German Aerospace Center

Wuppertal Institute for Climate, Environment and Energy

UC DAVIS PLUG-IN HYBRID & ELECTRIC VEHICLE RESEARCH CENTER

Regional Trends in Electromobility

Subproject within the research project:

Global Perspectives and LCA of Electromobility

- STROM-Assist

Regional study

Regional study North America

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PLUG-IN HYBRID & ELECTRIC VEHICLE RESEARCH CENTER

Contributing authors:

Dr. Tom Turrentine
PH&EV Research Center
University of California, Davis
tturrentine@ucdavis.edu

Dahlia M. Garas
PH&EV Research Center
University of California, Davis
dmgaras@ucdavis.edu

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Abbreviations

BEV	Battery Electric Vehicle
CA	California
CAFÉ	Corporate Average Fuel Economy (standards)
CARB	California Air Resources Board
CEC	California Energy Commission
CVT	Continuously Variable Transmission
DOE	United States Department of Energy
EPA	Environmental Protection Agency
EVSE	Electrical Vehicle Supply Equipment
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas Emissions
GVWR	Gross Vehicle Weight Rating
HDV	Heavy Duty Vehicle
HEV	Hybrid Electric Vehicle
HOV	High Occupancy Vehicle (or carpool) lanes
ICE	Internal Combustion Engine
LDV	Light Duty Vehicle
LEV	Low Emission Vehicle
MOU	Memorandum of Understanding
NHTSA	National Highway Transportation and Safety Administration
OEM	Original Equipment Manufacturer (Automotive companies)
PEV	Plug-in Electric Vehicle, including both BEVs and PHEVs
PHEV	Plug-in Hybrid Electric Vehicle
PZEV	Partial Zero Emission Vehicle
SAE	Society of Automotive Engineers (governing vehicle standards)
SULEV	Super Ultra Low Emission Vehicle
TOU	Time of Use (used in electricity rates)
ULEV	Ultra Low Emission Vehicle
QC	Quick Charging (also sometimes referred to as Fast Charging)
WI	Wuppertal Institute
ZEV	Zero Emission Vehicle

Summary

This report presents the state of the electric transportation industry and market in the United States as of the end of 2013. In this report, we look at the historical context of regulations in the US, as well as specifically in California, which is leading not only the US, but also the world in terms of plug-in electric vehicle adoption.

While electric vehicles have been around since the turn of the last century, they didn't gain a strong base of support until the air quality problems in Los Angeles lead to the creation of the California Air Resources Board in 1967 (http://www.arb.ca.gov/html/brochure/history.htm) and the fuel crises of 1980 reinvigorated automaker research into electric drive technologies. Since then, funding, research, and support for electric drive vehicles has gone through several up-and-down cycles. The current state of the market for electric drive vehicles is the result of increasing national fuel economy standards and the continued push for Zero Emission Vehicles (ZEV) in California and several other states who have adopted the ZEV mandate, as well as improvements in the technology, increasing fuel costs and awareness of the impacts of greenhouse gas emissions.

The current market is strong in certain regions, and currently growing with the addition of each new plug-in vehicle model offered onto the market. The incentives, both monetary and non-monetary, offered by states, regions, and the federal government seem to be playing a significant role in the launch of this early market, according to buyers. This has led to specific markets in certain states with much higher PEV adoption rates than surrounding areas or states, due to the variability in incentives, as well as other factors, such as weather, motivations, and charging infrastructure. We look at the history of hybrid vehicle adoption in the US as a potential model for the path that plug-in vehicles may take, and consider the additional variables that may accelerate or decelerate the adoption. In the US, those factors that are likely to help accelerate the market for PEVs are: increasing federal fuel economy standards, California and other states adopting even stricter emissions requirements for vehicles, increasing fuel prices, and availability of incentives for participants in the early PEV market. Those factors that may temper the growth of the market include: variability in political support for electromobility, the continued high cost of batteries and components for plug-in vehicles compared to internal combustion engine vehicles, tapering of financial incentives, inconsistent charging infrastructure, and a lack of experience or understanding of PEVs compared to conventional vehicles by the broader car-buying population.

1 The Project STROM-Assist

1.1 Project background: STROM and STROM-Assist

The accompanying research project STROM-Assist aims at identifying key technologies for the deployment of electric vehicles in the future. Basis for the accompanying research is the funding program by the German Federal Ministry of Education and Research called STROM, in which 18 electric mobility projects are involved[1]. The total program has a funding sum of around € 180 million. The project consortia include vehicle manufacturers, tier-1 and tier-2 suppliers, universities and research institutes. The program has a strong approach towards applied concepts and practices with a high market potential in the future. The STROM-projects cover the following categories (technology cluster):

- Vehicle Concept
- Lightweight Construction
- Electric Engine
- Thermo Management of Batteries and Motors
- Power Electronics
- Range Extender

The projects in this program will focus on the technical development of such technologies. STROM-Assist accompanies these projects by reflecting national research efforts within the context of developments in electro mobility in different global regions.

1.2 Scope of the subproject "Regional Trends in Electro mobility"

The subproject "Regional Trends in Electro mobility" aims at identifying and analyzing major trends in the field of electro mobility. The trend analysis will monitor research effort and upcoming technologies, policies, products and market developments in different focus regions around the world continuously to enable a systematic analysis of global trends. The regional trend analysis for electro mobility is a major keystone for the project success and therefore cooperation with renowned international institutions in the field of electro mobility is foreseen.

Objects of analysis in the subproject "Regional Trends in Electro mobility" include various forms of battery-electric, road-based vehicles ranging from e-bikes to electric buses, while the focus is on electric passenger cars. The analysis covers vehicles that have electric assisted drive systems as well as vehicles that derive all power from batteries. The focus is on all-electric passenger cars (BEV) and plug-in hybrid electric vehicles (PHEV). Mild hybrids and full hybrid are only included in the analysis if these vehicle types are of high relevance in the study region. Furthermore, associated technologies, infrastructures, business models and mobility concepts are under investigation. The analysis covers not only well-known vehicle technologies and mobility concepts, but also includes innovative approaches for electro mobility. At some points it may be necessary to include other vehicle technologies and mobility concepts in the analysis to assess the role of electro mobility. The term "vehicle" subsequently will address road-vehicles only.

[1] Information on programs funded by the Federal Ministry: http://www.bmbf.de/en/14706.php

1.3. Methodology Regional Study North America

The results presented in this document are based on desktop research, on a review of scientific literature and grey literature as well as on interviews with local stakeholders. A researcher team consisting of representatives of the German Aerospace Center and the University of California Davis conducted the interviews in September and October 2013 in North America. The consultation of local experts served to obtain information that complemented the result of the literature review. The interviews provided additional information especially concerning ongoing developments and related to topics, which are insufficiently covered in public documents. In addition, current experiences and expert assessments and opinions on the further development of electric mobility in North America were collected. The focus of our study was on the situation of the United States, since interviews were also carried out with experts from Canada the results of these interviews are included in the study.

The interviews within the framework of the regional study North America focused on four branches:

- Policy framework and strategies (e.g. funding programmes and budgets, standards and regulations, infrastructure and electricity industry, adequacy of the current policy framework)
- Focus areas of research and development (e.g. research topics, organisation of the electric mobility research, cooperation between different actors)
- Economy and industry (e.g. main manufacturers of electric vehicles, strategies and business models in the broader sense)
- Consumer and markets (trends, acceptance of electric vehicles, current users)

Representatives of 18 different institutions were interviewed. Among these institutions were car manufacturers, associations or respective umbrella organisations, utility providers, research institutes, ministries and agencies (see Table 1). Often, experts from different departments within the respective institutions took part in the interviews.

Table 1: Overview about the interview partners of the research trip to North America

Institution	Department	Sector
BMW Group	Governmental Affairs, Office California	Industry
City Car Share, San Francisco	eFleet Program	Industry
EV Grid	Electric Vehicles, Battery Management Systems, Vehicle to Grid / Grid Integrated Vehicles (V2G/GIV), Grid-tied Stationery & Mobile Energy Storage	Industry
Ford Motor Company	Vehicle Electrification and Infrastructure	Industry
General Motors	Global Energy Systems & Infrastructure Commercialization	Industry
Greenlots	Electric vehicle charging networks	Industry
Mitsubishi Motors	Mobile Emissions, Regulatory Affairs &	Industry

North America	Certification	
Mercedes-Benz North America	Fuel Cell Vehicle Operations USA, Group Research & Advanced Engineering	Industry
Google Inc.	EV Initiatives	Industry
Ministry of Transportation, Ontario	Sustainable Transportation Office, Advanced Manufacturing Branch	Policy
U.S. Department of Energy	Vehicle Technologies Office, Vehicle Technologies Program, Energy Efficiency and Renewable Energy	Policy
Electric Mobility Canada	-	Policy
Plug-In Electric Vehicle Collaborative	Communications & Business Development	Policy
Center for Climate and Energy Solutions	Transportation Initiatives	Research/Policy
California Polytechnic State University	Electric Engineering Department, Electric Power Institute	Research
Stanford University	Center for Automotive Research at Stanford (CARS)	Research
The National Academies	Energy and Environmental Systems, Environmental Studies and Toxicology	Research
University of California, Davis	Institute of Transportation Studies	Research

The results were reviewed and structured according to the four fields of investigation. The outcomes of the interviews were used anonymously in the regional study and are summarized at in the end of each thematic field.

2 The Study Region: USA

As of March 2014, total plug in vehicle registrations for the US are about 230,000 units (not including two wheel or low speed vehicles). Sales in 2013 were 96,000 units, about .65% of the market. The market is very small but just about doubling each of the last two years. About 1/3 of these sales are in California, whose regulations and technology sector are pushing electrification.

USA background

The United States is a highly urbanized, industrial society, with a strong history of "automobility." The electric vehicle industry and market that is developing in the United States (particularly in California) in the last few years is the outcome of that successful automobility, a need for radical reductions of tailpipe emissions, demand for carbon reduction and energy independence.

The history of industrial and social development in the United States centers on the story of automobile manufacturing, as well as the social mobility the automobile offers to Americans. The automobile figures centrally in the development of American cities, their rapid growth at the turn of the 19^{th} to the 20^{th} century, growing incomes for the workers in the steel and automotive sectors, as well as the building of roads. Automobile ownership soared as Americans moved from the country to the city, but not city centers, rather given the individual mobility that Americans were afforded by the auto, American cities spread out in a suburban pattern. One city that set the pattern for this type of auto-centric lifestyle was Los Angeles. Los Angeles grew quickly in the Post-World War I period, by 1927, the ratio of car ownership was already 1 to every 3 citizens. In older American cities, such as Chicago, the ratio was significantly lower, 1:9, with more dense urban centers. At this time European cities, for example Berlin, had only 1 car per 400 residents (Brilliant 1989).

Initially, American cities had trolleys and trains systems that allowed radial growth, and the subdividing of land on the urban boundaries. Car culture encouraged in-fill between these spoke like structures. In Los Angeles, train systems were eventually replaced by road systems for buses and cars, with freeway systems developing in the 1950s. Broad boulevards were cut through the downtown areas, and freeways were developed to connect not only hub like structures between the downtown and suburbs, but also to connect industrial areas around the periphery of the city (Bottles 1987).

Along with this new urban form, a new lifestyle grew, in which activities, including shopping, work, schools, recreation, dining, movies and vacations became increasingly accessed by personal vehicles. In the 1920's the cost of vehicles, especially used vehicles dropped so low as to allow not only middle class but also, working class families to have automobiles. Relationships also became shaped and reliant on vehicle travel. Americans in these suburbs became increasingly mobile, moving to new neighborhoods, away from family and friends. Lives became regional, in which freeways accessed schools, doctors, friends and even places of worship.

Automobiles figured so strongly in American culture that family life as well as personal development has often centered on learning to drive, and eventually owning a vehicle. Minority rights in society have developed closely around the vehicle, and the ability of women or minority ethnic groups to own a vehicle was closely tied to having opportunities for work, and access to education. As a result, transit systems in the Unites States declined rapidly after World War II. The war itself, along with the continued immigration, and rapid economic growth cemented this new type of suburban city. Housing and vehicle costs dropped and incomes grew rapidly.

The hegemony of the automobile lifestyle spread through most American cities, with the exception of cities such as New York and San Francisco, which given their watery boundaries, maintained older patterns of density. These cities still have subways, trolley systems, and high density walk able neighborhoods. Most other cities sprawled, getting less dense, and often their cores became areas of poverty, with fewer jobs, older neighborhoods. Wealth fled these cities, moving to suburban regions, some of them into gated and exclusive areas. Workers also left the cores, to get away from the poverty and racial tensions in the core areas.

The automotive sector, including making steel, plastic, and other materials, parts, manufacturing, building roads, servicing vehicles, financing vehicles and roads, selling vehicles, even repairing and scrapping vehicles has been a core industry and jobs provider for American industrialization. Financing for example, made it possible for Americans to pay for increasingly large, powerful and technically sophisticated vehicles. The oil industry also grew around this auto dependent culture. American oil companies developed regionally, in Pennsylvania, Texas, Oklahoma, and California. Refineries were built near ports, like Los Angeles, Seattle, New Jersey, and chemical industries grew near these refineries.

Cementing the American love for and dependency on vehicles was the development of the federal interstate highway system. Beginning in the 1950s, this project sought to connect American cities with a system of 47,000 miles of high speed freeways (as opposed to toll roads) In the older Northeast and Midwest, these freeways connected more densely developed and industrial regions, supplementing the trains and canals and lakes that move goods and materials. In the West, the freeway system connected cities across a more sparse landscape. While initially Americans favored taxes on gasoline to expand the freeway system, taxes remained much lower than in other countries.. Federal as well as state taxes on gasoline remained stable and low over decades, fluctuating in "real price" between $1.50 and $3.80 between 1976 and 2014 (EIA Real Petroleum Prices, 2014). One feature of the American road system is that most of the construction, and maintenance is conducted by individual States, the federal government collects revenues from gasoline and diesel sales, and returns it to state departments of transportation, who build and maintain the roads.

Thus, American lifestyles and economies are highly dependent on automobiles. While efforts to change that are part of planning goals of most cities, for which freeways and congestion are increasingly a problem, and the US economy has diversified since the late 20th century, automobiles continue to be a dominant sector of the economy and essential in most situations to access to work, shopping, recreation, and emergency services. Train and bus systems are poorly developed, except in a few dense cities and carry a small number of riders. Most commuters in the United States who use trains or subways to commute are heavily concentrated in a few major metropolitan regions. New York City accounts for one third of all transit trips in the US. Thus, while reductions in vehicle use, and greater densification of cities are important features in a more energy efficient system, passenger vehicles will continue to be the dominant players in the US transportation system for many years.

3 Regional trends in electro mobility in USA

As presented above, American infrastructure for transit, walking, trains, buses, walking and biking are underdeveloped except in a few locations and cites. Therefore electrification of vehicles offers a pathway toward significant carbon reductions, reduced dependency on petroleum fuels, and improving local air quality.

Developing a sustainable electric vehicle industry is a complex, long term, multi-sectorial undertaking, involving numerous actors in industry and government. It is unlikely that an electric vehicle industry would develop without a coordinated government and industry effort, given the overall maturity of the conventional market, the many hurdles electric vehicles face in meeting costs, reliability and market volume.

Battery powered electric vehicles (BEVs) were a significant portion of the vehicle market early in the 20th century, prior to easy availability of gasoline, starter motors for gasoline powered vehicles, and good road systems that encouraged longer trips away from cities

Electrics used lead acid batteries, were mainly found in dense urban situations, and were the preferred means of travel for wealthy women, who could have vehicles charged and delivered by electric services. Gasoline vehicles were exceedingly dirty, noisy, and injuries were common when starting with the engine crank. By the 1930s, electrics disappeared from the market in the United States (Schiffer M. 1994).

While a few auto companies conducted limited research on BEVs in the 1950s and 60s, it was not until the oil crisis and worsening air quality, primarily in California, and particularly in the Los Angeles basin in the 1970s, that Americans and auto companies began to reconsider electric vehicles. However, batteries had not progressed much, and energy densities were not sufficient for modern vehicles, which weighed over two thousand pounds on average and seated five people. Most battery powered vehicle experiments had to focus on small vehicles, with low speed DC drive systems. At this point, researchers in the Department of Energy in the US began to experiment in earnest in electric drives (Riley, R. 1994).

Los Angeles air quality in the 1960s and 1970s had deteriorated so much, that smog alerts were becoming a regular feature of life, and the snow capped mountains and beautiful inland valleys were clouded in a semi-permanent gray-brown haze, or smog, – occasionally clearing. The problems with air quality and associated lung diseases prompted the development of the Clean Air Act, signed by President Richard Nixon, whose hometown of Wittier had some of the dirtiest air in Los Angeles. However, the problems of Los Angeles were comparably worse and intractable compared to most other cities, given the trapped air (inversions) in the region and its intense quantity of vehicles.

