.01	0.01	0.1	0.05	0.05
RTG Cranes	2.45	0.27	0.27	0.11	0.01	0.01	0.12	0.05	0.05

[93] http://www.arb.ca.gov/regact/2011/cargo11/cargoappb.pdf

[94] “Roadmap to Electrify Goods Movement Subsystems for the Ports of Los Angeles and Long Beach,” Consultant Report by TIAX LLC for the Ports of LA and LB, February, 2012.

Airport Ground Support Equipment (GSE). Forecasts for total pieces of GSE in California are based on the ACRP report[95] of national GSE using the Federal Aviation Administration (FAA) national and California enplanements[96] for 2010 to scale for California GSE. The FAA enplanement data shows California had approximately 11% of total national enplanements in 2010. The FAA forecasts for national and total enplanements were used to scale the 2010 GSE population to 2020 and 2030 and the same California proportion of the national average (11%) was used to determine total California GSE. The 2010 electrified population was estimated by using the Los Angeles World Airports Sustainability Plan[97] which indicates that 100% of Ontario Airport GSE and 24% of LAX is electrified, and information from Southwest that all of its GSE at San Jose International Airport (SJC) is electrified (approximately 50% of gates and enplanements at SJC). Based on the FAA enplanement data for these three airports, approximately 15.8% of the GSE in California was electrified in 2010. The “In Line with Current Adoption” case assumes that only LAX increased its GSE population from 2010 to include 100% of push tractors, container loaders, belt loaders and baggage tractors which make up 56% of individual gate GSE. This results in a total California GSE penetration of 23.7% in 2020 and 2030. The "Aggressive Adoption" case assumes a port-like mandate with 40% of GSE being electrified in 2020 and 60% in 2030. This is consistent with EPRI’s estimate that approximately 30% of airport GSE could be electrified in 2015. The “In Between” case is directly in between the other two cases.

The electricity consumption was calculated by using the EPRI Technical Update[98] of GSE electrical load for narrow-body and wide-body gates combined with the CARB OFFROAD model for activity (hrs/yr). Based on a report by The MITRE Corporation[99], only 20.8% of planes are wide body. This data was used to assume that 20.8% of gates in California are wide-body gates. ICF assumed the same proportion of narrow-body and wide-body gates GSE were electrified. The consumption per gate was escalated to 2020 and 2030 based on the ratio of increased enplanements and the assumption that there would be no new gates to handle the increased enplanements but rather higher utilization of the existing gates.

Displaced petroleum was calculated by taking the electricity consumed and converting to gasoline and diesel using CARB fuel consumption factors in lb per brake horsepower-hr (lb/bhp-hr) and the energy density of gasoline and diesel. GHG emission reductions were based on emission factors from Table 32. The weighted average of CARB emission factors by GSE horsepower share from the OFFROAD model was used to calculate criteria pollutant emissions. Criteria pollutant emission factors can be found in Table 44 below.

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[95] ACRP Report 78: Airport Ground Support Equipment (GSE): Emission Reduction Strategies, Inventory, and Tutorial (2012)

[96] http://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/

[97] http://www.lawa.org/uploadedFiles/LAWA/pdf/Sustainability%20Plan%20%28Final%29.pdf

[98] EPRI Technical Update: Alternative Ground Support Equipment Electrification Analysis (2010)

[99] https://www.mitre.org/sites/default/files/pdf/bhadra_analysis.pdf

Table 44. Airport GSE Criteria Pollutant Emission Factors

	NOx (g/bhp-hr)	ROG (g/bhp-hr)	PM (g/ bhp-hr)
Gasoline, 2013-2030	1.79	0.072	0.297
Diesel - 2013	3.08	1.34	1.34
Diesel - 2020	0.17	0.01	0.01
Diesel - 2030	0.1	0.07	0.07

High Speed Rail. The forecasts for High Speed Rail were based on the 2012 Business Plan[100] with the “In Line with Current Adoption” case only taking into account the initial operating section (IOS) in 2020 and 2030, the “In Between" case including the IOS in 2020 and Bay to Basin in 2030 and the "Aggressive Adoption" case including the IOS in 2020 and the Phase 1 Blended in 2030. Figure 9 shows the high speed rail operating scenarios. The total train set miles and service were modeled using the train schedule in the business plan and the energy consumption factor of 54 kWh/train set mile for an 8 car train.[101] Passenger-miles were calculated using the estimated passengers, percent of interregional travel and the estimated amount of track (mi) in each year from the business plan.

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[100] http://www.hsr.ca.gov/About/Business_Plans/2012_Business_Plan.html

[101] http://www.hsr.ca.gov/docs/programs/merced-fresno-eir/final_EIR_MerFres_TA3_06C_EnergyUse.pdf

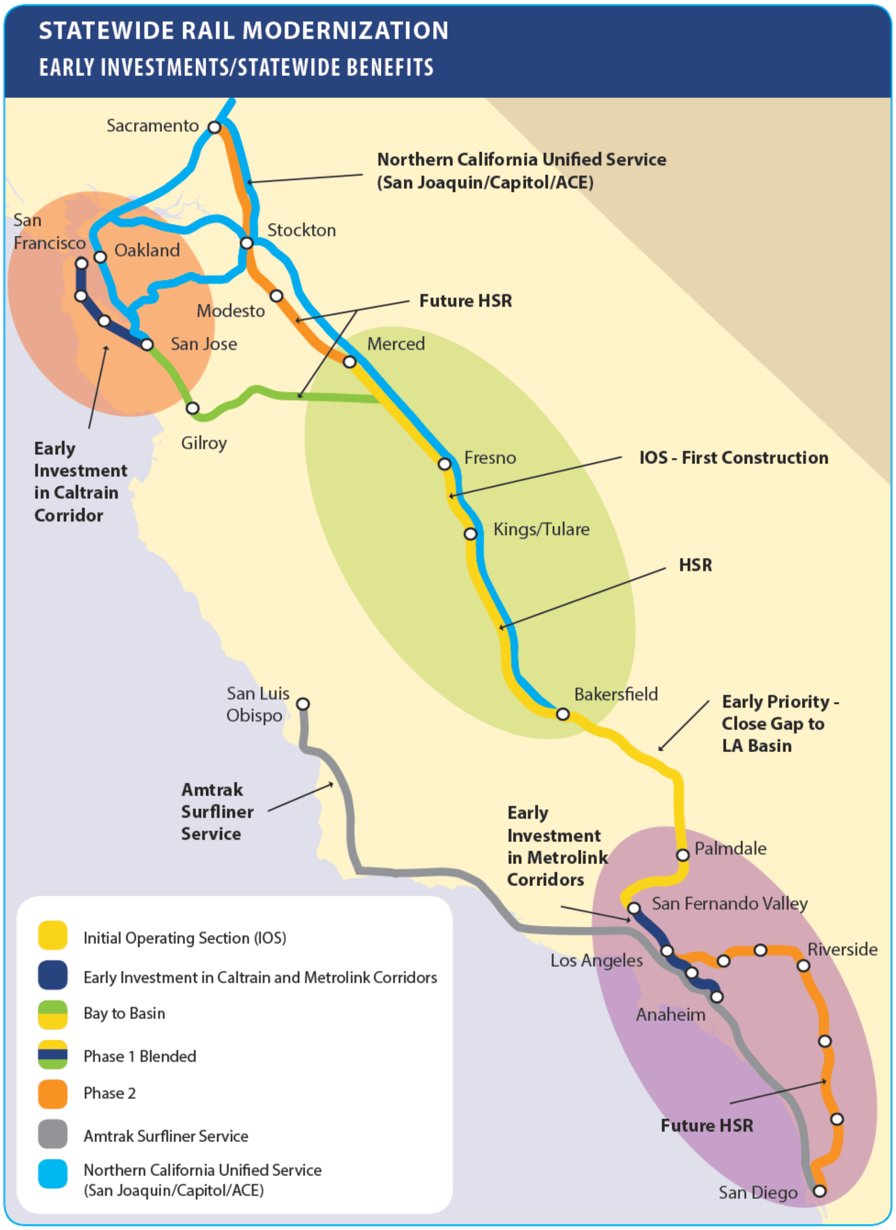

Figure 9. High-Speed Rail Operating Scenarios[102]

Petroleum (diesel) consumption displaced is calculated by assuming that high speed rail displaces transit buses and assuming that interregional buses would have 50% occupancy. The total number of passenger-miles is converted to fuel consumption by using the National Transit Database to determine the fuel consumption per passenger-mile at 50% occupancy of California buses. The factors in Table 32 were used to calculate GHG reductions. Criteria pollutant emission reductions were determined by using the factors in Table 45 below from the EMFAC model. The ratio of passenger-miles/bus-miles at 50%

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[102] http://www.hsr.ca.gov/docs/about/legislative_affairs/HSR_Reducing_CA_GHG_Emissions_2013.pdf

occupancy was used to calculate the total emissions. This methodology is simpler than that used by the High Speed Rail Authority, which includes displacing airline and passenger car miles.[103] The GHG emissions reductions from this analysis are lower than those from the High Speed Rail Authority due to the assumptions for electricity production. The High Speed Rail Authority assumes all renewable electricity, while this analysis assumes marginal electricity from 33% renewables and 67% natural gas. The GHG emission reduction calculations would be similar if the same electricity mix was used.

Table 45. Transit Bus Criteria Pollutant Emission Factors

	NOx (g/mi)	ROG (g/mi)	PM (g/mi)
Transit Bus	0.586	0.0304	0.0338

Light, Heavy and Commuter Rail. Light, Heavy and Commuter Rail analysis includes the rail systems in Table 46 below.

Table 46. Rail Systems Included in the Light, Heavy and Commuter Rail Analysis

Light Rail	Heavy Rail	Commuter Rail
LA Metro – Light	BART	Electrified Caltrain
Sacramento	LA Metro Subway	
San Diego		
SF – Cable Car		
SF – Light Rail		
SF – Trolly Bus		
Santa Clara VTA		

Statistics from the National Transit Database were used to calculate the “In Line with Current Adoption”, “In Between” and "Aggressive Adoption" cases for passenger-miles and resulting electricity consumption. The “In Line with Current Adoption” case for Light and Heavy Rail uses the passenger-miles per track mile from 2011 for each system and takes into account planned increases in track length in 2020 and 2030 to calculate increases in passenger-miles in 2020 and 2030. The "Aggressive Adoption" case takes into account the trends in passenger-miles per track mile from 2007 to 2011 and continues these trends when positive (if negative the 2011 passenger-miles per track mile factor is used) with the planned increases in track length shown in Table 47 below.

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[103] http://www.hsr.ca.gov/docs/about/legislative_affairs/HSR_Reducing_CA_GHG_Emissions_2013.pdf

Table 47. Planned Increases in Track Length

Light/Heavy Rail Lines	Starting Track Length (miles)	Increased Track Length (miles) and Year
Los Angeles Light Rail	116.3	8.6 (2012); 6.6 (2015); 11 (2016); 8.5 (2018); 2 (2019); 1.9 (2020); 12 (2025)
Sacramento	73.4	1.1 (2012); 12.8 (2021)
San Diego	102.6	11 (2018)(
San Francisco Light Rail	103.5	1.7 (2019)
Santa Clara	79.6	10 (2018); 6 (2030)
Los Angeles Heavy Rail	34.1	
BART	267.6	3.2 (2014); 5.4 (2015); 16 (2018)

The “In Between” case is directly in between the “In Line with Current Adoption” and "Aggressive Adoption" cases. The “In Line with Current Adoption” case for commuter rail is zero, assuming that Caltrain would not be electrified. The “In Between” case scales the National Transit Database passenger-miles with the Caltrain 2014 Strategic Plan[104] estimate for passengers until 2018 (the last year in the plan) and uses the 0.8% annual growth from 2007 to 2011 to forecast the 2018 estimate of passenger-miles to 2020 and 2030. The "Aggressive Adoption" case uses a linear project of the estimated 2014 to 2018 passenger-miles to 2020 and 2030.

Electricity consumption for commuter rail is calculated using the estimated passenger-miles and the kWh/passenger-mile for the SEPTA (Southeastern Pennsylvania Transportation Authority) electrified commuter rail from the NTD. The electricity consumption for light and heavy rail is calculated using the 2011 kWh/passenger-mile from the NTD for each system and the forecasted passenger-miles. Diesel displaced by electrified commuter rail is based on the average diesel consumption per passenger-mile for 2009 to 2011 from NTD for the Caltrain and the projected passenger-miles. Displaced conventional fuel (either diesel or natural gas) is based on the average diesel or natural gas consumption per passenger-mile for the local transit bus fleet for each rail system and the projected passenger-miles.

The factors in Table 32 were used to calculate GHG reductions. Criteria pollutant emission reductions were determined by using the factors in Table 48 below from the EMFAC model for diesel urban bus. The state average ratio of passenger-miles to revenue-miles from the NTD was used convert passenger-miles to bus miles for the calculation of total criteria pollutants.

Table 48. Transit Bus Emission Factors

	NOx (g/mi)	ROG (g/mi)	PM (g/mi)
Transit Bus	0.586	0.0304	0.0338

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[104] http://www.caltrain.com/projectsplans/Plans/CaltrainStrategicPlan-2014.html

Dual Mode Catenary Trucks on I-710 / SR 60. The forecasts for electricity consumption and displacement of petroleum, GHG and criteria pollutant emissions is based on the annual average daily traffic (AADT) of heavy duty trucks from the California Department of Transportation (DOT) on I710 and SR-60[105] for 2009 to 2011. Forecasts of TEU from the San Pedro Bay Container Forecast are used to project AADT to 2020 and 2030. The “In Line with Current Adoption” case assumes that the catenary system is not built, with zero electrification. The “In Between” case only considers the potential electrification of the proportion of trucks making frequent or semi-frequent trips to the Ports of Los Angeles or Long Beach and only on the I-710. Based on Port of Long Beach data[106], this is approximately 80.7% of trips to the port and therefore is assumed to be the same percentage of AADT on the I710. The “In Between" case assumes 35% of frequent and semi-frequent truck trips are electrified in 2020 and 100% in 2030. The "Aggressive Adoption" case forecasts that all AADT have the potential to be electrified and 35% and 100% of all I-710 truck trips could be electrified in 2020 and 2030. The "Aggressive Adoption" case also forecasts that 65% of SR-60 trips will be electrified in 2030. The truck miles per AADT of 15.51 for I-710 and 32.58 for SR-60 were used to convert truck trips to truck miles.

Electricity consumption for the “In Between” case is based on the “In Line with Current Adoption” estimate of 2.7 kWh/truck-mile and the "Aggressive Adoption" case electricity consumption is based on the high estimate of 3.0 kWh/truck-mile.[107] Displaced diesel consumption is based on a fuel economy of 5.85 miles per gallon from EMFAC 2011 in 2020 and 2030 for heavy-duty class 8 trucks and forecasted truck-miles.

The factors in Table 32 were used to calculate GHG reductions. Criteria pollutant emission reductions were determined by using the factors for in-use and idling in Table 49 below from the EMFAC model for heavy-duty class 8 trucks. The weighted average of the Port of Long Beach daily trips per truck[108] was used to convert AADT to number of trucks for calculating the idling emissions.

Table 49. Heavy-Duty Class 8 Truck Criteria Pollutant Emission Factors

	NOx In-Use (g/mi)	NOx Idle (g/vehicle/day)	ROG In-Use (g/mi)	ROG Idle (g/vehicle/day)	PM In-Use (g/mi)	PM Idle (g/vehicle/day)
2020	1.002	30.49	0.136	5.87	0.0402	0.0787
2030	1.003	30.49	0.137	5.87	0.0400	0.0787

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[105] http://traffic-counts.dot.ca.gov/

[106] http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3371

[107] Memo from Brian Burkhard (Transpo Group) to the Gateway COG and LAMTA, “Truck Catenary System Update to Transpo Group’s July 11 Memo,” August 28, 2012.

[108] http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3371

Medium-Duty Vehicles. The forecast of medium-duty vehicles is based on an ICF developed penetration of three EMFAC vehicle classes – including light-heavy duty trucks (two classes) and medium duty vehicles (Classes 2 and 3). The forecasts are based on an S-curve like adoption out to 2030, linked to new vehicles sales. ICF extracted vehicle populations from EMFAC and estimated annual new vehicles sales. Vehicle retirement was accounted for based on survivability profiles extracted from EMFAC. ICF made a subjective determination of the split between PHEVs and BEVs in each of the “In Line with Current Adoption”-, "In Between"-, and "Aggressive Adoption"-cases, with the latter having the most aggressive deployment of fully electric vehicles. In most cases, it was assumed that approximately 90% of vehicles deployed would be PHEVs; however, in the "Aggressive Adoption" case this was decreased to around 50%. The “In Line with Current Adoption”, "In Between", and "Aggressive Adoption" cases looked to achieve 5%, 10% and 50% of sales in 2030 which would achieve 1.5%, 2.9% and 13.4% of the population.

Electricity consumption was estimated based on an EER value of 3.4, provided by CARB for medium-duty electric vehicles.

The factors in Table 32 were used to calculate GHG reductions. Criteria pollutant emission factors were weighted based on the VMT and population of each of the vehicle classes considered.

Table 50. Medium-Duty Vehicle Criteria Pollutant Emission Factors

	NOx In-Use (g/mi)	NOx Idle (g/vehicle/day)	ROG In-Use (g/mi)	ROG Idle (g/vehicle/day)	PM In-Use (g/mi)	PM Idle (g/vehicle/day)
2020	0.538	0.242	0.067	0.090	0.005	0.003
2030	0.268	0.243	0.030	0.086	0.004	0.003

Heavy-Duty Vehicles. The forecast of heavy-duty vehicles is based on an ICF developed penetration of 23 EMFAC vehicle classes – including medium-heavy duty trucks (seven vehicle classes), heavy-heavy duty trucks (11 vehicle classes) and buses (five vehicle classes). The forecasts are based on an S-curve like adoption out to 2030, linked to new vehicles sales. ICF extracted vehicle populations from EMFAC and estimated annual new vehicles sales. Vehicle retirement was accounted for based on survivability profiles extracted from EMFAC. ICF made a subjective determination of the split between PHEVs and BEVs in each of the “In Line with Current Adoption”-, "In Between"-, and "Aggressive Adoption"-cases, with the latter having the most aggressive deployment of fully electric vehicles. In most cases, it was assumed that approximately 90% of vehicles deployed would be PHEVs; however, in the "Aggressive Adoption" case this was decreased to around 50%.

The “In Line with Current Adoption” case includes port trucks and buses increasing to a 5% sales rate by 2030. The "In Between" case includes all medium-heavy and heavy-heavy duty market segments with 10% sales in port trucks and buses and 5% sales for the remaining market segments in 2030. The

"Aggressive Adoption" case includes 50% sales for buses, 25% sales for port trucks and 15% sales for the remaining segments in 2030.

Electricity consumption was estimated based on an EER value of 2.7, provided by CARB for heavy-duty electric vehicles.

The factors in Table 32 were used to calculate GHG reductions. Criteria pollutant emission factors were weighted based on the VMT and population of each of the vehicle classes considered.

Table 51. Heavy-Duty Vehicle Criteria Pollutant Emission Factors

	NOx In-Use (g/mi)	NOx Idle (g/vehicle/day)	ROG In-Use (g/mi)	ROG Idle (g/vehicle/day)	PM In-Use (g/mi)	PM Idle (g/vehicle/day)
2020	3.397	42.536	0.211	6.869	0.075	0.127
2030	1.927	43.024	0.176	7.929	0.066	0.118

Appendix B: Costing Analysis Methodology and Assumptions

This appendix lists the major assumptions and data sources for the costing analysis in addition to detailed tables showing the analysis. Analysis for each technology was done on an annualized basis to determine costs and benefits. This includes using a 5% discount rate and the corresponding vehicle life or infrastructure life to determine annualized capital costs. In each section below is a set of tables identifying the main data sources and assumptions, the annualized private cost and benefit analysis, and annual societal benefit and monetization of those benefits using the values in Table 16. The annual capital costs (costs), operating cost savings (private benefits) and monetized societal benefits (societal benefits) are then fed into the tables in Section 3 to develop the benefit-cost ratios.

PEVs. Table 52 below shows the main data sources and assumptions for the PEV cost analysis. The analysis and results in the following tables are per PEV. Table 53 and Table 55 use the values in Table 52 to develop the annualized cost and private benefits of passenger cars and light truck, respectively. Table 54 and Table 56 show the annual societal benefits per PEV and the monetization of these benefits. The cost analysis and societal benefits are for a new PEV purchased in 2013, 2020 or 2030 and are compared to a new ICE in 2013, 2020 or 2030, respectively. See Appendix A for the details on the calculation of societal benefits. The assumptions below do not apply to Section 2 and are for costing analysis only.

Table 52. PEV Data Sources and Assumptions

Variable	Value	Source
Incremental Vehicle Costs	Various Values for PC and LT that can be found in Table 53 and Table 55	ICF with consultation from CalETC
EVSE Cost	Various Values for LEV 1 and LEV 2 charges that can be found in Table 53 and Table 55	ICF International (2013), Bay Area Plug-in Electric Vehicle Readiness Plan
Ratio of LEV1 of LEV for PHEVs and BEVs	PHEV10 – 100% LEV 1 PHEV20 – 100% LEV 1 PHEV40 – 90% LEV 1; 10% LEV 2 BEV – 30% LEV 1 and 70% LEV 2	ICF and CalETC assumption
Federal Rebate[109]	100% Value in 2013 50% Value in 2020 0% in 2030	ICF Assumption
State Rebate	$2,500/$1,500 BEV/PHEV in 2013 $1,000/$500 BEV/PHEV in 2020 $0/$0 BEV/PHEV in 2030	ICF Assumption
Vehicle/EVSE Lifetime	10 years (no battery replacement)[110] / 20 years	ICF Assumption
Discount Factor	5%	ICF Assumption
Annual VMT/eVMT	See Table 35	ICF/CalETC Assumptions and EV Project Data
Fuel Economy	New Vehicle MPG for ICE, HEV and EV – See Table 36	AEO2013
CA Average Electricity Prices – TOU and Domestic	Population weighted average of PGE, SCE, SDGE and SMUD service territories for 2013, 2020 and 2030 found in Table 53 and Table 55	Extracted from the E3 model for used in the Phase 2 report based on rates supplied by each utility
Gasoline Prices	2013 - $3.89 2020 - $4.34 2030 - $5.10	CEC IEPR 2013
Maintenance Costs	Lifetime Oil Change: ICE - $2,365.82; PHEV - $1,474.02; BEV - $0 Total Routine Maintenance: ICE - $4,591.66; PHEV - $3.677.06; BEV - $3,094.66	ORNL[111] and Tesla[112]

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[109] Federal Rebate values used: $2,500 for PHEV10; $4,000 for PHEV20; $7,500 for PHEV40 and BEV

[110] Based on required battery warranty of 10yr/100,000 mi for BEV and 10yr/150,000 mi

[111] ORNL (2010), Plug-In Hybrid Electric Vehicle Value Proposition Study. Available online at: http://www.afdc.energy.gov/pdfs/phev_study_final_report.pdf

[112] Tesla Motors, 2007, "The 21st Century Electric Car", http://www.fcinfo.jp/whitepaper/687.pdf

Table 53. PEV Passenger Car Annualized Cost Analysis

Passenger Car	Conventional			PHEV10			PHEV20			PHEV40			BEV		
() Denotes Cost Savings	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030
Vehicle															
Incremental Price ($)	-	-	-	$5,717	$2,524	$399	$11,434	$5,047	$798	$15,206	$6,448	$1,597	$16,380	$5,151	$197
Federal Rebate ($/car)	-	-	-	$2,500	$1,250	$-	$4,000	$2,000	$-	$7,500	$3,750	$-	$7,500	$1,875	$-
State Rebate ($/car)	-	-	-	$1,500	$500	$-	$1,500	$500	$-	$1,500	$500	$-	$2,500	$1,500	$-
Total Capital ($)	-	-	-	$1,717	$774	$399	$5,934	$2,547	$798	$6,206	$2,198	$1,597	$6,380	$1,776	$197
Annual Costs ($/yr)	-	-	-	$222	$100	$52	$768	$330	$103	$804	$285	$207	$826	$230	$26
Infrastructure															
LEV1 Percent	-	-	-	100%	100%	100%	100%	100%	100%	70%	70%	70%	10%	10%	10%
LEV2 Percent	-	-	-	0%	0%	0%	0%	0%	0%	30%	30%	30%	90%	90%	90%
LEV 1 ($/charger)	-	-	-	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
LEV 2 ($/charger)	-	-	-	$1,757	$1,326	$1,326	$1,757	$1,326	$1,326	$1,757	$1,326	$1,326	$1,757	$1,326	$1,326
Total Capital ($)	-	-	-	$200	$200	$150	$200	$200	$150	$667	$538	$451	$1,601	$1,213	$1,053
Annual Costs ($/yr)	-	-	-	$16	$16	$12	$16	$16	$12	$54	$43	$36	$128	$97	$84
Operating Costs															
Annual Gas VMT (mi/year)	14,965	14,965	14,965	11,315	11,315	11,315	7,665	7,665	7,665	3,796	3,796	3,796	0	0	0
Annual eVMT (mi/yr)	-	-	-	3,650	3,650	3,650	7,300	7,300	7,300	11,169	11,169	11,169	10,768	10,768	10,768
Total Gasoline Consumption (GGE/yr)	520	432	350	263	222	183	178	151	124	88	75	61	0	0	0
Total Electricity Usage (kWh/yr)	-	-	-	1,006	1,007	908	2,012	2,015	1,817	3,079	3,083	2,780	2,968	2,972	2,680
TOU Grid Price ($/kWh)	-	-	-	$0.11	$0.18	$0.26	$0.11	$0.18	$0.26	$0.11	$0.18	$0.26	$0.11	$0.18	$0.26
Domestic Grid Price ($/kWh)	-	-	-	$0.18	$0.28	$0.40	$0.18	$0.28	$0.40	$0.18	$0.28	$0.40	$0.18	$0.28	$0.40
Gasoline Price ($/GGE)	$3.89	$4.34	$5.10	$3.89	$4.34	$5.10	$3.89	$4.34	$5.10	$3.89	$4.34	$5.10	$3.89	$4.34	$5.10
TOU Electricity Cost ($/yr)	-	-	-	$115	$180	$234	$231	$361	$469	$353	$552	$717	$341	$532	$691
Domestic Electricity Cost ($/yr)	-	-	-	$181	$280	$361	$362	$559	$722	$554	$855	$1,105	$534	$825	$1,065
Gasoline Cost	$2,024	$1,873	$1,783	$1,024	$964	$931	$693	$653	$631	$343	$323	$312	$-	$-	$-
Fuel Cost Avoided	$2,024	$1,873	$1,783	$2,024	$1,873	$1,783	$2,024	$1,873	$1,783	$2,024	$1,873	$1,783	$1,456	$1,348	$1,283
Incremental Fuel Cost TOU Rate	$-	$-	$-	$(885)	$(728)	$(617)	$(1,100)	$(859)	$(683)	$(1,327)	$(998)	$(753)	$(1,116)	$(816)	$(591)
Incremental Fuel Cost Dom. Rate	$-	$-	$-	$(819)	$(629)	$(491)	$(968)	$(661)	$(430)	$(1,126)	$(694)	$(365)	$(922)	$(523)	$(217)
Incremental Maint. Cost ($/lifetime)	-	-	-	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(3,863)	$(3,863)	$(3,863)
Incremental Maint. Cost ($/yr)	-	-	-	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(386)	$(386)	$(386)
Total Cost															
Annual Incremental Capital Costs	-	-	-	$238	$116	$64	$785	$346	$115	$857	$328	$243	$955	$327	$110
Annual Incremental Fuel TOU Rate Cost	-	-	-	$(885)	$(728)	$(617)	$(1,100)	$(859)	$(683)	$(1,327)	$(998)	$(753)	$(1,116)	$(816)	$(591)
Annual Incremental Fuel Dom. Rate Cost	-	-	-	$(819)	$(629)	$(491)	$(968)	$(661)	$(430)	$(1,126)	$(694)	$(365)	$(922)	$(523)	$(217)
Annual Incremental Maintenance Cost	-	-	-	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(386)	$(386)	$(386)
Total Annual Costs TOU Rate	-	-	-	$(827)	$(793)	$(734)	$(496)	$(694)	$(749)	$(651)	$(851)	$(691)	$(547)	$(875)	$(868)
Total Annual Costs Domestic Rate	-	-	-	$(761)	$(694)	$(608)	$(364)	$(495)	$(495)	$(450)	$(547)	$(303)	$(354)	$(582)	$(494)