To deal with its special problems (some other parts of California have similar mountain bounded air basin issues), California was given special authority under the clean air act to regulate air pollution, in particular from automobiles. Governor Ronald Reagan formed the California Air Resources Board (CARB) to measure, regulate and control emissions. In fact, California, over the next decade, would tighten car pollution regulations to the point it became embattled with car companies and the federal government.

Even with great progress in emission controls, regulators and scientists at the air board determined in the 1980s that to finally clean up air in California's cities would require cars to have Zero Emissions. It was at this time some maverick engineers would show regulators a very advanced electric vehicle that would encourage them to move ahead with a Zero Emission Vehicle policy goal.

A central moment and event in the development of electric mobility in the United States was the development of a lightweight, extremely aerodynamic, powerful two seat, AC motor driven, vehicle called the Impact. It was developed at an advanced, largely autonomous division of GM in Los Angeles, under the guidance of Paul MacCready, an aeronautical inventor, and a team of electrical engineers. Paul MacCready was a visionary, who was famous for making and flying a human power aircraft over the English Channel. He assembled a team of electrical engineering experts who created a fast, sleek, battery powered, extremely lightweight and aerodynamic vehicle (Cronk S. 1995). Additionally this vehicle introduced the use of computers in controls of the battery systems and motors. A team of air quality regulators from the California Air Resources Board were introduced to the Impact in 1990 and Roger Smith, the CEO of General Motors declared the Impact "the future" on Earth Day 1990. The surprising power and performance of this vehicle encouraged California regulators at CARB to develop the Zero Emission Vehicle (ZEV) mandate in 1990. The ZEV mandate required the six major vehicle manufactures to sell in 1998, 2% of their vehicles as ZEVs, increasing to 5% in 2001. (G. Collantes[2] 2006) These were primary sales leaders in California, with sales of over 75,000 per year in California and included GM, Ford, Toyota, Honda, Chrysler and Nissan. This law stunned automakers, which were already embattled with regulators in California over the low emissions requirements.

The only drive train with this possibility was the electric vehicle (although this would also encourage development of fuel cell vehicles). Car companies would also develop hybrid and eventually plug-in hybrids partly in response to this bold demand, alternatives to the costly, and range limited electric, which they thought would have very few buyers,

The ZEV mandate had a multi-year build-up in which automakers would develop prototypes. CARB would hold hearings about whether such vehicles would indeed sell and whether the technology was ready, and cost goals (particularly for batteries) could be met. Much of the focus was on batteries, whether they could really last, would store enough energy to power the vehicle for required speeds and distances, and would be cost effective. In 1996, ARB realized that the vehicle technology was not ready for market in 1998, and worked to develop a compromise with automakers.

As a result of the 1996 hearings, and in private meetings, the Air Resources Board postponed the ZEV mandates, and instead decided to conduct a market and vehicle demonstration, a suggestion Toyota had made in 1990. A Memorandum of Agreement was developed. With small numbers of pre-market vehicles, including an update of the GM Impact, called the EV1, and other vehicles from Chrysler, Toyota, Honda, Ford, and Nissan automakers developed small pre-commercial vehicle programs

[2] Collantes, Gustavo O. (2006) The California Zero-Emission Vehicle Mandate: A Study of the Policy Process, 1990-2004. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-06-09

There were no charger standards, and unfortunately automakers split between two types of charger systems, Toyota and GM using inductive paddles and Ford, and Chrysler and Honda using conductive plugs. This resulted in the "charger wars", which was not resolved until the Society for Automotive Engineers (SAE) rules on J1772 in 2009. During this period, a new battery technology, nickel metal hydride, was scaled up for large format applications at the Ovonic Battery Company. This battery was the result partly of the Department of Energy Battery research program and was installed in a number of GM EV1s. NiMH would go on to be the battery chemistry used in the now successful Prius hybrid platform as well as all other gasoline-electric hybrids currently on the market. Lithium-ion chemistries were becoming popular in consumer electronics, but at the time, Nissan was the only maker to use a lithium-ion battery in a vehicle, the Altra.

Automakers argued that these vehicles were not ready for market. CARB backed down from its demands, and postponed the mandate. The OEMs for the most part shut down their programs and shifted their research focus largely to hybrid technologies and fuel cells, convinced that batteries were not ready for full battery electric vehicles. There were a few other demonstrations of BEVs in the US outside California, notably the North East, in Boston and Vermont where electrical engineers, notably Solectria Corporation were developing new technologies, such as regenerative braking systems, heat pumps for interior heating and cooling.

Development of Plug-in Hybrid Vehicles

In the post ZEV mandate era, a few notable happenings were the development of the Nissan hyper-mini, which used lithium ion batteries; 17 of these vehicles were demonstrated in California at UC Davis. This period was mostly marked by surge a in interest and development of fuel cell hybrid electric vehicles by a number of auto companies and governments, in particular GM, Honda and Daimler.

The next most notable event in the USA for electric mobility was the development of plug-in hybrid electric vehicles. Several OEMs, including Volvo and Volkswagen, tinkered with PHEVs and promoted these designs in the 1990s. Since the early 1990's Dr. Andy Frank at UC Davis had been developing prototype plug-in hybrid vehicles, vehicles with an integrated electric drive train, with power from a grid charged battery and gasoline motor to both power the vehicle and charge the battery so as to overcome the range limitations. These proof-of-concept vehicles were developed for the US DOE sponsored student competitions, and were parallel, power-split vehicles employing an electric motor, very small gasoline engine, two clutches, and either a manual or continuously variable transmission (CVT). They were able to achieve fuel economies nearly double the conventional vehicle, and operate in an all-electric mode for 40-60 miles (Johnston et al, 1998, Meyr et al, 2002).

In 2004, enthusiasts of Frank's designs were able to put a larger battery in Toyota Prius hybrid vehicles and create a practical, plug-in hybrid vehicle. This vehicle demonstrated the potential of plug-in hybrids to power companies, such as Southern California Edison, the Electric Power Research Institute, and Argonne National Labs. A coordinated research project among these partners encouraged a new round of interest in grid-connected vehicles, primarily in California. In 2007, GM, following interest in this type of technology, and discouraged with BEVs, began a program to develop a new PHEV with 40 miles of all electric range, the Chevy Volt.

3.1 US Government / policies / public infrastructure

3.1.1 Actors

Federal

The Department of Energy is the primary actor in the Federal government, carrying out research, research support, loans to entrepreneurs and support of market development. The Environmental Protection Agency is the second most important federal actor: the role of the EPA is to enforce the Clean Air Act and other Environmental Laws, many of them originating in the 1970s. EPA in effect regulates the tailpipe emissions of vehicles and power companies, as well as industrial emissions. The Department of Commerce is the agency which distributes tax credits in support of the PEV market.

State

The most important regional actor is the State of California, primarily the California Air Resources Board, which has regulatory power over automakers, and distributes cash rebates to electric vehicle buyers. Second in California is the California Energy Commission which award research grants, and importantly implementation grants for electric vehicle planning activities, infrastructure development. Third most important public actor in California is the California Public Utilities Commission that regulates the power industry. This agency determines the price of electricity for private homes, businesses, and public charging companies. In recent years, the governor's office and the legislature have become active in this arena; notably California Governor Jerry Brown has issue an executive order for CA agencies to advance the plug-in vehicle market.

Next are the power companies. The United Sates has over 2000 electric power companies, some working across big regional sectors, and some much smaller, serving only local and rural communities, making the actions in this sector exceedingly difficult to coordinate. In particular, the auto companies are not accustomed to coordination with all of these power companies. The Electric Power Research Institute does coordinate a program of cooperation between GM and over 200 utilities, Moreover; there are both private and public utilities. It will be common for electric vehicle buyers to live in one company's area, work in another company's territory. Nevertheless, this actors are important in local and regional context, and shape rates. In particular, some of these companies will face challenges from the added load of charging, in particular, the Western States power companies are forced to size their power demands around air conditioning loads at peak high temperature events in the dry desert summer afternoon sand evenings (including of course California). Thus, adding load from charging demand at these times is a problem (unless off set by solar). Electric vehicles can be an asset or problem depending on local programs.

Additionally, there is a set of Zero Emission Vehicle compliance states in addition to California. The Clean Air Act allowed for other states to choose California's compliance program, which are out of compliance with the Clean Air Act standards for air quality in their communities. The governors of 8 states—California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont—have signed a memorandum of understanding (MOU) to take specific actions to put 3.3 million zero emission vehicles on the roads in their states by 2025, along with the refuelling infrastructure required to support those vehicles.

Zero-emission vehicles include battery-electric vehicles, plug-in hybrid-electric vehicles, and hydrogen fuel-cell-electric vehicles; the technologies can be applied in passenger cars, trucks and transit buses.

Some states, notably heavily Democratic strongholds, such as California or New York have taken stronger positions on carbon reduction within their state and local jurisdictions. In California, there is a new set of laws, aimed at city planning, to reduce Vehicle Miles Traveled. including:

Cities

Notably, some large cities and city regions in the United States have taken a position to promote electric vehicles, primarily through efforts of their mayors, in cooperation with regional partners. Some notable cities in this regard are Portland Oregon, San Francisco, Los Angeles, San Jose, Austin Texas and Seattle Washington. Each of these cities has taken special actions to encourage electro-mobility.

Air Quality Control Districts

Another set of important actors in the USA are regional air quality control districts. Often these are better funded than cities, and can distribute funds and develop programs that cities are unable to fund. The Bay Area Air Quality Management District, and the Southern California Air Quality Management District are well-funded regional partners that are funding things like infrastructure development, consumer outreach and even purchase incentives for PEVs. The San Joaquin Air Quality Control district has offered incentives to PEV buyers larger and in addition to the State Incentives.

Regional planning agencies

Each city region in the United States has this type of planning organizations for transportation to plan and fund roads, transit and regional programs. These regional actors usually have boards comprised of majors and other elected local politicians, and have staffs that develop and update regional plans that received federal funding from taxes on gasoline. These agencies and government coalitions can upgrade local plans to included need infrastructure and regional plans than can incentivize electric transport. In California, such organizations have recently been included in required planned reductions of greenhouse gases; electrification of transportation is one of the major strategies for these plans, along with reductions in travel, and energy efficiency in transportation.

Regional and Municipal Transportation Commissions

These organizations are the ones who operate regional transit services, including buses, light rail, local trains and things like rideshare programs. These can be another source of funding and support for electrification.

Public Private Collaborative Organizations

California has formed a public private collaboration called the Plug-in Electric Vehicle Collaborative. (http://www.pevcollaborative.org) This organization includes representatives from automakers, state agencies, power companies, charging network suppliers, universities and non-profit organizations. The collaborative meets three times per year to discuss challenges and opportunities, and cooperate on shared problems and also lead public events, such as a recent Governor-industry event in San Francisco, in which Governor Jerry Brown met with industry leaders who announced new initiatives by their companies.

3.1.1.1 United States Federal Government

The United States Department of Energy (DOE) has been the federal government agency involved with the development of electric vehicles, through primary research and development programs beginning as far back as the first oil crisis in the 1970s. The US government was primarily interest in battery electric vehicles to reduce American's growing dependence on imported oil, primarily middle east and more recently Venezuelan heavy crude (used for heating oil in the North East United States), which has been seen as a security threat to the US economy. Initial programs, under the Carter presidency, financed interest in biofuels and batteries. These programs were cut during the Reagan years, but with the Clinton presidency, a new program, initiated by Vice President Al Gore, increased funding, and brought the major auto companies into developing high efficiency diesel hybrids. Additionally, spurred by California's ZEV program, the DOE increased research in batteries.

The postponement of the ZEV program and the election of Republican President George Bush shifted efforts to hydrogen fuel cell vehicles (FCEVs) for several years, dividing funding among many R&D programs for combustion, fuel cells, plug-in hybrids and batteries. The difficulties of developing a hydrogen infrastructure and hurdles in vehicle costs have delayed FCEVs from immediate commercialization.

The recession of the past few years, financial rescue of GM, soaring fuel prices, and Obama administration combined to encourage commitment to a new energy economy through stimulus funding. An integrated set of policies were put together to initiate a new battery industry in the United Sates, electric vehicle manufacturing capabilities, and the development of a vehicle charger industry and rollout of charger infrastructure. A few start-up PEV makers, notably Tesla, Coda and Fiskar received loan guarantees from the US DOE in economic stimulus programs. The success and failures of these firms is being closely watched. Tesla appears to be a great early success at selling luxury vehicles, while the others have failed. However, it is still early for Tesla, who has only one assembly plant, and is still at a boutique level of production around 25,000 units per year.

While the Obama Presidency remains committed to electrification, a recent domestic oil and natural gas boom, resulting from new drilling technology has shifted the energy landscape in several important ways. First, United States has reduced its percentage of imported oil to the lowest percentage in decades. Second, this oil boom has slowed the rise in oil prices, and natural gas, at almost one half its price a few years ago, has resulted in a dramatic shift in the electricity sector from coal to natural gas.

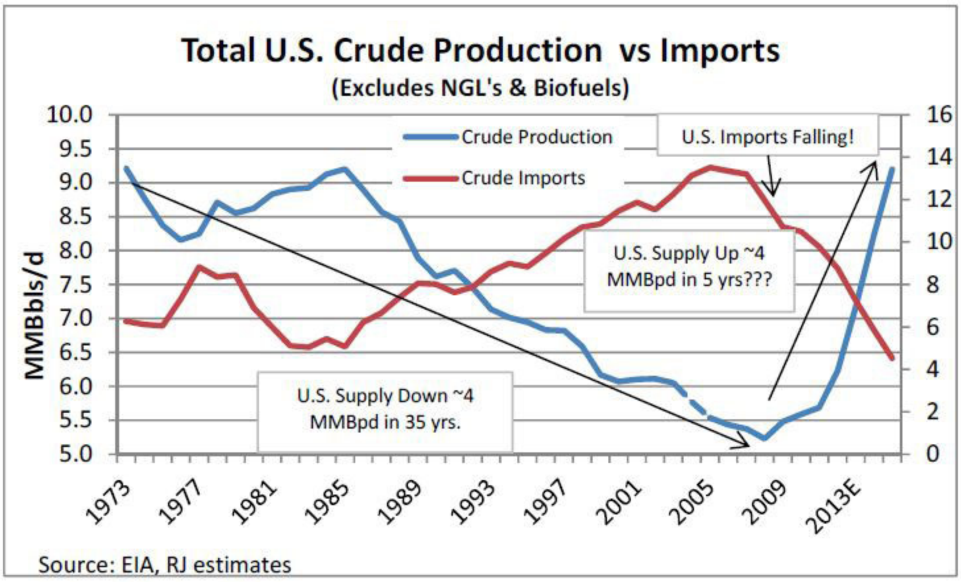

Figure 1 US Crude oil production, 1973 - 2013

The effects of this dramatic oil boom are just beginning to be felt; some early impacts counting against the success of electric vehicles are a somewhat more stable price of gasoline in the USA (varied from $3.79 high to a $3.30 low) which with the recovering economy has sent American's back to buying larger vehicles in late 2013.

On the positive side for EVs, the natural gas boom is resulting in lower priced electricity in 2012, thus shifting some electricity production to natural gas (although prices of natural gas have risen in late 2013 and early 2014 due to a cold winter and high demand for natural gas).

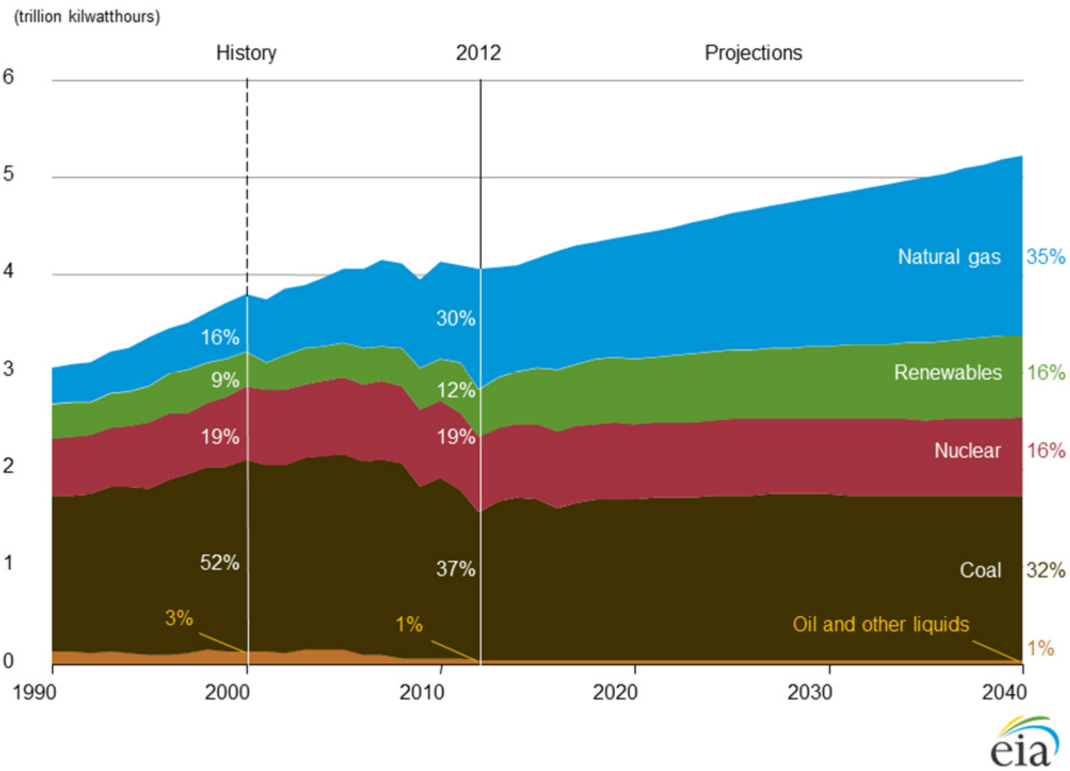

Figure 2: Electricity generation by fuel, 1990 - 2040

3.1.1.1.1 Corporate Average Fuel Economy (CAFE) standards

In 1975, after the 1974 oil embargo, the United States issued a number of laws design to increase fuel efficiency of vehicles, to reduce USA dependence on imported oil, primarily oil from the Middle East. The foremost of these were the CAFE standards, which induced the automakers to a higher average fuel economy.

CAFE standards were revised in July 2012, with tough new goals for 2025, the most famous of which is a 54 mpg average requirement for each manufacturer. Actually, this standard allows for improvements in air conditioning and other systems, thus the real mpg goal is more like 49 mpg. The National Highway Traffic Safety Administration (NHTSA) regulates CAFE standards and the U.S. Environmental Protection Agency (EPA) measures vehicle fuel efficiency, developing the fuel economy ratings and labels.

Notably, California's Low Emission Vehicle (LEV) and ZEV programs are now coordinated with the Federal Environmental Protection Agency (EPA) emissions and CAFE goals. There is considerable debate about whether the auto companies will need to use electric vehicles to meet their CAFE requirements. The EPA is the agency that certifies the fuel economy ratings of electric and plug-in electric vehicles. Currently, they do not measure upstream efficiency of power plants (or upstream efficiency of oil and natural gas production either).

Electric, plug-in hybrid, and fuel-cell vehicles already garner very high CAFE ratings, as they use little or no gasoline, but to encourage their sales, the government will factor each sale of an electric vehicle by 2.0 in model year 2017. In other words, if you sell 10,000 electric vehicles—either battery powered or fuel cell—they will be counted as 20,000 when calculating that company's fleet fuel economy. This factor will phase down to a multiplier of 1.5 by 2021. For plug-in hybrids, the factor will start at 1.6 in 2017 and phase down to 1.3 in 2021.

3.1.1.1.2 Federal Vehicle Classifications

Generally the US Department of Transportation (US DOT) and Federal Highway Administration (FHWA) breaks down vehicle types as either light duty vehicles (LDVs) or Heavy Duty Vehicles (HDVs). Only LDVs are subject to fuel economy regulations. The FHWA Vehicle classes with definitions are as follows, and the following table breaks down the Passenger car and other two-axle, four-tire single unit vehicles according to the definitions used in fuel economy guidelines by the US Department of Energy (US DOE). A vehicle with more than two axles would most likely be considered an HDV (source: https://www.fhwa.dot.gov/policy/ohpi/vehclass.htm).

Motorcycles -- All two or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handlebars rather than steering wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles.

Passenger Cars -- All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.

Other Two-Axle, Four-Tire Single Unit Vehicles -- All two-axle, four-tire, vehicles, other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Other two-axle, four-tire single-unit vehicles pulling recreational or other light trailers are included in this classification. *Because automatic vehicle classifiers have difficulty distinguishing class 3 from class 2, these two classes may be combined into class 2.*

Buses -- All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be a truck and should be appropriately classified.

NOTE: In reporting information on trucks the following criteria should be used:

1. Truck tractor units traveling without a trailer will be considered single-unit trucks.
2. A truck tractor unit pulling other such units in a "saddle mount" configuration will be considered one single-unit truck and will be defined only by the axles on the pulling unit.
3. Vehicles are defined by the number of axles in contact with the road. Therefore, "floating" axles are counted only when in the down position.
4. The term "trailer" includes both semi- and full trailers.

Two-Axle, Six-Tire, Single-Unit Trucks -- All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with two axles and dual rear wheels.

Vehicle Size Classes Used in the Fuel Economy Guide

CARS		
Class	**Passenger & Cargo Volume (Cu. Ft.)**	
Two-Seaters	Any (cars designed to seat only two adults)	
Sedans		
Minicompact	less than 85	
Subcompact	85 – 99	
Compact	100 – 109	
Mid-Size	110 – 119	
Large	120 or more	
Station Wagons		
Small	less than 130	
Mid-Size	130 – 159	
Large	160 or more	
TRUCKS		
Class	**Gross Vehicle Weight Rating (GVWR)***	
Pickup Trucks	**Through 2007**	**Beginning 2008**
Small	Less than 4,500 lbs.	Less than 6,000 lbs.
Standard	4,500 to 8,500 lbs.	6,000 to 8,500 lbs.
Vans	**Through 2010**	**Beginning 2011**
Passenger	Less than 8,500 lbs.	Less than 10,000 lbs.
Cargo	Less than 8,500 lbs.	
Minivans	Less than 8,500 lbs.	
Sport Utility Vehicles		
	Through 2010	**Through 2010**
All	Less than 8,500 lbs.	Less than 10,000 lbs.
	Beginning 2013	
Small	Less than 6,000 lbs.	
Standard	6,000 - 9,999 lbs.	
Special Purpose Vehicles	**Through 2010**	**Beginning 2011**
	Less than 8,500 lbs.	less than 8,500 lbs. or less than 10,000 lbs., depending on configuration

* Gross Vehicle Weight Rating (GVWR) is calculated as truck weight plus carrying capacity.

Fuel Economy regulations do not apply to HDVs, so they are not tested.

Source: www.fueleconomy.gov/feg/info.shtml

3.1.1.2 California and zero emissions vehicles

For decades, California has been pushing for lower tailpipe emissions to deal with its air pollution. California has developed a web of regulations, research and development, incentives and implementation programs to encourage zero emission vehicles as well as a clean energy and a green vehicle industry in California. This web of laws is designed to ensure momentum and financial support throughout the next two decades based on long term tax laws passed in 2013. This program has been influential in kick starting the electric vehicle industry in California, providing a market, infrastructure, and advantages (such as HOV lane access) for plug-in vehicles.

The progress in electrification is significant; as of March 2014, the California market added about 70,000 new “plug-in electric vehicles” to its fleet. Sales are around 2% of annual vehicle sales in California (annual vehicle sales average around 1.5 million vehicles). These are about 30-40% of US sales of PEVs (California accounts for about 12% of all vehicle sales in the United States). Over 90% of these purchases are by private citizens, mostly in California’s coastal cities. California is also home to Tesla Motors, which has sold about 1/3 of its vehicles in California.

Background

California citizens are well aware of the health problems from dirty air in their region due to pollution crises in the 1950s and 60s. A combination of mountains that trap dirty air, 27 million vehicles as well as dust particles from agriculture and special regulatory authority allowed by the Federal Government under the Clean Air Act combined to make California and in particular Los Angeles a crucible of development for electric vehicles. When the auto industry left California in the 1960s, this freed California regulators from the political pressure of automakers; it was California’s auto owners, not the makers with political power.

Additionally, a significant percentage of renewable energy from hydroelectric, wind, solar and geothermal, as well as natural gas allowed California to have relative clean energy production compared to the rest of the United States. California developed an agency — the California Energy Commission— that has fostered efficiency in California’s power sector. These characteristics have favored electric vehicles to be a solution to local air quality problems as well as a low carbon solution in the LA region. Southern California power companies – Southern California Edison and Los Angeles Department of Water and Power were both innovators and leaders in the area of electric vehicles.

Another ingredient was the technology sector; California has drawn electrical engineers from around the world to Silicon Valley and its aerospace industry. Its University system has included California Institute of Technology, the competitor to Massachusetts Institute of Technology. Both schools competed heavily in solar car race challenges. The students in these contests went on to the early developers of EVs for Hughes Aircraft and Solectria. Students at Stanford went on to form Tesla. Students at UC Davis went on to develop PHEVs at GM and elsewhere.

California’s Air Resources Board (ARB) and the Zero Emissions Vehicle (ZEV) program

As discussed earlier, the most significant historical event in the United States for electrification was the independent, loosely managed development of the GM Impact and the decision of California Air Resources Board to mandate a percentage of ZEVs. Due to its inability to meet regional air-quality goals, primarily in Los Angeles, in the 1980s, California was given special legal rights to effect its own tailpipe standards on carmakers. As a result, California has always led the nation, and in some case the world towards strict emissions controls. For many emissions regulations, the ARB has been the “tail that wagged the dog” in developing emissions controls for vehicles in the United States.

But even for the ARB and its regional representative the South Coast Air Quality Board that regulated the Los Angeles region, the ZEV program was an unprecedented regulatory action. Ironically, in 1990, the ZEV requirements were only a footnote in a much larger Low Emission Vehicle program for California, which was tightening the emissions standards for California. While previous regulations merely required the installation of well understood technologies, the ZEV program launched into unknown territory, requiring technologies which had not yet been developed (such as advanced automobile motive batteries) and required customers to buy vehicle technologies affecting them which had not yet been available and tested in the market. The ZEV mandate was something brand new, a program meant to encourage or even force OEMs to develop new technologies for lower emissions.

In 1996, after a two year demonstration period (called the Memorandum of Agreement - MOA), during which six automobile companies leased several hundred BEVs each in California, the ZEV mandate was postponed a decade because it was determined the technology was not ready, the price of vehicles was too high, and customers were not ready to adopt the initial design. However, many first buyers disagreed with the arguments, saying they loved their vehicles, and wanted ARB to continue its mandate.

Despite the postponement, the ARB continued its interest in the ZEV goals, and pursued hydrogen fuel cells and PHEVs in the years after the MOA period. Today, the ZEV program continues as a “technology development “ program. While ZEVs were originally meant to meet local air quality goals, the State of California was getting serious about climate change. California’s electrical sector was much more efficient than the rest of the nation due to decoupling of electricity prices from demand. That is, in the 1970s, California electric regulators decided that electricity prices would go down when users conserved energy. As a result, California has much more efficient use of energy than the rest of the United States, and also a greater share of hydroelectric power than many other parts of the nation.

Thus the electricity sector in California does not have as big a share of greenhouse gas forcing gases as in other parts of the US, but its giant automobile culture (23 million light duty vehicles) accounts for more than 40% of CO_2 production in California. CARB was given responsibility, and its programs would now be attentive to CO_2, effectively focusing attention on the full lifecycle emissions of vehicles, thus fuel economy, greater use of Low Carbon Fuels, and in particular hydrogen and electricity (California EPA, 2011).

In 2009, the California Air Resources Board developed the Advanced Clean Cars (ACC) program, which combines the control of smog-causing pollutants and GHG emissions into a single coordinated package of requirements for model years 2015 through 2025 and assures the development of environmentally superior cars that will continue to deliver the performance, utility and safety car owners have come to expect.

The Zero Emission Vehicle regulation acts as the technology-forcing piece of the ACC program, pushing manufacturers to produce ZEVs and Plug-in Hybrid Electric Vehicles (PHEVs) in the 2018 through 2025 model years. In addition, the ACC program also includes amendments to the Clean Fuels Outlet (CFO) requirements that will assure that ultra-clean fuels such as hydrogen are available to meet vehicle demands brought on by amendments to the ZEV regulation.

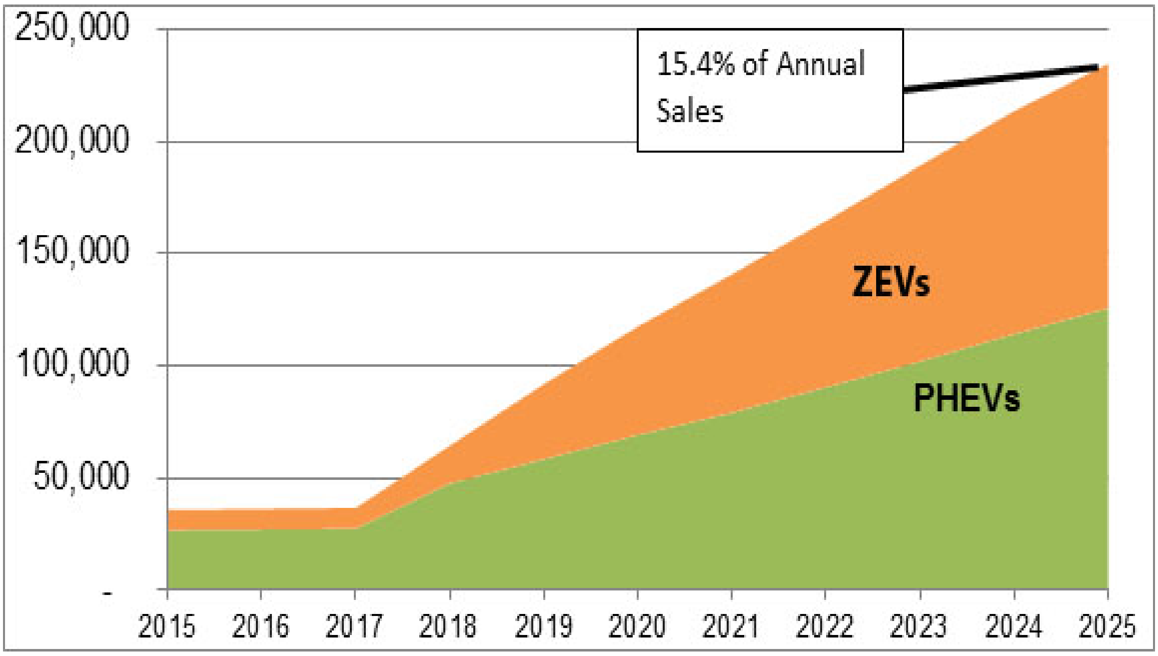

Figure 3: ZEV production requirements through 2025 (from the ZEV mandate)

Beyond 2025, the driving force for lower emissions will be climate change. In order to meet the 2050 GHG goal, the new vehicle feet will need to be primarily composed of advanced technology vehicles such as electric and FCVs by 2035 in order to address fleet turnover. Accordingly, the ACC program coordinates the goals of the LEV, ZEV, and CFO programs in order to lay the foundation for commercialization and support of ultra-clean vehicles.