Table 54. PEV Passenger Car Annualized Societal and Monetized Societal Benefits

Passenger Cars	PHEV10			PHEV20			PHEV40			BEV		
	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030
Annual Societal Benefits per Vehicle												
Petroleum Displacement (GGE/yr)	257	209	167	342	281	226	432	357	288	374	311	252
GHG Emission Benefits (MT/yr)	2.56	2.09	1.63	3.16	2.60	2.03	3.78	3.14	2.45	3.16	2.65	2.06
NOX (tons/yr)	2.27E-04	1.37E-04	4.67E-05	4.32E-04	2.56E-04	7.95E-05	6.49E-04	3.82E-04	1.14E-04	6.20E-04	3.64E-04	1.07E-04
PM (tons/yr)	3.61E-05	1.69E-05	6.64E-07	7.13E-05	3.31E-05	7.81E-07	1.09E-04	5.03E-05	9.04E-07	1.05E-04	4.84E-05	7.37E-07
VOC (tons/yr)	3.74E-04	2.58E-04	1.47E-04	6.51E-04	4.39E-04	2.33E-04	9.45E-04	6.31E-04	3.24E-04	8.88E-04	5.89E-04	2.97E-04
Monetized Societal Benefits per Vehicle												
Petroleum Displacement	$113.46	$90.82	$70.22	$150.91	$121.92	$94.98	$190.61	$154.87	$121.22	$165.17	$134.70	$105.75
GHG Emission	$28.19	$25.06	$26.14	$34.71	$31.21	$32.48	$41.61	$37.72	$39.20	$34.81	$31.75	$32.95
NOx	$1.06	$0.70	$0.28	$2.02	$1.30	$0.48	$3.03	$1.94	$0.70	$2.90	$1.85	$0.65
PM	$52.35	$27.92	$1.31	$103.44	$54.70	$1.54	$157.59	$83.08	$1.79	$151.62	$79.81	$1.46
VOC	$0.42	$0.31	$0.21	$0.73	$0.54	$0.33	$1.06	$0.77	$0.46	$0.99	$0.72	$0.42

Table 55. PEV Light Truck Annualized Cost Analysis

Light Truck	Conventional			PHEV10			PHEV20			PHEV40			BEV		
() Denotes Cost Savings	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030
Vehicle															
Incremental Price ($)	-	-	-	$7,509	$3,442	$1,027	$15,017	$6,884	$2,055	$20,142	$8,873	$3,280	$24,035	$8,251	$1,995
Federal Rebate ($/car)	-	-	-	$2,500	$1,250	$-	$4,000	$2,000	$-	$7,500	$3,750	$-	$7,500	$1,875	$-
State Rebate ($/car)	-	-	-	$1,500	$500	$-	$1,500	$500	$-	$1,500	$500	$-	$2,500	$1,500	$-
Total Capital ($)	-	-	-	$3,509	$1,692	$1,027	$9,517	$4,384	$2,055	$11,142	$4,623	$3,280	$14,035	$4,876	$1,995
Annual Costs ($/yr)	-	-	-	$454	$219	$133	$1,233	$568	$266	$1,443	$599	$425	$1,818	$632	$258
Infrastructure															
LEV1 Percent	-	-	-	100%	100%	100%	100%	100%	100%	70%	70%	70%	10%	10%	10%
LEV2 Percent	-	-	-	0%	0%	0%	0%	0%	0%	30%	30%	30%	90%	90%	90%
LEV 1 ($/charger)	-	-	-	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
LEV 2 ($/charger)	-	-	-	$1,757	$1,326	$1,326	$1,757	$1,326	$1,326	$1,757	$1,326	$1,326	$1,757	$1,326	$1,326
Total Capital ($)	-	-	-	$200	$200	$150	$200	$200	$150	$667	$538	$451	$1,601	$1,213	$1,053
Annual Costs ($/yr)	-	-	-	$16	$16	$12	$16	$16	$12	$54	$43	$36	$128	$97	$84
Operating Costs															
Annual Gas VMT (mi/year)	14,965	14,965	14,965	11,315	11,315	11,315	7,665	7,665	7,665	3,796	3,796	3,796	0	0	0
Annual eVMT (mi/yr)	-	-	-	3,650	3,650	3,650	7,300	7,300	7,300	11,169	11,169	11,169	10,768	10,768	10,768
Total Gasoline Consumption (GGE/yr)	687	593	471	336	309	232	228	209	157	113	104	78	0	0	0
Total Electricity Usage (kWh/yr)	-	-	-	1,326	1,242	1,039	2,652	2,483	2,077	4,058	3,800	3,178	3,912	3,663	3,064
TOU Grid Price ($/kWh)	-	-	-	$0.11	$0.18	$0.26	$0.11	$0.18	$0.26	$0.11	$0.18	$0.26	$0.11	$0.18	$0.26
Domestic Grid Price ($/kWh)	-	-	-	$0.18	$0.28	$0.40	$0.18	$0.28	$0.40	$0.18	$0.28	$0.40	$0.18	$0.28	$0.40
Gasoline Price ($/GGE)	$3.89	$4.34	$5.10	$3.89	$4.34	$5.10	$3.89	$4.34	$5.10	$3.89	$4.34	$5.10	$3.89	$4.34	$5.10
TOU Electricity Cost ($/yr)	-	-	-	$152	$222	$268	$304	$444	$536	$466	$680	$820	$449	$656	$791
Domestic Electricity Cost ($/yr)	-	-	-	$239	$345	$413	$477	$689	$826	$730	$1,054	$1,263	$704	$1,016	$1,218
Gasoline Cost	$2,672	$2,575	$2,400	$1,309	$1,339	$1,181	$887	$907	$800	$439	$449	$396	$-	$-	$-
Fuel Cost Avoided	$2,672	$2,575	$2,400	$2,672	$2,575	$2,400	$2,672	$2,575	$2,400	$2,672	$2,575	$2,400	$1,922	$1,853	$1,727
Incremental Fuel Cost TOU Rate	$-	$-	$-	$(1,211)	$(1,013)	$(951)	$(1,481)	$(1,223)	$(1,064)	$(1,767)	$(1,445)	$(1,184)	$(1,473)	$(1,197)	$(936)
Incremental Fuel Cost Dom. Rate	$-	$-	$-	$(1,124)	$(891)	$(806)	$(1,308)	$(979)	$(774)	$(1,502)	$(1,071)	$(740)	$(1,218)	$(836)	$(509)
Incremental Maint. Cost ($/lifetime)	-	-	-	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(1,806)	$(3,863)	$(3,863)	$(3,863)
Incremental Maint. Cost ($/yr)	-	-	-	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(386)	$(386)	$(386)
Total Cost															
Annual Incremental Capital Costs	-	-	-	$470	$235	$145	$1,249	$584	$278	$1,496	$642	$461	$1,946	$729	$343
Annual Incremental Fuel TOU Rate Cost	-	-	-	$(1,211)	$(1,013)	$(951)	$(1,481)	$(1,223)	$(1,064)	$(1,767)	$(1,445)	$(1,184)	$(1,473)	$(1,197)	$(936)
Annual Incremental Fuel Dom. Rate Cost	-	-	-	$(1,124)	$(891)	$(806)	$(1,308)	$(979)	$(774)	$(1,502)	$(1,071)	$(740)	$(1,218)	$(836)	$(509)
Annual Incremental Maintenance Cost	-	-	-	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(181)	$(386)	$(386)	$(386)
Total Annual Costs TOU Rate	-	-	-	$(921)	$(959)	$(987)	$(413)	$(820)	$(967)	$(451)	$(984)	$(904)	$86	$(854)	$(980)
Total Annual Costs Domestic Rate	-	-	-	$(834)	$(836)	$(842)	$(240)	$(575)	$(677)	$(186)	$(610)	$(460)	$342	$(494)	$(552)

Table 56. PEV Light Truck Annualized Societal and Monetized Societal Benefits

Light Trucks	PHEV10			PHEV20			PHEV40			BEV		
	2013	2020	2030	2013	2020	2030	2013	2020	2030	2013	2020	2030
Annual Societal Benefits per Vehicle												
Petroleum Displacement (GGE/yr)	350	285	239	459	384	314	574	490	393	494	427	339
GHG Emission Benefits (MT/yr)	3.51	2.88	2.42	4.25	3.64	2.96	5.04	4.44	3.53	4.18	3.77	2.94
NOX (tons/yr)	2.24E-04	1.37E-04	5.08E-05	4.18E-04	2.51E-04	8.07E-05	6.23E-04	3.72E-04	1.12E-04	5.93E-04	3.52E-04	1.03E-04
PM (tons/yr)	3.48E-05	1.62E-05	4.27E-07	6.85E-05	3.15E-05	2.04E-08	1.04E-04	4.77E-05	-4.10E-07	1.00E-04	4.57E-05	-5.99E-07
VOC (tons/yr)	4.23E-04	2.98E-04	1.86E-04	7.11E-04	4.93E-04	2.80E-04	1.02E-03	6.99E-04	3.79E-04	9.46E-04	6.49E-04	3.43E-04
Monetized Societal Benefits per Vehicle												
Petroleum Displacement	$154.58	$123.50	$100.50	$202.46	$166.68	$131.91	$253.21	$212.45	$165.21	$218.03	$185.18	$142.38
GHG Emission	$38.60	$34.54	$38.68	$46.76	$43.66	$47.29	$55.41	$53.32	$56.41	$45.97	$45.19	$47.03
NOx	$1.05	$0.70	$0.31	$1.95	$1.28	$0.49	$2.91	$1.89	$0.68	$2.77	$1.79	$0.63
PM	$50.53	$26.76	$0.84	$99.28	$51.98	$0.04	$150.96	$78.71	$(0.81)	$145.11	$75.50	$(1.19)
VOC	$0.47	$0.36	$0.26	$0.79	$0.60	$0.40	$1.14	$0.85	$0.54	$1.06	$0.79	$0.49

Forklifts. Table 57 below shows the main data sources and assumptions for the forklift cost analysis. All analyses and results in the following tables are per forklift. The 8,000 lb forklift is assumed to operate on gasoline and the 19,800 lb forklift to operate on diesel. Table 59 uses the values in Table 57 to develop the annualized cost and private benefits. Table 60 shows the annual societal benefits per forklift and the monetization of these benefits. The cost analysis and societal benefits are for a new forklift purchased in 2013 and are compared to a new ICE forklift 2013. See Appendix A for the details on the calculation of societal benefits for forklifts.

Table 57. Forklift Data Sources and Assumptions

Variable	Value	Source
Vehicle, Battery and Charger Costs	Values in Table 59	Direct quotes from dealers – Hawthorne and SCMH
Operating Life	Conventional Fuel Lift – 7 yrs / 21,000 hrs 8,000lb Electric – 8 yrs / 24,000 hrs 19,800ln Electric – 8 yrs / 24,000 hrs	Conventional: OFFROAD model; Electric: ratio of Electric/Conventional from Hyster[113]
Charger Life	14 yrs	Previous CalETC Study
Fraction of Regular and Fast Charge	Regular Charge: 72.5% Fast Charge: 27.5%	Previous CalETC Study
Annual Usage	3,150 hrs/yr (525 6-hr shifts/yr)	Previous CalETC Study
Battery Sizes	8,000 lb – 43.6 kWh 19,800 lb – 124 kWh	Survey of existing electric forklifts including Kalmar, Nissan, and CAT
Electricity Usage	80% battery depletion per 6-hr shift	ICF Assumption
Electricity Grid Cost	Regular Charge - $0.18/kWh Fast Charge - $0.32/kWh	Previous CalETC Report with update for current rate schedules: See Table 58
Discount Factor	5%	ICF Assumption
Gasoline and Diesel Prices	2013 Gasoline - $3.89/gal (used as surrogate for propane) 2013 Diesel - $3.91/gal	CEC IEPR 2013
Gasoline and Diesel Fuel Consumption	Gasoline – 0.70/gal Diesel – 1.10/gal	OFFROAD Model
Maintenance Costs	Electricity – 22 hrs/yr Conventional – 40 hrs/yr $26/hr for Labor	Previous CalETC Study

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[113] "Timely Replacement of Lift Trucks," Hyster Company, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&ved=0CIIBEBYwCA&url=http%3A%2F%2Fwww.hyster.com%2FWorkArea%2FDownloadAsset.aspx%3Fid%3D8589935299&ei=qDbsUqW-BdO1kQecuoDQAg&usg=AFQjCNGiyt9PkuQeuuMU03LatU2bIQqAIA&sig2=7nT4Qh_ufsaK4VgPZqfk8A&bvm=bv.60444564,d.eW0

Table 58. Forklift Electricity Rate Assumptions

	SCE	PG&E	LADWP/Public	SDGE
Tariff Schedule	TOU-8	E-19 Mandatory	A-3	AL-TOU
Share of Electricity	35%	35%	20%	10%
Summer Share	33%	50%	33%	42%
Winter Share	67%	50%	67%	58%
Charging Power Demand	11kW: Regular 34.88kW: Fast	11kW: Regular 34.88kW: Fast	11kW: Regular 34.88kW: Fast	11kW: Regular 34.88kW: Fast
Percent Subject to Time Demand Charges	25%	25%	25%	25%
Percent Subject to Facility Demand Charges	100%	100%	100%	100%

Table 59. Forklift Annualized Cost Analysis

	Conventional 8,000 lb	Electric 8,000 lb	Conventional 19,800 lb	Electric 19,800 lb
() Denotes Cost Savings	Gasoline/LPG	Electric	Diesel	Electric
Forklift				
Forklift High Cost ($/truck)	$23,500	$38,000	$165,000	$170,000
Forklift Low Cost ($/truck)	$31,500	$34,000	$165,000	$170,000
Battery High Cost ($/battery)		$13,000		$14,280
Battery Low Cost ($/battery)		$9,850		$12,750
Forklift Operating Life	7	8.9	7	8.4
Battery Operating Life		8.9		8.4
Batteries per forklift		1.0		2
Total Capital - High	$23,500	$51,000	$165,000	$198,560
Total Capital - Low	$31,500	$43,850	$165,000	$195,500
Annual Costs -High	$4,061	$7,234	$28,515	$29,526
Annual Costs -Low	$5,444	$6,219	$28,515	$29,071
Charger				
Regular Charger Cost - High		$4,650		$5,000
Regular Charger Cost - Low		$3,500		$3,500
Fast Charger Cost - High		$15,000		$15,000
Fast Charger Cost - Low		$10,000		$10,000
Regular Charger (%)		72.5%		72.5%
Fast Charger (%)		27.5%		27.5%
Charger Life		14		14
Total Capital - High		$7,496		$11,375
Total Capital - Low		$3,913		$7,825
Annual Costs - High		$757		$1,149
Annual Costs - Low		$395		$791
Operating Costs				
Annual Usage (hr/year)	3,150	3,150	3,150	3,150
Total Electricity Usage (kWh/yr)		18,312		52,080
Regular Grid Cost ($/kWh)		$0.18		$0.12
Fast Grid Cost ($/kWh)		$0.32		$0.17
Electricity Cost ($)		$4,046		$7,082.67
Gasoline/Diesel Fuel Cost ($)	$9,193		$13,593	
Annual Maint. Cost ($)	$2,452	$1,546	$2,452	$1,546
Total Cost				
Annual Incremental Capital Costs - High		$4.587		$3,355
Annual Incremental Capital Costs - Low		$1,736		$2,523
Annual Incremental Operating Cost ($)		$(6,053)		$(7,416)
Total Annual Costs - High		$(1.466)		$(4,061)
Total Annual Costs - Low		$(4,317)		$(4893)

Table 60. Forklift Annualized Societal and Monetized Societal Benefits

	8,000 lb Electric	19,800 lb Electric
Annual Societal Benefits		
Petroleum Displacement (GGE/yr)	2,205	4,043
GHG Emission Benefits (MT/yr)	18.33	29.93
NOX (tons/yr)	0.016	0.021
PM (tons/yr)	3.18E-04	0.001
VOC (tons/yr)	0.009	0.004
Monetized Societal Benefits		
Petroleum Displacement	$972.83	$1,783.66
GHG Emission	$201.59	$329.22
NOx	$73.38	$97.18
PM	$461.55	$1,116.31
VOC	$10.27	$4.30

Truck Stop Electrification. Table 61 below shows the main data sources and assumptions for the TSE cost analysis. All analyses and results in the following tables are per truck stop (20 spaces).Table 63 uses the values in Table 61 to develop the annualized cost and private benefits. Table 64 shows the annual societal benefits per truck stop and the monetization of these benefits. See Appendix A for the details on the calculation of societal benefits for TSE.

Table 61. TSE Data Sources and Assumptions

Variable	Value	Source
Vehicle Side Cost	328 - 600	Carrier Transicold and DiamondPower APU
Operating Life	7 yrs	Previous CalETC Study
Spaces Per Truck Stop	20	Previous CalETC Study
Capacity Factor	0.6	Previous CalETC Study (SCE/ IdleAir)
Idle Hours to Plug-In per Day	8	ICF Assumption
Market Share	Plug-In APU – 75% IdleAir – 25%	Previous CalETC Study
Facility Infrastructure Costs ($/space)	Plug-in APU: $2,600 - $6,000 IdleAir - $5,000 - $10,000	Plug-in APU – Previous CalETC study (Shorepower); IdleAir – Ethan Garber of IdleAir
Facility Operating Life	20 yrs	Previous CalETC Study
Power Requirement	1.39 kW	Previous CalETC Study
Electricity Grid Cost	Plug-In APU - $0.16/kWh IdleAir - $0.15/kWh	Previous CalETC Report with update for current rate schedules: See Table 62
Discount Factor	5%	ICF Assumption
Diesel Prices	2013 Diesel - $3.91/gal	CEC IEPR 2013
Diesel Fuel Consumption	Diesel – 0.21/gal	Anti-Idling ISOR
Labor Costs	IdleAir - $105,000/yr	Previous CalETC Study (NYSERDA)

Table 62. TSE Electricity Rate Assumptions

	SCE	PG&E	LADWP/Public	SDGE
Tariff Schedule	GS-2	A-6	A-2 (B)	AL-TOU
Share of Electricity	35%	35%	20%	10%
Summer Share	50%	75%	50%	42%
Winter Share	50%	25%	50%	58%
Power Demand (kW)	Plug-In APU – 27.7 IdleAir – 83.2			
Percent Subject to Time Demand Charges	0%	0%	0%	0%
Percent Subject to Facility Demand Charges	100%	100%	100%	100%

Table 63. TSE Annualized Cost Analysis

	Plug-In APU/ Shorepower	IdleAir
Vehicle		
Incremental High Cost ($/truck)	$600	$-
Incremental Low Cost ($/truck)	$328	$-
Spaces per Truck Stop	20	60
Capacity Factor	0.6	0.6
Idle Hours to Plug-In (hr/day/truck)	8	8
Stop Based Trucks	36	108
TSE Technology Life (yrs)	7.0	7
Total Capital per Truck Stop - High	$21,600	$-
Total Capital per Truck Stop - Low	$11,808	$-
Annual Costs per Truck Stop - High	$1,244	$-
Annual Costs per Truck Stop -Low	$680	$-
Facility		
Infrastructure Cost - High ($/space)	$6,000	$10,000
Infrastructure Cost - Low ($/space)	$2,600	$5,000
Facility Project Life (yrs)	20	20
Total Capital - High	$120,000	$600,000
Total Capital - Low	$52,000	$300,000
Annual Costs - High	$9,629	$48,146
Annual Costs - Low	$4,173	$24,073
Operating Costs		
Annual Usage (hr/year/space)	5,256	5,256
Total Electricity Usage (kWh/yr/space)	7,290	7,290
Regular Grid Cost ($/kWh)	$0.16	$0.15
Electricity Cost ($/stop)	$23,762	$66,857
APU Diesel Fuel Consumption	0.21	0.21
Diesel Fuel Cost ($/gallon)	$3.91	$3.91
Diesel Cost Savings ($/stop/yr)	$85,492	$256,476
Annual Labor Cost ($)	$-	$105,000
Total Cost		
Annual Incremental Capital Costs - High	$10,873	$48,146
Annual Incremental Capital Costs - Low	$4,853	$24,073
Annual Incremental Operating Cost ($)	$(61,730)	$(84,619)
Total Annual Costs per Stop - High	$(50,856)	$(36,474)
Total Annual Costs per Stop- Low	$(56,877)	$(60,546)

Table 64. TSE Annualized Societal and Monetized Societal Benefits

	Plug-In APU/ Shorepower	IdleAir
Annual Societal Benefits (Per Truck Stop)		
Petroleum Displacement (GGE/yr)	25,427	76,282
GHG Emission Benefits (MT/yr)	233	700
NOX (tons/yr)	1.658	4.975
PM (tons/yr)	0.014	0.043
VOC (tons/yr)	0.084	0.251
Monetized Societal Benefits (Per Truck Stop)		
Petroleum Displacement	$11,218	$33,655
GHG Emission	$2,566	$7,698
NOx	$7,754	$23,262
PM	$20,917	$62,751
VOC	$94	$281

Transport Refrigeration Units. Table 65 below shows the main data sources and assumptions for the TRU cost analysis. All analyses and results in the following tables are per facility (19 spaces). All TRUs are assumed to operate on diesel if not plugged in. Table 67 uses the values in Table 65 to develop the annualized cost and private benefits. Table 68 shows the annual societal benefits per facility and the monetization of these benefits. The cost analysis and societal benefits are for new e-standby TRUs purchased in 2013 and are compared to new non e-standby TRUs purchased in 2013 that comply with LEV III. See Appendix A for the details on the calculation of societal benefits for TRUs.

Table 65. TRU Data Sources and Assumptions

Variable	Value	Source
Vehicle Side Cost	Semi - $3,700 - $5,000 Bobtail - $550 - $650	Dealers for Thermoking and Carrier Transicold
Operating Life	16 yrs	Previous CalETC Study
Spaces Per Facility	19	ARB 2005 ISOR
Capacity Factor	0.6	Previous CalETC Study
Annual Operating Hours in California	Semi In-State: 1,325 hrs/yr Semi Out of State: 210 hrs/yr Bobtail: 1,360 hrs/yr Bobtail <11hp: 1,360 hrs/yr	ARB 2011 TRU ISOR
Fraction of Time at the Facility for e-standby	30%	ARB2011 TRU ISOR and Conversations with CARB Staff
Facility Infrastructure Costs ($/space)	Semi - $4,300 Bobtail - $1,500	Previous CalETC Study (EPRI)
Facility Operating Life	20 yrs	Previous CalETC Study
Power Requirement	Semi - 8 kW Bobtail – 6 kW Bobtail <11hp – 2 kW	Previous CalETC Study
Electricity Grid Cost	Semi - $0.25/kWh Bobtail - $0.27/kWh Bobtail <11hp - $0.24/kWh	Previous CalETC Report with update for current rate schedules: See Table 66
Discount Factor	5%	ICF Assumption
Diesel Prices	2013 - $3.91/gal	CEC IEPR 2013
Diesel Fuel Consumption	Semi - 0.85 gal/hr Bobtail – 062 gal/hr Bobtail <11hp – 0.29 gal/hr	OFFROAD model and EPRI

Table 66. TRU Electricity Rate Assumptions

	SCE	PG&E	LADWP/Public	SDGE
Tariff Schedule	TOU G-3	E-19 Mandatory	A-3	AL-TOU
Share of Electricity	35%	35%	30%	0%
Summer Share	33%	50%	33%	42%
Winter Share	67%	50%	67%	58%
Power Demand (kW)	Semi – 152 kW Bobtail – 152 kW Bobtail <11 HP – 43.7 kW			
Percent Subject to Time Demand Charges	20%	20%	20%	20%
Percent Subject to Facility Demand Charges	20%	20%	20%	20%

Table 67. TRU Annualized Cost Analysis

	Semi In-State	Semi Out of State	Bobtail	Bobtail <11 HP
Horsepower Category	25-50	25-50	11-25	<11
Truck				
Incremental High Cost ($/truck)	$5,000	$5,000	$650	$650
Incremental Low Cost ($/truck)	$3,700	$3,700	$550	$550
Hook-ups per Facility	19.0	19	19	19
Capacity Factor	0.6	0.6	0.6	0.6
Annual Operating Hours in CA (hr/truck)	1,325	210	1,360	1,360
Fraction of Time at Facility to Plug-In	0.3	0.3	0.3	0.3
Facility Based Trucks	251	1585	245	245
TRU Technology Life (yrs)	16	16	16	16
Total Capital per Truck Stop - High	$1,256,151	$7,925,714	$159,097	$159,097.06
Total Capital per Truck Stop - Low	$929,552	$5,865,029	$134,621	$134,621
Annual Costs per Truck Stop - High	$115,905	$731,305	$14,680	$14,680
Annual Costs per Truck Stop -Low	$85,770	$541,166	$12,421	$12,421
Facility				
Infrastructure Cost - ($/hook-up)	$4,300	$4,300	$1,500	$1,500
Facility Project Life (yrs)	20	20	20	20
Total Capital	$81,700	$81,700	$28,500	$28,500
Annual Costs	$7,538	$7,538	$2,630	$2,630
Operating Costs				
Baseline Fuel Consumption (gal/hr)	0.85	0.85	0.62	0.29
Annual Usage (hr/year/hook-up)	5,256	5,256	5,256	5,256
Electricity Load (kW)	8	8	6	2
Total Electricity Usage (kWh/yr/hook-up)	42,048	42,048	31,536	11,826
Regular Grid Cost ($/kWh)	$0.25	$0.25	$0.27	$0.24
Electricity Cost ($/facility)	$196,427	$196,427	$164,240	$52,957
Diesel Cost Savings ($/facility/yr)	$331,898	$331,898	$242,090	$112,142
Total Cost				
Annual Incremental Capital Costs - High	$123,443	$738,843	$17,310	$17,310
Annual Incremental Capital Costs - Low	$93,308	$548,704	$15,051	$15,051
Annual Incremental Operating Cost ($)	$(135,471)	$(135,471)	$(77,851)	$(59,185)
Total Annual Costs - High	$(12,028)	$603,372	$(60,541)	$(41,876)
Total Annual Costs - Low	$(42,163)	$413,233	$(62,799)	$(44,134)

Table 68. TRU Annualized Societal and Monetized Societal Benefits

	Semi In-State	Semi Out of State	Bobtail	Bobtail <11 HP
Annual Societal Benefits (Per Facility)				
Petroleum Displacement (GGE/yr)	98,715	98,715	72,004	33,354
GHG Emission Benefits (MT/yr)	818	818	590	293
NOX (tons/yr)	7.402	7.402	8.375	3.211
PM (tons/yr)	0.022	0.022	0.052	0.020
VOC (tons/yr)	0.221	0.221	0.175	0.089
Monetized Societal Benefits (Per Facility)				
Petroleum Displacement	$43,552	$43,552	$31,767	$14,715
GHG Emission	$8,996	$8,996	$6,494	$3,227
NOx	$34,609	$34,609	$39,157	$15,014
PM	$31,979	$31,979	$75,490	$29,041
VOC	$247	$247	$195	$100

California Transportation Electrification Assessment

Phase 2: Grid Impacts

October 23, 2014

Energy+Environmental Economics

Schedule CAC-2

California Transportation Electrification Assessment

Phase 2: Grid Impacts

October 23, 2014

Energy and Environmental Economics, Inc.
101 Montgomery Street, Suite 1600
San Francisco, CA 94104
415.391.5100
www.ethree.com

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Abbreviations and Acronyms

AEO	Annual Energy Outlook
ARB	California Air Resources Board
BEV	Battery Electric Vehicle
CARB	California Air Resources Board
CEC	California Energy Commission
CH4	Methane
CHE	Cargo Handling Equipment
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
CO2E	Carbon Dioxide Equivalent
CPI	Consumer Price Index
CPUC	California Public Utilities Commission
DER	Distributed Energy Resources
DGE	Diesel Gallon Equivalent
EER	Energy Equivalency Ratio
EIA	United States Energy Information Administration
EPA	US Environmental Protection Agency
EVSE	Electric Vehicle Supply Equipment
FCV	Fuel Cell Vehicle
GGE	Gasoline Gallon Equivalent
GHG	Greenhouse Gas
GSE	Ground Support Equipment
GWh	Gigawatt-hour
HOA	Home Owners Association
HP	Horsepower
HSR	High Speed Rail
ICE	Internal Combustion Engine
IOU	Investor Owned Utility
ISOR	Initial Statement of Reasons
kW	Kilowatt
kWh	Kilowatt-hour

LCA	Lifecycle Analysis
LCFS	Low Carbon Fuel Standard
LEV	Low Emission Vehicle
MDU	Multi-Dwelling Unit
MT	Metric Ton
NMOG	Non-Methane Organic Gases
NOx	Oxides of Nitrogen
O&M	Operational and Maintenance
PEV	Plug-In Electric Vehicles
PHEV	Plug-In Hybrid Electric Vehicles
PHEV10	PHEV with 10 miles equivalent all electric range
PHEV20	PHEV with 20 miles equivalent all electric range
PHEV40	PHEV with 40 miles equivalent all electric range
PM	Particulate Matter
RIM	Ratepayer Impact Measure
ROG	Reactive Organic Compounds
RTG	Rubber Tire Gantry
SCT	Societal Cost Test
SPM	Standard Practice Manual
TE	Transportation Electrification
TEA	Transportation Electrification Assessment
TOU	Time of Use
TRU	Transport Refrigeration Unit
TRC	Total Resource Cost Test
TSE	Truck Stop Electrification
TTW	Tank-To-Wheel
ULETRU	Ultra Low Emission TRU
VOC	Volatile Organic Compounds
WTT	Well-To-Tank
WTW	Well-To-Wheels
ZEV	Zero Emission Vehicle

1. Executive Summary

California has set a bold target of reducing GHG emissions to 80% below 1990 levels by 2050.[1] Achieving the 2050 goal will require significant innovation and a fundamental, holistic transformation of the transportation system, which accounts for about 38 percent of total emissions in the state. Governor Brown's Executive Order B-16-2012 establishes a goal of having 1.5 million zero emission vehicles (ZEVs) on California's roadways by 2025.[2] Looking further ahead to 2050, the California Air Resources Board (CARB) Climate Change Scoping Plan states that ZEVs will need to make up most of California's fleet[3] and Executive Order B-16-2012 establishes a 2050 target for reduction of greenhouse gas emissions from the transportation sector equaling 80 percent less than 1990 levels.[4] 2050 pathways studies find that 70% of vehicle miles traveled — including almost all light-duty vehicle miles — must be powered by electricity.[5] As ambitious as California's GHG goals are, EPA ambient air quality compliance deadlines in 2023 and 2032 will require even more acceleration of ZEV adoption. California utilities will be called upon to provide readily accessible, low-carbon electricity to fuel the state's transportation needs.[6]

1.1. Transportation Electrification Assessment

1.1.1. PHASE 1 REPORT: ENVIRONMENTAL AND SOCIETAL BENEFITS

The California Transportation Electrification Assessment (TEA) documents the crucial role that transportation electrification will have in meeting GHG and

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[1] Governor Executive Order S-3-05, June 6, 2005. http://gov.ca.gov/news.php?id=1861

[2] See http://www.arb.ca.gov/msprog/zevprog/zevprog.htm

[3] California Air Resources Board (CARB). "First Update to the Climate Change Scoping Plan." May 2014. http://www.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf

[4] Exec. Order B-16-2012 available at http://gov.ca.gov/news.php?id=17472; Also see Exec. Order No. S-03-05 (June 1, 2005), available at http://gov.ca.gov/news.php?id=1861

[5] Williams, James H et al. "The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity." Science 335.6064 (2012): 53–9.