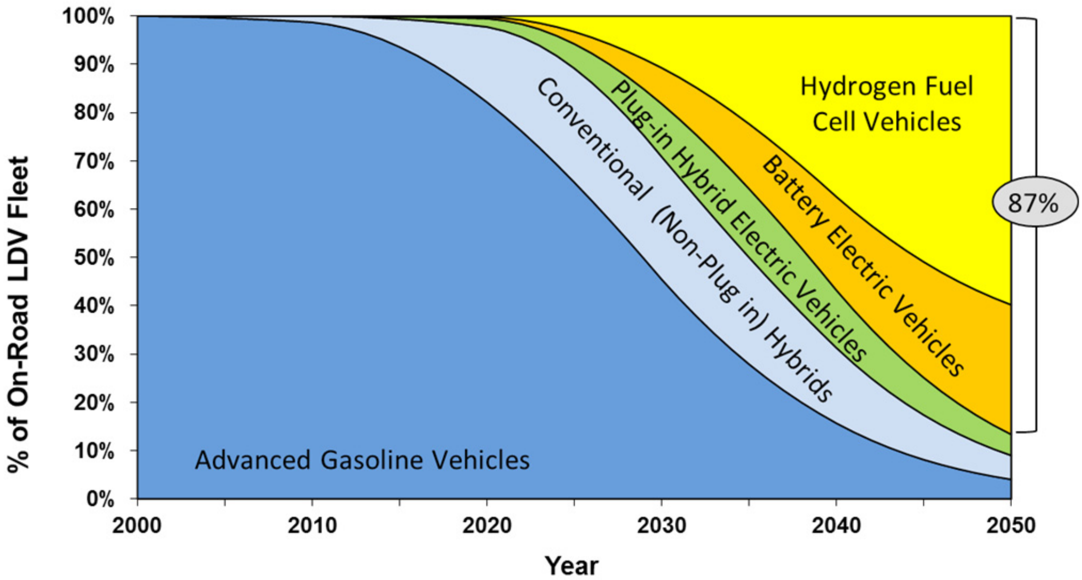

Figure 4: On-road light duty vehicle fleet by vehicle type through 2050 (from ZEV mandate)

Production requirements for auto manufacturers

• 2012 to 2014: – 12,500 ZEVs – 58,000 Plug-in hybrid EVs

• 2015 to 2017: – 50,000 ZEVs– 83,000 Plug-in hybrid EVs

• Advanced Clean Cars rulemaking will increase volumes 2018+ to launch sustainable market

The Low Carbon Fuels Standard

Carbon goals in California, set by Assembly Bill 32, and informed by scientific methods of modeling “well to wheels” greenhouse gas and energy use of various fuel pathways has resulted in the development of what is called the Low Carbon Fuels Standard. This standard was developed to reduce the carbon content of transportation fuels, in particular gasoline. This would mean understanding the origins of oil and the estimating the carbon used in its production. One source being targeted was Canada’s Alberta tar sands oil, which uses an unusual amount of energy to produce, primarily using natural gas to heat tar sand to make oil flow, as well as other higher energy extraction of shale oil and imported oils like Venezuelan heavy crude. Additionally, the LCFS is aimed at increasing the efficiency of refineries and distribution of petroleum based fuels. The LCFS will result in some emphasis on electricity for transport fuels in the future, primarily by rewarding utilities with credits.

CEC and CPUC Programs

An important, non-regulatory agency in California has been the California Energy Commission, which is charged with monitoring, conducting research on new technologies and planning energy use in California. The commission develops, for example, solar energy and wind projects, promotes energy efficiency, and surveys vehicle energy use in the state. The commission has been responsible for helping utilities meet efficiency goals, as well as more recent renewable energy goals.

Transportation fuels are a new area of work for the commission, in particular electricity. It funded the Plug-In Hybrid & Electric Vehicle Research Center at UC Davis through its Public Energy Interest Research (replace in 2013 by the EPIC program. The CEC is the primary agency in California to fund the development of charging infrastructure development through its AB118 program, which also helps fund the California Electric Vehicle rebate program.

Another agency that works in parallel with the CEC is the California Public Utilities Commission (CPUC). The main work of the commission has been to set rates, and protect California rate payers from monopoly tendencies of public utilities. However, in recent years the CPUC has join other state agencies to work on the problems of climate change.

Governor Brown’s Executive Order and Action Plan

California Governor Brown issued an executive order directing the state government to help accelerate the market for ZEVs in CA in March 2012. The Executive Order established several steps toward meeting the goal of 1.5 million ZEVs in CA by 2025, including specific strategies and actions that state agencies should take to meet this goal. For the purposes of this executive order and action plan, ZEVs include hydrogen fuel cell electric vehicles (FCEVs) and both battery electric (BEVs) and plug-in hybrid electric vehicles (PHEVs). The action plan was the result of an interagency working group led by the Governor’s office, including several state agencies and other entities, and builds upon existing work already underway at these agencies. In addition, the action plan benefitted from extensive input through workshops and comments from outside stakeholders. This action plan will be adjusted over time to meet the needs of the changing market.

The action plan is divided into three time periods, and includes several key milestones for each phase (Brown, 2013).

By 2015:

- The state's major metropolitan areas will be able to accommodate ZEVs through infrastructure plans and streamlined permitting
- Private investment and manufacturing in the ZEV sector will be growing
- The state's academic and research institutions will contribute to ZEV market expansion by building understanding of how ZEVs are used

By 2020:

- The state's ZEV infrastructure will be able to support up to 1 million vehicles
- The costs of ZEVs will be competitive with conventional combustion vehicles
- ZEVs will be accessible to mainstream consumers
- There will be widespread use of ZEVs for public transportation and freight transport

By 2025:

- Over 1.5 million ZEVs will be on CA roadways and their market share will be expanding
- Californians will have easy access to ZEV infrastructure
- The ZEV industry will be a strong and sustainable part of CA's economy
- CA's clean, efficient ZEVs will annually displace at least 1.5 billion gallons of petroleum fuels.

3.1.1.3 Other States

The efforts of other states in the US can be divided in to two primary categories. Section 177 States which are under the Federal Clean Air Act, are allowed to choose to follow California emissions rules, and the remaining states which follow the Federal Clean Air Act Standards for vehicle emissions. The ten Section 177 states that have adopted the CA standard include:

1. Connecticut
2. District of Colombia
3. Maine
4. Maryland
5. Massachusetts
6. New Jersey
7. New York
8. Oregon
9. Rhode Island
10. Vermont

3.1.2 Objectives and Strategies

The objectives of electrification of transportation are multiple:

- Cleaner air in America’s cities
- Fuel diversification away from fossil fuels and energy independence in the transport energy sector
- Reduction of greenhouse gas emissions and the development of sustainable transportation and a viable battery industry
- Innovation in the green technology sector and development of clean energy jobs, and modernization of the automotive industry
- Integration of plug-in vehicles in the energy grid to balance loads and potentially enable larger amounts of energy storage

The primary national goals of electrification are currently fitted into the Clean Air and Petroleum Reduction Legislation discussed above. In California, electrification is fitted into a web of regulations, tax laws, incentives, public investments and local planning. Politics in the United States have made it difficult for Climate Change goals to be enacted into law; conservative parties and companies have made it almost impossible to pass laws aimed at reducing greenhouse gases in the energy sector. Therefore carbon reduction strategies are fitted into the Clean Air Act and Petroleum Reduction goals; and instead of new regulations aimed at climate problems, the EPA regulates the emissions of power plants, industry, and vehicles through the Clean Air Act, a decades old regulation.

3.1.3 Financial support and incentives

3.1.3.1 Federal Tax Credits

The Federal Government offers PEV buyers a federal tax credit which is calculated based on battery size, with a minimum size of 5 kWh, receiving $2500, plus an additional $417 for each kWh of capacity over 5kWh, with a maximum size of $7500 (16 kWh and larger battery capacities). The goal of this tax credit was to support PEV sales and is also targeted at supporting a nascent battery manufacturing industry in the US. There is much interest in shifting this tax credit to an instant rebate program. These are available up to 200,000 qualifying vehicles per manufacturer, beginning in 2010 and will phase out after that sales goal is achieved (IRC-30D).

3.1.3.2 State rebates and tax credits

As of 2013, there are wide ranges of state –specific purchase incentives for PEV buyers. In Colorado, there is up to $6000 available for electric or plug-in hybrid buyers, as a tax credit. In California, there is a purchase rebate or “purchase vouchers” of $2,500 (1813 EUR) for Zero Emission Vehicles (BEV, CNG, and BEVx) and $1,500 (1088 EUR) for plug-in hybrids that qualify under the Clean Vehicle Rebate Project.

States	Incentive	Price Cap	Note
COLORADO	Innovative Motor Vehicle Credit	$8,260	did not include Conversion vehicles
GEORGIA	Zero Emission Vehicle Tax Credit	$5,000	20% of vehicle cost, up to $5,000
ILLINOIS	Illinois Alternate Fuels Rebate Program	$4,000	80% of cost, up to 4000
KENTUCKY	Alternative Fuel Vehicle Credit	$3,000	10% of cost, up to 3000
PENNSYLVANIA	Alternative Fuel Incentive Grant Program (AFIG)	$3,000	for EVS and PHEVs
CALIFORNIA	Clean Vehicle Rebate Project (CVRP)	$2,500	range $1500-2500
TEXAS	Alternative Fuel Vehicle Rebate	$2,500	4500 kg or less--vehicles
UTAH	Alternative Fuel Vehicle Credit	$2,500	Tax Credit, 35% of price up to $2500
INDIANA	Indiana Alternative Fuel Vehicle Grant Program	$2,000	
SOUTH CAROLINA	PHEV Tax Credit	$2,000	$667-2000, starting at 4 kwh battery
MARYLAND	PEV Tax Credit	$1,000	$600-1000 dependent on battery
MONTANA	Alternative Fuel Vehicle Credit	$500	for vehicles 4535.92 kg or less
RHODE ISLAND	Warren County Alternative Fuel Vehicle Credit	$100	one county in the state of RI

Table 2: List of States with PEV purchase incentives.

HOV lanes

There are a number of metropolitan locations in the US that offer PEV access to special High Occupant Vehicle Lanes (HOV) as well at preferential access to High Occupant and Toll Lanes (HOT). These are particularly important in some California cities including the Bay Area, Los Angeles, and San Diego; Washington DC area, Texas, and Seattle. They are built to encourage carpooling for commuters, and access is given to certain vehicles or occupancy levels on a state-by-state basis.

3.1.3.3 Local incentives

There are a variety of substantial local incentives across the United States, including:

- Sales incentives by local air quality districts (Fresno California)
- Preferential parking locations (airports and public lots),
- Discount and free parking (for example free parking in a downtown garages in Sacramento)
- Free charging offered by employers like Cisco, Universities, Google or Evernote

- Free charging at shopping centers (Walgreens and Target)
- Discounted electricity rates for electric vehicles from power providers, in particular for use of nighttime electricity

3.1.4 Power generation, supply and storage

There are several important features about the US power sector that are different from Europe and are determining factors in the ongoing development of the market, meaning that electricity cost very, as do emissions, infrastructure development and potential for PEV grid integration.

1. With over 300 utility companies in the US,
    a. individuals can pay as low as 2 cents per kWh (Eastern Washington) and as high as 38 cents per kWh (Hawaii).
    b. Some Americans pay a flat rate all the time (Massachusetts 19 cents per kWh all the time) while some as in San Diego can choose among 5 different plans including special time of use (TOU) EV rates which are very low priced at middle of the night (5 cents per kWh) and peak daytime in summer (34 cents per kWh). Other aspects of these plans include Tier rates. Several California utilities have to four Tiered rates, which escalate the cost of electricity the more electricity a household uses.
    c. The carbon footprint of each of these 300 utilities is different, with some heavily coal, and others hydroelectric or natural gas.
    d. The regulatory landscape for supporting, or servicing PEV charging infrastructure is very different in each of these utilities

1. The US power sector has 202 “investor” owned utilities, and a much larger number of municipal utilities as well as rural cooperatives, totaling 3,269 individual utility entities. Most municipally owned utilities are smaller in size and reach, with limited resources to adopt new metering technologies, special time-of-use (TOU) rates, and renewable energy resources, though there are several exceptions. One of the impacts of this is that electric vehicle buyers and driver are confronted with a wide range of electricity costs in the United States,

Electricity costs as perceived by the consumer—relative to gasoline costs—represent another factor affecting consumer perceptions and purchase decisions. Although regional variability in electricity costs are high (as well as variability seasonally and by time of day in some regions), we provide a discussion of how consumer perceptions about these costs affect their potential to purchase EVs. Keep in mind that it is likely that much of PEV driver behavior around electricity prices so far is shaped by the high income of the first generation of buyers, for whom the potential savings gained by careful choices is not as important.

A useful fact to begin this discussion is that a compact electric car, like the five-passenger Nissan Leaf gets about three-four miles per kWh depending on speed and heating/cooling needs of the cab interior (HVAC loads). The average price of residential electricity in the USA is 12.7 cents per kWh (EIA, 2013). Hence, on average, an electric vehicle owner in the US who charges at home, will pay about 4 cents per mile (these numbers include taxes) for electricity. While averages do not describe all markets, most electricity in the US is in the range of 10-15 cents per kWh (EIA, 2013), which would mean 3-5 cents per mile. However, there are many exceptions, extremes and complexity. A driver can pay as low as 2 cents a mile for night-time industrial electricity in Eastern Washington, and 12 cents a mile for residential electricity in Hawaii or on a summer afternoon in San Diego. And then, many PEV drivers across the US have been getting electricity for free at workplaces.

For comparison, gasoline in USA in October 2013 was about $3.50 per gallon (EIA Petroleum, 2014). A vehicle comparable to the Leaf with very good gas mileage is the Prius, with about 50 miles per gallon, although a more common fuel economy would be average passenger cars -35 mpg. This would mean the Prius costs 6.5 cents per mile in the US and the average passenger car costs about 10 cents a mile in the US in October 2013.

So, an average rule of thumb is that PEVs in most places, in September 2013, will cost less than one-half the cost per mile of a comparable-sized gasoline vehicle. Driving 10,000 miles in a gasoline compact in 2013 cost around $1000 for gasoline that year; a comparable sized BEV will cost less than $500 in 2013. The cost of electricity for a PHEV will vary greatly according to driving patterns, how much the driver plugs in and the design of the PHEV. However, a number of PEV drivers are paying much less, charging for free at work and getting low off-peak and special PEV rates from their utility (over 1/3rd of BEV drivers have solar panels offsetting their electricity costs) (Tal et al, 2013).

Moving beyond an average rule of thumb shows just how complicated electricity pricing can get. For example, some regional areas, in particular California, have Tier rates, to discourage high consumption, and Tier allowances vary according to climate. For example the base rate in San Diego is 14 Cents per kWh (San Diego Gas & Electric, 2014). This base has summer and winter allowances, and is calculated at 50-60% average consumption for a San Diego household in four distinct climates, coastal to inland deserts. Tier 2 is electricity consumed above the base at 100-130 % of base; Tier 3 is 34 Cents and is electricity consumed at 130-200% of base; Tier 4 is 36 cents and is all electricity above 200%. Electric Vehicle Time of use is another way to be charged and results in off Tiers to 19 cents at off peak (6 pm to 12 am and 5am to 12 pm, 29 cents on peak (12 pm to 6 pm) and 16 cents “super off peak” (12-5 am). It gets even more complicated with commercial and industrial rate plans.

The effect is that the price of electricity for an electric vehicle has a huge variation. A household that consumes excessive electricity (like wealthy folks with a big home in the desert who keep the air conditioning on all day) will be paying Hawaii prices if they add a PEV to their vehicles.

To conclude this section, electricity should cost most drivers in US about half as much per year as would gasoline. However, with some care to sign up for special prices, take advantage of night-time prices in some markets, and accessing some free electricity at workplaces and shopping malls, PEV drivers could save more.

Greenness of the electricity

Other aspects that affect consumer perceptions and likelihood of buying EVs include the perceived “greenness” of the vehicle, which includes not only the greenness of the electricity supply used to charge the vehicle, but also issues related to how batteries will be disposed of and their contribution to environmental degradation, as well as what is referred to as “wheel to well” (or in this case, “wheel to electricity generation”) that captures the lifetime emissions of the vehicle from production (all inputs), transportation of the vehicle to the dealership for sale, and useage and disposal of the vehicle at end-of-life.

PEV to grid integration

Throughout the US, but most pronounced in the West, power generation is shaped by daytime demands for air conditioning, and low demand for electricity at night, in particular during dry, hot summer months. Thus, electric vehicles present a potential way to fill in a nighttime lull in power demand. (This diurnal pattern is not as pronounced in humid climates where air conditioning is in demand all night, or in regions with electricity used for nighttime heating).

The utility sector is affected by the electrification of mobility in a number of ways. Primarily of course, electric travel represents a significant new market. While power companies are confident that they will be able to supply adequate energy for PEVs, especially given the expected slow development of the market, nevertheless, faces equipment and distribution at the local distribution level. There is also potential for vehicle batteries to store access nighttime energy and return some of it to the grid at hours of highest demand.

As with most of the other sectors, the power companies which were most active in electric vehicles early, were the large power companies in the Los Angeles region, the Los Angeles Department of Water and Power which covered the Los Angeles city proper, and the Southern California Edison Company (SCE) investor owned utility covering most of the surrounding areas of the Los Angeles Region. Other active utilities in California were the Sacramento Municipal Utility District as well as Pacific Gas & Electric, also the largest utility in the United States.

Company	Sector
Alabama Power/Southern Company	Utility
Arizona Public Service	Utility
Avista Corp	Utility
BTCPower	Utility
Burbank Water & Power	Utility
CenterPoint Energy	Utility
CPS Energy	Utility
DTE Energy	Utility
Duke Energy	Utility
Florida Power & Light	Utility
Gulf Power Company	Utility
Hawaiian Electric Company, Inc.	Utility
Idaho Power Company	Utility
Madison Gas & Electric	Utility
Manitoba Hydro	Utility
Maui Electric Co.	Utility
NESCAUM	Utility
Oncor Electric Delivery	Utility
Orlando Utilities Commission	Utility
Portland General Electric	Utility
Sacramento Municipal Utility District	Utility
Salt River Project	Utility
San Diego Gas & Electric	Utility

Seattle City Light	Utility
Southern California Edison	Utility
Southern Company	Utility
TECO Energy	Utility
Tennessee Valley Authority	Utility
Westar Energy (Kansas)	Utility
Ameren Missouri	Utiliy

Table 3: List of Utilities Active in the PEV Industry

The most active of these and longest active was SCE, which created its own labs for testing batteries and vehicles, and created some of the largest commercial fleets of electric vehicles, including several hundred RAV 4 Toyota EVs, which acquired several million miles of use. Additionally, SCE began a program of investing in clean and renewable energy sources.

The list of utilities with early BEV programs includes Arizona public services, Austin Power and Energy in Texas, Duke Energy in the south eastern US, Detroit Energy in Michigan, Excel Energy in Boulder Colorado, Seattle Power and Light in Washington state, as well as Portland Gas and Electric in Oregon.

Important programs at these utilities are special electric prices for renewable electricity (primarily solar, particularly available in CA utilities) and for electric vehicles, with a sub-meter for the vehicle charger that is based on the time of use of the electricity for vehicle charging.

3.1.5 Provision of infrastructure

There are a wide variety of infrastructure providers in the United States. Several are EVSE manufacturers, and these stations are sold directly to consumers or through retail outlets, such as hardware stores, but are not companies that participate in the supplemental services associated with public charging. Many companies participate in both home charging equipment that comes with vehicles, as well as public charging equipment and charging services. Still other companies are focused primarily on the services and data management of public charging infrastructure rather than equipment manufacturing. Figure 5 below shows the three charging levels used in the United States.

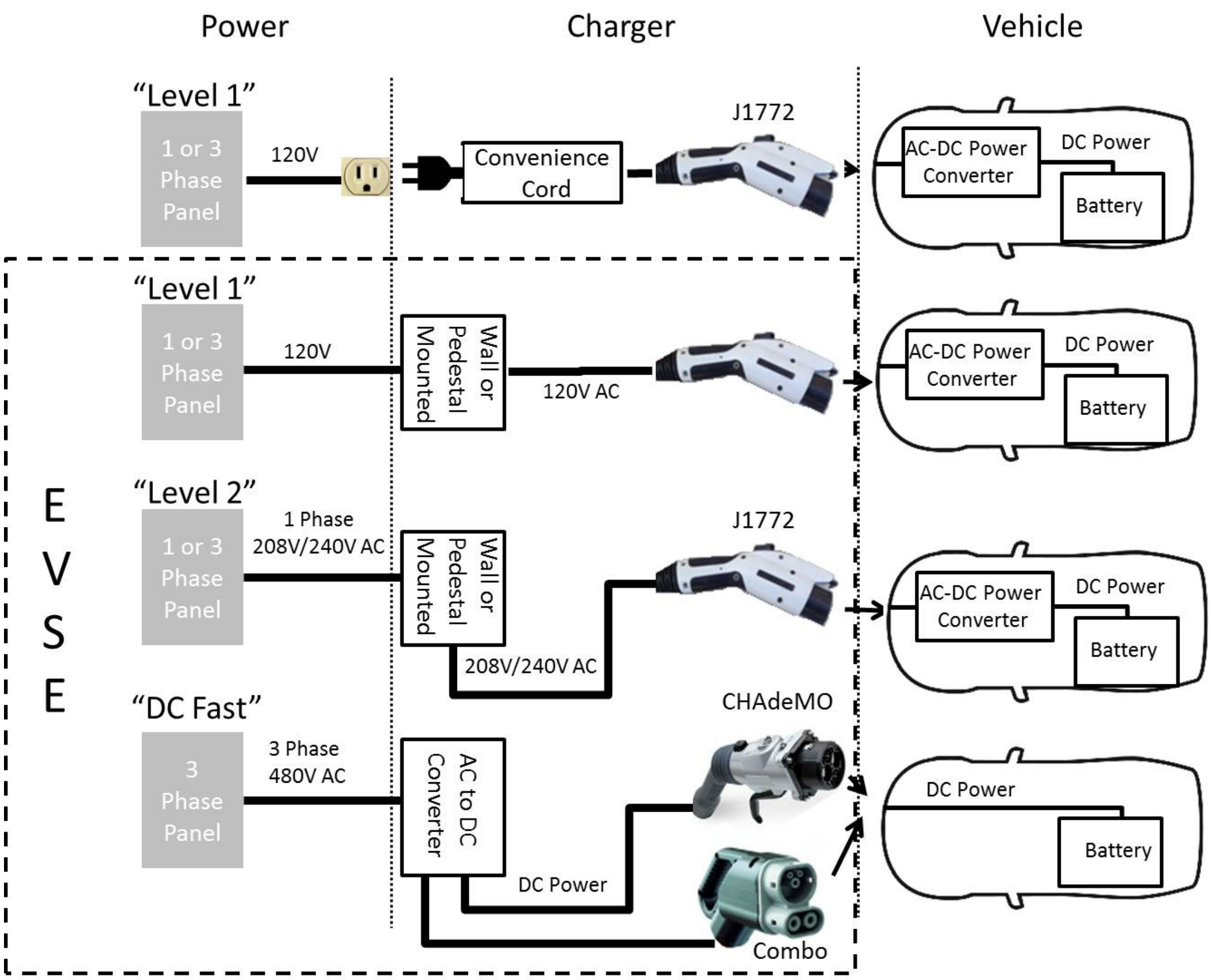

Figure 5: Charging Levels in the United States

As of 2013, the following is a list of EVSE products compatible with the SAE J1772-2009 charging standard (http://en.wikipedia.org/wiki/SAE_J1772#Competing_standards):

- AeroVironment home charging station for the Nissan Leaf[31]
- ClipperCreek CS-40[32]
- Coulomb Technologies CT500, CT2000, CT2100, and CT2020 families of Charge-Point Networked Charging Stations[33]
- EATON [2] Pow-R-Station Family of Electric Vehicle Charging Stations [3]
- ECOtality Blink home wall-mount and commercial stand-alone charging stations[34][35]
- EVoCharge – Retractable Reel EVSE's designed to support Residential, Commercial and Industrial Markets.
- GE Wattstation available in 2011[36]
- GoSmart Technologies ChargeSPOT line of charging stations
- GRIDbot's "UP" family of charging stations
- Hubbell PEP Stations - http://www.hubbell-wiring.com/press/pdfs/WLDEE001.pdf
- Leviton evr-green home charging stations at a range of power levels, with separate pre-wire kit that allows one to plug in to a NEMA 6 240V receptacle[37]
- Schneider Electric / Square D EVLink Charging Solutions for residential, commercial, and fleet charging solutions.
- SemaConnect ChargePro Charging Stations

- Shorepower Technologies ePump line of fully customizable EVSE; indoor and outdoor solutions for cars and trucks.
- TucsonEV - J1772 Adapter Boxes, Inlets and Plugs with and without cord, 70A and 30A. We will soon have a J1772 Compatible EVSE for up to 240v/30amps
- CIRCONTROL CIRCARLIFE product range includes EV charging infrastructure with post and wall mount units with J1772 standard
- OpenEVSE Project - Open Source Design for EVSE.

SAE standards for PEVs

The Society of Automotive Engineers (SAE) International is a global association of engineers and technical experts working in the aerospace and automotive industries, based in Pennsylvania. SAE International hosts conferences, continuing education programs in specific topics, and voluntary consensus standards development. SAE creates and manages more aerospace and ground vehicle standards that any other entity in the world. Some of the many relevant standards related to plug-in vehicles are listed here, most of which are widely adopted by industry in the US (SAE Hybrid-EV Committee, 2014):

- J1711 – Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, including Plug-In Hybrid Vehicles (a dynamometer-based testing protocol).
- J1772 – Plug-In Vehicle Conductive charging standard for the charging connector (including physical, electrical and communications specifications).
- J1773 - SAE Electric Vehicle Inductively Coupled Charging
- J2293 - Energy Transfer System for Electric Vehicles - Part 1: Functional Requirements and System Architectures and Part 2: Communication Requirements and Network Architecture
- J2836 – Use cases for Wireless Charging Communication for Plug-In Electric Vehicles
- J2907 – Hybrid Motor Ratings
- J2908 – Hybrid Electric Powertrain Power Test Methods and Definitions.
- J2953 - Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

3.1.6 Results of the interviews with stakeholders: opinions on government activities and policies

Governmental role in supporting electric vehicle deployment

In the United States the national government has the task of a steering entity which introduces regulations in close cooperation with the industry. On national level, the purchase of an EV is

The national labs have a strong influence in policy making in the United States. The government consults the national labs on currently relevant research topics and formulates new policies based on the consultation.

Market incentives

Market incentives are the most important reason why the deployment of EVs has been so successful in the United States. The idea behind such incentives is to raise the attractiveness of EVs in terms of purchasing prices when compared to conventional vehicles. The purchase incentives are given out by either federal or regional governments and also by a number of employers/companies. Experts agreed that the current EV market still depends largely on these incentives as sales are still growing on a small level. As of today, an EV buyer receives up to 7,500 US-$ as a tax credit (national purchase incentive). Some states are giving additional incentives which are added to the national incentive. The state of California has the highest purchase incentives of all states. A high number of EV sales is observed during the last months of the year compared to other months because many car buyers like to wait until the end of the year when they can receive the tax credits back in early the next year. Purchase incentives are under a large discussion due to their importance in these initial stages of EV deployment. In 10 years, as an expert stated, it is possible that the technology development leads to reduced vehicle prices, which allow the phasing-out of purchase incentives of EVs. Some experts mentioned their concerns that policy makers may want to reduce purchase incentives in near future. They say it would jeopardize the positive and sustainable development of EV sales. Also incentives are planned in rather short-term which makes it difficult for manufacturers and dealers to plan their vehicle production and deployment. This especially applies to times when funding is running out and new funds are not yet approved.

Other incentives to electric vehicle drivers

Besides financial incentives the government is giving EV users other benefits. Drivers of electric vehicles are allowed to use the so called car pool or HOV lanes. Especially in cities such as Los Angeles the usage of HOV lanes brings a big advantage in terms of travel time. In other cities EV drivers do not have to pay when using public parking spaces. During the interviews it was mentioned that the impact of non-monetary benefits on the purchase decision of an electric vehicle is very large, for some buyers even larger than the purchase incentive. It was also mentioned that a large portion of Tesla Model S drivers did not apply for the tax credit when they bought the car, the reason was thought to be avoiding the bad publicity of “using tax payers money to fund the luxury car buyers” or they just do not need the additional incentive and therefore don’t apply for it. The typical buyer of a Tesla Model S is supposedly someone who can afford to own it as a second car and who is eager to be one of the first to use such new technology.

A term which was largely used as a key factor for a successful deployment is raising the awareness of new car buyers. EV drivers organize Ride&Drive’s where bypassing people have the chance to ride an EV and they are explained the characteristics and advantages of electric vehicles. Especially the higher purchasing costs and lower operational costs are new to many drivers of conventional cars. Such Ride&Drives are for instance organized at parking spaces of shopping malls. Also it gives the possibility to clear questions about the availability of charging stations and the process of applying for an own station at home.

Regulations and standards

A challenge which was mentioned quite often is the necessity to deal with different charging standards, especially those of fast charging. There are three major standards which co-exist on the roads: Tesla runs its own super charger network in California, Japanese manufacturers equip their cars with the CHAdeMO charger and European EVs need charging stations with the SAE-J1772 standard. At early stages it was assumed that the Japanese standard will prevail over the others and therefore charging stations with this standard were set up first, which now showed to be a mistake as experts stated. The intention now is to focus on stations which can serve different standards which is for instance in the Netherlands already the case on a larger scale.

Charging Infrastructure

Improving the charging infrastructure is a major next issue to be solved, many experts stated this. The network is rather unreliable and there are problems with EVs not being able to charge at any station due to their charging standard. Also, in California users of Tesla Supercharger network see a problem of jammed charging stations coming. In terms of reliability the network has to be able to cope with a stronger load factors also in locations outside the city network where people charge at home. The average current is 110 V for the residential energy network and cars would thus also charge with the Level 1 current. Charging a large vehicle battery at this current may result in long charging periods, thus an upgrade to the Level 2 (220 V) current is offered for homes and at public charging stations. In some cases it is technically not possible to install the upgraded charging solution because the aged network does not support it. Some experts mentioned though that also 110 V can be just enough to charge a small battery overnight which in many cases is enough for short trips and longer standing periods.

The process of licencing a private charging station with Level 2 differs between states. Several initiatives are helping those interested in applying for a home charging utility to know the application process better. Also the costs differ substantially. Due to the different situation of the energy grid among states the improvement of the grid is a rather local task than steered from national side. Many experts see the local utility providers as the entity which has to act on grid problems. The government is said to play a small role when it comes to find solutions for a reliable network. The ones that people trust more to solve them are private and local entities.

Energy Grid and Fuel Prices

Future fuel and energy prices will have strong impact on the demand for EVs. The prices for fuel and electricity are much lower in the United States compared to Germany. A steady increase of the oil price is foreseen, however at a moderate rate. This is largely due to the importance of the oil industry for the United States economy. The taxation of fossil fuels is a way which the government can take to make alternatives such as electric vehicles more attractive. This applies for a situation where prices for electricity would rise at a lower speed.

EV deployment in California

The states show very different ambitions to develop electric mobility. Two characteristics are displaying this: the government's efforts in investing in measures to reduce emissions and its willingness to give privileges to EV users. California takes a leading role in terms of EV sales and their deployment. Nearly 40% of all electric vehicle sales come from California. The Toyota Prius was the most often sold car in 2012, which is also an indicator for the weak preference of California people towards domestic brands. According to those experts interview in California, the state's leading role as a high-tech business place with innovative people who like it to be pioneers. California has no auto industry, except Tesla, and a rather environmental friendly energy mix. The objective is to reach an energy mix share of 33% coming from renewable sources until 2020. The level of CO_2 emissions should be reduced to the level of 1990.

EV deployment in Canada

Electric mobility in Canada is, as it is the case in all North America, a mobility concept for cities. Therefore the deployment challenges observed in Canada are similar to those in the U.S. Due to the large distances between cities, EVs are mentioned not to be able to become a long distance travel alternative in the near future. In cities car ownership is reducing constantly, which makes people favour for instance car sharing. Car sharing is becoming rapidly popular in Canada. As it is the case in the U.S., experts confirmed that the share of small cars is growing in the national vehicle fleet which again lets cars of an average EV size be a reasonable option.

3.2 Research Funding and Institutions

3.2.1 Actors

The primary actors in the electric vehicle research community are automakers, Universities, the Department of Energy National Labs. There are some smaller startup and other firms conducting research, notably some of the power industry, notably Southern California Edison and its research partnership the Electric Power Research Institute, and Edison Institute have conducted research on electric vehicles for several decades. There are Non-governmental Organizations who also conduct research, including the Union of Concerned Scientists and the National Resources Defense Fund. This research is usually aimed at supporting electrification efforts. The key participants in the Research arena are shown in tables 4-7 below, by sector, including the Government (from regional through federal levels), non-profits, research and consulting companies, and key Universities working in electric transportation.