[6] CARB. (2012). Vision for Clean Air : A Framework for Air Quality and Climate Planning. http://www.arb.ca.gov/planning/vision/vision.htm. See also Greenblatt, Jeffery B. Estimating Policy-Driven Greenhouse Gas Emissions Trajectories in California: The California Greenhouse Gas Inventory Spreadsheet (GHGIS) Model. Lawrence Berkeley National Laboratory (LBNL), LBNL-6451e. November 2013. http://eetd.lbl.gov/sites/all/files/lbnl-6451e.pdf

ambient air quality goals. The Phase 1 Report (TEA Phase 1 Report)[7] describes the market size, environmental and societal benefits of 20 market segments of transportation electrification (TE), focusing on four segments in particular: plug-in electric vehicles (PEVs), forklifts, truck stop electrification and transport refrigeration units. PEVs are the largest of the segments studied: 2.3 million PEVs (CARB's "ZEV 'Most Likely' Scenario") could displace 5.8 million metric tons (MMT) of GHG in 2030, 50% of the total GHG reduction for all TE sectors in the TEA Phase 1 report's "in-between" adoption scenario.

1.1.2. PHASE 2 REPORT: PEV GRID IMPACTS

This TEA Phase 2 Report provides an in-depth analysis of electric utility costs that will be incurred to support PEV charging, with an emphasis on utility distribution systems. We use the inputs and results from this and the Phase 1 Report to describe the impacts of PEV charging under a variety of scenarios. We perform the analysis collectively for Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E) and Sacramento Municipal Utility District (SMUD), all of which provided detailed distribution system data for the study. We use CARB and California Public Utility Commission (CPUC) adopted methods to show that PEVs are cost-effective, providing benefits for electric utilities, their customers and the state as whole.

1.2. PEVs Provide Regional and Societal Benefits

The California air and utility regulators have developed cost-effectiveness tests to allocate funding and resources to the most beneficial programs. The CARB approach determines which air quality initiatives are the most effective by comparing both the quantitative and societal value of the emission reduction against the cost of implementing less polluting technologies.[8] The TEA Phase 1 Report employs this approach to show that the societal benefits to California, including reduced emissions and reduced consumption of petroleum fuels are larger than the incremental costs of electric versus internal combustion engine (ICE) vehicles.

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[7] TEA Phase 1 Report. Available at http://www.caletc.com/wp-content/uploads/2014/08/CalETC_TEA_Phase_1-FINAL.pdf

[8] CARB. " Staff Proposal Regarding the Maximum Feasible and Cost-effective Reduction of Greenhouse Gas Emissions from Motor Vehicles," November 2013. http://www.arb.ca.gov/cc/factsheets/cc_isor.pdf page viii , and CARB and CalTrans. "Methods to Find the Cost-Effectiveness of Funding Air Quality Projects" May 2005. http://www.arb.ca.gov/planning/tsaq/eval/eval.htm

The CPUC has developed a framework to determine when the utility and societal costs of energy production "avoided" by load reductions from energy efficiency, demand response and distributed generation (collectively distributed energy resources or DER) are greater than the costs of programs promoting them. For this report we use the CPUC avoided cost framework to show that the benefits of PEVs are greater than the incremental PEV costs and the additional infrastructure needed to support them.

1.2.1. PEVS PASS CARB AND CPUC COST-EFFECTIVENESS TESTS

We first determine whether California as a state is *economically* better off with PEVs. We compare the *monetized* costs and benefits that represent actual cash transfers into or out of the state to determine whether California achieves net economic benefits with additional PEV adoption (The CPUC Total Resources Cost Test or TRC). The benefits include the federal tax credit for PEVs, gasoline savings and reduced cap-and-trade GHG allowance costs, which total about $20,000 per vehicle under our time-of-use (TOU) rate/load shape scenario (Figure 1).[9] The costs include incremental costs of the vehicle, charging infrastructure costs, distribution system upgrades and the avoided costs for delivered energy. Total costs are just under $15,000 per vehicle, for a net benefit of approximately $5,000 over the life of each PEV.

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[9] Per the Standard Practice Manual, the TRC for California includes federal, but not state, tax credits and rebates as a benefit.

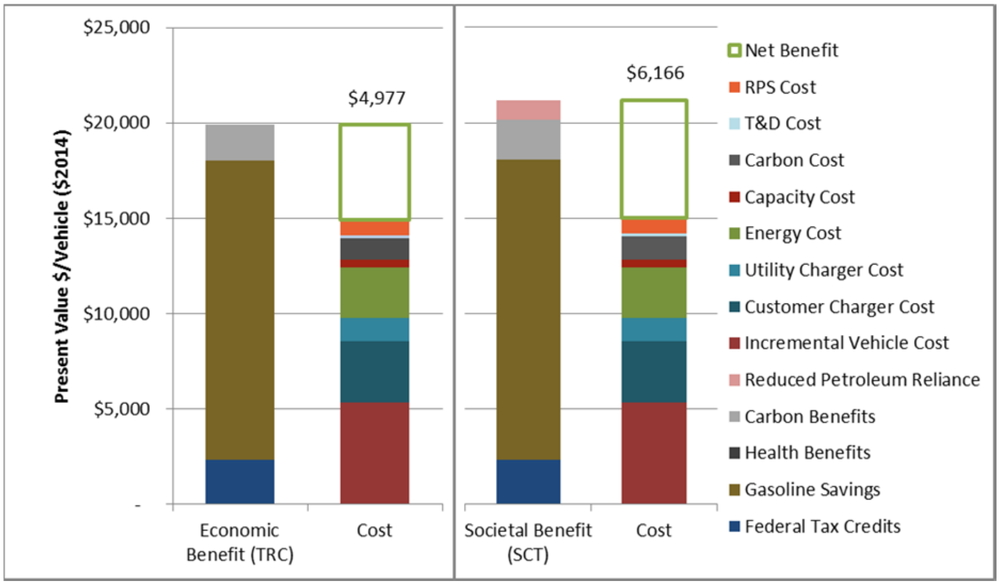

Figure 1. Regional Monetized and Societal Benefits

We expand the evaluation to include environmental and societal benefits that are not monetized in actual cash transactions, but still provide direct and quantifiable benefits to California. This Societal Cost Test (SCT) includes benefits for health and reduced reliance on petroleum from the Phase 1 report – benefits that are included in the CARB cost-effectiveness method and described as benefits in the interest of utility ratepayers in Public Utilities Code (PUC) 740.3 and 740.8. In addition, we replace the cap-and-trade GHG allowance costs with a higher estimate of the societal value of reducing GHG emissions. This increases the net benefit to about $6,600 per vehicle, $1,200 (22%) higher than the net benefit under the TRC. This is provided primarily as an illustrative and somewhat conservative result; alternative assumptions could produce net societal benefit values that are much higher.

1.2.2. ROLE OF THE FEDERAL TAX CREDIT

Currently, PEV's provide net economic benefits to California partially because the federal government provides a tax credit for PEVs. Accelerating PEV adoption in the state results in a direct benefit of increasing the amount of federal funds that are directed to California before the cap for the federal tax credit is reached. Increasing adoption also has the indirect benefits of accelerating technological learning and increasing economics of scale in PEV production, which in turn reduces vehicle costs. For a PEV purchased in 2023, the net benefits are lower without the tax credit, but still positive at about $2,700 per vehicle. In 2030, with continued reduction in PEV costs and increases in gasoline prices, net benefits increase to about $5,600 per vehicle, higher than they were in 2015 with the federal tax credit.

1.3. PEV Charging Decreases Rates for all Utility Customers

We use an additional CPUC cost test to show that PEVs also benefit all utility customers and not just the PEV owners themselves. The Ratepayer Impact Measure (RIM) shows that the utility bills PEV owners pay more than offset the costs incurred by the utility to deliver the electricity to charge the vehicles. From the utility customer perspective, revenues from PEV charging are a benefit and the resources expended to deliver electricity for charging are costs. Under each of four rates and charging load shape scenarios studied, additional revenue from PEV charging exceeds the marginal costs to deliver electricity to the customer, providing positive net revenues that put downward pressure on rates (Figure 2). The tiered and flat rate scenarios provide the highest revenues, but also have the highest supply costs, as there is no economic incentive to shift charging to lower cost off-peak periods. The mixed flat and TOU rate and all TOU scenarios do shift charging to off-peak hours, when both the rates and the cost of delivered electricity are lower. The TOU rate scenario results in the lowest net revenues, but also yields the lowest costs for both the utility and the PEV owner.

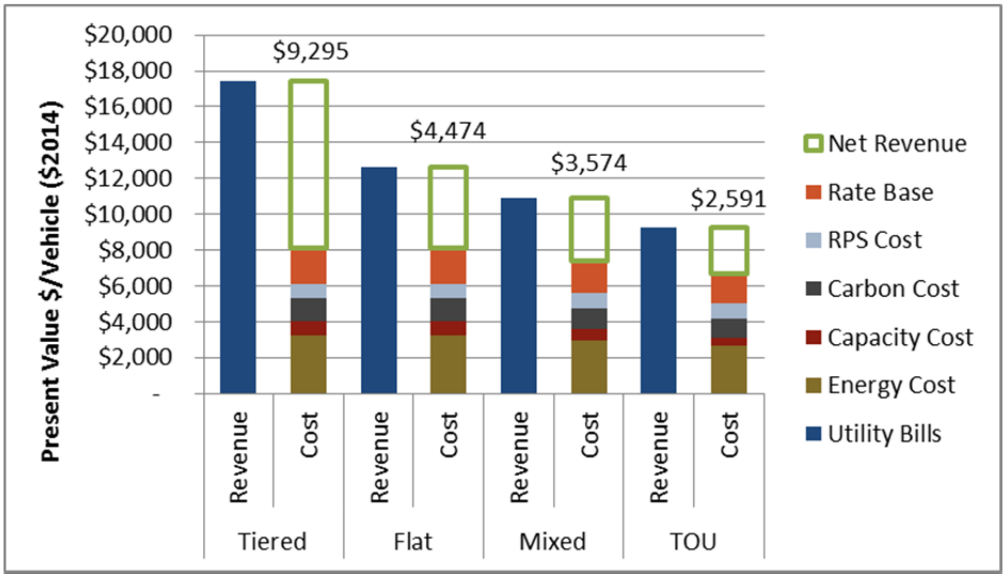

Figure 2. Utility Customer Benefits: Present Value of Revenue and Costs per Vehicle (Ratepayer Impact Measure Cost-test)

1.4. Distribution Costs are Modest in the Near-term

1.4.1. DISTRIBUTION COSTS FOR RESIDENTIAL CHARGING ARE MANAGEABLE IN THE NEAR TERM

One of the main concerns regarding PEV charging has been the impact on utility distribution grids from clustering of PEVs in specific neighborhoods. We use historical hybrid electric vehicle (HEV) registration data and census data to model clustering of PEVs. We then match the PEV clusters to individual circuit, feeder and substation locations for PG&E, SCE, SDG&E and SMUD. We then calculate the incremental load and distribution upgrade costs driven specifically by PEV charging at each location from 2014 through 2030.

For the scenarios studied, distribution upgrade costs for residential charging are manageable. Even under the most aggressive PEV adoption scenario with a flat rate load shape, present value distribution upgrade costs through 2030 are $1.4 billion, roughly $140 million per year across the four utilities or 1.5% of the 2012 distribution revenue requirement of $9 billion for the four utilities. Even with clustering, PEV adoption does not lead to dramatic increases in feeder or substation upgrade costs. Section 1.5 discusses how these distribution costs are significantly reduced with TOU rates that shift PEV charging to off-peak periods.

1.4.2. COSTS TO ACCELERATE PEV ADOPTION WITH MULTI-FAMILY, WORKPLACE AND PUBLIC CHARGING INFRASTRUCTURE MAY BE MORE SIGNIFICANT

Distribution and charging infrastructure costs for multi-family, public and workplace charging locations may be a more significant challenge. These include the so-called “make-ready” or “stub” costs to provide service from the customer meter to individual charging stations. Under the ZEV Most Likely adoption case, charging infrastructure costs total $3.8 billion through 2030, with costs to install Level 2 (240 volt) chargers assumed to be $1,700 and $8,000 at residential and commercial locations respectively. Actual costs will vary by site and depend to a significant extent on the number and cost of public and workplace charging installations as a proportion of the total PEV fleet. Furthermore, our scenarios assume most charging occurs at home - we did not analyze the cost required to dramatically increase access to charging and multi-family, public or workplace locations, which will be necessary to achieve the high penetration of PEVs contemplated under 2050 pathway scenarios. Understanding the costs and implications of multi-family, public and workplace charging for PEV adoption will be an important subject of further study.

1.5. Managed Charging Increases Grid Benefits

1.5.1. BENEFITS OF TOU RATES

Shifting charging to off-peak periods significantly increases the net benefit of PEVs for California – this notwithstanding the finding of modest distribution impacts discussed above. The $5,000 net TRC benefits under the TOU rate/load shape scenario (Figure 1) are $1,400 per vehicle (28%) higher than the $3,600 per vehicle for the tiered and flat rate scenarios (not shown). Charging off-peak reduces the cost of generation, including carbon allowances, by $740 per vehicle. It also defers or avoids investment in generation, transmission and distribution capacity for a combined benefit of $640 per vehicle. Under the ZEV most likely adoption scenario the present value benefit of TOU as compared to flat rate charging is $1.2 billion.

1.5.2. DYNAMIC CHARGING FOR VEHICLE GRID INTEGRATION

PEVs can potentially support higher penetrations of renewable generation on the electric grid – an additional benefit that is not included in the cost-test results presented above. Because most solar generation in the state is located in Southern California and projects must by online by 2016 to be eligible for the Investment Tax Credit,[10] the southern part of the state will experience levels of renewable penetration close to or exceeding 40% before 2020.[11] This will lead to periods of overgeneration where non-dispatchable fossil and renewable generation exceed load.[12] PEV charging can provide grid benefits by absorbing excess generation and reducing the size of the evening ramp in net load.

To illustrate the potential benefits, we compare the cost of delivering electricity for PEV charging under a seasonal TOU and dynamic vehicle grid integration (VGI) rate scenario with 40% renewable penetration. The dynamic VGI scenario reduces the present value of charging costs per vehicle from over $1,400 to under $600 for a net benefit of $850 per PEV. These results were developed using methods and assumptions developed for the SDG&E VGI Application (A. 14-04-014) that is currently before the CPUC. They are not directly comparable to the results presented elsewhere in this report, but are presented to highlight VGI charging as a potential benefit that warrants further investigation.

1.6. New Metrics are Needed to Evaluate PEVs as a GHG Reduction Strategy

We show that PEVs can pass current cost-effectiveness evaluation methods that were developed to evaluate supply and demand side resources on a comparable basis in utility resource planning. In the existing framework, demand side resources that reduce or shift load are valued for reducing the costs and emissions required to meet forecasted demand for energy. These values are based largely on the costs of today's conventional supply side resources that are avoided with distributed resources.

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[10] Business Energy Investment Tax Credit, 26 USC § 48 enacted January 2, 2013. See http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1

[11] "Valuing Energy Storage as a Flexible Resource", Energy and Environmental Economics, June 2014. https://ethree.com/documents/E3_Storage_Valuation_Final_Phase_1.pdf

[12] "Investigating a Higher Renewables Portfolio Standard in California", Energy and Environmental Economics, January 2014. https://ethree.com/documents/E3_Final_RPS_Report_2014_01_06_with_appendices.pdf

Meeting GHG goals and air quality requirements will require transformative acceleration of PEV adoption and unprecedented levels of coordination and cooperation between the utility and transportation sections. New cost-effectiveness metrics are needed to support the infrastructure development to accomplish these goals.

1.6.1. ACCELERATING PEV ADOPTION REQUIRES INFRASTRUCTURE INVESTMENT

By August 2014, over 100,000 PEVs had been sold in California, accounting for roughly 40% of the US market and exceeding sales of hybrid electric vehicles in their first four years on the market a decade ago.[13] We compare current adoption against two future projections in Figure 3. The ZEV "Most Likely" PEV adoption scenario from the TEA Phase 1 Report exceeds 2 million PEVs by 2030, and CARB's 2012 "Vision for Clean Air" includes a scenario to meet 2050 climate goals that exceeds 4 million PEVs by 2030.[14] As ambitious as these scenarios are, EPA ambient air quality standards will require even more rapid early adoption of PEVs. Neither scenario meets the 2023 or 2032 compliance deadline for ozone attainment in South Coast and San Joaquin regions.[15] PEV adoption must not just exceed the historical pace of HEV sales, but continue to grow through 2030 at an arithmetic rate in the ZEV Most Likely scenario and a geometric rate under the CARB vision scenario to achieve 2050 GHG reduction targets.

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[13] Lee, Morgan. "CA Has 100K Plug-in Cars, and Counting." San Diego Union-Tribune 8 Sept. 2014.

[14] CARB. Vision for Clean Air : A Framework for Air Quality and Climate Planning. 2012

[15] Greenblatt, Jeffery B. "Estimating Policy-Driven Greenhouse Gas Emissions Trajectories in California." 2013

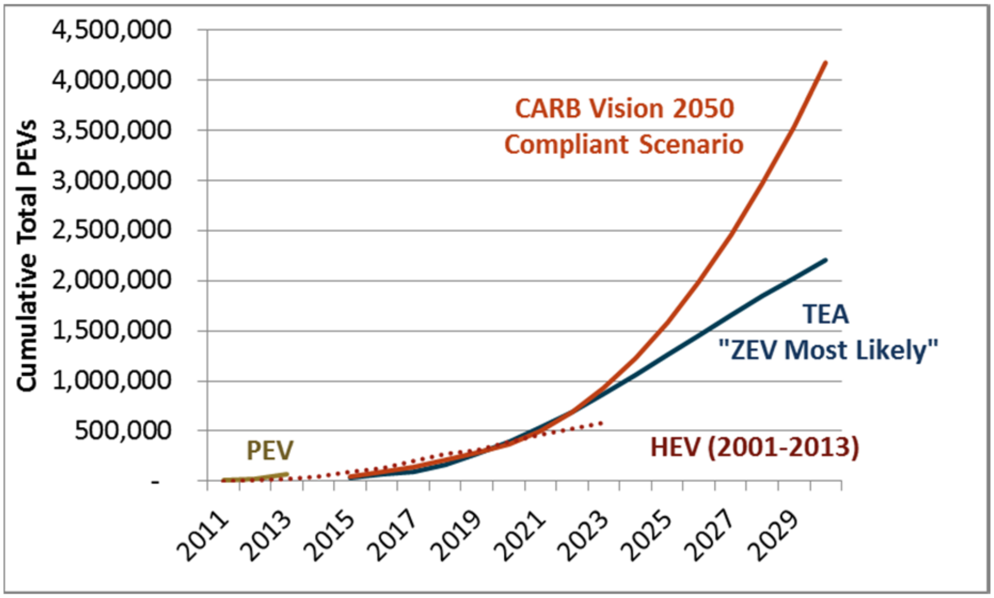

Figure 3. PEV Adoption Scenarios

Most PEV charging is expected to occur at home, but public and workplace charging is nevertheless critical to motivate PEV purchases by reducing range anxiety and to increase electric vehicle miles traveled (eVMT). There are approximately 5,800 public charging outlets and an additional 1,000 private outlets in California (not including home chargers).[16] The California Statewide Plug-In Electric Vehicle Infrastructure Assessments find that public and workplace charging stations must support roughly 230,000 to 410,000 PEV charging sessions daily in 2020 to support the ZEV adoption goal of 1.5 million vehicles by 2025.[17] By 2020, the number of PEVs must increase by a multiple of 3.5 from today, whereas public and workplace charge points will have to increase by more than a factor of 18 at the lower of the above estimates.

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[16] http://www.afdc.energy.gov/fuels/electricity_locations.html accessed October 2, 2014.

[17] National Renewable Energy Laboratory (NREL). California Statewide Plug-In Electric Vehicle Infrastructure Assessment. For the California Energy Commission, CEC-600-2014-003. May 2014. Public and workplace charge points from Table 4, p. 16 and charge events per day from Table 8, p. 32. http://www.energy.ca.gov/2014publications/CEC-600-2014-003/CEC-600-2014-003.pdf

1.6.2. NEW METRICS FOR EVALUATING COST-EFFECTIVENESS ARE NEEDED

PEVs are fundamentally different from other distributed energy resources in two key respects. First, PEV's provide net benefits and emissions reductions to California, but the generation needed to serve PEV load will result in emissions increases in the power sector. Second, whereas the primary purpose of promoting DER has been to reduce the costs and emissions required to meet forecasted load, California seeks to accelerate PEV adoption to meet GHG reduction and air quality targets. Furthermore, achieving these goals will require fundamental market transformation in both the utility and transportation sectors with new and unconventional technologies that are not widely used today.

Although we show that PEV's can be cost-effective using existing CPUC and CARB methodologies, these tests were not developed to address these statewide challenges. We propose that new tests are needed to evaluate initiatives designed to meet long-term GHG reduction targets. Even with the addition of health and environmental benefits, early investments intended to encourage market transformation often do not pass cost-effectiveness evaluation initially, but only after technological development and wide-spread adoption drive costs down.[18] Furthermore, current tests do not explicitly address how environmental and GHG benefits in the transportation sector can or should be considered against increased emissions in the utility sector. New approaches will need to be developed to compare the relative costs of achieving GHG reductions across utility, transportation and other sectors of California's economy.

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[18] Emerging technology programs in energy efficiency are a prime example - the purchase price and cost of ownership for LED bulbs, compact florescent bulbs (CFLs) and front-loading clothes washers have fallen even as performance has increased.

2. Introduction

California has set itself the ambitious challenge of reducing its greenhouse gas emissions to 80% below 1990 levels by 2050. Achieving this goal will require changes in many sectors of the Californian economy, but few will be as important as those that take place in transportation. Transportation accounts for about 38% of California's total emissions, the largest of any economic sector.[19] The path that California's transportation sector takes in the next decade will thus be a key determining factor in whether California is able to meet its climate goals. Governor Jerry Brown's goal and CARB's regulation to have 1.5 million zero emissions vehicles on the road by 2025 are an important step toward California's 2050 climate goal.

Electric vehicles and their connection to California's electric grid are one of the most rapidly evolving clean transportation options. Relative to their gasoline counterparts in California, plug-in hybrid electric vehicles (PHEV) reduce "well-to-wheel"[20] GHG emissions and smog forming emissions by 60%. For battery electric vehicles (BEV) the reductions are even higher - 85% for GHG and 90% for smog forming emissions.[21]

The first commercially available plug-in electric vehicle was introduced in 2010,[22] and new models from a variety of companies have been introduced every year since.[23] Studies evaluating the technology pathways needed to meet 2050 climate goals find that 70% of vehicle miles traveled — including almost all light-duty vehicle miles — must be powered by electricity.[24,25,26,27] Battery manufactures and

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[19] "2014 Edition: California Greenhouse Gas Emission Inventory: 2000-2012." California Air Resources Board, 2014. Accessed 13 Oct 2014. http://www.arb.ca.gov/cc/inventory/pubs/reports/ghg_inventory_00-12_report.pdf

[20] "Well-to-wheel" includes emissions from fuel production and delivery (well-to-tank) and vehicle use (tank-to-wheel)

[21] CARB. "Advanced Clean Car Summary." Figure 6 and Figure 7, p. 16. http://www.arb.ca.gov/msprog/consumer_info/advanced_clean_cars/acc.htm. Accessed October 15, 2014

[22] "The History of the Electric Car." U.S. Department of Energy, 2014. Accessed 13 Oct 2014. http://www.energy.gov/articles/history-electric-car

[23] "Electric Vehicle Timeline: Electric Cars, Plug-In Hybrids, and Fuel Cell Vehicles." Union of Concerned Scientists, 2014. Accessed 13 Oct 2014. http://www.ucsusa.org/clean_vehicles/smart-transportation-solutions/advanced-vehicle-technologies/electric-cars/electric-vehicle-timeline.html#.VDx9USlkFps

[24] Williams, James H et al. "The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity." 2012.