Company	Sector
Advanced Energy	Government
Air Resources Board	Government
Argonne National Laboratory	Government
ARPA-E	Government
Bay Area Air Quality Management District	Government
California Air Resources Board	Government
California Energy Commission	Government
California Governor's Office	Government
CALTRANS	Government
City of San Diego	Government
Clean Fuels Ohio	Government
County of San Diego	Government
Fresno Council of Governments	Government
Natural Resources Canada	Government
North Central Texas Council of Governments (NCTCOG)	Government
Ontario Ministry of Transportation	Government
Oregon Department of Transportation	Government
South Coast Air Quality Management District	Government
U.S. Department of Energy, EE	Government
Washington State Department of Transportation	Government

Table 4: List of Key Government Research organizations

Company	Sector
Californation Electric Transportation Coalition	Non-profit
California Plug-In Electric Vehicle Collaborative	Non-profit
Center for Climate and Energy Solutions (C2ES)	Non-profit
Clean Fuel Connection, Inc.	Non-profit
Drive Oregon	Non-profit

Lightning Rod	Non-profit
Natural Resources Defense Council	Non-profit
PEV Collaborative	Non-profit
Plug In America	Non-profit
Plug in Central Coast	Non-profit
Securing America's Future Energy	Non-profit
Sierra Club	Non-profit
Union of Concerned Scientists	Non-profit

Table 5: List of Key Research focused non-profit groups

Company	**Sector**
AECOM	Research/Consulting
Black & Veatch	Research/Consulting
Brazell & Company	Research/Consulting
California Center for Sustainable Energy	Research/Consulting
CALSTART	Research/Consulting
Capgemini	Research/Consulting
Edison Electric Institute	Research/Consulting
Efficient Drivetrains Inc.	Research/Consulting
Energy and Environmental Economics, Inc.	Research/Consulting
Energy Foundation	Research/Consulting
Electric Power Research Institute	Research/Consulting
ICF International	Research/Consulting
Idaho National Laboratory	Research/Consulting
Modelytic	Research/Consulting
National Renewable Energy Laboratory	Research/Consulting
National Research Council	Research/Consulting
Oak Ridge National Lab	Research/Consulting
Redfield Consulting Services	Research/Consulting
Southwest Research Institute	Research/Consulting
Tellus Power	Research/Consulting
Verdant Vision	Research/Consulting

Table 6: List of Key Research and Consulting firms

Company	**Sector**
Carnegie Mellon University	University
Clemson University	University
Colorado State University	University
CSU Long Beach	University
Cuyamaca College	University
Macomb Community College	University
NC Solar Center/NC State University	University

New Jersey Institute of Technology	University
North Carolina State University / NC Solar Center	University
The Ohio State University Center for Automotive Research	University
The University of Texas at Austin	University
UC Berkeley	University
UC Davis – Plug in Hybrid and Electric Vehicle Research Center	University
UC Irvine	University
UC Los Angeles	University
University of Michigan	University

Table 7: List of Key Research Universities

3.2.2 Research Funding

The Department of Energy has been the main source of public funding on advanced electric vehicles. At the provincial level, the California Energy Commission and few other power companies, such as New York Power Authority have funded research on electric vehicles, primarily in regards to their impact on the regional power grid.

The following chart shows investments by DOE in hybrid, plug-in hybrid and battery electric vehicles from 1976-2012. This does not include stimulus loans (for example to Tesla) or Advanced Research (such as ARPA-E) which could be battery research but not targeted at electric vehicles.

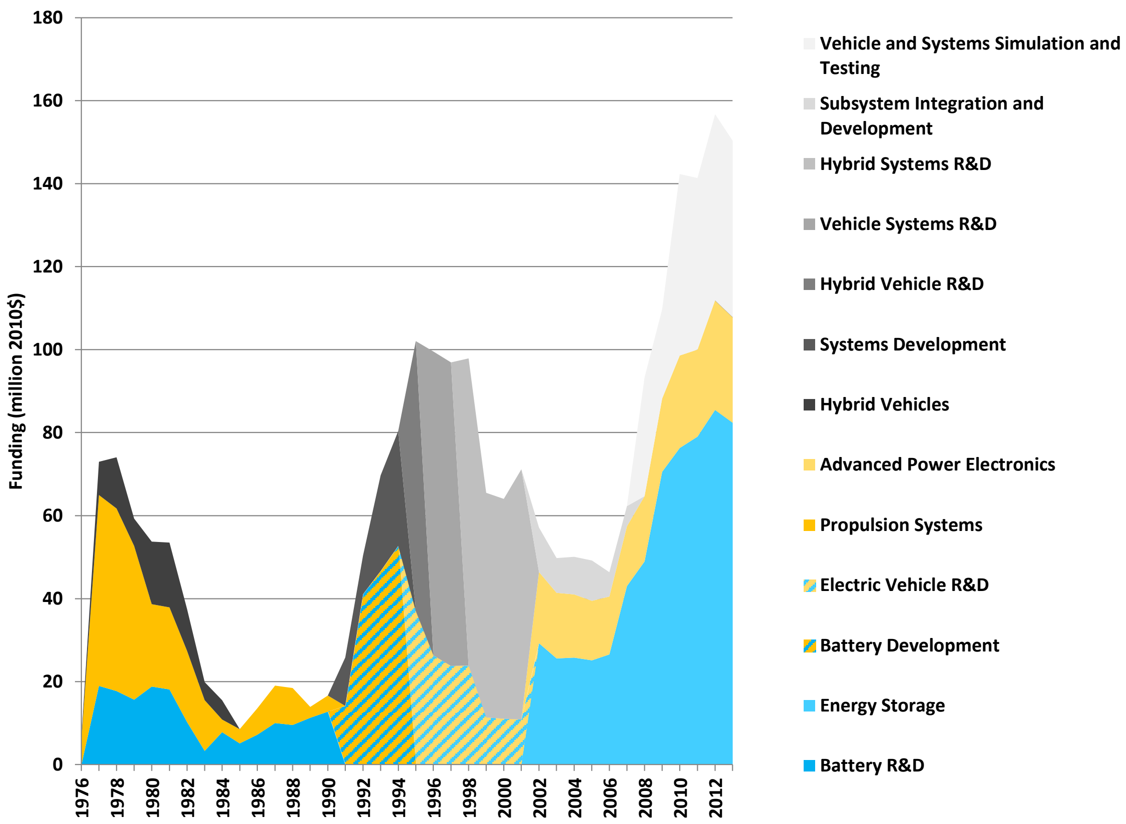

Figure 6 DOE research in hybrid, plug-in hybrid and battery electric technology development

Federal Incentives for Producers and Buyers of PEVs

Incentive	Description	Budget amount in billions of dollars
Tax Credits for Buyers of New PEVs	Tax Credits up to $7,500 per vehicle	$2 (2009-2019)
Electric Drive Vehicle and Battery Component Manufacturing Initiative	Grants to Manufacturers of batteries and other parts of PEVs	$2 (life of program)
Transportation Electrification Initiative	Grants to Establish, Demonstrate, Evaluate and Education Projects to Accelerate Introduction and Use of PEVs	$.4 (life of program)
Advanced Technology Vehicle Manufacturing Program	Up to $25 billion in direct loans to manufacturers of automobiles and parts to promote the production of high –fuel-efficiency vehicles	$3.5 billion (estimated costs of $8.4 billion in loans through 2012) $2.4 billion so far for PEVs / early pay back of Tesla loans has reduced costs.

Source Congress of the United States Congressional Budget Office: Effects of Federal Tax Credits for the Purchase of Electric Vehicles September 2012.

3.2.3 Status Quo of R&D landscape

Research on vehicles, vehicle concepts, powertrain and transportation concept: The Office of Energy Efficiency and Renewable Energy (EERE)

At the Department of Energy, the primary agent of research on vehicles and batteries is the EERE. This office is located in Washington DC in the Department of Energy Forrestal building. Vehicle research is in the mobile technologies program, currently under Patrick Davis. This program includes all battery research, vehicle powertrain. There are additional programs on electric vehicles in the office of electric power.

3.2.3.1 DOE Vehicle Technology Program

The US Department of Energy is the primary source of research programs and research money for electrification of vehicles. Electric vehicle research has been a well-funded program for many decades, primarily battery research, but that applied to hybrids; plug in hybrids as well as “all battery electric vehicles (ABEs)” (the preferred term at DOE)

These programs have primarily been used to fund research programs with the major “Detroit” auto companies, but in recent years have funded new startup battery, motors, power electronics, and other specialized component-focused companies.

Electric vehicle research and implementation support has come primarily through four programs.

- American Recovery and Reinvestment Act of 2009

RECOVERY ACT AWARDS FOR TRANSPORTATION ELECTRIFICATION

Applicant	DOE Award (Dollars in Millions)	Project Locations	Project Focus
Advanced Vehicle Electrification			
Electric Transportation Engineering Corp. (ETEC) (known as Ecotality North America)	$114.8	Headquarters: Phoenix, AZ Manufacturing: Michigan Deployment: Phoenix (AZ), Tucson (AZ), San Diego (CA), San Francisco (CA), Los Angeles (CA), Portland (OR), Eugene (OR), Salem (OR), Corvallis (OR), Seattle (WA), Nashville (TN), Knoxville (TN), Memphis (TN) and Chattanooga (TN), Washington D.C., Dallas (TX), Fort Worth (TX), and Houston (TX).	ECOtality is deploying more than 13,000 AC level 2 charging stations in residential, commercial, and public locations and 225 DC fast chargers in select cities. This infrastructure is being deployed in conjunction with 8,300 electric drive vehicles including the Nissan Leaf and the Chevy Volt. This project includes the collection of a comprehensive set of data from both charging stations and vehicles, enabling analysis to understand how consumers utilize electric-drive vehicles and charging infrastructure.
Chrysler, LLC	$48	*Manufacturing*: Auburn Hills, MI *Deployment*: partner fleets	Develop, validate, and deploy more than 140 advanced plug-in hybrid electric pickups.
Coulomb Technologies	$15	*Manufacturing: San Jose, CA; Deployment:* Boston, MA, Bellevue/Redmond, WA, Sacramento, CA, San Jose/San Francisco Bay Area, Los Angeles, CA, Austin, TX, Southern Michigan (including Grand Rapids, Lansing, Ann Arbor, Detroit), New York City, NY, Washington DC/Baltimore, Orlando/Tampa, FL	Coulomb is deploying 4,600 AC level 2 charging stations in residential and commercial locations. This infrastructure is being deployed in conjunction with 2,400 electric drive vehicles including the Chevy Volt and Ford Transit Connect EV. This project includes the collection and analysis of data from the charging stations.
South Coast Air Quality Management District (SCAQMD)	$45.4	*Headquarters:* Diamond Bar, CA *Deployment:* 50 different utilities and fleets including EPRI in Palo Alto, CA	Develop a fully integrated, production plug-in hybrid system for Class 4-7 vehicles. Demonstrate a fleet of over 250 trucks and shuttle buses.
Navistar, Inc. (Truck)	$39.2	*Manufacturing*: Elkhart County, IN; *Deployment:* Portland, Chicago, and Sacramento	Develop, validate, and deploy 950 advanced battery electric delivery trucks with a 100 mile range.

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Updated: October 2011

Applicant	DOE Award (Dollars in Millions)	Project Locations	Project Focus
Transportation Sector Electrification			
Cascade Sierra Solutions	$22.2	*Headquarters:* Coburg, OR; *Deployment:* 50 U.S. truck stop electrification sites	Deployment of truck stop electrification infrastructure at 50 sites along major U.S. Interstate corridors and provide 5,450 rebates for truck modification to idle reduction technologies.
Advanced Vehicle Electrification + Transportation Sector Electrification			
General Motors	$30.5	*Manufacturing:* Michigan; *Deployment:* several utility partners' fleets	Develop, analyze, and demonstrate 155 Chevrolet Volt Extended Range Electric Vehicles (EREVs) in conjunction with electric utility partners.
Smith Electric Vehicles	$32	*Manufacturing:* Kansas City, MO; *Deployment:* Several partners' fleets	Develop and deploy approximately 500 electric medium-duty trucks with a 100 mile range.
Advanced Electric Drive Vehicle Education Program			
West Virginia University (NAFTC)	$6.9	Morgantown, WV State of South Carolina	• *Educational programs for:* Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public • *Partnering with:* NAFTC Headquarters and members; West Virginia Department of Education; South Carolina Department of Education; Greater New Haven Clean Cities Coalition; Innovation Drive, Inc.; Advanced Vehicle Research Center; Auto Exposure LLC; Big Fish Advertising and Public Relations; MotorWeek; Sabre Engineering; Northeast Utilities
Purdue University	$6.1	State of Indiana West Lafayette, IN	• *Educational programs for:* Graduate, Undergraduate and Secondary Students; Teachers; Technicians; General Public • *Partnering with:* University of Notre Dame; Indiana University Purdue University at Indianapolis (IUPUI); Purdue University – Calumet; Indiana University – Northwest; Ivy Tech Community College
Colorado State University	$5	State of Colorado State of Georgia Fort Collins, CO Boulder, CO Atlanta, GA	• *Educational programs for:* Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public • *Partnering with:* CSU; Georgia Institute of Technology; Arapahoe Community College; Douglas County School System; Nissan NA; KShare; Ricardo; AM General; Motion Reality, Inc.
Missouri University of Science and Technology	$5	Rolla, MO Warrensburg, MO Linn, MO St. Louis, MO Kansas City, MO Lee's Summit, MO	• *Educational programs for:* Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Mechanics; Emergency Responders; General Public • *Partnering with:* University of Central Missouri; Linn State Technical College; St. Louis Science Center; Smith Electric Vehicles U.S. Corporation (SEV-US); Kokam America Inc.

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Applicant	DOE Award (Dollars in Millions)	Project Locations	Project Focus
Wayne State University	$5	Detroit, MI Warren, MI	• *Educational programs for:* Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public • *Partnering with:* NextEnergy; Macomb Community College
National Fire Protection Association	$4.4	Quincy, MA	• *Educational programs for:* Emergency Responders • *Partnering with:* Fire Protection Research Foundation; Automotive Alliance; NREL
Michigan Technological University	$2.98	Houghton, MI (Western Upper Peninsula of MI)	• *Educational programs for:* Graduate, Undergraduate and Secondary Students; General Public • *Partnering with:* Argonne National Laboratory; AVL; GM; Eaton; Horiba; MathWorks; Schweitzer Engineering Laboratories; Woodward
University of Michigan	$2.5	Detroit, MI Ann Arbor, MI Dearborn, MI Flint, MI	• *Educational programs for:* Graduate, Undergraduate and Secondary Students; Teachers; General Public • *Partnering with:* University of Michigan – Dearborn; Kettering University; Ford; GM; Chrysler; Eaton Corp; DTE Energy; Mentor Graphics; Ballard; Quantum Technologies; A123 Systems
J. Sargeant Reynolds Community College	$0.72	Commonwealth of Virginia and Neighboring Mid-Atlantic States.	• *Educational programs for:* Secondary Students; Technicians • *Partnering with:* James Madison University; Virginia Department of Education; Ford; GM; Toyota; Firestone/Bridgestone
City College of San Francisco	$0.5	San Francisco , CA	• *Educational programs for:* Secondary Students; Service Personnel, Technicians • *Partnering with:* Chabot College; Central Shops; Pat's Garage; Perfect Sky Inc.

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- Department of Energy, Office of Energy Efficiency and Renewable Energy 2013-2015.
    - EVs Everywhere Grand Challenge 2015 $209 million (includes $111 million batteries and electric drive –
        - Goals are 75% reductions in costs- $125 kWh batteries , 400 wh/lt
        - Electric drive systems: $8 kWh cost, 4 kW per lt, 94% system efficiency
    - Batteries and electric drive: 2013 $111 million; 2014 $108 million; 2015 (requested) $135 million

Millions of dollars	2013	2014 (enacted)	2015 (requested)
Batteries and electric drive	$111,663	$108,935	$135,531
Vehicle systems simulations an testing	$44,763	$43,474	$39,500
Material light-weighting	$40,336	$38,137	$54,069

Total Vehicle Technologies program connected to electrification

EV Everywhere goals (2022)	Costs			
Batteries	$125 kWh	400 Wh/L	250 Wh/kg	200 Wh/kg
Drive Systems	$8 kW (55kWh system = $400	4 kW/L	1.4 kW p kg	94% efficient
Materials light-weighting		35% body	25% chassis & suspension	5% interior
Workplace charging	Ten-times increase in participation over 2012-2017			

2012: EV Everywhere Grand Challenge: Reduce cost of vehicles and target other primary barriers in next 10 years

3.2.3.2 DOE battery research program

Since before the ZEV era, the DOE has made advanced battery research a central mission. During the ZEV mandate, this area of research grew into the largest research program at DOE. The DOE has funded some very successful R&D projects, with patents, although it has not been able to translate that into commercial success, and almost all manufacturing of advanced batteries, such as NiMH has continued to happen in Japan, Korea and increasingly mainland China. Under the Obama administration, and with use of stimulus funds and loan guarantees, the US government is trying to kick-start a nascent automotive lithium battery-manufacturing program, with factories in Michigan, Ohio, Boston and Tennessee.

Annual Battery Research budget: ($30 million)

DOE also houses research for the electric power grid, including research into the effects of battery charging on local and regional grid demand.