[25] Wei, Max et al. "Deep Carbon Reductions in California Require Electrification and Integration across Economic Sectors." Environmental Research Letters 8.1 (2013): 14038.

[26] Greenblatt, Jeffery B. "Estimating Policy-Driven Greenhouse Gas Emissions Trajectories in California." 2013.

[27] Scown, Corinne D et al. "Achieving Deep Cuts in the Carbon Intensity of U.S. Automobile Transportation by 2050: Complementary Roles for Electricity and Biofuels." Environmental science & technology 47.16 (2013): 9044–52.

auto makers are focused on reducing the cost and increasing the capability of electric vehicles, and the number and variety of PEV models is growing each year. To enable and encourage accelerated PEV adoption, infrastructure must be deployed to provide readily accessible charging not just in single-family homes, but also in multi-family, public and workplace locations. This report suggests that charging stations and the distribution infrastructure required to serve them can be deployed with net benefits for the economy, environment and all utility ratepayers.

2.1. Transportation Electrification Assessment

The California Transportation Electrification Assessment Phase 1 Report (TEA Phase 1 Report)[28] describes the market size, environmental and societal benefits of transportation electrification (TE), focusing on four segments in particular: plug-in electric vehicles (PEVs), forklifts, truck stop electrification and transport refrigeration units. The Phase 1 Report found that 2.3 million PEVs could displace 5.8 million metric tons (MMT) of GHG in 2030, 50% of the total GHG reduction for all TE sectors in the "In Between" adoption scenario. On an individual basis, a battery electric vehicle (BEV) displaces 252 gallons of gasoline equivalent (GGE) and 2.06 metric tons (MT) of GHG in 2030 relative to an ICE.[29]

Achieving these environmental benefits and meeting long-term GHG goals with increased PEV adoption will also require a corresponding acceleration in the deployment of charging stations and their supporting infrastructure on both the utility and customer side of the electric meter. Widespread PEV adoption must be supported by dramatically increased access to charging at single-family, multi-family and workplace locations alike.[30]

This TEA Phase 2 Report provides an in-depth analysis of electric infrastructure costs that will be incurred to support PEV charging, with an emphasis on utility distribution systems. We use the inputs, scenarios and results from the Phase 1 Report to describe the impacts, costs and benefits of PEV adoption for electric utilities, their customers and the state as whole. We perform the analysis collectively for PG&E, SCE, SDG&E and SMUD, all of which provided detailed distribution system data for the study.

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[28] TEA Phase 1 Report. Available at http://www.caletc.com/wp-content/uploads/2014/08/CalETC_TEA_Phase_1-FINAL.pdf
[29] TEA Phase 1 Report, Table 54, p. 86.
[30] Traut, Elizabeth J. et al. "US Residential Charging Potential for Electric Vehicles." Transportation Research Part D: Transport and Environment 25 (2013): 139–145.

2.2. PEV Cost-Effectiveness Evaluation

The TEA Phase 1 Report presents results largely following the CARB cost-effectiveness method that evaluates the incremental cost of emission-reducing technologies against the quantity and societal value of the emissions reduced.[31] CARB uses this method to determine which programs are providing the most cost-effective emissions reductions.

In this TEA Phase 2 Report, we present results using California Public Utilities Commission (CPUC) Standard Practice Manual (SPM) cost-tests with E3's Distributed Energy Resources (DER) Avoided Cost Framework. The DER Avoided Cost Framework was developed to calculate the utility and societal costs "avoided" by load reductions from energy efficiency and demand response, but is equally applicable to load increases from energy storage or PEVs. The CPUC cost-effectiveness framework compares the incremental costs of distributed resources against the costs the utility would otherwise incur to deliver energy to the customer. Each of five SPM cost-tests represents different perspectives of individual stakeholder groups within California and for the region as a whole.

We describe the PEV adoption and load shape scenarios employed for the analysis in Section 3. In Section 4, we describe how we mapped PEV clusters to specific locations on the distribution systems of the utilities to quantify load impacts and the costs of PEV related distribution upgrades. We describe how we perform cost-effectiveness analysis following CARB and CPUC methods in Section 5. The results, which show that PEVs provide economic, societal and ratepayer benefits are presented in Section 6. In Section 7 we describe the potential for daytime PEV charging to provide addition benefits under higher levels of renewable penetration. Section 8 describes why we must develop new cost-effectiveness metrics to evaluate PEVs and a GHG reduction strategy. Finally, we summarize our conclusions in Section 9.

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[31] CARB. " Staff Proposal Regarding the Maximum Feasible and Cost-effective Reduction of Greenhouse Gas Emissions from Motor Vehicles." 2013 and CARB and CalTrans. "Methods to Find the Cost-Effectiveness of Funding Air Quality Projects" 2005

2.3. Infrastructure Investment Needed to Support PEV Adoption

By August 2014, over 100,000 PEVs had been sold in California, accounting for roughly 40% of the US market and exceeding sales of hybrid electric vehicles in their first four years on the market a decade ago.[32] We compare current adoption against two future projections in Figure 4. The ZEV "Most Likely" PEV adoption scenario from the TEA Phase 1 Report exceeds 2 million PEVs by 2030, and CARB's 2012 "Vision for Clean Air" includes a 2050 scenario that exceeds 4 million PEVs by 2030.[33] As ambitious as these scenarios are, EPA ambient air quality standards will require even more rapid early adoption of PEVs. Neither scenario mentioned above meets the 2023 or 2032 compliance deadline for ozone attainment in South Coast and San Joaquin regions.[34] PEV adoption must not just exceed the historical pace of HEV sales, but continue to grow through 2030 arithmetically in the ZEV Most Likely scenario exponentially under the CARB vision scenario to achieve 2050 GHG reduction targets.

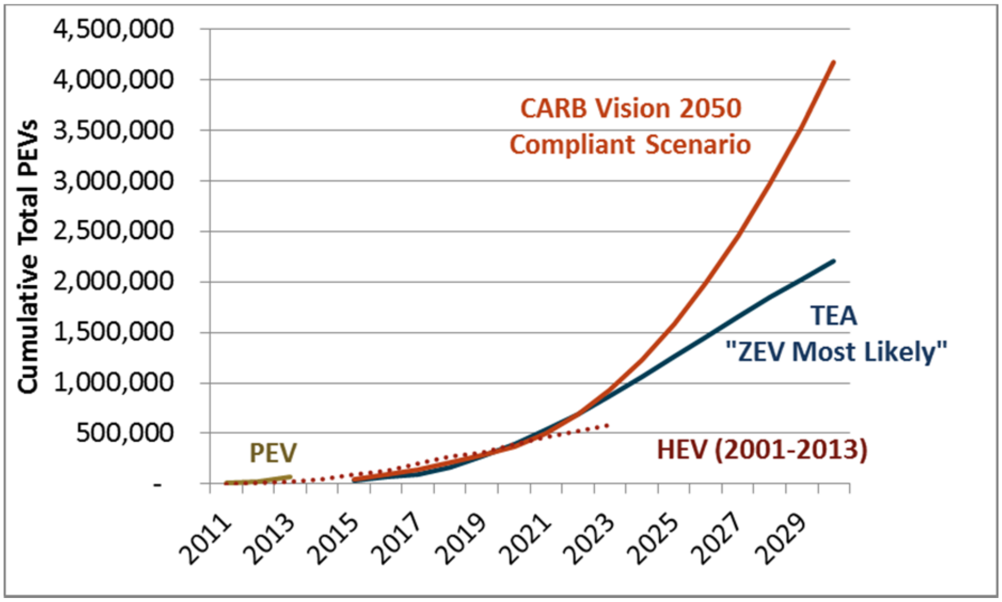

Figure 4. PEV Adoption Scenarios

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[32] Lee, Morgan. "CA Has 100K Plug-in Cars, and Counting." San Diego Union-Tribune 8 Sept. 2014.

[33] CARB. "Vision for Clean Air : A Framework for Air Quality and Climate Planning." 2012.

[34] Greenblatt, Jeffery B. "Estimating Policy-Driven Greenhouse Gas Emissions Trajectories in California." 2013.

Most PEV charging is expected to occur at home, but public and workplace charging is nevertheless critical to motivating PEV purchases by reducing range anxiety and increasing electric vehicle miles traveled (eVMT). If PEVs are to reach substantial penetration levels in the passenger and commercial vehicle markets, new infrastructure must be deployed to support them. Home charging is convenient in many aspects, but alone is not sufficient to support the high market penetration of EVs envisioned to meet GHG and air pollution targets. At home charging is not currently available for most renters or multi-family residences, which limits PEV adoption. Furthermore, if owners rely solely on at home charging, eVMT for PEVs is limited to the range provided by a single battery charge. If EVs are to gain widespread popularity and contribute substantially to emissions reductions in the transportation sector, a readily accessible network of publicly available chargers will be essential.

From today's starting point, it appears that the number of public and workplace charge points must grow at an even faster rate than PEVs themselves. There are approximately 5,800 public charging outlets and an additional 1,000 private outlets California (not including home chargers).[35] The California Statewide Plug-In Electric Vehicle Infrastructure Assessments find that public and workplace charging stations must support roughly 230,000 to 410,000 PEV charging sessions daily in 2020 to support the ZEV adoption goal of 1.5 million vehicles by 2025.[36] By 2020, the number of PEVs must increase by a multiple of 3.5 from today, whereas public and workplace chargers will have to increase by a more than a factor of 18 at the lower of the above estimates.

2.4. PEVs as a GHG Reduction Strategy

The cost tests presented above were developed to evaluate supply and demand side resources on a comparable basis in utility resource planning. Demand side resources that reduce or shift load are valued for reducing the costs and emissions required to meet forecasted demand for energy.

Programs promoting PEV adoption and charging infrastructure deployment are uniquely positioned to provide GHG reductions and utility customer benefits. However, PEVs are fundamentally different from distributed energy resources heretofore considered in utility integrated resource planning in two key respects.

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[35] http://www.afdc.energy.gov/fuels/electricity_locations.html accessed October 2, 2014.

[36] NREL. " California Statewide Plug-In Electric Vehicle Infrastructure Assessment." 2014. Public and workplace charge points from Table 4, p. 16 and charge events per day from Table 8, p. 32

First, PEV's provide net benefits and emissions reductions to California, but the generation needed to serve PEV load will result in emissions increases in the power sector. Second, whereas the primary purpose of promoting DER has been to reduce the costs and emissions required to meet forecasted load, California seeks to accelerate PEV adoption to meet GHG reduction and air quality targets. Evaluating PEVs as a GHG reduction strategy will require a more comprehensive evaluation of utility and transportation sector costs and benefits, including long-term GHG and criteria pollutant emissions benefits.

Public Utility Code (PUC) Sections 740.3 and 740.8 suggest one step in this direction.[37] The code describes direct benefits from low-emission vehicles that are "interests" of ratepayers, including:

- Providing safer, more reliable, or less costly gas or electrical service
- Promoting energy efficiency
- Reducing health and environmental impacts from air pollution and greenhouse gas emissions and
- Increased use of alternative fuels.

This report describes how PEV's, even without vehicle-to-grid (V2G) capability, can reduce average rates and increase the beneficial use of existing utility infrastructure. With properly designed dynamic rates or managed charging, PEV's increase grid reliability under high RPS scenarios by absorbing overgeneration and reducing morning and evening ramps. PEVs compared to their gasoline counterparts on a "well-to-wheel" basis[38] increase electric loads, but reduce total energy use, providing significant reductions in GHG and criteria pollutant emissions (see Introduction, p. 24). Finally, with accelerated vehicle adoption, the electric (and natural gas) utilities can provide increased quantities of alternative transportation fuel in the near-term with existing and ubiquitous transmission and distribution infrastructure.

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[37] See http://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=PUC&division=1.&title=&part=1.&chap ter=4.&article=2.

[38] Well-to-wheel basis means including all of the fuel related emissions from fuel feedstocks (e.g. crops or fossil fuel mines and wells) and fuel production and delivery(e.g. power plant or refinery), jointly well-to-tank, and vehicle use (tank-to-wheel).

3. PEV Adoption and Load Shape Scenarios

3.1. Vehicle Forecasts

A working group of utility and consultant staff developed three vehicle adoption scenarios included in the Phase 1 report and used for this analysis. The scenarios are designed not to be precise predictions of future vehicle adoption, but rather to illustrate grid impacts and cost and benefits under a low, medium and high adoption scenario (Figure 5). The three scenarios are:

- **ZEV Compliance**: ZEV compliance assuming a 50/50 split between PEVs and fuel cell vehicles.
- **ZEV Program "Most Likely Compliance Scenario"**: In the development of the Zero Emission Vehicle Program, CARB staff developed a most likely compliance scenario.[39] This scenario was modified to reflect recent PEV sales data and to extend out to 2030.
- **ZEV Program Scenario x 3**: This scenario is three times larger than the ZEV program's most likely compliance scenario.

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[39] CARB. "Staff Report: Initial Statement of Reasons: 2012 Proposed Amendments to the California Zero Emission Vehicle Program Regulations." http://www.arb.ca.gov/regact/2012/zev2012/zevisor.pdf

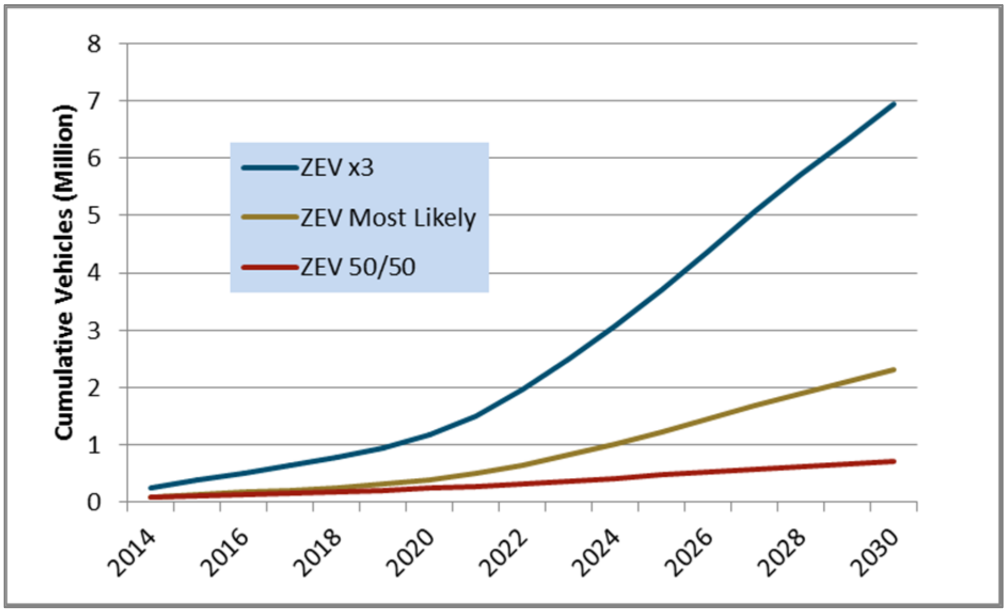

Figure 5. PEV Adoption Scenarios

3.2. Energy Consumption

The working group developed energy consumption estimates based on vehicle miles traveled and energy consumption by PEV type data from the EV Project (Table 1). Data from utilities in California and reported by The EV Project indicates that about 74-80 percent of charging is happening at home and 20-26 percent is happening away from home. The working group assumed that 80 percent of charging will occur at home for most of the scenarios.

Table 1. PEV Energy Consumption (kWh), by Vehicle Type[40]

Vehicle Type	Vehicle Miles Traveled		eVMT		Energy Consumption (kWh)					
	Daily	Annual	Daily	Annual	Daily			Annual		
					Res	Non-Res	Total	Res	Non-Res	Total
PHEV10	41	14,965	10.0	3,650	2.8	0.7	3.5	1,022	256	1,278
PHEV20			20.0	7,300	5.6	1.4	7.0	2,044	511	2,555
PHEV40			30.6	11,169	8.6	2.1	10.7	3,127	782	3,909
BEV	29.5	10,768	29.5	10,768	8.3	2.1	10.3	3,016	754	3,770

3.3. Load shapes

The working group developed several normalized load shapes with the general characteristics described below and illustrated in Figure 6.

- **L1 Home** with TOU rate: Level 1 charging at home is a proxy for charging of PHEVs with smaller batteries, like the PHEV10 or PHEV20. The normalized profile is based on a similar start time as L2 charging; however, it is stretched out over a longer period.
- **L2 Home** with TOU Rate: Level 2 charging at home is a proxy for BEV or PHEV40 charging.
- **Non TOU Home**: Residential charging in the non-TOU case is a modified version of what is reported in the EV Project for Nashville, Tennessee – a region without a TOU rate. The modifications were made based on the at-home arrival times reported in the National Household Transportation Survey (NTHS).

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[40] TEA Phase 1 Report, Table 35, p. 68

- **L2 Non-Residential**: The non-residential charging is a proxy for workplace charging (weekdays) and public charging (weekends) and is used in the TOU scenario and the Flat Rate Scenario. Assumed to be all Level 2 charging.

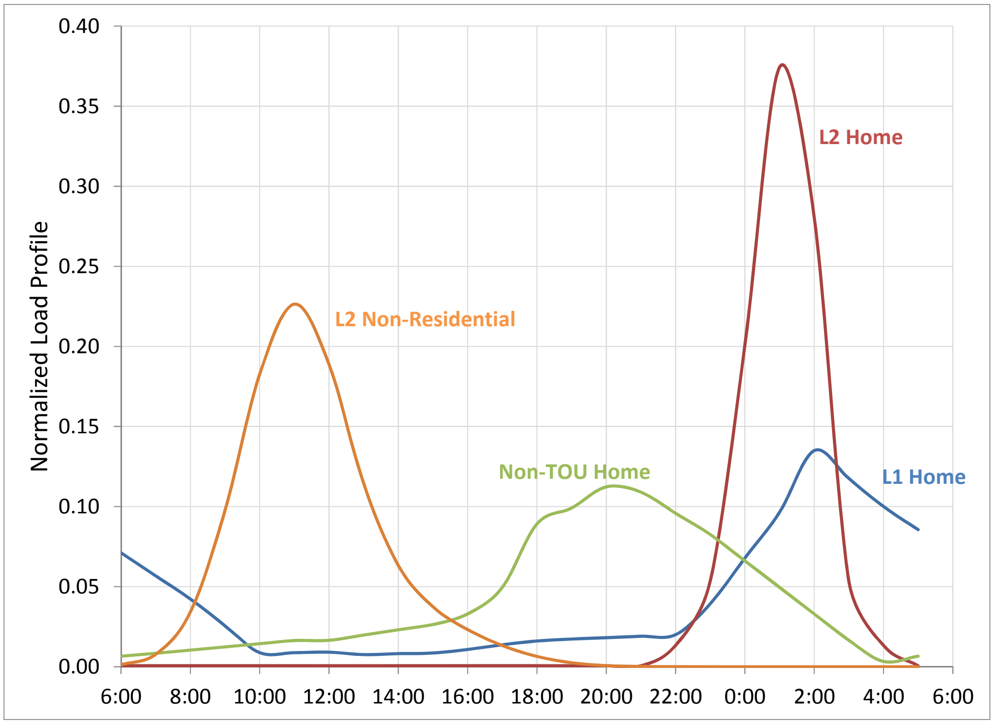

Figure 6. Load Profiles for Various Charging Scenarios

3.4. Rate and Load Shape Scenarios

The working group developed four scenarios that represent a combination of rates and load profiles (Figure 7):

- **Tiered Rate Scenario:** This scenario assumes that PEV drivers charge immediately when they arrive at a destination (Flat Rate Scenario Load Shape). A tiered, non-TOU rate applies to residential charging and a flat rate applies to commercial charging

- **Flat Rate Scenario**: This scenario assumes that PEV drivers charge immediately when they arrive at a destination (Flat Rate Scenario Load Shape). A flat rate applies to residential and commercial charging (no tiers or TOU variation).
- **Mixed Rate Scenario**: This scenario assumes a 50-50 split between the TOU Rate Scenario (below) and the Flat Rate Scenario. This includes both load shapes and retail rates.
- **TOU Rate Scenario**: PEVs are assumed to charge on TOU rates with the majority of charging shifted to off-peak times.

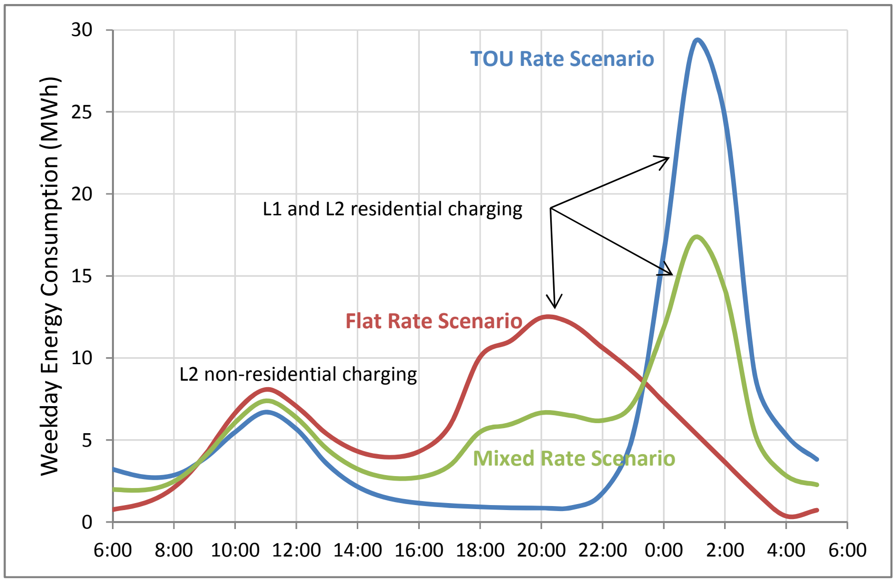

Figure 7. Illustrative Charging Load Shapes for 15,000 PEVs

4. Analysis of PEV Grid Impacts

The potential impact on the utility distribution system is one of the primary concerns related to PEV charging. For this study, with significant support from utilities, we performed an in-depth analysis of the PEV-related load growth and associated distribution feeder and substation upgrades.

4.1. PEV Clustering

PEVs, like HEVs and rooftop solar photovoltaics (PV), will cluster in certain areas. Clustering presents a potential challenge for the utility distribution system, as a few PEVs charging coincident with the distribution peak could exceed the rated capacity of installed equipment. To account for clustering, we allocated the forecasted PEV adoption to ZIP+4 zones with weightings based on historical hybrid electric vehicle (HEV) adoption.

Polk vehicle registration data provides the number of HEVs located in each ZIP+4 area in California. We used this data in combination with census demographic data to apportion PEV vehicle adoption forecasts by ZIP+4 area based on historical HEV adoption. We assume that the majority of PEV buyers will also want to install convenient home charging equipment. We therefore assume that PEV adoption will be more heavily weighted towards areas with single family (SF) and owner occupied dwellings and use census data to adjust PEV allocations accordingly. An example of the adjusted HEV numbers used to apportion PEV adoption for ten ZIP+4 areas is shown in Table 2.

Table 2: Example HEV Registration Data by ZIP+4

ZIP+4	SF Owner	MF Owner	SF Renter	MF Renter	Census Modifier	# of HEVs	Adj. HEVs
92127-1708	47%	20%	21%	9%	54%	15	8.1
92130-2122	100%	0%	0%	0%	100%	15	15.0
92131-2965	31%	35%	14%	16%	41%	15	6.2
92101-1128	4%	15%	17%	61%	10%	13	1.3
92111-7319	23%	37%	12%	19%	34%	13	4.4
92123-3839	55%	12%	22%	5%	60%	13	7.8
92117-5531	50%	6%	37%	4%	55%	7	3.8
92121-2312	66%	16%	14%	3%	72%	7	5.0
92009-7516	19%	27%	16%	23%	27%	4	1.1
92009-7802	64%	19%	11%	3%	70%	4	2.8

4.2. Utility Distribution Systems

Utility staff was very helpful in gathering and providing detailed distribution system data for use in this study. Distribution system data was provided by PG&E, SCE, SDG&E, and SMUD. For consistency across all utilities, we developed a common topology for use in describing each system (Figure 8). The distribution system equipment categories and their approximate size ratings are:

- **Substation** (~75-150 MVA): Distribution substation, including high-voltage (high-side) switches, fuses, etc.
- **Substation Transformer** (~12-70 MVA): Low-voltage (low-side) transformers, bus, breakers, fuses, switches, etc.
- **Feeder** (~2-30 MVA): Primary voltage feeder connected to low side bus of substation, primary conductor, breakers, fuses, switches, and pad mount transformers.
- **Circuit** (75-2,000 kVA): Secondary voltage circuit between feeder and customer interconnection, distribution transformer, final line/network/pole mount transformer, secondary conductor, distribution panel.

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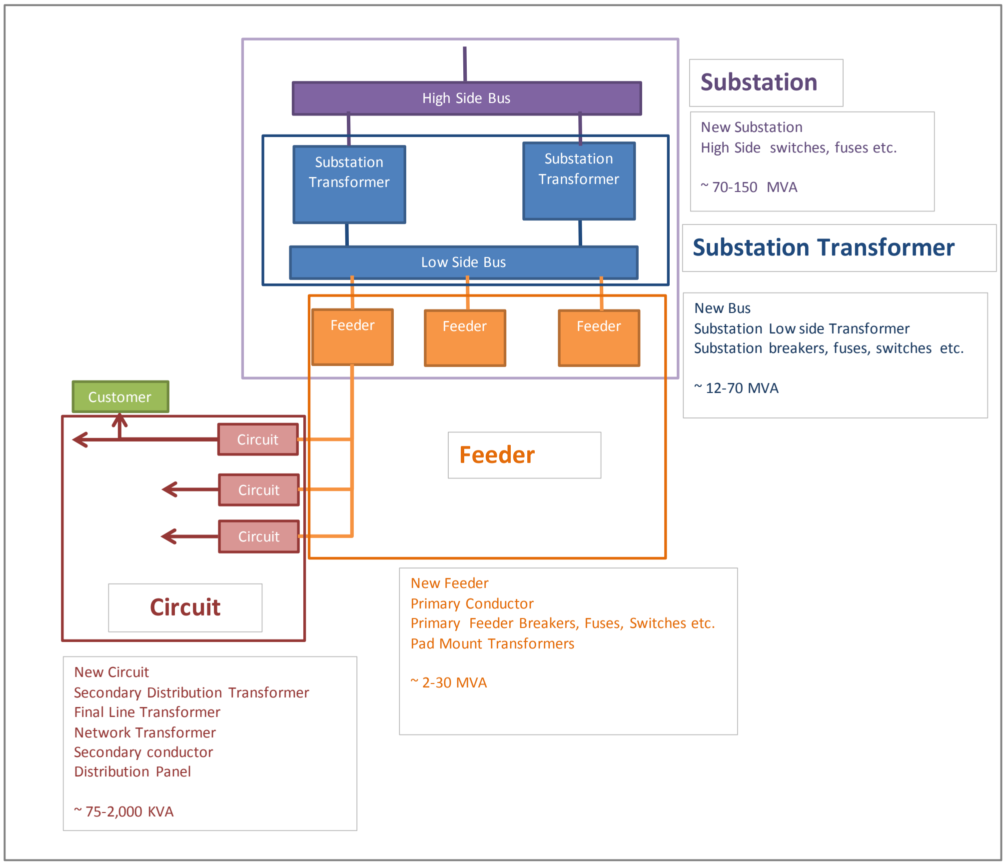

Figure 8. Distribution System Topology

4.2.1. DATA PROVIDED

The data provided by the utilities is illustrated in Table 3. Each utility provided detailed information on the circuits, feeders and substations in their service territory, including capacity rating, utilization, peak loads, and number of residential and commercial accounts and forecasted load growth. The utilities also provided latitude and longitude location information for each data point.

Table 3: Example Utility Distribution Data

	Substation Name	Rating (kV)	Sub Rating (MVA)	Bank Rating (MVA)	Feeder Capability (MW)	Peak kW	Peak Day for Feeder	Available Capacity (kW)	Utilization	Growth	Non Res	Res
Circuit	Valley	21	151	45	19.0	14,267	6/29/2013	4,733	75%	1.25%	288	3,612
Circuit	Valley	21	151	45	21.3	15,224	7/1/2013	6,076	71%	1.25%	168	3,498
Circuit	Valley	21	151	45	21.8	5,056	7/1/2013	16,744	23%	1.25%	116	1,249
Substation Bus					45.0	34,545		10,455	77%	1.25%		
Circuit	Valley	21	151	45	22.6	18,750	6/29/2013	3,850	83%	1.25%	256	3,730
Circuit	Valley	21	151	45	19.0	13,905	7/1/2013	5,095	73%	1.25%	253	4,212
Substation Bus					45.0	32,566		12,434	72%	1.25%		
Circuit	Valley	21	151	45	21.5	13,903	7/1/2013	7,597	65%	1.25%	357	4,097
Circuit	Valley	21	151	45	22.6	17,290	7/3/2013	5,310	77%	1.25%	312	3,753
Circuit	Valley	21	151	45	19.0	5,103	7/1/2013	13,897	27%	1.25%	114	1,581
Substation Bus					45.0	36,051		8,949	80%	1.25%		
Circuit	Valley	12	151	16	9.1	6,067	7/1/2013	3,033	67%	1.25%	105	1,683
Circuit	Valley	12	151	16	5.0	2,421	7/1/2013	2,579	48%	1.25%	22	710
Substation Bus					14.1	8,488		5,612	60%	1.25%		
Substation			151.0		149.1	111,223		37,450	75%	1.25%		

In all, the investor-owned utilities (IOUs) provided data for 7,894 feeders and 1,607 substations located in their respective service territories. SMUD provided data at the circuit level, for a much larger number of data points, over 73,000. SMUD's substations also tend to be smaller than those of the IOUs', accounting for the larger number substations relative to its size as compared to the IOUs.

Table 4: Distribution Data Provided by Each Utility

	Circuits & Feeders	Substations
PG&E	3,186	780
SCE	4,031	706
SDG&E	677	121
SMUD	73,786	637

4.2.2. DISTRIBUTION SYSTEM UPGRADE COSTS

Each utility provided a utilization that would trigger a circuit, feeder or substation upgrade. For each type of upgrade, the utilities also provided average upgrade sizes and costs representative of their respective systems (Table 5 and Table 6). As load at each location exceeds rated capacity, upgrades are added in that year. The cost of distribution system upgrades is added to the utility rate base and included in the cost-effectiveness analysis. The model looks forward several years to determine whether a single (larger) new substation or substation upgrade or several (smaller) feeder upgrades are more cost-effective. The utilities also estimated the percentage of existing substation locations at which upgrades could feasibly be performed (e.g., have sufficient high-side capacity and land area to add a new low-side bus). The lower cost substation expansion upgrades were limited according to the utility input so that the model would implement higher-cost new substations in some cases.

Table 5. Circuit/Feeder Upgrade Costs

	PG&E	SCE	SDG&E	SMUD
Size (MVA)	10	10	10	0.57
Underground Cost ($)	$2,045,000	$2,045,000	$2,045,000	$7,691
Overhead Cost ($)	$1,810,000	$1,810,000	$1,810,000	$7,691
Utilization Upgrade Trigger	90%	90%	90%	115%

Table 6. Substation Upgrade Costs

	PG&E	SCE	SDG&E	SMUD
Expansion Size (MVA)	30	30	30	30
Expansion Cost ($)	$3,800,000	$5,000,000	$1,500,000	$2,500,000
New Size (MVA)	60	60	60	35
New Cost ($)	$18,400,000	$47,000,000	$31,800,000	$5,000,000
Utilization Upgrade Trigger	90%	90%	90%	90%
Pct. Eligible for Expansion	50%	50%	60%	33%

4.3. Mapping PEV Clusters to Distribution System

The final step in the clustering analysis is mapping each ZIP+4 cluster of PEVs to circuits and feeders on the utility distribution systems. Geographic Information System (GIS) analysis mapped each ZIP+4 area to the closest utility circuit or feeder according to its latitude and longitude information. In nearly all cases, there is a one to one mapping of PEV ZIP+4 clusters to a single circuit (for SMUD) or feeder (for the IOUs).

4.4. PEV Load Impacts

With the combination of the PEV adoption scenarios, PEV load shapes and PEV clusters, we calculated the PEV-related peak load growth that would occur at each location on the distribution system for each scenario. With the utility distribution system data, we are able to calculate utilization at each point with the total forecasted load growth, including incremental PEV charging load. The results are illustrated for the San Francisco Bay Area in (Figure 9). This figure shows the percentage utilization of each point on the distribution system with the ZEV Most Likely adoption scenario and Mixed Rate scenario, assuming no additional capacity-related upgrades. In 2010, most locations are green or light yellow, indicating utilization below 100%. By 2020 several locations have changed from green to yellow and a few are red, indicating utilization of close to 150% or more. By 2030, most, but not all locations are close to or greater than 100% utilization.

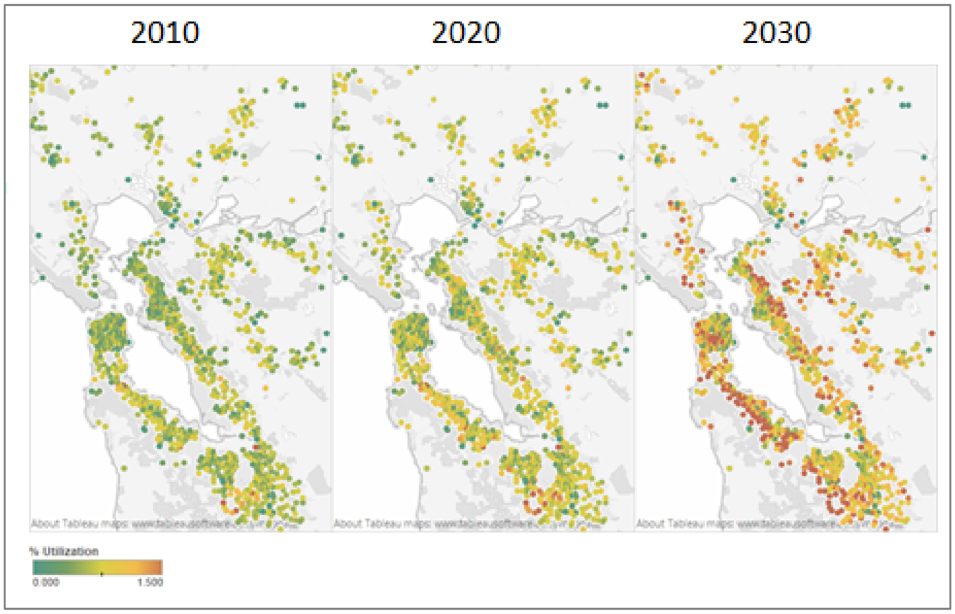

Figure 9. Distribution System Utilization with PEV Charging

4.5. PEV Related Distribution Upgrades

To examine the grid impacts specific to PEV charging, we first model distribution upgrades required to meet the base case forecasted load growth provided by each utility. We then add the hourly PEV-charging load for each adoption and rate scenario to the base case load forecast and model the required distribution upgrades. We count the incremental distribution upgrades in the PEV charging case as being PEV related. The additional distribution upgrade cost with PEV charging is due to both a greater number of required upgrades and some upgrades being required earlier than they are in the base case without PEVs.

The upgrades associated specifically with PEV loads are illustrated in Figure 10 and Figure 11. The maps on the left show upgrades required under the ZEV Most Likely – Mixed Rate scenario for the Los Angeles and San Francisco Bay areas respectively. The maps on the right show the upgrades required under the higher ZEV x 3 adoption scenario.

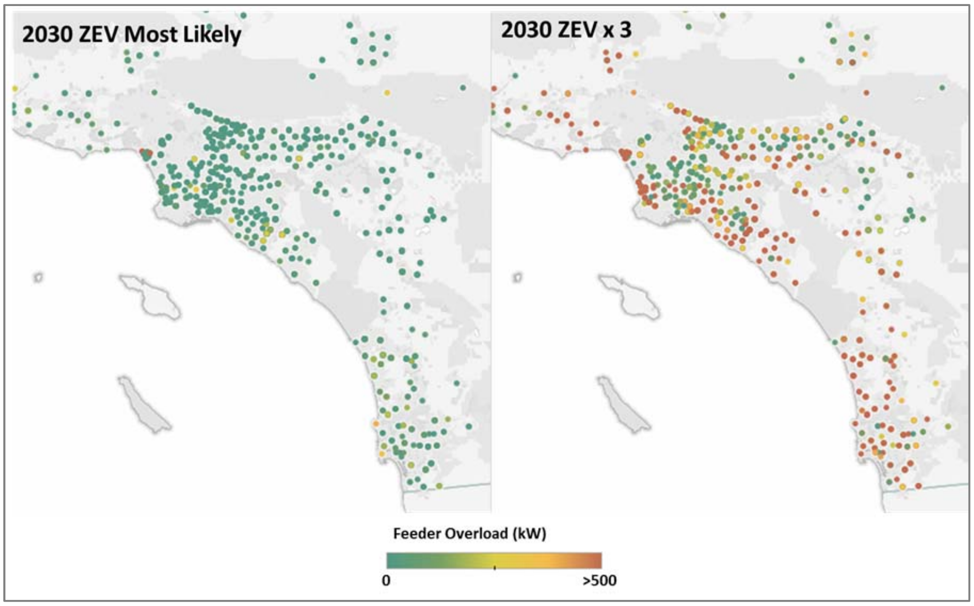

Figure 10. 2030 Distribution System Upgrades Driven by PEV Charging: Los Angeles Area

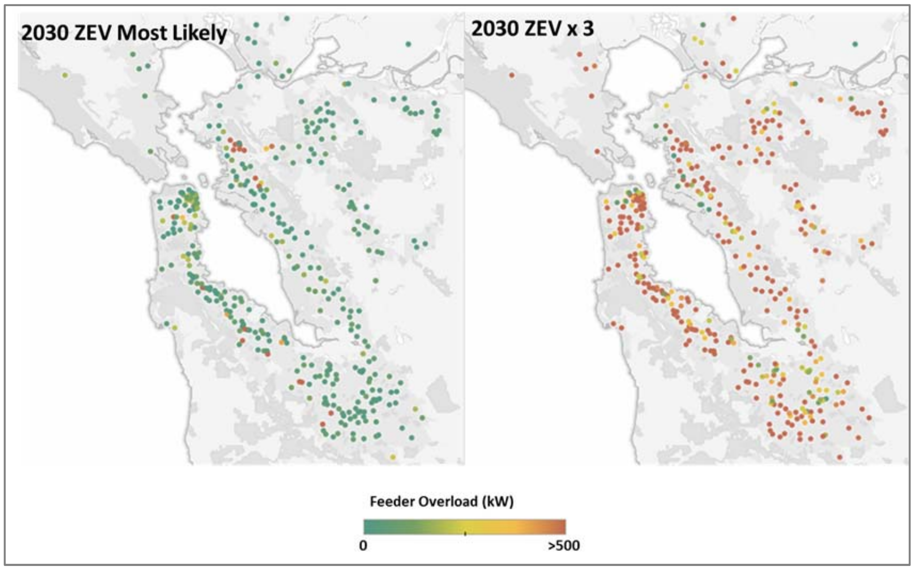

Figure 11. 2030 Distribution System Upgrades Driven by PEV Charging: San Francisco Bay Area

4.6. PEV Charging and Infrastructure Costs

The input assumptions for this Phase 2 report are largely the same as those used in the TEA Phase 1 Report. One difference is that the utility working group members suggested they are experiencing higher costs to install service for commercial Level 2 (L2) charging than the ~$1,700 assumed in Phase 1. Cost varies widely due to a number of factors at each specific site and is difficult to quantify precisely at this early stage of adoption. We use a more conservative estimate of $8,000 per commercial Level 2 charger. Costs to provide new electric service are $1,700 and borne by the utility. The "make-ready" costs to deliver electricity from the point of utility interconnection to the charger and charger itself are assumed to cost $6,300 and to be paid by the customer. For fleet vehicles, one Level 2 charger is installed per vehicle. For residential PEVs, we assume two Level 2 commercial chargers are installed for every ten vehicles (0.2 chargers per PEV).

Table 7. PEV Charging and Infrastructure Costs

	Charging Infrastructure Cost		
	L1 Residential	L2 Residential	L2 Commercial
Customer	$200	$1,000	$6,300
Utility		$700	$1,700
Total	$200	$1,700	$8,000

4.7. Distribution System Costs

4.7.1. DISTRIBUTION COSTS FOR AT HOME CHARGING

Recall that the scenarios assume the 80 percent or more of vehicle charging will occur at home. Under these scenarios studies, we find that the incremental feeder and substation upgrades driven specifically by incremental PEV charging to be relatively small. In the non-TOU rate scenarios, the present value costs are just under $400 million in the ZEV Most Likely adoption case (Figure 12). TOU Rates shift charging off-peak and reduce upgrade costs by over 40% to under $150 million. Under the more aggressive ZEV x 3 adoption case, the present value distribution costs increase to $910 million (Figure 13). Note that the distribution upgrade costs do not increase linearly between the ZEV Most Likely and ZEV x 3 case. At higher levels of adoption, the available capacity of the existing system is exhausted more quickly, and the PEV related upgrades are larger in both number and size. Nevertheless, even at the ZEV x 3 adoption case, annual distribution costs are roughly $9 million per year - less than 1% of the 2012 distribution revenue requirement of $9 billion for the four utilities.

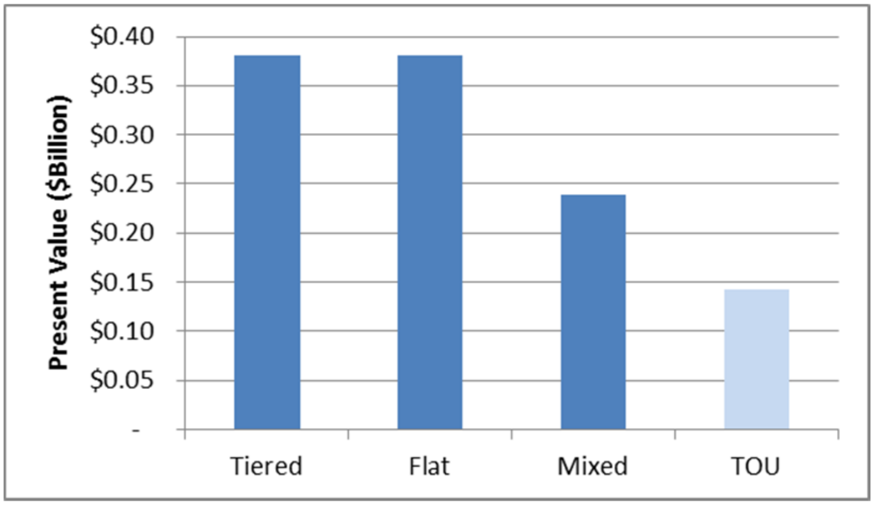

Figure 12. Present Value Distribution Upgrade Costs by Rate/Load Shape Scenario

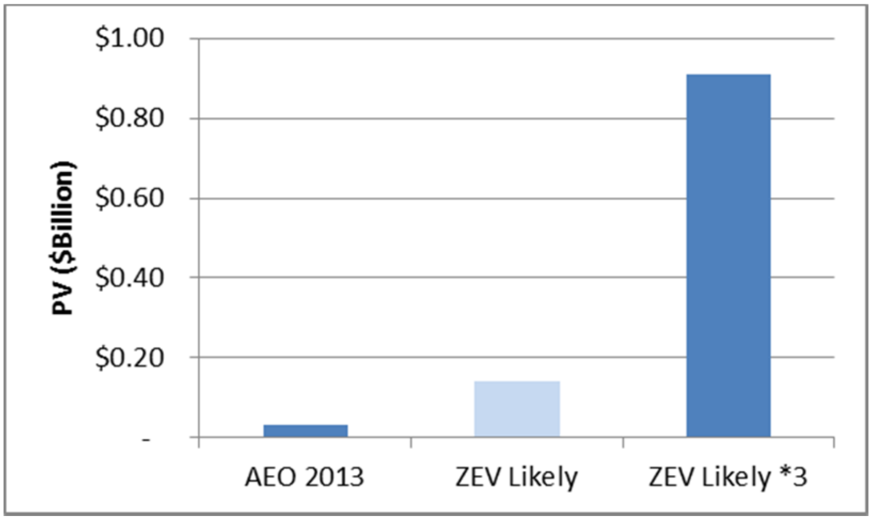

Figure 13. Present Value Distribution Upgrade Costs by Adoption Scenario

4.7.2. INFRASTRUCTURE COSTS FOR MULTI-FAMILY, PUBLIC AND WORKPLACE CHARGING

The adoption and load shape scenarios developed for this study do not include high levels of public and workplace charging. Furthermore, we use an average cost of

$8,000 to represent make ready costs for multi-family and workplace Level 2 charging. Other studies propose that higher access to multi-family, public and workplace charging will be necessary to promote PEV ownership beyond single family home owners. Public and workplace charging will also be needed to maximize the eVMT realized from PEVs. Dramatically increasing charging at these locations may well require make-ready and other infrastructure costs not fully represented in this study.

In addition, in Section 7 below, we discuss the potential benefits of daytime PEV charging to manage higher penetrations of renewables on the grid. Higher levels of daytime charging to absorb excess generation will provide benefits, but may also coincide at times with peak loads on the distribution system. Avoiding PEV charging coincident with peak distribution loads can be achieved with managed charging, but alternative strategies to absorb overgeneration will be required during those hours. Maximizing the availability of PEVs as a resource for renewable integration may require additional fortifications to the distribution system not contemplated in this study.

5. Cost-Effectiveness Analysis

5.1. Cost-Effectiveness Framework

5.1.1. CARB COST-EFFECTIVENESS METHOD

The TEA Phase 1 Report presents cost-benefit results using the CARB cost-benefit method for evaluating air quality improvement projects. The CARB cost-benefit method defines the cost-effectiveness of an air quality project based on "the amount of pollution it eliminates for each dollar spent."[41] The CARB cost-benefit method calculates a cost in $/unit of emission (e.g., ton, pound, gram) to determine which measures and programs are the most cost-effective. Costs include CARB funding for the incremental cost of the "clean" technology relative to its "standard" counterpart. For this report, it is important to emphasize that the CARB cost-benefit method does not include energy utility costs incurred to serve alternative fueled vehicles (AFVs).

5.1.2. CPUC COST-EFFECTIVENESS FRAMEWORK

5.1.2.1. CPUC Cost-effectiveness Tests

The origins of cost-effectiveness tests for distributed energy resources (DER), including energy efficiency, demand response and distributed generation, are found in the 1974 Warren-Alquist Act that established the California Energy Commission (CEC) and specified cost-effectiveness as a leading resource planning principle. Later, the 1983 California Standard Practice Manual of Cost-Benefit analysis of Conservation and Load Management Programs (SPM) developed five cost-effectiveness tests for evaluating energy efficiency programs. These approaches, with minor updates, continue to be used today and are the principal

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[41] CARB. " Staff Proposal Regarding the Maximum Feasible and Cost-effective Reduction of Greenhouse Gas Emissions from Motor Vehicles." 2013 and CARB and CalTrans. "Methods to Find the Cost-Effectiveness of Funding Air Quality Projects" 2005

approaches used for evaluating DER programs across the United States.[42] The five cost tests are summarized in Table 8.

Table 8. The Five Principal Cost Tests Used for Distributed Energy Resources

Cost Test	Acronym	Key Question Answered	Summary Approach
Participant Cost Test	PCT	Will the participants benefit over the measure life?	Comparison of costs and benefits to the customer installing the measure
Utility/Program Administrator Cost Test[43]	UCT/PAC	Will utility bills increase or decrease?	Comparison of program administrator costs to supply side resource savings
Ratepayer Impact Measure	RIM	Will utility rates increase or decrease?	Comparison of changes in utility revenues to supply side resource savings, with administrator costs included
Total Resource Cost	TRC	Will the total costs of energy in the utility service territory decrease?	Comparison of program administrator and customer costs to utility resource savings
Societal Cost Test	SCT	Is the utility, state or nation better off as a whole?	Comparison of society's costs of energy efficiency to resource savings including non-energy benefits (NEBs)

The basic structure of each cost test involves a calculation of the total benefits and the total costs in dollar terms from a certain vantage point to determine whether or not the overall benefits exceed the costs. A test is positive if the benefit-to-cost ratio is greater than one, and negative if less than one. Results are reported either in net present value dollars (method by difference) or as a ratio (i.e., benefits/costs).

Each of the cost-effectiveness tests provides a different kind of information about the impacts of DER programs from different vantage points in the energy system.

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[42] The California SPM was first developed in February 1983. It was later revised and updated in 1987-88 and 2001 and a Correction Memo was issued in 2007. The 2001 California SPM and 2007 Correction Memo can be found at: http://www.cpuc.ca.gov/PUC/energy/electric/Energy+Efficiency/EM+and+V/

[43] The UCT/PAC was originally named the Utility Cost Test. As programs management has expanded to government agencies, not-for-profit groups and other parties, the term "Program Administrator Cost Test" has come into use, however the computations are the same. This document refers to the UCT/PAC as PAC for simplicity.

On its own, each test provides a single stakeholder perspective. Together, multiple tests provide a comprehensive approach. The TRC and SCT cost tests help to answer whether DERs are cost-effective for society overall. For the purpose of this analysis, society is defined as the residents of the state of California. The costs and benefits are totaled for society as a whole, irrespective of who pays the costs or who receives the benefits. Intra-regional transfers, such as utility incentives or customer bills, are not considered, as they represent an exchange from one party to another within the region considered.

The PCT, PAC, and RIM help to answer whether the portfolio and design of a proposed program is balanced from participant, utility, and non-participant perspectives, respectively. Looking at the cost tests together helps to characterize the attributes of a program or measure to enable decision-making, to determine whether some measures or programs are too costly, whether some costs or incentives are too high or too low, and what adjustments need to be made to improve distribution of costs and benefits among stakeholders.

Table 9: Summary of Cost Test Components for Load Reductions

Component	PCT	PAC	RIM	TRC	SCT
Deferred/avoided capital investment		+	+	+	+
Utility energy production/purchase savings		+	+	+	+
Quantifiable variable and environmental cost savings				+	+
Non-energy benefits					+
Equipment and install costs	-			-	-
Incentive payments/utility direct install costs	+	-	-		
Program administrative and overhead costs		-	-	-	-
Customer bill savings/reduced utility revenue	+		-		

+	= Benefit	-	= Cost

5.1.2.2. *CPUC Avoided Costs*

The benefits/(costs) of reduced/(increased) energy consumption are calculated using the CPUC and CEC-adopted avoided cost methodology used for evaluating DER. The avoided cost methodology developed by E3 has been updated and improved through several CPUC and CEC proceedings. The most recent update was performed by E3 for the 2013 Net Energy Metering Cost-effectiveness Evaluation, which was also subsequently used for the 2016 CEC Title 24 Time Dependent Valuation Update. The avoided costs include six components listed in Table 10.

Table 10: Components of Avoided Costs

Component	Description
Generation Energy	Estimate of hourly marginal wholesale value of energy adjusted for losses between the point of the wholesale transaction and the point of delivery
System Capacity	The marginal cost of procuring Resource Adequacy resources in the near term. In the longer term, the additional payments (above energy and ancillary service market revenues) that a generation owner would require to build new generation capacity to meet system peak loads
Ancillary Services	The marginal cost of providing system operations and reserves for electricity grid reliability
T&D Capacity	The costs of expanding transmission and distribution capacity to meet customer peak loads
CO2 Emissions	The market cost of carbon dioxide emissions (CO2) associated with the marginal generating resource
Avoided RPS	The cost reductions from being able to procure a lesser amount of renewable resources while meeting the Renewable Portfolio Standard (percentage of retail electricity usage).

The avoided costs are illustrated in Figure 14 and Figure 15. On an illustrative spring weekday, generation energy is the dominant cost (Figure 14). Generation capacity and T&D capacity costs are allocated predominately to a limited number of summer peak hours (Figure 15).

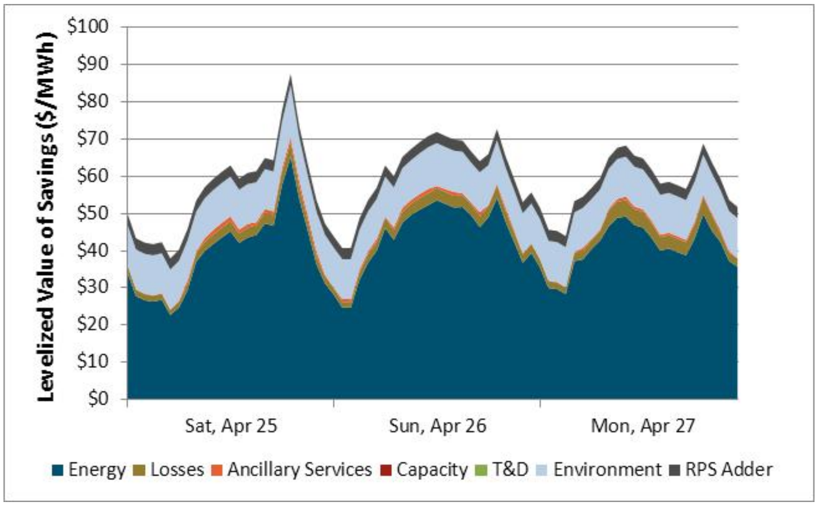

Figure 14. DER Avoided Costs – Spring Weekdays

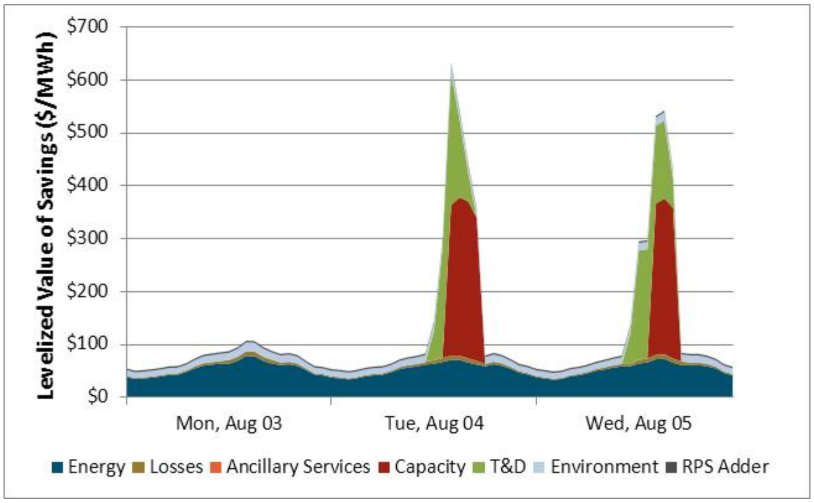

Figure 15. DER Avoided Costs – Summer Peak Days

5.1.3. PUC CODE 740.8 RATEPAYER BENEFITS

Section 740.3 of the California Public Utilities Commission code stipulates that in order for utilities to rate base investments for electric-powered and natural gas-fueled low-emission vehicles infrastructure, these investments must be “in the ratepayers' interest."[44] Section 740.8 further clarifies the phrase "ratepayers' interest" to include both direct benefits to the ratepayers and certain societal benefits. These societal benefits include increased energy efficiency, reduced health and environmental impacts from air pollution, reduced greenhouse gas emissions, and increased use of alternative fuels[45]. In order to maximize our model's relevance to the current policy context, our model includes these same benefits when performing the societal cost-benefit tests. The model incorporates them quantitatively as the monetary values of reducing criteria air pollutants ($/ton), reducing greenhouse gas emissions ($/MT), and displacing petroleum ($/GGE). Criteria air pollutants included in the model include nitrous oxides (NOx), particulate matter (PM), and volatile organic compounds (VOC). The values of reducing the three criteria air pollutants are combined into a health-benefit value for each PEV scenario. Table 11, below, shows the values from the Phase 1 Report used for displaced petroleum and criteria air pollutant benefits. For this report, we use the CPUC DER Avoided Cost values for GHG, which are higher than those used in the Phase 1 Report (Table 12). The avoided cost values for GHG are intended to represent the monetized costs of GHG emissions under California's cap-and-trade allowance program.