Table 8: ARRA Awards for vehicle battery and component manufacturing

Updated: October 2011

RECOVERY ACT AWARDS FOR ELECTRIC DRIVE VEHICLE BATTERY AND COMPONENT MANUFACTURING INITIATIVE

Applicant	DOE Award (Dollars in Millions)	Project Locations	Technology
Cell, Battery, and Materials Manufacturing Facilities			
Johnson Controls, Inc.	$299.2	Holland, MI Lebanon, OR (Entek)	Production of nickel-cobalt-metal battery cells and packs, as well as production of battery separators (by partner Entek) for hybrid and electric vehicles.
A123 Systems, Inc.	$249.1	Romulus, MI Brownstown, MI	Manufacturing of nano-iron phosphate cathode powder and electrode coatings; fabrication of battery cells and modules; and assembly of complete battery pack systems for hybrid and electric vehicles.
KD ABG MI, LLC (Dow Kokam)	$161	Midland, MI	Production of manganese oxide cathode / graphite lithium-ion batteries for hybrid and electric vehicles.
Compact Power, Inc. (on behalf of LG Chem, Ltd.)	$151.4	Holland, MI	Production of lithium-ion polymer battery cells for the GM Volt using a manganese-based cathode material and a proprietary separator.
EnerDel, Inc.	$118.5	Indianapolis, IN	Production of lithium-ion cells and packs for hybrid and electric vehicles. Primary lithium chemistries include: manganese spinel cathode and lithium titanate anode for high power applications, as well as manganese spinel cathode and amorphous carbon for high energy applications.
General Motors Corporation	$105.9	Brownstown, MI	Production of high-volume battery packs for the GM Volt. Cells will be from LG Chem, Ltd. and other cell providers to be named.
Saft America, Inc.	$95.5	Jacksonville, FL	Production of lithium-ion cells, modules, and battery packs for industrial and agricultural vehicles and defense application markets. Primary lithium chemistries include nickel-cobalt-metal and iron phosphate.
Exide Technologies with Axion Power International	$34.3	Bristol, TN Columbus, GA	Production of advanced lead-acid batteries, using lead-carbon electrodes for micro and mild hybrid applications.
East Penn Manufacturing Co.	$32.5	Lyon Station, PA	Production of the UltraBattery (lead-acid battery with a carbon supercapacitor combination) for micro and mild hybrid applications.
Advanced Battery Supplier Manufacturing Facilities			
Celgard, LLC, a subsidiary of Polypore	$49.2	Charlotte, NC	Production of polymer separator material for lithium-ion batteries.
Toda America, Inc.	$35	Battle Creek, MI	Production of nickel-cobalt-metal cathode material for lithium-ion batteries.
Chemetall Foote Corp.	$28.4	Silver Peak, NV Kings Mtn., NC	Production of battery-grade lithium carbonate and lithium hydroxide.
Honeywell International Inc.	$27.3	Buffalo, NY Metropolis, IL	Production of electrolyte salt (lithium hexafluorophosphate ($LiPF_6$)) for lithium-ion batteries.
BASF Catalysts, LLC	$24.6	Elyria, OH	Production of nickel-cobalt-metal cathode material for lithium-ion batteries.
EnerG2, Inc.	$21	Albany, OR	Production of high energy density nano-carbon for ultracapacitors.
Novolyte Technologies, Inc.	$20.6	Zachary, LA	Production of electrolytes for lithium-ion batteries.
FutureFuel Chemical Company	$12.6	Batesville, AR	Production of high-temperature graphitized precursor anode material for lithium-ion batteries.
Pyrotek, Inc.	$11.3	Sanborn, NY	Production of carbon powder anode material for lithium-ion batteries.
H&T Waterbury DBA Bouffard Metal Goods	$5	Waterbury, CT Holland, MI	Manufacturing of precision aluminum casings for cylindrical cells.

Applicant	DOE Award (Dollars in Millions)	Project Locations	Technology
Advanced Lithium-Ion Battery Recycling Facilities			
TOXCO Incorporated	$9.5	Lancaster, OH	Hydrothermal recycling of lithium-ion batteries.
Electric Drive Component Manufacturing Facilities			
General Motors Corporation	$105	White Marsh, MD Wixom, MI	Construction of U.S. manufacturing capabilities to produce the second-generation GM global rear-wheel electric drive system.
Delphi Automotive Systems, LLC	$89.3	Kokomo, IN	Expansion of manufacturing for existing electric drive power electronics components for both passenger and commercial vehicles.
Allison Transmission, Inc.	$62.8	Indianapolis, IN	Increasing U.S. capacity to manufacture hybrid systems for the commercial truck market.
Ford Motor Company	$62.7	Sterling Heights, MI	Producing a Ford electric drive transaxle with integrated power electronics in an existing Ford transmission facility.
Remy, Inc.	$60.2	Anderson, IN	Establishing a standardized platform of hybrid electric motors and controls.
UQM Technologies, Inc.	$45.1	Frederick, CO	Expanding established propulsion systems into a volume manufacturing environment.
Magna E-Car Systems of America, Inc.	$40	Muncie, IN Holly, MI	Increasing production capacity of advanced automotive electric drive system component manufacturing plants located in the U.S.
Electric Drive Subcomponent Manufacturing Facilities			
KEMET Corporation	$15.1	Simpsonville, SC	Production of DC bus capacitors including soft wound film and stacked film capacitors necessary for electric drive system power electronics.
SBE, Inc.	$9.1	Barre, VT	Outfitting of a high-volume manufacturing facility to build DC Bus Capacitors for the electric drive vehicle industry.
Powerex, Inc.	$8.1	Youngwood, PA	Creating an electric drive semiconductor development, qualification, and production center.

DOE EV project

The US DOE spend $230 million from the American Recovery and Reinvestment act to fund the EV Project in nine regions across the US, including 16 cities and interstate corridors. The goals of the project was to build and study mature EV charging infrastructure, and use lessons learned to enable the efficient deployment of charging infrastructure for plug-in vehicles across the US on a wider scale. The project involved a 50% cost share by private sector and non-federal government partners, including ECOtality, Nissan, and Chevrolet, with the primary federal data collection and oversight being conducted by Idaho National Laboratory (INL). The nine regions were located in 7 states, Washington, Oregon, California, Arizona, Texas, Tennessee and Washington, D.C. These regions were considered "early launch regions" and included early charger (residential, public level 2, and DC fast chargers) and vehicle deployment (Chevrolet Volt and Nissan Leaf). The project studied the infrastructure deployment process, customer driving and charging behavior for the two distinct vehicle types (PHEV and BEV), electric grid impacts, and served as a proving grounds for codes, standards and permitting around this new technology and infrastructure(Smart and Schey). While this project did lead to strong markets in the early launch regions, the quick development of public charging infrastructure, and new insights into consumer behaviors, the lead infrastructure developer, ECOtality declared bankruptcy in late 2013.

3.2.3.3 Clean Cities Coalitions

The bulk of Federal Support for electrification of vehicles (not including the tax credits of $2500-$7500 which are distributed from another branch of government) is developed through the Clean Cities Program at the Department of Energy. The primary mission of the Clean

Cities program is petroleum dependency reduction and some emphasis on Clean Air laws, although a second less advertised goal is green house gas reduction. The Clean Cities Program has two components – an information program on alternative fueled and efficiency of vehicles run by scientists at the National Renewable Energy Labs and the actual Clean Cities program, which supports 65 Clean Vehicle Coalition across the USA.

Clean Cities Coalitions, are locally organized groups that promote alternative fuels and clean vehicle solutions in their regions. These groups receive modest core funding of $25,000 per year to support local activities, such as Ride and Drives, and compete for modest grants to support programs. Most of the support goes to vehicle subsidies in the midsize trucks area, most of these go to government and private fleets. These coalitions are based on local organizational principles, and vary greatly in their success. In previous years, efforts have focused on natural gas trucks, ethanol blends and liquid petroleum gas. In recent years, there has been an increased focus on electric vehicles and more emphasis on the getting more private buyers.

Clean Cities has been the main channel of Federal efforts to support the development of local charging infrastructure, primarily though ARRA stimulus funding under Obama. This program included $400 million for support of infrastructure and planning grants.

($25 million)

Clean Cities Community Electric Vehicle Readiness Projects

The Clean Cities Community Readiness and Planning for Plug-In Electric Vehicles and Charging Infrastructure awards were announced in September, 2011 by the Department of Energy. This included awards for 16 projects covering 24 states and the District of Columbia, and totalled $8.5 million in funding. The awards were designed to help communities forge public-private partnerships to plan for and develop strategies to support the adoption of PEVs and the correstponding charging infrastructure installation. A list of award recipients in included in the table, as well as shown on the map below. Each grantee developed a PEV readiness plan that was specific to their region in spring 2013 (Frades, 2014).

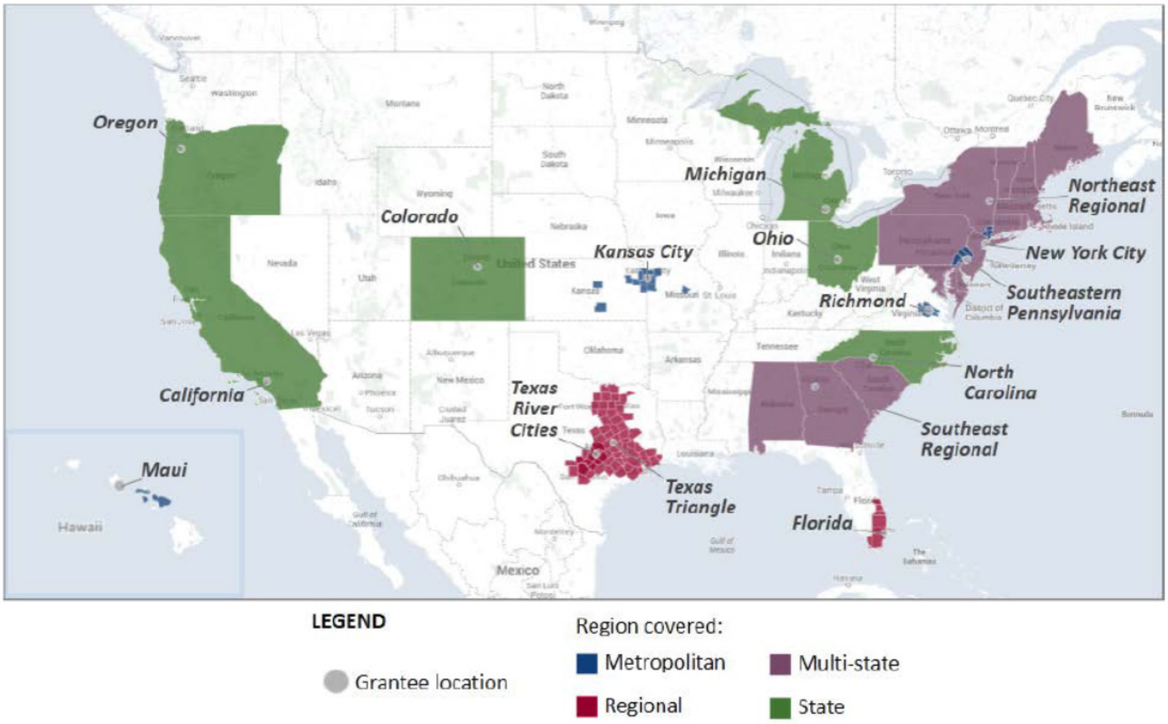
Table 9: Table of Regions receiving EV Readiness Project funding (Frades, 2014)

Shorthand Description of Region	**Region Covered in Readi-ness Plan**	**Awardee**	**Award Amount**
California	California, with individual plans covering the Bay Area, Central Coast, Sacramento, San Diego, San Joaquin, and South Coast regions	South Coast Air Quality Management District	$1,000,000
Colorado	Colorado	American Lung Association of the Southwest	$500,000
Florida	Southeast Florida region, with consideration given to statewide policy and planning	South Florida Regional Planning Council	$500,000

Kansas City	Greater Kansas City Kansas & Missouri area with consideration given to state policy and planning	Metropolitan Energy Information Center, Inc.	$441,178
Maui	Maui, Hawaii with consideration given to statewide policy and planning	University of Hawaii	$299,693
Michigan	Michigan	Clean Energy Coalition	$500,000
New York City	New York City	New York City and Lower Hudson Valley Clean Communities, Inc.	$418,612
North Carolina	North Carolina, with individual plans covering Greater Asheville, Greater Charlotte, Greater Triangle, Piedmont Triad regions as well as a statewide plan	Centralina Council of Governments	$500,000
Northeast Regional	Connecticut, Delaware, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and the District of Columbia	New York State Energy Research and Development Authority	$994,500
Ohio	Ohio	Clean Fuels Ohio	$500,000
Oregon	Oregon	Oregon Business Development Department	$485,000
Richmond	Richmond region, with consideration given to Virginia statewide policy and planning	Virginia Department of Mines, Minerals and Energy	$429,051
Southeast Regional	Georgia, Alabama, South Carolina	Center for Transportation and the Environment	$545,400
Southeastern Pennsylvania	Five counties of Southeastern Pennsylvania (Bucks, Chester, Delaware, Montgomery, and Philadelphia)	Delaware Valley Regional Planning Commission	$387,698
Texas River Cities	Central Texas region, including the greater Austin and San Antonio communities, with consideration given to statewide policy and planning	City of Austin, Austin Energy	$499,782

Texas Triangle	Texas Triangle region including Dallas-Fort Worth, Houston-Galveston, and San Antonio-Austin urban areas, with consideration given to statewide policy and planning	Center for the Commercialization of Electric Technologies	$500,000

Map of Locations of Clean Cities Community Readiness and Planning for Plug-In Electric Vehicles and Charging Infrastructure grantees and regions covered (Frades, 2014).



3.2.3.4 National Renewable Energy Labs (Clean Cities Support)

NREL is a national laboratory dedicated to renewable energy sources, primarily solar, wind and geothermal. Additionally, it has a battery research lab, and provides technical support for electric and hydrogen fuel cell vehicle programs. NREL provides support to the Clean Cities program in a number of consumer information support services, many of these are web based information services that are part of the Department of Energy website, and are designed to inform the public on fuel economy (fueleconomy.gov) as well as alternative fueled vehicle products, analysis (of carbon impacts, petroleum reduction). Also, the lab provides experts to Clean Cities Coalitions to speak, and answer questions on the phone.

3.2.3.5 Oak Ridge National Lab (Knoxville Tennessee)

There is a program at ORNL on mobile energy use. One unique program at ORNL is focused on wireless transfer of energy, both from stationary pads as well as in the road or dynamic charging.

3.2.3.6 Idaho National Lab

INL is the location of electric vehicle testing, most of which is actually conducted at a test track in Arizona. The focus of this testing has been to measure energy consumption, as well as battery durability. INL is also the home office of the Electric Vehicle Project.

3.2.3.7 Argonne National Lab (Chicago, Illinois)

Argonne is the location at which batteries and vehicles are tested under laboratory conditions. Recently it received a new grant from the DOE to be the National Battery Research Hub. Argonne also has done much collaborative research with automakers, to test their vehicles on its equipment. Finally, Argonne has been the source programs aimed at collaboration with China to promote electrification of vehicles.

3.2.3.8 DOE EVs Everywhere Program (one of Obama's Grand Challenges)

In spring 2012, Obama reinvigorated its commitment to developing an electric vehicle industry, announcing an EV Everywhere Challenge. This program was developed through five stakeholder workshops in 2012, but was kept under wraps during he recent elections, While Obama was re-elected in Fall 2012, the budget struggles in the US have kept EVs Everywhere under wraps until a new budget was signed in January 2014. In early March 2013, the first new program, EV Workplace Challenge was announced, with the support of industry. The workplace challenge was to refocus Federal efforts on working with employers, to influence sales to employees, whereas most previous efforts focused on commercial fleets.

3.2.3.9 Advanced Research in Programs in Energy (ARPA-E)

The DOE also funds advanced research projects under the Advanced Research Projects Agency- Energy. Most of these projects are support of a few million dollars to promising, long term big payoff energy research, on things like post lithium batteries, advanced biofuels or smart grid ideas.

3.2.4 Environmental Protection Agency

The US EPA is the government agency, which executes Federal Environmental Law, most importantly the Clean Air Act. The Clean Air Act importantly is the source of the authority of California to regulate the emissions of vehicles to ensure clean air for its citizens. The EPA is the agency, which measures and certifies the emissions levels of vehicles sold in the United States. While the EPA does not develop technology, it does testing of vehicles.

3.2.5 Research on vehicle technology and vehicle components

There is some vehicle technology and component research, primarily performance and reliability testing, that occurs at the National Laboratories, primarily Argonne National Lab and Idaho National Lab. However the vast majority of vehicle technology and component work happens at the automaker, or Original Equipment Manufacturer (OEM) and Tier 1 supplier level. Tier 1 suppliers are companies that are direct component suppliers to the automakers, these companies are often specialized in a certain type of component and have long-term development and production contracts with the OEMs, including responsibilities for continued product improvement or renewal.

Much of the continued vehicle technology and component research is closely guarded by the OEMs and their suppliers, and is not discussed until it is available in production vehicles.

3.2.5.1 Vehicle Technology

Automakers in the US are looking at a broad range of vehicle technologies for their future vehicle fleets, from improving efficiency of conventional ICE vehicles, to hybrid and electric vehicles in the mid-term, with long-term research efforts extending to fuel-cell vehicle technology. They expect their production fleets to consist of a variety of vehicle technologies and fuels for the next several decades.