For the economic regional benefits included in the TRC, we use the CPUC DER Avoided Cost values for GHG. For this study, we assume it is a natural extension in the spirit of the SPM to include the GHG benefits in the transportation sector as a benefit as a counterpart to the GHG cap and trade emission costs in the electric sector. We recognize, however, this interpretation has not been explicitly been adopted by the CPUC. For the SCT, in lieu of the monetized cap-and-trade allowance values, we use a higher societal value of avoided GHG emissions.[46]

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[44] "CAL. PUC. CODE §740.3: California Code – Section 740.3." *FindLaw.* Thomson Reuters, 2014. Web. Accessed 2 Sept 2014. http://codes.lp.findlaw.com/cacode/PUC/1/d1/1/4/2/s740.3

[45] "CAL. PUC. CODE §740.8: California Code – Section 740.8." *FindLaw.* Thomson Reuters, 2014. Web. Accessed 2 Sept 2014. http://codes.lp.findlaw.com/cacode/PUC/1/d1/1/4/2/s740.8

[46] Presentation by Energy and Environmental Economics at CPUC Workshop on Societal Cost Test. http://www.cpuc.ca.gov/NR/rdonlyres/3A3835F9-070B-4068-8717-42177AB342AD/0/SCTWorkshop6132013.pdf

Table 11. Factors for Monetizing Societal Benefits

Societal Benefit	Unit	2013	2020	2030
Displaced Petroleum[1],[2]	$/GGE	$0.44	$0.43	$0.42
NOx[5],[6]	$/ton	$4,675	$5,082	$6,098
PM 41,42	$/ton	$1,450,038	$1,650,681	$1,977,357
VOC 41,42	$/ton	$1,118	$1,20	$1,423

Table 12. GHG Values

GHG Cost	Unit	2013	2020	2030
Phase 1 Report [3],[4]	$/Metric Ton	$11	$12	$16
CPUC Avoided Costs	$/Metric Ton	$17	$37	$73
Societal Value	$/Metric Ton	$49	$56	$70

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[1] Leiby, P. Estimating the Energy Security Benefits of Reduced U.S. Oil Imports, ORNL/TM-2007/028, March 2008

[2] EPA RFS Annual Rulemaking, Updated Energy Security Benefits, 2012. EPA-HQ-OAR-2010-0133-0252, Available online at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2010-0133-0252

[5]Diesel Emissions Quantifier Health Benefits Methodology, EPA, EPA-420-B-10-034, August 2010. Available online: http://www.epa.gov/cleandiesel/documents/420b10034.pdf

[6] EPA/HNTSA, Draft Joint Technical Support Document: Proposed Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, EPA-420-D-11-901, November 2011.

[3] Interagency Working Group on Social Cost of Carbon. 2010. Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. February. United States Government. http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf

[4] Interagency Working Group on Social Cost of Carbon. Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, United States Government, May 2013.

Table 13: Detailed Cost Test Components for PEV Charging Load Increase

Component	PCT	RIM	TRC	SCT (740.8)
PEV Customer costs and benefits				
Incremental Vehicle Costs	-		-	-
Gasoline Savings	+		+	+
Utility Bills	-	+		
Federal Tax Credits	+		+	+
State Tax credits	+			
PEV Charger Cost				
Utility Asset		-	-	-
Customer Assets	-		-	-
Admin Costs				
Utility Program Administration		-	-	-
Electricity Supply Costs				
Energy Costs		-	-	-
Losses Cost		-	-	-
A/S Cost		-	-	-
Capacity Cost		-	-	-
T&D Cost		-	-	-
RPS Cost		-	-	-
Utility GHG Allowance Costs		-	-	-
Societal Benefits				
Transportation GHG Allowance Costs			+	+
“Societal” value for CO2				+
Health benefits				+
Decreased Petroleum Use				+

6. Cost-Effectiveness Results

We present the cost-effectiveness results using two metrics. The first is the present value of costs and benefits through 2030, provided in 2014 dollars. The second is the present value costs and benefits per PEV, also in 2014 dollars. Unless otherwise specified, the results presented are for the ZEV Most Likely adoption and TOU rate scenarios.

6.1. PEVs Provide Regional Economic Benefits

Detailed TRC results are shown in Figure 16 for the ZEV Most Likely – TOU Rate and Load Shape Scenario. The levelized benefits – the federal tax credit, gasoline savings and reduced GHG emissions – total about $20,000 per vehicle.[47] The costs include incremental costs of the vehicle, charging infrastructure costs, distribution system upgrades, and the CPUC DER costs for delivered energy.

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[47] Per the Standard Practice Manual, the TRC for California includes federal, but not state, tax credits and rebates as a benefit.

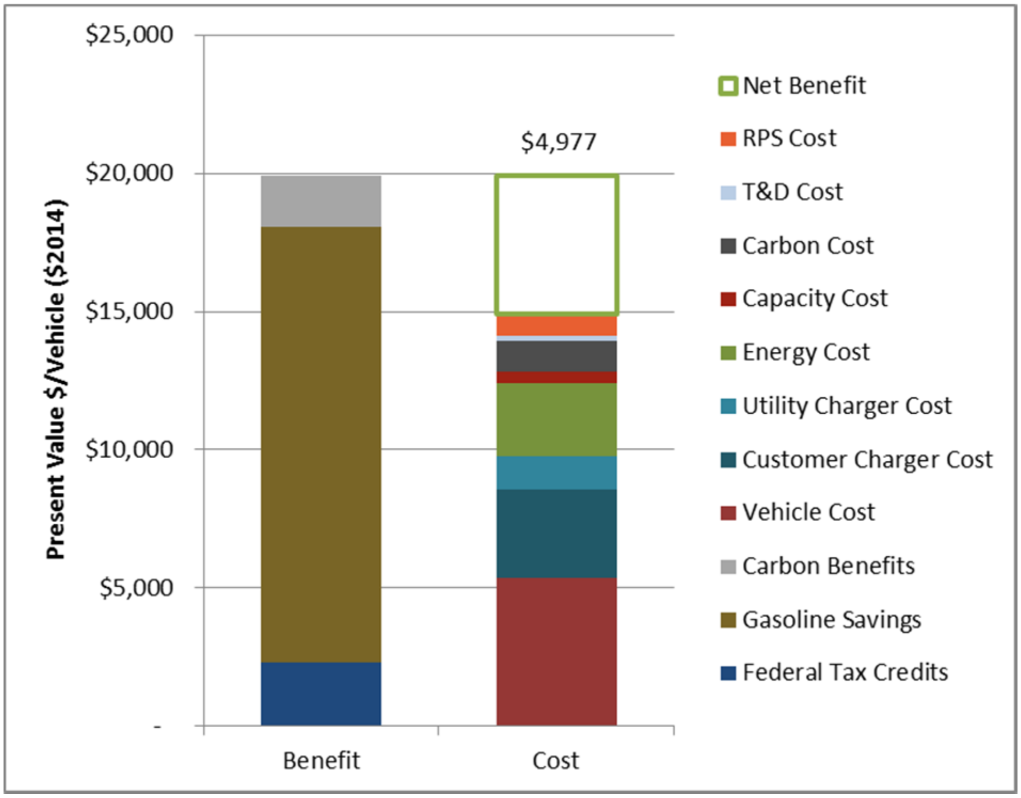

Figure 16. Per Vehicle TRC Costs and Benefits TOU Rate Scenario

The TRC costs for the four rate and load shape scenarios are shown in Figure 17 and Figure 18. The costs of providing energy are the same for the Tiered and Flat rate scenario, which provide no incentives to shift charging to off-peak hours. Under these two scenarios, the TRC net benefit is $3.14 billion or $3,597 per vehicle. With more charging shifted away from peak hours, the TRC net benefits are higher under the Mixed and TOU rate/load-shape scenarios. The net benefits under the TOU scenario are $4.34 billion, equivalent to the $4,977 per vehicle shown above.

The $5,000 net TRC benefits under the TOU rate/load shape scenario are $1,400 per vehicle (28%) higher than the $3,600 per vehicle for the tiered and flat rate scenarios. Charging off-peak reduces the cost of generation, including carbon allowances, by $740 per vehicle. It also defers or avoids investment in and generating, transmission and distribution capacity for a combined benefit of $640 per vehicle. Under the ZEV Most Likely Adoption Scenario the present value benefit of TOU as compared to flat rate charging is $1.2 billion.

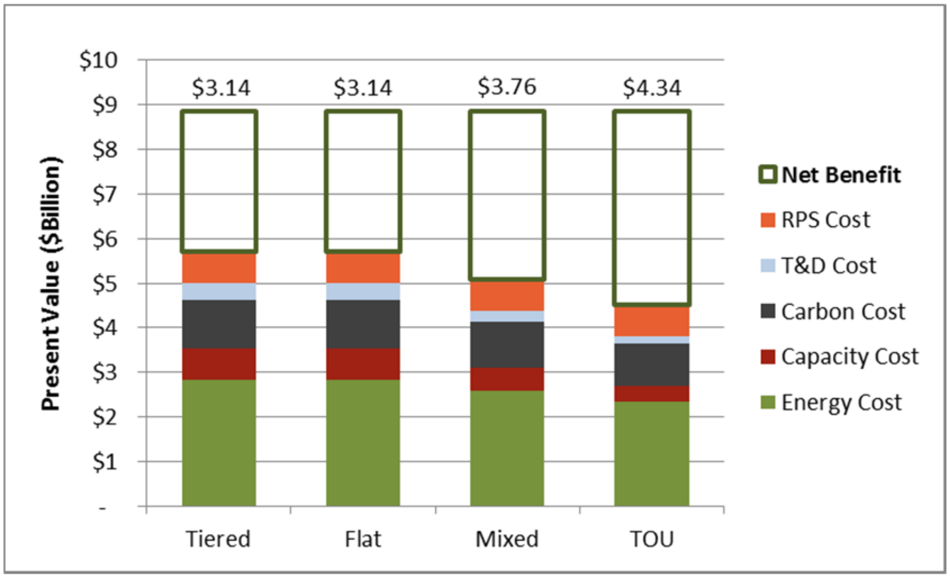

Figure 17. Present Value TRC Electricity Costs and Net Benefits by Rate Scenario

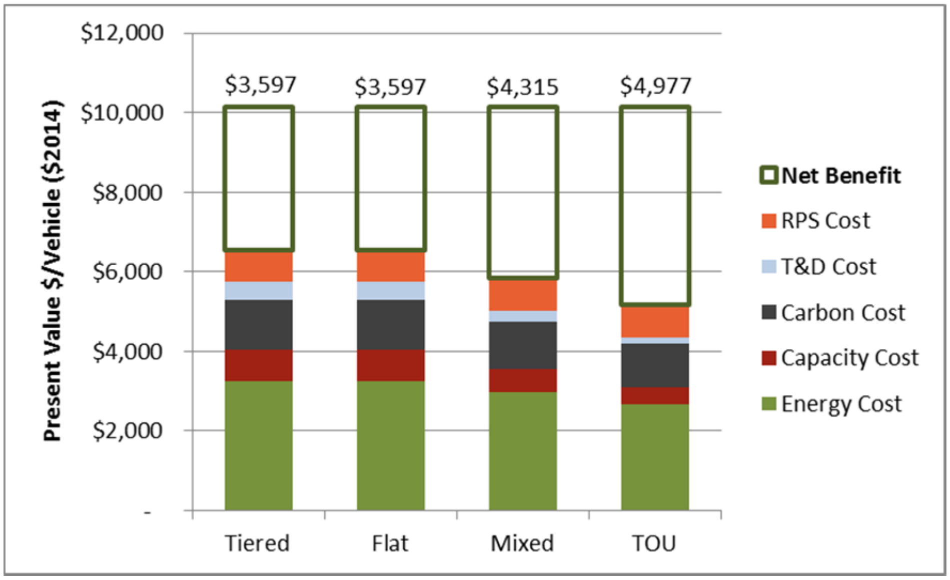

Figure 18. Per Vehicle TRC Electricity Costs and Net Benefits by Rate Scenario

6.1.1. VEHICLE COST ASSUMPTIONS

The incremental vehicle costs of PEVs relative to comparable ICE vehicles are expected to decline over time (Table 14). Vehicle cost reductions that come with technological learning and increasing economies of scale depend on growing adoption of PEVs. It is often the case for new technologies with promising potential to transform markets, programs to encourage adoption with education and incentives are required. Here we see the importance of the federal tax credit (Table 15) for PEVs in the TRC.

Table 14: Incremental Vehicle Costs[48]

	2014	2020	2030
PHEV10	5,121	2,524	399
PHEV20	10,241	5,047	798
PHEV40	13,535	6,448	1,597
BEV	14,205	5,151	197

Table 15: Federal Tax Incentive[49]

Vehicle	Incentive
PHEV10	$2,500
PHEV20	$4,000
PHEV40	$7,500
BEV	$7,500

The TRC costs and benefits are shown over time in Figure 19 (in present value nominal dollars for each respective year of adoption). In 2015, net economic benefits for California of roughly $3,500 per vehicle are achieved only with the inclusion of the federal tax credit. By 2023, caps for the federal tax credit have been reached, but vehicle costs have declined and gasoline prices increased such that there are net benefits of about $2,500 (in $2023) per vehicle even without the federal tax credit. By 2030 PEVs are nearing parity with comparable ICE vehicles in

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[48] TEA Phase 1 Report, Table 53, p. 85
[49] TEA Phase 1 Report, Table 53, p. 85

terms of cost and the net benefits have risen to around $5,200 per vehicle (in $2030)

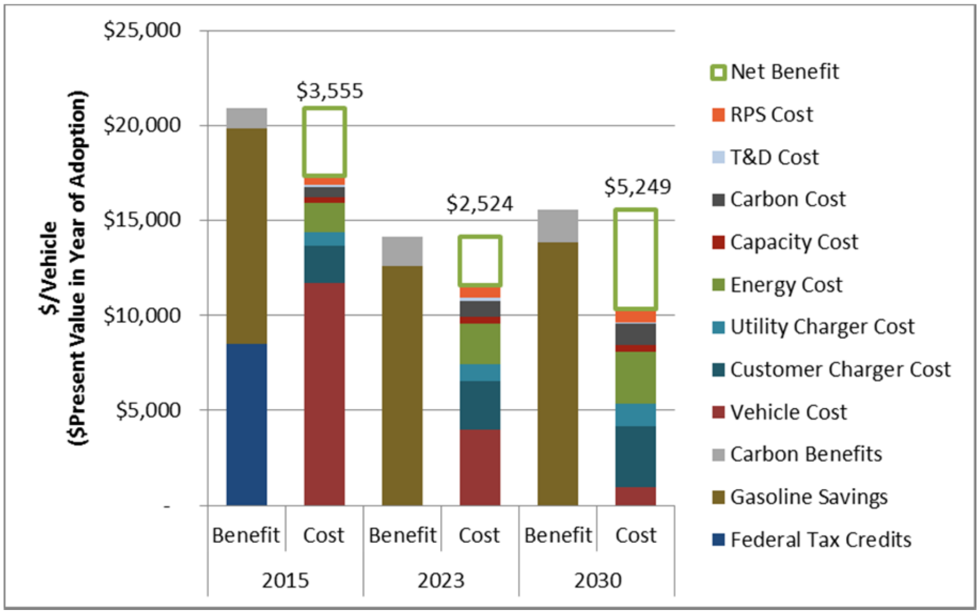

Figure 19. Per Vehicle TRC Electricity Costs and Net Benefits by Rate Scenario

6.2. PEVs Provide Societal Benefits

With the addition of the environmental and health benefits described in Public Utility Code 740.3 and 740.8, the net benefit calculated with our “740.8” SCT is nearly $1 billion than the TRC. The net benefit per vehicle is $6,200, 24% higher than for the TRC.

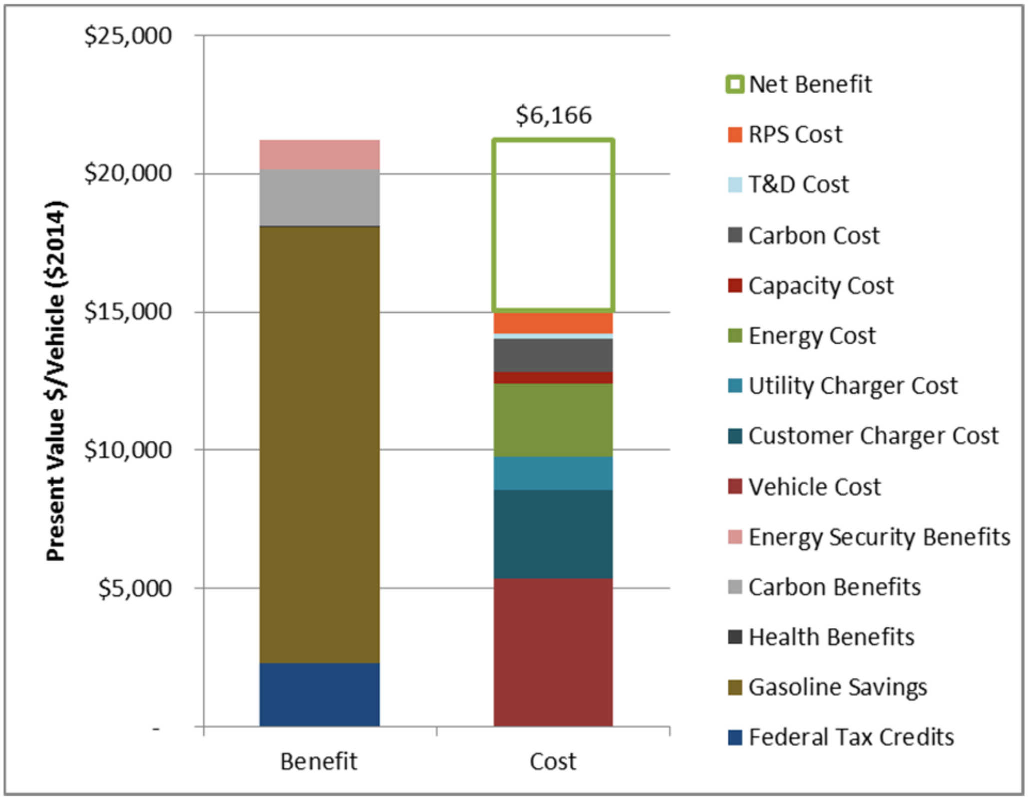

Figure 20. Per Vehicle SCT Costs and Benefits

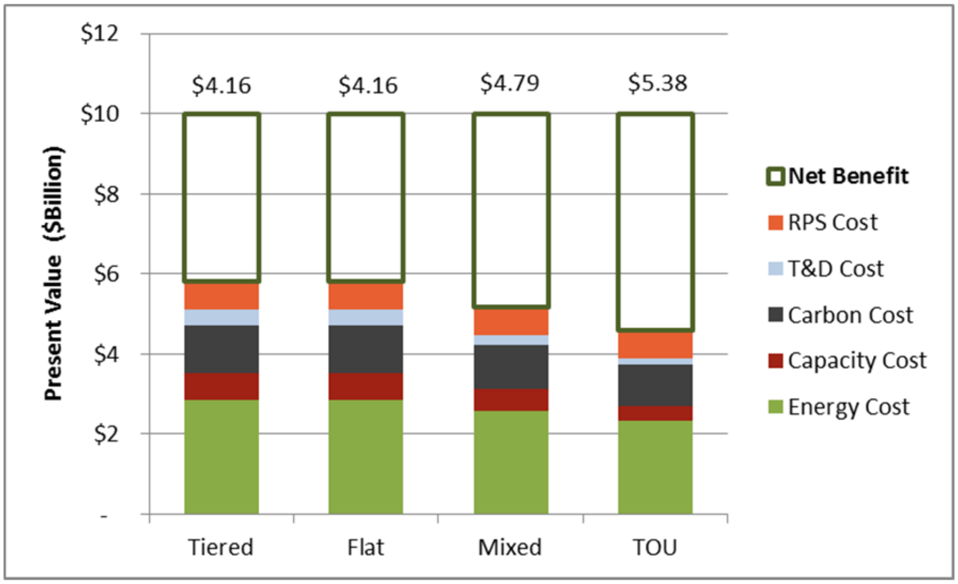

Figure 21. Present Value SCT Electricity Costs and Benefits by Rate Scenario

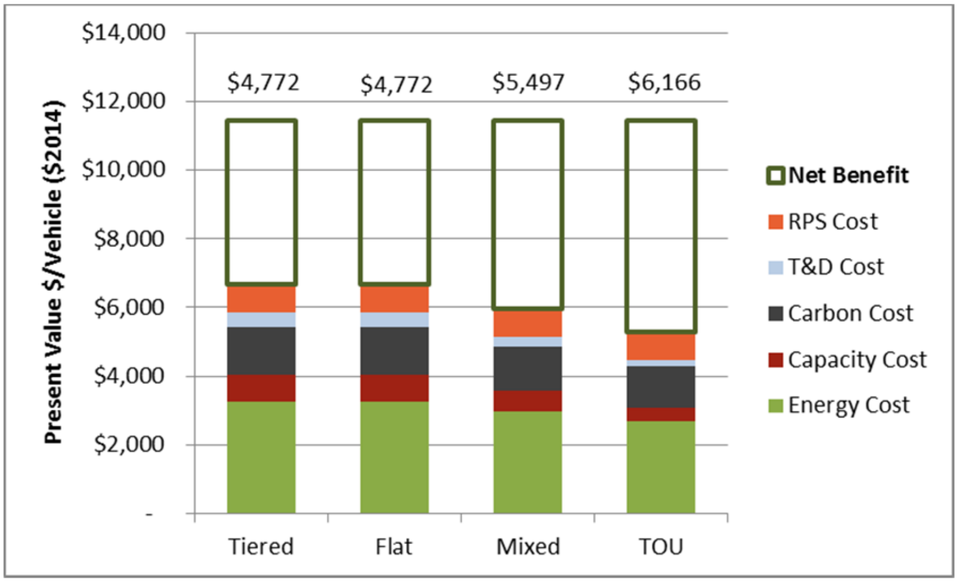

Figure 22. Levelized per Vehicle SCT Electricity Costs by Rate Scenario

6.3. PEV Charging Reduces Rates for All Ratepayers

The present value of utility customer benefits through 2030, calculated using the RIM test, is shown for the ZEV Most Likely adoption scenario with the utility obligation to serve division of infrastructure cost (Figure 23). The Tiered and Flat Rate Scenarios have the highest costs of the rate scenarios, but they also have the highest revenues. The high revenues outweigh the high costs, resulting in the highest net benefits, respectively $8.11 and $3.90 billion. The revenues and costs of delivered energy are lower under the Mixed and TOU rate and load shape scenarios, but the net benefits are still positive by $3.12 and $2.26 billion. With the rates used in our analysis, the RIM test is positive under all scenarios and sensitivities studies. The TOU rate scenario yields lower net revenues for the utility and its ratepayers, but also provides lower costs for delivered energy (next section) and higher net benefits for PEV owners, which encourages adoption.

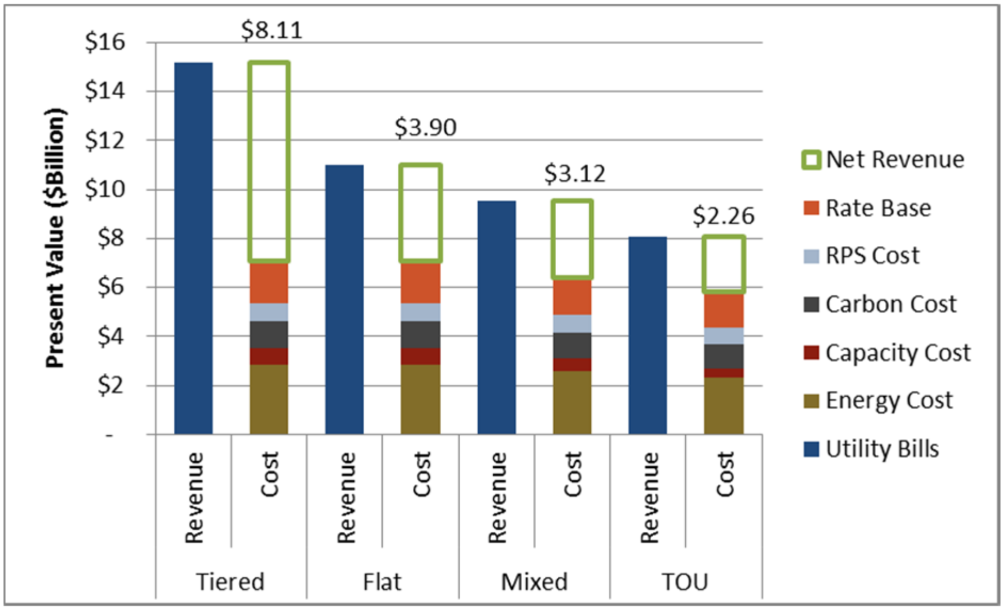

Figure 23. Present Value RIM Revenues and Costs by Rate Scenario

The same results presented in present value dollars per vehicle are shown in Figure 24. The levelized ratepayer benefits range from roughly $9,300 to $2,600 per vehicle.

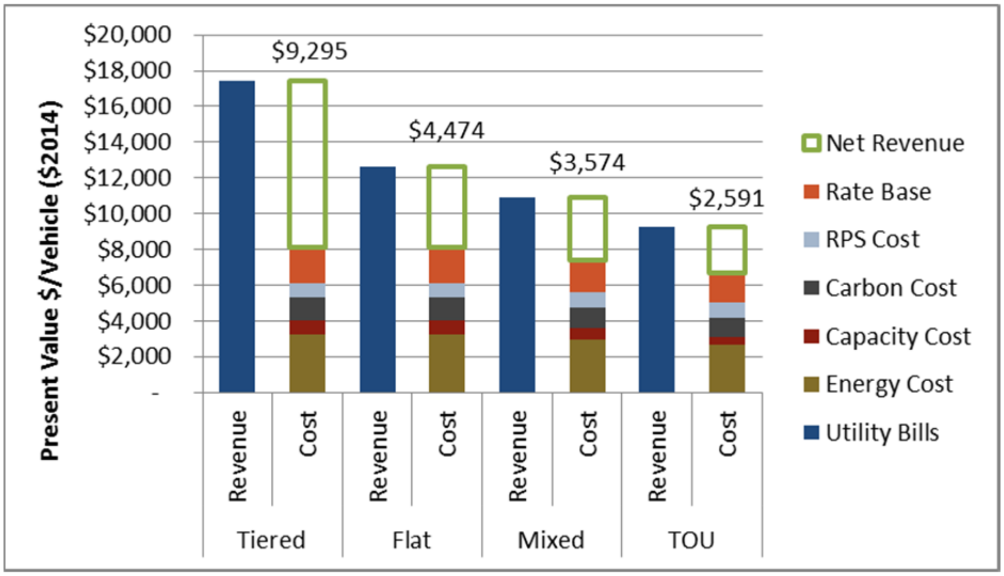

Figure 24. Present Value per Vehicle Ratepayer Costs and Benefits by Rate Scenario (ZEV Most Likely Vehicle Adoption)

6.3.1. RATE ASSUMPTIONS

Proposals for alternative rate designs are under active consideration at the CPUC. For this analysis, we do not attempt to predict the outcome of those proceedings, but instead model a range of alternative rate designs, including tiered, flat, and TOU rates. Rates assumptions are developed from existing tariffs and utility input and are not intended to be precise forecasts (Table 16). Tiered rates (Table 17) are taken from Decision 14-06-029 in the Rate Structure Proceeding (R. 12-06-013).[50]

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[50] See CPUC Decision 14-06-029 , Attachment E, "Comparison of Non-CARE Rates".

Table 16: Average Charging Rates in 2014

Cents/kWh	PG&E	SCE	SDG&E	SMUD
Residential				
Tiered Rate	27.4	26.1	32.3	17.6
Flat Rate	18.0	18.0	18.0	17.8
Mixed Rate	15.7	13.5	18.5	13.5
TOU Rate	11.2	10.5	17.2	9.2
Commercial				
Commercial	20.7	10.4	13.9	11.4

Table 17: Tiered Rate Charging Assumptions

Cents/kWh	PG&E	SCE	SDG&E	% PEV Charging	SMUD	% PEV Charging
Tier 1	14.7	14.9	17.3		9.5	1%
Tier 2	17.6	19.3	20.4	33%	17.8	99%
Tier 3	29.6	27.9	37.7	33%		
Tier 4	35.7	31.9	39.7	33%		

7. Dynamic Vehicle Grid Integration

Supporting higher penetrations of renewable generation on the electric grid is an additional benefit that can be provided by PEVs. This benefit is not included in the cost-test results presented above, but is illustrated here as a potential benefit that merits further investigation and analysis.

We illustrate the potential benefits using the dynamic VGI charging model developed by E3 to support SDG&E's application that is currently before the CPUC (A. 14-04-014). The model minimizes the cost of charging to PEV customers based on assumed driving patterns and price signals provided in the form of retail electric rates. This model uses a high RPS avoided cost scenario described below to quantify the costs of PEV charging under a 40% RPS scenario.

The model developed for the SDG&E application models dynamic VGI benefits using an hourly VGI rate that is determined in the day-ahead and sent as a price signal via a retail rate for PEV charging. The benefits illustrated here are not specific to the approach proposed by SDG&E. Rather, they are generalizable to any proposed approach or program that directly controls or incentivizes PEV charging specifically to manage flexibility challenges that are anticipated under higher renewable penetration levels.

7.1. Flexibility Challenges

Using E3's stochastic production simulation model REFLEX, E3 quantified the flexibility needs of the California grid under 40 and 50% RPS scenarios.[51] REFLEX is specifically designed to investigate flexible capacity needs and value with variable renewable resources (VER). REFLEX performs random draws of weather-correlated load, wind, solar, and hydro conditions taken from a very large sample of historical and simulated data. It characterizes the need for system ramping capability through stochastic treatment of load, wind and solar generation, hydropower conditions, dispatchable generator outages and other random variables on multiple time scales: annual, monthly, diurnal, hourly and sub-hourly. The model uses

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[51] See https://ethree.com/public_projects/reflex.php

optimal unit commitment and economic dispatch to model the ability of the system's dispatchable resources to respond to a full range of conditions. Flexibility violations such as shortages in upward or downward ramping capability are characterized according to their likelihood, duration and depth, using metrics that are analogous to conventional reliability metrics such as LOLP, Loss of Load Probability Expectation (LOLE), and Expected Unserved Energy (EUE).

There are five distinct types of flexibility challenges that the system will face under high renewable penetration:

1. **Downward ramp**: as solar generation increases in the morning, flexible resources will be needed to ramp generation down (or ramp load up).

2. **Minimum generation**: to accommodate solar generation during the day, fossil generation will need to turn off, or operate at minimum levels, but still be ready to increase generation in the late afternoon and early evening.

3. **Upward Ramp**: in the evening, as solar generation declines, other generating resources will need to ramp up (or load ramp down).

4. **Peaking Capacity**: sufficient resources will be needed to meet peak loads with sufficient reserve margins.

5. **Sub-hourly Flexibility (not shown)**: flexible resources will be required to provide both existing and new types of ancillary services, including frequency regulation, flexi-ramp and load following.

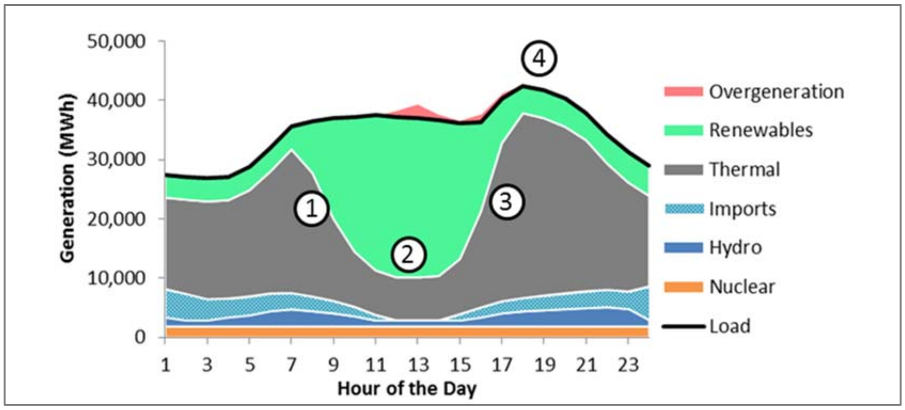

Figure 25: Renewable Integration Challenges

The Utility High RPS Study models flexibility needs in high RPS scenarios in 2022 and finds that the largest renewable integration challenge is "overgeneration". [52] Overgeneration occurs when "must-run" generation—non-dispatchable renewables, combined-heat-and-power (CHP), nuclear generation, run-of-river hydro and thermal generation that is needed for grid stability—is greater than loads plus exports. Overgeneration can occur even in a highly flexible power system if there is simply not enough load to absorb the available quantity of renewable energy during a given hour. However, additional overgeneration or curtailment of renewable output may occur due to lack of power system flexibility as well.

7.2. High RPS Energy Values

Hourly incremental energy value estimates are developed using the E3 Renewable Energy Flexibility (REFLEX) model and the E3 Renewables Portfolio Standard (RPS) model.[53] Using these models, E3 developed a California statewide dispatchable resource supply stack which ranks generators by variable energy cost, including the cost of carbon dioxide (CO_2) emissions. The resource stack is used to correlate statewide net load and marginal energy value. E3 uses a gross load forecast with two renewable penetration levels: 33% and 40%.[54] The 33% renewable penetration level represents the 33% RPS goal for the California utilities and the 40% level represents the 33% RPS plus future renewable and distributed photovoltaic installations.[55]

Statewide hourly net load data (statewide gross load forecast[56] minus renewable generation) are created for eight representative day types described below. The end results are marginal hourly energy prices in dollars per kWh for each hour for each of the eight day types. The eight day types are weighted to represent a 365-day year. Table 6-8 describes the eight day types selected to reflect combinations

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[52] E3. "Investigating a Higher Renewables Portfolio Standard in California." (2014)

[53] See E3's 33% RPS Calculator with Output Module: https://www.ethree.com/documents/LTPP/Model%20w%20OutputModule%20-%202007.zip.

[54] *See* E3's "Renewable Energy Flexibility (REFLEX) Results California ISO Webinar" (December 9, 2013), http://www.caiso.com/Documents/RenewableEnergyFlexibilityResults-Final_2013.pdf

[55] See SDG&E's current Net Energy Metering enrollments and enrollment MW cap: http://www.sdge.com/clean-energy/net-energy-metering/overview-nem-cap.

[56] See "California Energy Demand 2014 - 2024 Final Forecast, Volume 1: Statewide Electricity Demand, End-User Natural Gas Demand, and Energy Efficiency" - Final Staff Report. CEC-200-2013-004-SF-V1 (December 2013), http://www.energy.ca.gov/2013publications/CEC-200-2013-004/CEC-200-2013-004-SF-V1.pdf.

of gross load conditions (high or low) and renewable generation conditions (high or low). Each day type was assigned a weight, such that the eight day types can be combined to represent a full year. This energy price component replaces the DER model's energy price.

Table 18: 40% RPS Representative Day Types

Day #	Month	Day Type	Load Level	Renewable Level	Day Weight (%)
1	March	Weekday	Low	High	10.1%
2	March	Weekend	Low	High	8.2%
3	July	Weekday	High	High	7.1%
4	September	Weekday	High	Low	6.6%
5	September	Weekend	High	Low	0.3%
6	August	Weekday	High	High	15.6%
7	November	Weekend	Low	Low	20.0%
8	December	Weekday	Low	Low	32.1%

We recalculate the CPUC "standard" avoided costs using the generation portfolio and net load shape for the 40% RPS scenario. This provides a new set of 8,760 hourly avoided costs. The energy prices are taken from the REFLEX model and system and T&D capacity value allocated to the highest net load hours in our future RPS scenario.

We use the 40% RPS avoided costs to illustrate the benefit of using PEV loads as a flexible resource. During a March weekend with low loads and high renewables, avoided costs are negative during the day, indicating that there is a value to adding load to absorb overgeneration and reduce the morning and evening MW ramp requirements. In a September weekday high load low renewables day, avoided cost values are negative in the early afternoon, but extremely high later in the day due to the allocation of system and T&D capacity values to those hours.

7.3. Benefits of Dynamic Charging for Renewable Integration

To demonstrate the benefits of dynamic VGI charging, we compare the cost of delivering electricity for PEV charging under a TOU rate and dynamic hourly VGI rate scenario. We assume that vehicle adoption, eVMT, and charging infrastructure costs remain the same between the TOU and VGI scenario. The hourly avoided costs of delivered energy for PEV charging also remain the same. The only difference between the scenarios is the retail PEV charging rate and the timing of when the charging occurs.

We recalculate the CPUC "standard" avoided costs using the generation portfolio and net load shape for the 40% RPS scenario. This provides a new set of 8,760 hourly avoided costs. The energy prices are taken from the REFLEX model and system and T&D capacity value allocated to the highest net load hours in our future RPS scenario.

We use the 40% RPS avoided costs to illustrate the benefit of using PEV loads as a flexible resource. During periods with low loads and high renewables, avoided costs are negative during the day, indicating that there is a value to adding load to absorb overgeneration and reduce the morning and evening MW ramp requirements. Avoided costs are high later in the day driven both by the evening ramp requirements and the allocation of system and T&D capacity values to peak load hours.

With the TOU rate scenario, residential charging occurs on SDG&E's EV-TOU rate and commercial charging under AL-TOU. These rates provide consistent TOU rates for the summer and winter months respectively. The VGI scenario uses a dynamic hourly rate based on the avoided costs developed for the 40% RPS scenario shown above.

The impact of a dynamic VGI rate on PEV charging behavior is illustrated in Figure 26 and Figure 27. With the TOU rate, most charging occurs at night at home when the TOU rate is the lowest. Some charging occurs at work in the late morning as vehicles arrive at work and before the on-peak TOU period. The TOU rate does successfully discourage charging during the evening ramp and peak net load period, but does not actively encourage charging to absorb overgeneration. Note also that nighttime charging spikes at midnight as all PEVs start charging immediately at the start of the super off-peak TOU period.

The dynamic VGI rate is designed to mirror hourly avoided costs (Figure 27). This has two positive impacts. The nighttime charging is shifted to the early morning and the peak charging level is reduced. This reduces the early morning ramp rate as load increases before solar generation begins. In addition, a significant portion of the charging is shifted to the late morning/early afternoon during peak solar generation and minimum net loads. The avoided-cost value is negative during the day and high during the peak net load hour of hour ending (HE) 19. This indicates that increasing load during the afternoon has a positive value, absorbing overgeneration and reducing the net load ramp in the late afternoon/early evening.

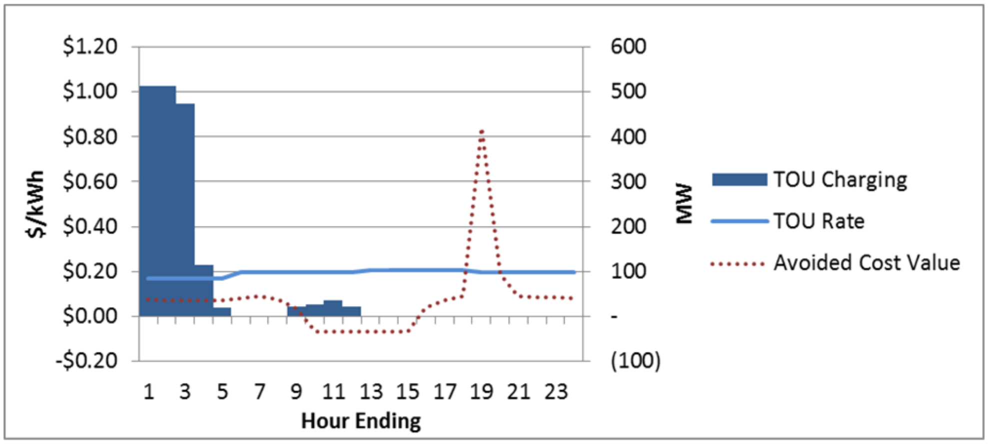

Figure 26. TOU PEV Charging, Retail Rate and Avoided Cost Value – March Weekday: Low Load/High Renewables

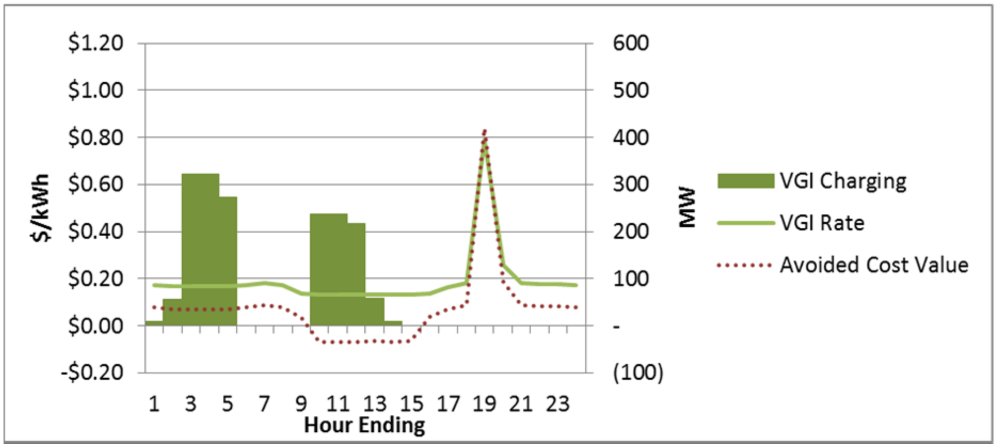

Figure 27. VGI PEV Charging, Retail Rate and Avoided Cost Value – March Weekday: Low Load/High Renewables

Both the TOU and VGI rate successfully discourage charging during peak loads. However, the TOU rate is constant across the summer and winter seasons and does not follow changes in renewable generation and net loads that will change dramatically in the spring and the fall under a 40% RPS scenario. The VGI rate, on the other hand, can encourage afternoon charging in the spring and fall when overgeneration is high, but discourage charging during the same period in the summer when afternoon loads exceed renewable and must take generation.

For this illustrative example, The VGI scenario reduces the present value of charging costs per vehicle form around $1,400 to under $600 - a net benefit of $850 per PEV (Figure 28). This represents a cost reduction from the RIM, TRC and SCT perspective. Due to different assumptions and time periods, these results are not directly comparable to the cost-benefit results presented above.

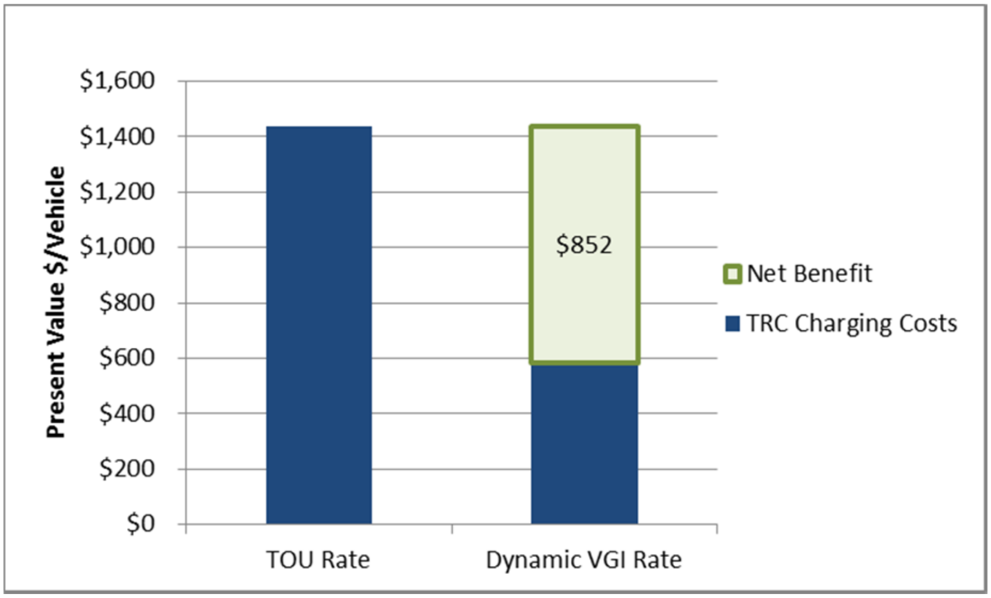

Figure 28. Present Value TRC Charging Costs per Vehicle

These illustrative benefits of dynamically managing charging with an hourly VGI rate must be presented with two caveats. First, we are comparing a seasonally adjusted TOU rate from today's tariffs with a future 40% RPS scenario. A TOU rate in a 40% RPS world might look different than today, adjusting monthly rather than seasonally for example. This would shrink, but not eliminate the relative benefits of VGI charging. Second, increasing daytime charging may impose additional costs on the distribution grid, even if charging during peak load hours can be avoided. These results assume that no additional distribution upgrades are required.

8. Evaluating PEVs as a GHG Reduction Strategy

We show that PEVs can pass current cost-effectiveness evaluation methods that were developed to evaluate supply and demand side resources on a comparable basis in utility resource planning. In the existing framework, demand side resources that reduce or shift load are valued for reducing the costs and emissions required to meet forecasted demand for energy. These values are based largely on the costs of today's conventional resources supply side resources that are avoided with distributed resources.

Meeting GHG goals and air quality requirements will require transformative acceleration of PEV adoption and unprecedented levels of coordination and cooperation between the utility and transportation sections. New cost-effectiveness metrics are needed to support the infrastructure development to accomplish these goals.

8.1. New Metrics for Evaluating Cost-Effectiveness are Needed

The cost tests presented above were developed to evaluate supply and demand side resources on a comparable basis in utility resource planning. Demand side resources that reduce or shift load reduce are valued for reducing the costs and emissions required to meet forecasted demand for energy. The costs of supply side resources avoided with distributed resources are based largely on today's conventional resources.

PEVs are fundamentally different from other distributed energy resources in two key respects. First, PEV's provide net benefits and emissions reductions to California, but the generation needed to serve PEV load will result in emissions increases in the power sector. Second, whereas the primary purpose of promoting DER has been to reduce the costs and emissions required to meet forecasted load, California seeks to accelerate PEV adoption to meet GHG reduction and air quality targets. Furthermore, achieving these goals will require fundamental market transformation in both the utility and transportation sectors with new and unconventional technologies that are not widely used today.

Although we show that PEV’s can be cost-effectiveness using existing CPUC and CARB methodologies, these tests were not developed to address these statewide challenges. We propose that new tests are needed to evaluate initiatives designed to meet long-term GHG reduction targets. Even with the addition of health and environmental benefits, early investments intended to encourage market transformation often do not pass cost-effectiveness evaluation initially, but only after technological development and wide-spread adoption drive costs down.[57] Furthermore, current tests do not explicitly address how environmental and GHG benefits in the transportation sector can or should be considered against increased emissions in the utility sector. New approaches will need to be developed to compare the relative costs of achieving GHG reductions across utility, transportation and other sectors of California’s economy.

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[57] Emerging technology programs in energy efficiency are a prime example - the purchase price and cost of ownership for LED bulbs, compact florescent bulbs (CFLs) and front-loading clothes washers have fallen even as performance has increased.

9. Conclusions

In this TEA Phase 2 Report, we quantify the costs and benefits of plug-in electric vehicles (PEVs) for utilities, their customers and the state of California. We use cost-effectiveness methods from the California Air Resources Board (CARB) and the California Public Utilities Commission (CPUC) to show that PEVs reduce rates for utility customers and provide net economic and societal benefits for California as a whole. A detailed analysis of PEV clustering finds only modest cost impacts for the distribution system, but more accelerated deployment of multi-family, public and workplace chargers may pose higher infrastructure costs. Even with modest distribution system impacts, there is a significant benefit for managed charging in reduced generation, carbon and infrastructure cost. Even though we find PEVs are cost-effective using existing cost tests, new tests are needed to properly evaluate PEVs a GHG reduction strategy that requires rapid transformation in both the utility and transportation sectors.

Our conclusions from the analysis performed for this study are:

- PEV charging increases the utilization of the existing distribution system and requires only modest feeder and substation upgrade costs, even under the most aggressive adoption scenario.
- Managed charging, either through utility dispatch or pricing incentives (and without vehicle-to-grid capability), lowers the cost of PEV charging and the infrastructure required to support it. Net total resource cost-test benefits increase by 28% relative to the non-TOU rate scenarios.
- "Make ready" costs for multi-family, public and workplace charging are larger than distribution upgrade costs and may pose a more significant barrier to PEV adoption.
- Over the long-term, PEV rates can be designed to provide sufficient net revenues to more than cover short-term and long-term marginal costs, lowering average rates for non-PEV owners in the rate class.

- Over time, with reduced incremental vehicle costs and increasing gasoline prices, PEVs provide net total resource cost-test benefits for California even without the federal tax credit.
- In the near-term, accelerated investment in enabling technology and infrastructure is needed to support PEV adoption and market transformation. Such investment may not pass current cost-effectiveness tests, but still provide net utility customer and societal benefits in the long-term.
- Current CARB and CPUC cost-effectiveness tests evaluate resource measures largely against “traditional” investments based on current technology. More comprehensive methods are need to evaluate alternative strategies towards meeting GHG and ambient air quality targets, which will require significant investment in new technologies and infrastructure.
- Dynamic charging can provide significant additional benefit under high RPS scenarios by absorbing overgeneration and reducing morning and evening ramps. In our illustrative example the benefits from an hourly dynamic charging rate were about $850 per vehicle relative to a time-of-use rate.
- The increased benefits provided by time-of-use rates and dynamic charging show the quantifiable benefits of actively engaging both customers and utilities in managed PEV charging. Utility or government programs funding PEV charging infrastructure should also include strong incentives for PEV owners, site hosts and third party charging station operators to engage in managed charging that is responsive to grid needs.

The societal cost-test as presented here produces net benefits that are 22% higher than the total resource cost-test test using health and reduced reliance on imported petroleum benefits from the TEA Phase 1 Report. Alternative sources for benefit values could provide net benefits that are substantially higher.

Appendix A: 740.3 & 740.8 Text

§ 740.3: (a) The commission, in cooperation with the State Energy Conservation and Development Commission, the State Air Resources Board, air quality management districts and air pollution control districts, regulated electrical and gas corporations, and the motor vehicle industry, shall evaluate and implement policies to promote the development of equipment and infrastructure needed to facilitate the use of electric power and natural gas to fuel low-emission vehicles. Policies to be considered shall include both of the following:

(1) The sale-for-resale and the rate-basing of low-emission vehicles and supporting equipment such as batteries for electric vehicles and compressor stations for natural gas fueled vehicles.

(2) The development of statewide standards for electric vehicle charger connections and compressed natural gas vehicle fueling connections, including installation procedures and technical assistance to installers.

(b) The commission shall hold public hearings as part of its effort to evaluate and implement the new policies considered in subdivision (a), and shall provide a progress report to the Legislature by January 30, 1993, and every two years thereafter, concerning policies on rates, equipment, and infrastructure implemented by the commission and other state agencies, federal and local governmental agencies, and private industry to facilitate the use of electric power and natural gas to fuel low-emission vehicles.

(c) The commission's policies authorizing utilities to develop equipment or infrastructure needed for electric-powered and natural gas-fueled low-emission vehicles shall ensure that the costs and expenses of those programs are not passed through to electric or gas ratepayers unless the commission finds and determines that those programs are in the ratepayers' interest. The commission's policies shall also ensure that utilities do not unfairly compete with nonutility enterprises.

§ 740.8: As used in Section 740.3, "interests" of ratepayers, short- or long-term, mean direct benefits that are specific to ratepayers in the form of safer, more reliable, or less costly gas or electrical service, consistent with Section 451, and activities that benefit ratepayers and that promote energy efficiency, reduction of health and environmental impacts from air pollution, and greenhouse gas emissions related to electricity and natural gas production and use, and increased use of alternative fuels.

Appendix B: PEV Rate Impacts

9.1. PEVs Reduce Average Rates for All Customers

To illustrate the rate impacts of incremental load in general, consider the case of a customer adding a large HVAC unit to provide air conditioning. The customer will pay a retail rate for electricity to operate the HVAC unit. The $/kWh retail rate will usually include both an allocation of embedded fixed costs and the forecasted variable marginal costs of delivered energy to provide service to the customer. As a result, during most or perhaps even all hours of the year, the retail rate will exceed the utilities actual short-run marginal cost of delivered energy. The retail rate will therefore provide net revenues to the utility – revenues that will recover fixed costs incurred by the utility to serve load. If the net revenues are high enough, they may also fully recover the long-run marginal cost of delivered energy – including fixed costs for new generation and T&D capacity. Alternatively, the customer may sign up for a demand response or critical-peak pricing program such that the HVAC load can be served with minimal investment in new capacity. In either case, net revenue more than recovers long-term marginal costs to serve the customer's rate class. In such a case, the new HVAC load would reduce the allocation of fixed costs that must be recovered from all other customers, and, all else being equal, would reduce average rates for the customer class in the next rate case.

If, on the other hand, expensive new investments in generation or T&D capacity are required to serve the new HVAC load (that is coincident with utility peak loads), the retail rate may provide net revenues over and above short-term, but not long-term marginal costs. In this case, the new load will, all else being equal, increase average rates in the next rate case.

Turning specifically to the case of PEVs, we first consider a "default" case (Figure 1) where the customer charges their car with a relatively high domestic rate – either in a higher tier or during higher priced on-peak TOU periods. As in the HVAC case described above, the retail rate will provide net revenue above short-term variable costs and contribute to the recovery of fixed costs. Again, if the retail rate and net revenue is sufficiently high, the revenue will also more than cover long-term PEV-related capacity, infrastructure, and program costs and ultimately provide downward pressure on average rates for non PEV customers.

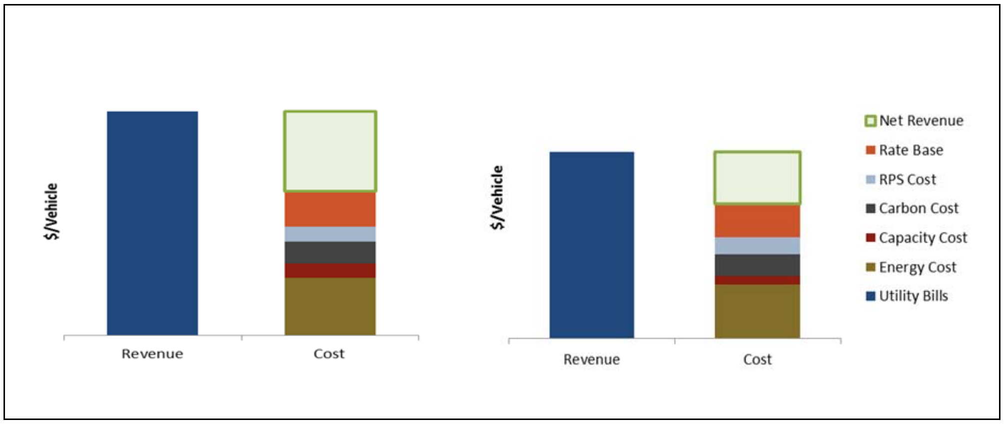


Figure 29. Illustration of Net Revenues without (left) and with (right) TOU Rates

We next consider a generic managed charging case (Figure 2) in which a TOU or other type of dynamic rate encourages off-peak charging when both retail rates and marginal variable costs of delivered energy are lower. Shifting charging to a lower price period reduces the total revenue to the utility, but also reduces the marginal cost of delivered energy and still provides net revenues.

Our analysis suggests that PEV charging rates can be designed to fully recover embedded fixed costs short-run variable costs and long-run marginal (fixed) costs, such that they will provide net revenues and reduce average rates for non-PEV customers. Absent any specific cost treatment, this net revenues will contribute to utility fixed cost recovery and reduce the $/kWh allocation fixed cost in retail rates. This lowers the utility system average rate for all customers. Alternatively a portion of the net revenues can be specifically allocated recover up front utility PEV infrastructure and program costs. In this way PEV programs can be self-funded over the long-term. All PEV related costs are recovered from PEV owners, no costs are imposed on other ratepayers and in fact, retail rates to non-PEV owners in the rate class are reduced.

Examining Figures 1 & 2, the reader will note that the net revenue and contribution to fixed cost recovery for the managed charging case may be greater or lower than in the default case. At first glance, the potential for lower net revenues might appear argue against a managed charging program, but this would be an incorrect conclusion. Managed charging scenario shifts charging to periods when the short-term marginal cost of generation is lower and away from on-peak periods that drive the need for long-term capital investment in new generation and T&D capacity. Critically, in both the default and managed charging cases, PEV load growth can reduce average rates for non-PEV customers, but only in the managed case can utilities also actively reduce the fixed capacity, variable and environmental costs of serving new PEV load. In addition, reducing the cost of PEV charging reduces the cost of PEV ownership for the customer, increasing the economic incentive for PEV adoption. As we show below, a utility sponsored managed charging program will thereby increase net TRC and SCT benefits to the region as a whole relative to the default case.

9.2. Terminology

- **Managed charging**: General, catch-all term for PEV charging that is controlled or incentivized by the utility.
- **VGI charging**: Specific term for dynamic PEV charging that is controlled or incentivized by the utility to mitigate overgeneration and ramp issues associated with higher penetrations of renewable generation.
- **Short-run marginal costs**: variable cost of generating energy and delivering it to the end-user.
- **Long-run marginal costs:** all fixed and variable costs required to generate and deliver energy to the end-user.
- **Embedded fixed costs**: fixed capital costs of existing utility system included in retail rates.
- **Allocation of fixed cost**: the utility fixed costs included in $/kWh retail rates.
- **PEV capacity costs**: new capital investment in system generating and T&D capacity needed to deliver electricity to customer.
- **Utility PEV infrastructure costs**: utility capital costs associated with make-ready, service drop and utility managed or VGI charging to serve customers with PEVs.
- **Customer PEV infrastructure costs**: customer capital costs associated with panel upgrades and charging equipment to charge PEVs.
- **PEV program costs**: all utility overhead, marketing and administrative costs associated with promoting PEV adoption and managed VGI charging.
- **Domestic rate**: retail whole house rate (can be flat, TOU, Tiered).
- **PEV rate**: retail rate for separately or sub-metered PEVs (can be flat, TOU).
- **TOU rate**: retail rate that varies by time-of-use.
- **PEV revenue:** utility retail rate revenue from PEV charging.
- **Net revenue**: PEV revenue minus marginal cost (term to be used in place contribution to margin).

Appendix C: Overgeneration

9.3. How Soon Will Overgeneration Occur?

While there is currently no legislated RPS requirement above 33%, there are several reasons overgeneration is likely to occur at significant levels before 2020:

- **Renewable procurement is on a trajectory to hit 40% levels**: Even absent a legislative requirement, procurement is on track to exceed 33% in 2020. Project failure in recent solicitations has been much lower than anticipated based on prior experience. Large declines in PV prices have also accelerated procurement outside of IOU RPS solicitations.
- **Statewide model without transmission constraints**: The production simulation case modeled in REFLEX did not include transmission and associated constraints that would increase overgeneration challenges.
- **Solar development is concentrated in Southern California**: Solar project development is heavily weighted to Southern California. The South of Path 15 (SP15) zone will reach 40% RPS generation levels and experience overgeneration much sooner than the state as a whole.
- **Investment Tax Credit**: Most of the solar projects planned are endeavoring to begin operation before the end of 2016 to ensure their eligibility for the Federal Investment Tax Credit.
- **Production simulation tends to overstate system flexibility**: Production simulation tends to overstate system operational flexibility. E3 took steps to constrain hydro generation and imports to realistic levels. However, the model does assume all fossil generation can be dispatched by the CAISO within operating constraints. In reality, self-scheduled generation may not be readily available for flexible dispatch by the CAISO.

Indeed, negative prices due to overgeneration have already occurred in California, in advance of even 33% RPS. Figures 2-4 show total generation, renewable generation and SP-15 prices for March 6, 2014. Figure 2 shows that the thermal units are ramped down in the middle of the day to accommodate ~3,000 MW of solar generation (Figure 3). This leads to several intervals with negative prices between HE 11 and HE 17 (Figure 4).

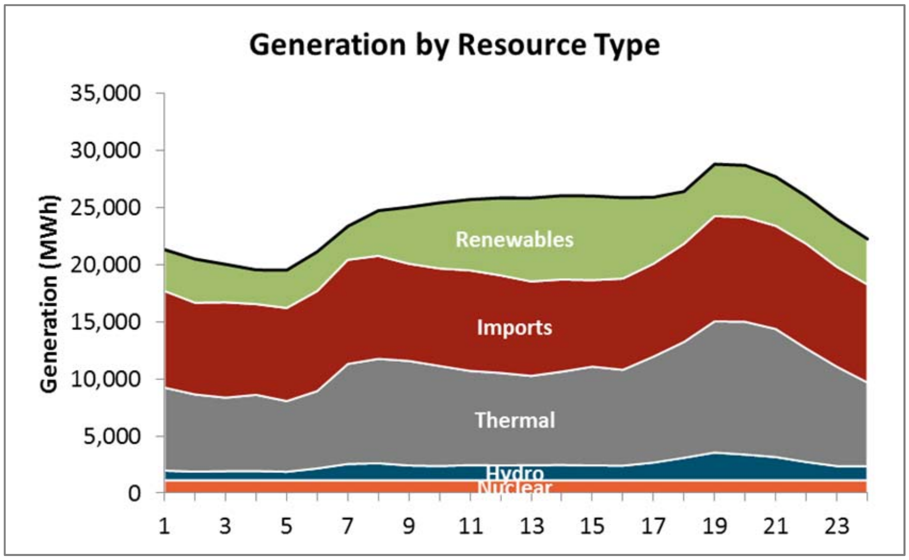


Figure 30: CAISO March 6, 2014 – Generation by resource type

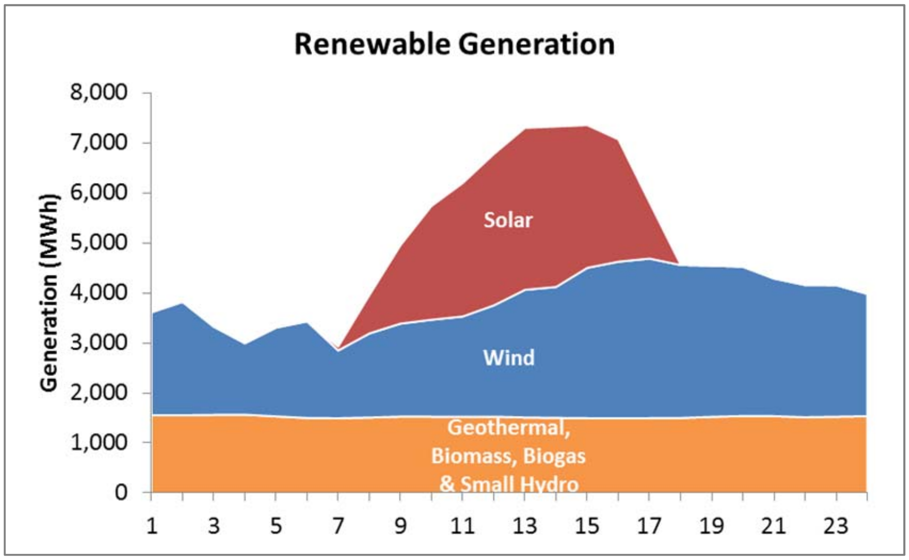


Figure 31: CAISO March 6, 2014 – Renewable generation

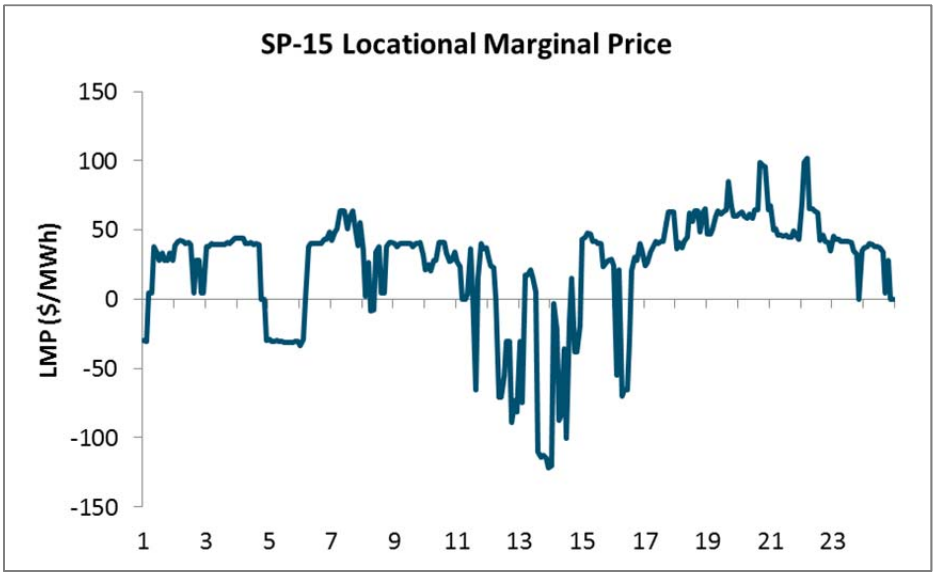


Figure 32: CAISO March 6, 2014 – SP-15 locational marginal price (LMP)

9.4. Value of Avoiding Renewable Curtailment

One solution to overgeneration is to curtail renewable generation. However, curtailment may be an expensive strategy. The immediate cost of curtailment is that the utility cannot use zero emission and marginal cost generation that has already been contracted and paid for. Curtailing renewable generation can also make it more difficult for utilities to achieve RPS and GHG emission reduction goals, which can impose additional costs on the utility.

If utilities have procured resources to meet the RPS with the expectation that a certain level of renewable energy will be delivered from these resources, frequent renewable curtailment may increase the risk of being out of compliance in a given year. There are two strategies for minimizing this risk: 1) the utility can procure additional renewable resources to comply with RPS targets; or 2) the utility can procure resources that provide enough flexibility to ensure that energy from their renewable resources can be delivered (such as energy storage). For a utility, the choice between these two options will depend on the cost of procuring additional renewables versus the cost of procuring flexible resources, as well as the incremental fuel and operating costs associated with each option.

E3 has developed a low and high avoided curtailment value scenario to illustrate the impact of curtailment on system costs and flexible resource value (using methods further described in Appendix A). The low case reflects a scenario where utilities have procured sufficient renewable generation to meet RPS targets, even with anticipated curtailment levels, and do not need to procure additional renewables. Hence, there is no cost to the utility for replacement renewable generation. The high case presumes that utilities must procure additional renewables to meet required RPS targets when curtailment occurs. In the high case, the replacement cost for renewable generation is $125/MWh, reflecting a higher levelized cost for PV that has a lower capacity factor due to its being curtailed on a regular basis. A high cost of curtailment leads to negative values for energy when overgeneration occurs (Figure 9). We refer here to energy value rather than prices because the wholesale market prices for energy will not necessarily reflect the cost of curtailment to the utility.

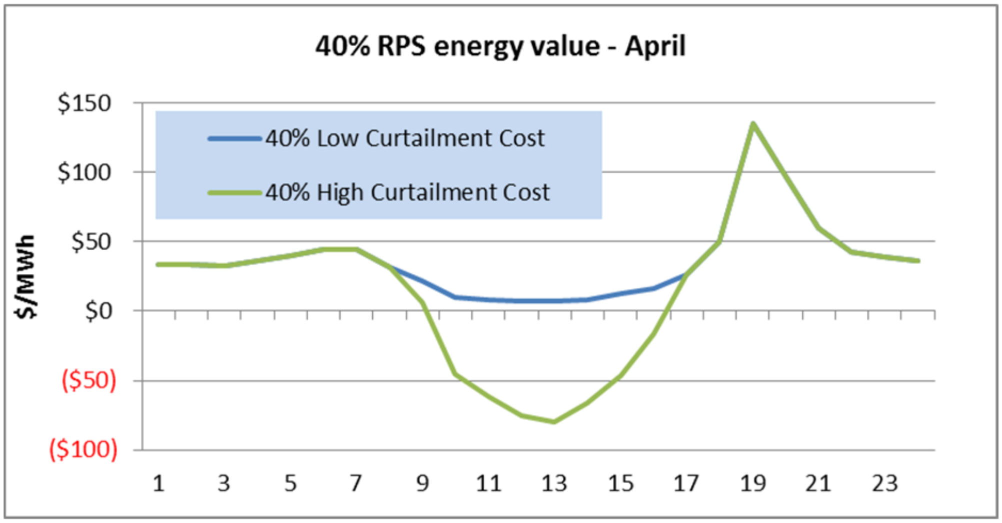


Figure 33: Average hourly energy value in April under 40% RPS scenario with low and high cost of curtailment

Plug-in Electric Vehicle Deployment in California:

An Economic Jobs Assessment

The California Electric Transportation Coalition commissioned UC Berkeley economist Dr. David Roland-Holst to conduct an economic analysis of the projected job benefits that will be created through the growth of a plug-in electric vehicle market in the state.

Overview

There has been much anecdotally said about green jobs and jobs creation related to alternative-fuel vehicles. The California Electric Transportation Coalition (CalETC) wanted to provide some academic analysis providing deeper insights into the actual economic and jobs impacts of deployment of Plug-in Electric Vehicles (PEVs) in the light-duty sector. Because of the prevalence of personal vehicle use in California, it is hardly surprising that significant technological change will have sizeable and lasting macroeconomic impacts. Generally speaking, the most robust finding of this study is that **statewide economic growth and employment rise with the degree and scope of PEV adoption.** When vehicle owners realize their gas savings, whether households or businesses, those savings are spent on goods and services and the result is higher state economic growth and employment.

Key Findings

- Electric Vehicles can be a catalyst for economic growth, contributing nearly 100,000 additional jobs by 2030.
- On average, a dollar saved at the gas pump and spent on the other household goods and services creates 16 times more jobs than a dollar spent on refined petroleum product.
- Unlike the fossil fuel supply chain, the majority of new demand financed by PEV efficiency savings goes to in-state services, a source of diverse, bedrock jobs.
- Individual Californians gain from electric car deployment whether they buy an electric car or not. Average real wages and employment increase across the economy and incomes grow faster for low- and middle- income groups than for high-income groups.

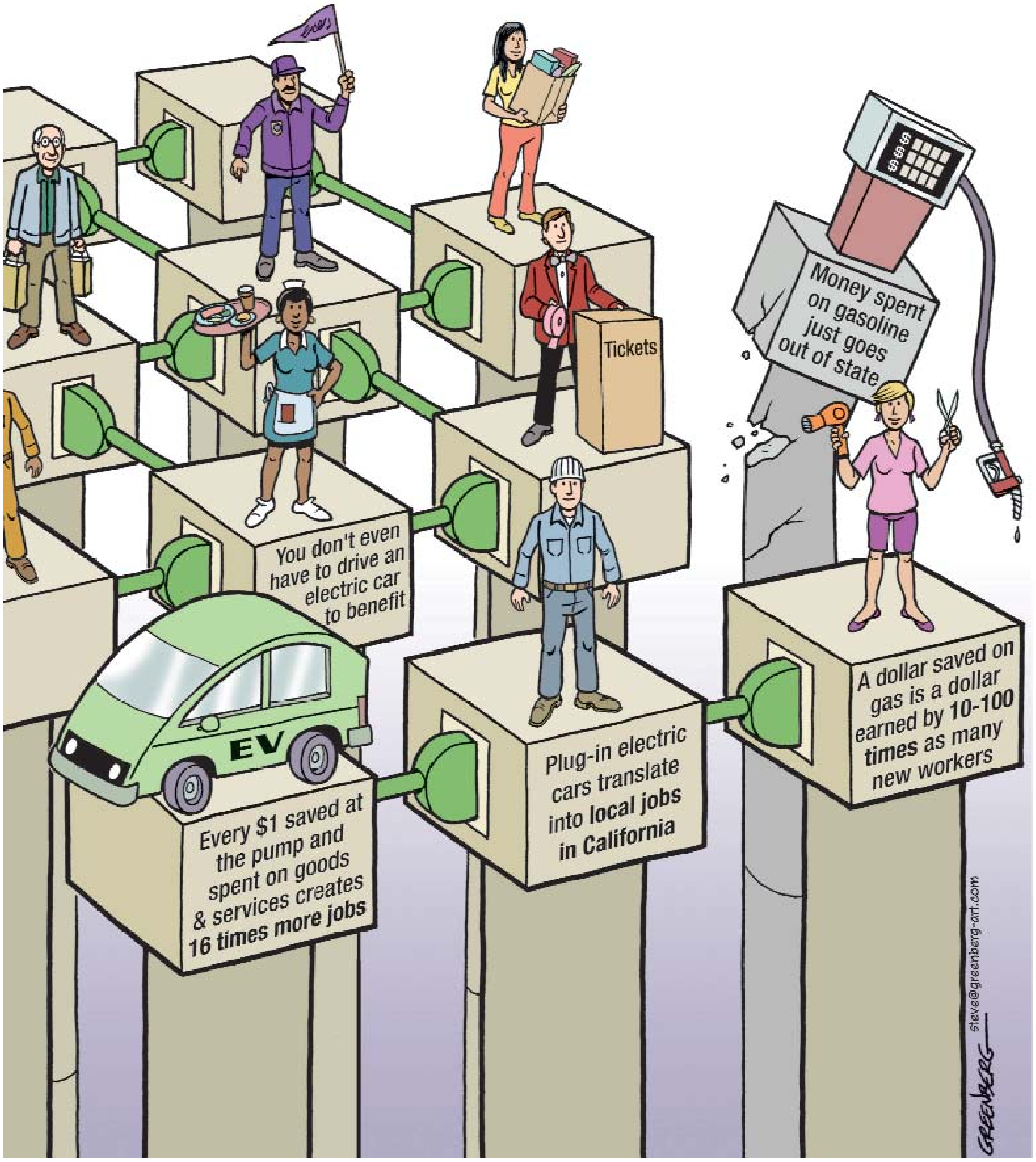
How do Plug-in Electric Vehicles Create More Jobs?

PEV adoption stimulates economic growth by reducing the cost of transportation fuel, promoting transportation efficiency and reducing fuel use, thereby saving money for households and businesses. These savings are spent on basic needs and services that create more jobs than the petroleum fuel supply chain.

Plugging in Revs Up the California Economy

■ As California drivers struggle with gas prices well over $4 per gallon, a new economic research report shows that plug-in electric cars can create nearly 100,000 California jobs and provide a powerful local economic stimulus that will benefit people of all incomes.

CalETC
California Electric Transportation Coalition



How do Non-Plug-in Electric Vehicle Owners Plug into Job Benefits?

Detailed analysis of economy-wide impacts show that low, middle and high income households all gain from PEV deployment, regardless of who buys PEVs or their income levels. This is because the spillover effects of gas savings that are spent in the local economy are widespread, creating jobs across nearly every sector of the economy and raising average real wages.

Most of the jobs created by PEV deployment are in service sectors such as healthcare and entertainment. Jobs in these sectors are in-state and at low risk of being outsourced.

Where are the New Jobs Created?

Except for sectors directly linked to the fossil fuel supply chain, transportation fuel savings stimulate job creation across all economic activities where consumers and businesses spend money. This leads to employment growth far beyond "green" sectors and "green-collar" occupational categories. The oil & gas sector does not lose jobs per se, but instead experiences slower job growth overall over a twenty-year timeframe under these scenarios.

What is the PEV Growth Dividend?

The PEV growth dividend arises from a relatively simple mechanism called "expenditure shifting." Household and business fuel savings are spent on new vehicle technology and other consumer goods and services. Because spending on goods and services creates more jobs per dollar of demand than the fossil fuel supply chain, the result of this shift is employment growth. New jobs in turn lead to more spending, with its own induced income and employment stimulus, extending the growth cycle that economists call the multiplier process.

What were the Analytic Assumptions?

- The report considered two scenarios for PEV deployment. PEV 15 scenario assumes 15 percent of the new light-duty fleet of vehicles are PEVs by 2030 and PEV45 scenario assumes 45 percent of the new light-duty fleet of vehicles are PEVs by 2030. The PEV 15 scenario loosely correlates with the ZEV mandate, and the PEV 45 scenario loosely correlates with the state's 2050 goal for greenhouse gas emissions. However, they are not intended to be policy recommendations, rather they are intended to consider the macro-economic impacts of different PEV deployment scenarios.

- CalETC assumed an average gasoline price of about $4 per gallon and an average electricity price about $0.15 per kWh. The fuel cost estimates come from the US Energy Information Administration's Annual Energy Outlook Forecasts, adjusted for California.

- The incremental PEV costs are based on the McKinsey assessment of battery costs and the USEPA and NHTSA assessment of component costs.

- The report looked at deployment of three technologies: Plug-in Hybrid EV with 20 miles all-electric range; Plug-in Hybrid EV with 40 miles all-electric range; and pure Battery Electric Vehicle. For simplification the report assumed equal distribution of these technologies across the new vehicle fleet. The real finding of interest is that the more electric vehicle miles driven the greater the economic benefits.

- The report considered all incentives available in California, including the federal incentives but assume these incentive programs diminish over time and end by 2020.

- The report considered the credit value of the Low Carbon Fuel Standard (LCFS) regulation, which was minimal given our very conservative assumption that the credit value would only be $32.

What is the Berkeley Energy and Resources (BEAR) Model?

CalETC selected Berkeley and the BEAR model because the BEAR model has been thoroughly peer reviewed over many years. The BEAR model is a standard general equilibrium model that considers both direct and indirect effects across the economy, this kind of empirical evidence helps to improve the understanding of the many indirect benefits of PEV deployment.

What is CalETC?

CalETC is a non-profit association promoting economic growth, clean air, fuel diversity and energy independence, and combating climate change through the use of electric transportation. CalETC is committed to the successful introduction and large-scale deployment of all forms of electric transportation including plug-in electric vehicles, transit buses, port electrification, off-road electric vehicles and equipment and rail. With every major auto maker producing or planning to produce PEVs, California is poised to lead in diversifying the transportation fuel sector. CalETC will continue to support all aspects of the transition to electric transportation, working closely with our government, environmental, and industry partners to ensure success.

CalETC
California Electric Transportation Coalition
1015 K Street, Suite 200 Sacramento, CA 95814
www.caletc.com

ECONOMIC ANALYSIS

California Low Carbon Fuel Standard

California's Low Carbon Fuel Standard (LCFS) is delivering cleaner fuels, insulation from gas price spikes, cuts in greenhouse gas emissions, and healthier air while our economy continues to grow – and it's helping California maintain its leadership position in the fast-growing clean energy sector.

By spurring greater use of clean alternative fuels and vehicles, the LCFS will result in $1.4 – $4.8 billion in societal benefits by 2020 from reduced air pollution and increased energy security.

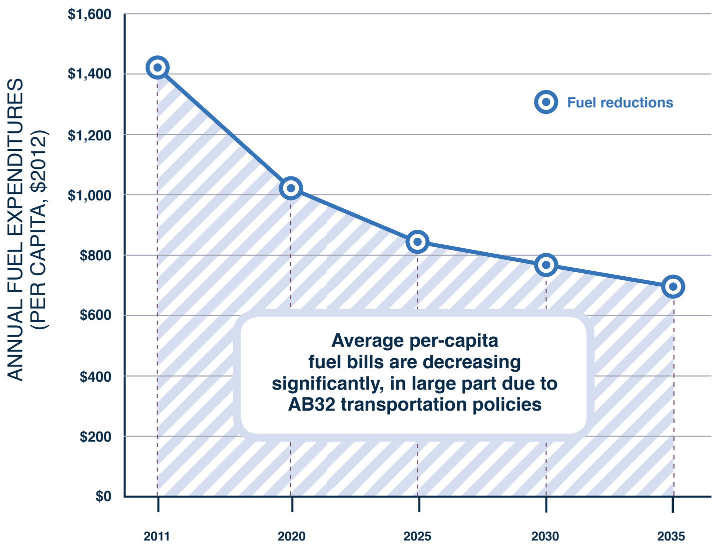
California's economy continues to grow

- A new study on the economic effects of the LCFS – including impacts on jobs, incomes and gross state product – shows the economy will continue to expand.
- Effects on the overall economy are less than one-tenth of one percent – ranging from 0.04% to -0.04%.
- The LCFS could mean 9,100 new jobs for California. This number could be higher, particularly if the state attracts more clean fuel production facilities and technology providers.
- The LCFS has already driven and will continue to drive significant investments in clean alternative fuel production, infrastructure and advanced vehicles – all necessary to continued economic growth.
- While this study only analyzes the economic effects of the LCFS through 2020, experts expect the policy's economic benefits to increase significantly by 2025 and beyond.

Oil industry claims that the LCFS would significantly increase the price of fuel are incorrect

- ICF International, known for its expertise in economic and policy analysis, did the study for a coalition of business groups.
- The potential costs for the petroleum industry to comply with the LCFS translate to $0.06 to $0.19 per gallon. As a point of comparison, prices in California have fluctuated by an average range of $0.75 per gallon for gasoline and $0.63 for diesel since 2010, largely due to global oil prices, refinery shutdowns and accidents, and seasonal demand.
- The potential value for clean fuel producers will range from $0.07 to $1.89 per gallon, depending on how much pollution is reduced by the fuel.
- This study uses transparent assumptions and a widely used economic model.
- An oil industry-sponsored Boston Consulting Group (BCG) study that found dramatic gas price effects of the LCFS was decisively discredited by an expert review panel. The panel said, "We are concerned about some of its assumptions, methodologies and results," and called it "limited," "incomplete," "based on an admittedly unlikely scenario," "pessimistic" and "outdated."

Californians’ fuel bills are going down *(per capita)*



Average per-capita fuel bills are decreasing significantly, in large part due to AB32 transportation policies

While not explicitly analyzed in this study, California’s clean energy policies under AB 32, including the LCFS and other transportation-related standards, already are driving down demand for petroleum – cutting fuel bills for Californians. Just as California’s energy efficiency policies have saved consumers more than $56 billion on their electricity bills over the last three decades, the state’s transportation standards will have similar effects, cutting fuel bills in the future.

Source: ARB and U.S. Energy Information Administration (EIA)

An abundance of alternatives already exists

Clean renewable fuels are available today, and the ICF study shows that we can meet the LCFS in 2020. Each fuel’s carbon score is a measure of the greenhouse gas emissions associated with the combination of all the steps in its extraction, production, refining, and final use. The lower the score, the cleaner the fuel.

FUEL SOURCE	**Biodiesel, Inedible Corn Oil**	**Biomethane**	**Biodiesel, Waste Grease**	**Renewable Diesel**	**Ethanol Cellulosic**	**Renewable Gasoline**	**Electricity**
CARBON SCORE	4	13	14	20	21	25	31
FUEL SOURCE	**Hydrogen**	**Ethanol, Sugarcane**	**CNG**	**LNG**	**Ethanol**	**Diesel**	**Gasoline**
CARBON SCORE	39	70	75	80	85	98	99

California Clean Fuels Project

Information in this fact sheet comes from a variety of reputable sources including ICF International’s study, California’s Low Carbon Fuel Standard: Compliance Outlook and Economic Impacts (April 2014), which was commissioned by a coalition of business groups, including: California Electric Transportation Coalition, Advanced Biofuels Association, California Natural Gas Vehicle Coalition, National Biodiesel Board, Environmental Entrepreneurs and Ceres.

SCHEDULE CAC-5
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