3.2.5.2 Vehicle Components

Tier 1 suppliers are likely focused on increasing efficiency and reducing component costs for the next generation of vehicle technology and components, while maintaining the highest level of manufacturing consistency and costs for their current products.

- Since their research efforts are closely guarded, we can only hypothesize that their focus will be on the following areas (specifically related to hybrid, PHEV, and BEVs):
- Reducing battery costs
- Weight reduction through use of advanced materials (such as carbon fiber)
- Size reduction and efficiency improvement of power electronics (DC-DC converters, inverters, including components such as Insulated Gate Bipolar Transistors)
- Wireless charging technology
- Emissions management technologies (catalytic converters, specifically for hybrid and PHEV systems)

3.2.5.3 Battery Technology

Battery technology research, as well, is closely guarded by the battery companies and the OEMs they may be affiliated with, as this is a primary component, both in terms of performance and expense for hybrid, PHEVs, and BEVs. Some research is being done at the chemical and material level at Universities around the country, looking at possible future battery chemistries. There is an enormous amount of effort and funding being poured into battery technology improvements across the country including by DOE (see Figure 6on just DOE funding) and private investments.

New battery technologies, such as Li-sulfer, Li-air, and Li-water being developed by company PolyPlus use Protected Lithium Electrode technology using a membrane to separate the lithium from the external electrolyte, it is impervious to liquids and gases, while still allowing the lithium to be electrochemically active. This technology, which has been measured at 1,300 Wh/kg could almost triple the theoretical energy density of Li-ion batteries, which is about 400-450 Wh/kg. While this company is piloting production of a non-rechargeable liseawater battery, they plan to move on to the more complex rechargeable chemistries li-sulfur and li-air, which could eventually make their way into first consumer electronics, and then PEVs in an estimated 10 years. The company PolyPlus is working with partners Johnson Controls and Corning, and has received $8.99M from the US DOE to finish the development and scale manufacturing of its Protected Lithium Electrode technology (Charged Aug./Sept. 2012, p.24-31).

3.2.6 Research on charging technology and infrastructure

There are dozens of research organizations studying various aspects of charging technology, including wireless charging technologies, as well as infrastructure needs and grid impacts for various EV fleet scenarios. This research is primarily being conducted at the private companies, universities, and national laboratories. A representative sample of some of the leading organizations working in this area is shown below.

Table 10: Research Organizations studying charging technology and infrastructure.

Organization	Type	Area of Research/Development
AeroVironment	EVSE Company	EVSE technology and deployment
ChargePoint	EVSE Company	EVSE technology and deployment
ECOtality	EVSE Company	EVSE technology and deployment
NRG	EVSE Company	EVSE technology and deployment
Quantum	EVSE Company	Wireless charging technology development
Argonne National Lab	National Lab (DOE)	Charging standards and cost reductions for EVSE
Idaho National Lab	National Lab (DOE)	Wireless charging technology testing
Pacific Northwest National Lab	National Lab (DOE)	Electrical grid impacts
Nissan	OEM	EVSE technology and deployment
Humboldt State University	University	Regional Infrastructure Modeling
UC Berkeley	University	Infrastructure needs and grid impacts
University of California, Davis	University	Infrastructure needs and grid impacts
University of California, Irvine	University	Infrastructure needs and grid impacts
University of California, Los Angeles	University	Infrastructure needs and grid impacts
University of Delaware	University	Vehicle-to-Grid (V2G) and grid impacts
Duke with Toyota & Energy Systems Network	Utility, OEM, Service provider	charging optimization for grid impacts
Electric Power Research Institute	Utility/Research Org.	Infrastructure needs and grid impacts

3.2.7 Research on business models and mobility concepts

UC Los Angeles and UC Berkeley are both looking at various business models and mobility concepts around electric transportation, often conducted through the schools of business. The most relevant work happening in this arena is pilot, demonstration, and new mobility concepts being launched by both small and large companies. Unfortunately, many of these new business models and mobility concepts and kept completely confidential by the companies researching them until they are publicly launched. These newly launched projects are discussed further in section 3.4.5.

3.2.8 Results of the interviews with stakeholders: opinions on the R&D

Research on vehicle technology and vehicle components

Plug-In Hybrids were mentioned as the most promising electric vehicles for regular car users who drive long distances. In large countries such as the U.S., range anxiety is an important issue. The success of pure electric vehicles depends largely on the upcoming advances in battery technology. According to expert estimations, the battery price can drop as low as 125 USD/kWh in the near future with more advanced battery technology or materials and with large sales numbers. Besides the battery there is also a high potential in improving the thermodynamics, mainly cooling or heating the vehicle components. The energy used today for thermodynamics is quite high and it bears a high potential for energy savings. This leads to a need for a strong focus on material sciences, which was mentioned especially in Canada as a main focus of R&D spending, which also includes lightweight construction. Fuel cell vehicles on the other hand are not foreseen to be an alternative drive train in the near future. An expert mentioned that if the battery technology improves significantly and there is no breakthrough in hydrogen production processes, fuel cell electric vehicles won't be a feasible mid-term solution.

3.3 Economy and industry

The plug in electric vehicle industry is of course in its infancy. The primary players are the car manufactures, primarily the major manufacturers. Additionally, there are part suppliers, including battery manufacturing, and electric component manufacturers.

3.3.1 Actors

The following table lists the companies that are actively engaging in the PEV industry, either through participation in public-private collaborations, research, demonstrations, or industry events.

Company	Sector
American Honda Motor Company, Inc.	Automaker
BMW Group	Automaker
Boulder Electric Vehicle	Automaker
Chrysler Group LLC	Automaker
Ford Motor Company	Automaker
Fuji Electric Corp. of America	Automaker
General Motors	Automaker
Honda R&D Americas, Inc	Automaker
Mahindra GenZe	Automaker
Mercedes-Benz USA	Automaker
Mitsubisihi Motors R&D	Automaker
Nissan Motor Co., Ltd, Nissan North America	Automaker
Odyne Systems, LLC	Automaker
Toyota Motor Engineering & Manufacturing North America, Inc.	Automaker
Toyota Motor Sales	Automaker
VIA Motors	Automaker

Table 11: List of participating Automakers

The following list of Automotive suppliers is not exhaustive, but lists the suppliers that are most engaged in the plug-in electric vehicle industry.

Company	Sector
AVL	Auto Supplier
Bosch Automotive Service Solutions	Auto Supplier
DENSO International America	Auto Supplier
Eaton Corporation	Automaker/ Supplier
Maxwell Technologies	Auto Supplier - Battery Manufacturer
Nichicon America Corporation	Auto supplier
Ricardo, Inc.	Auto Supplier

Table 12: List of engaged Automotive supplier companies

3.3.2 Vehicles, vehicle concepts, powertrain and transportation concepts

In addition to the current market offerings of 10 different makes and models of BEV and 7 PHEV models as of the end of 2013, there are many more plug-in vehicles planned by almost every major manufacturer. The current market includes:

Table 13: Current EV and PHEV offerings in the US market

Manufacturer	Model	Type	Est. EV Range
BMW	Active E	BEV	~100mi/161 km
Chevrolet	Spark	BEV	82 mi/132 km
Fiat	500e	BEV	87 mi/140 km
Ford	Focus EV	BEV	76 mi/122 km
Honda	Fit EV	BEV	82 mi/132 km
Mitsubishi	i (formerly iMiEV)	BEV	62 mi/100 km
Nissan	Leaf	BEV	84 mi/135 km
Smart	ForTwo EV	BEV	68 mi/109 km
Tesla	Model S	BEV	139-265 mi/224-426 km
Toyota	RAV4 EV	BEV	103 mi/166 km
Cadillac	ELR	PHEV	~ 35 mi/~ 56km
Chevrolet	Volt	PHEV	38 mi/61 km
Ford	C-Max Energi	PHEV	21 mi/34 km
Ford	Fusion Energi	PHEV	21 mi/34 km
Honda	Accord Plug-In Hybrid	PHEV	13 mi/21 km
Porsche	Panamera S E-Hybrid	PHEV	~20mi/ ~32 km
Toyota	Prius Plug-In Hybrid	PHEV	11 miles/18 km

Smaller manufacturers were also participating in the market: Azure Dynamics acquired the technology and assets of Solectria Corp in 2005, and in 2010 announced the availability of retrofitted Ford Transit connect EV (BEV), though they are now out of business and the vehicle is no longer available.

Table 14: Upcoming plug-in vehicle models (Autonews, 2013)

The next wave

Electric vehicles and plug-in hybrids planned by major automakers

Audi		**Mercedes-Benz**	
A3 e-tron plug-in hybrid	2014	SLS AMG E-cell EV	2013
BMW		B class EV	2014
i3 EV	2013	B class F Cell	2014
i8 plug-in hybrid	2014	C class plug in hybrid	2014
Chrysler		S class plug-in hybrid	2015

Fiat 500e	2013
Ford	
C-Max Energi plug-in hybrid	2013 MY
Fusion Energi plug-in hybrid	2013 MY
GM	
Chevrolet Spark EV (CA, OR, Canada & Korea only)	2013
Cadillac ELR plug-in hybrid	2014 MY
Honda	
Fit EV	2013
Accord plug-in hybrid	2014 MY
Redesign of FCX Clarity fuel cell electric vehicle	2016 MY
Hyundai	
Sonata plug-in hybrid	2016 MY
Infiniti	
Electric LE	2014 MY
Emerg-E plug-in hybrid	after 2015
Kia	
Soul EV	2015 MY
Optima plug-in hybrid	2016 (esti-mated)
Land Rover	
Range Rover plug-in hybrid	2013 or 2014
Mini	
Plug-in hybrid or EV (considering)	2014
Mitsubishi	
Freshening i EV	2015 MY
Outlander plug-in hybrid	2015 MY
Nissan	
Nissan NV200 electric cargo van	2015 or later
Smart	
ForTwo Electric	2013
Subaru	
Crosstrek Electric plug-in hybrid	2013
Tesla	
Model X crossover	2015 MY
Mid-sized sedan	2016 MY
Toyota	
Fuel-cell EV	2015
Next-generation Prius Plug-in	2016 MY
VW	
E-Golf EV	2014
Golf plug-in hybrid	2015 (possi-ble)

MY = model year Source: Company statements

3.3.2.1 Vehicle technology and vehicle components

United States has a 100 plus year history of automobile manufacturing, including some of the world's largest auto makers, including General Motors, Ford, Fiat Chrysler. These companies are the core investors in electrification of transportation, and have been researching electrification for many decades. In general, for American automobile companies, the technology is developed by engineers in the US, primarily their primary location for research and development in Michigan, but components may be built outside the US and shipped to the assembly plants. Vehicle assembly happens in the US, as well as Canada and Mexico as well as other countries around the world.

There have been some new entrants from the PEV world, notably Tesla, who is still a small boutique, luxury automaker, notably dominant in the luxury vehicle category.

3.3.3 Charging technology and infrastructure

The electric vehicle charging industry consists of three major components. The first is the manufacturers of the charging equipment, or EVSEs (Electric Vehicle Supply Equipment), second, the operations of the charging network, including reservation systems, memberships, and billing etc. Finally the site hosting the EVSE is a third party, often a host business, parking garage owner, or private users. Some companies are involved in both the design and manufacturing of the EVSE as well as the network operations, though others focus on just one portion of the industry. Table 15 lists most of the Electric Vehicle Supply Equipment (EVSE) manufacturers and charging network providers working in the United States, several of the major companies are introduced in more detail below.

Table 15: EVSE and Charging Network Provider Companies in the US.

Company	Sector
ABB INC	EVSE/Charging Network Provider
Advanced Charging Technologies	EVSE/Charging Network Provider
AeroVironment	EVSE/Charging Network Provider
ChargePoint	EVSE/Charging Network Provider
Clipper Creek	EVSE/Charging Network Provider
ClipperCreek, Inc.	EVSE/Charging Network Provider
Collaboratev	EVSE/Charging Network Provider
EV Grid, Inc.	EVSE/Charging Network Provider
EVCollective	EVSE/Charging Network Provider
KnGrid/RWE	EVSE/Charging Network Provider
Leviton Mfg. Co., Inc.	EVSE/Charging Network Provider
NRG Electric Vehicle Services/EVGo	EVSE/Charging Network Provider
PlugInConnect, LLC	EVSE/Charging Network Provider
Qualcomm	EVSE/Charging Network Provider
Recargo	EVSE/Charging Network Provider
Schneider Electric	EVSE/Charging Network Provider
SemaConnect	EVSE/Charging Network Provider
Efacec USA, Inc.	EVSE/Charging Network Provider
Greenlots	EVSE/Charging Network Provider
Gridscape Solutions	EVSE/Charging Network Provider
IES Synergy	EVSE/Charging Network Provider
Liberty PlugIns, Inc.	EVSE/Charging Network Provider
OpConnect LLC	EVSE/Charging Network Provider
RWE/KnGrid	EVSE/Charging Network Provider
Skychargers, LLC	EVSE/Charging Network Provider

3.3.3.1 Ecotality

Company Overview

Ecotality was a company based out of San Francisco who became a major player in the electric vehicle charging market when they were awarded the $100M government funded "EV Project" in 2009. Ecotality is known for its widespread network of Blink charging stations for passenger EVs. The company filed for Bankruptcy in October 2013.

Key Business Information

- Ecotality is primarily an infrastructure company that engaged in selling and installing charging equipment.[3]
- Revenues were generated through equipment sales, network subscription programs and usage fees, media advertising models and interface with utilities[4]
- The ECOtality brand had five major focuses for Sales and Marketing:
  - (i) The Blink line of charging stations for passenger electric vehicles
  - (ii) Paid usage of these chargers by Blink card holders
  - (iii) The Minit-Charger line of charging stations for airport and industrial applications
  - (iv) The Blink Network software innovation and analytics
  - (v) The Consulting and Professional Services of eTec Labs with solutions such as the EV Micro-Climate program.[5]
- The majority of revenue was created through the "sale" of the Blink network of charging stations. These sales were heavily subsidized by the federal grant.
- According to the mandate of the EV project, roughly three quarters of the installations were residential. This made any steady revenue stream in the form of service fees impossible. In addition, it was not even manufacturing the equipment, which was done by Roush Enterprises, with global power and technology firm ABB, Inc.[6]
- Since 2012, a manufacturing and design flaw had been detected in some 12,000 charging stations which had caused overheating or in extreme situations melting of the connector plug.[7]
- Realizing financial troubles, in the first half of 2013 Ecotality attempted to focus heavily on the commercial market by selling their charging equipment, but their efforts ultimately failed.[8]

Summary

Ecotality adopted the "Manufacturer – Network Operator" model. The charging stations are independently owned. Ecotality had no sustainable revenue source. Plans to generate revenue through equipment sales never materialized. 75% of chargers were installed in residential units, negating any chance of future revenue. These installations were highly subsidized by the DOE EV project. Also, technical failures to chargers did significant damage to brand value, weakening the charging network when compared to its competitors.

[3] http://seekingalpha.com/article/1657432-ecotality-may-have-failed-but-the-ev-industry-has-not

[4] http://yahoo.brand.edgar-online.com/displayfilinginfo.aspx?FilingID=9223517-960-461397&type=sect&dcn=0001144204-13-021878

[5] ibid

[6] http://seekingalpha.com/article/1657432-ecotality-may-have-failed-but-the-ev-industry-has-not

[7] ibid

[8] ibid

3.3.3.2 Better Place

Company Overview

Better Place was founded in 2007, with headquarters in Palo Alto, USA. However, most of its planning and operations were done from Israel. Better Place introduced a large-scale commercial pilot for battery-switching services. Operations launched in Israel, and operated in Denmark and the USA as well. Better Place filed for bankruptcy in May of 2013.

Key Business Information

- Better Place approached the Electric Vehicle market from a new, and completely unique approach. Instead of charging the car batteries while inside the vehicles, Better Place created a model utilizing battery swapping. In this model, Better Place was the Manufacturer, Network Operator, as well as the Site Host. The “All of the Above” model.
- Revenue was to be created through subscription plans for the use of the swapping and charging network. Plans varied based on how much the users drove. Cost savings for Better Place were to come by bulk charging batteries at off-peak hours on the grid.
- Due to the requirement of the battery swap, Better Place had to manufacture cars built specifically for this new network. It found a partner in Renault Nissan and launched in Israel, Denmark, and USA. Battery swapping was not allowed outside of the Better Place car network.
- The costs to create the infrastructure and the less than expected sales of compatible cars, proved detrimental, as Better Place was forced into bankruptcy.

Summary

The battery-swapping model is one that has great potential, but requires significant up front costs to implement. Not only the high infrastructure costs of the battery swapping stations, but the requirement for specific battery swapping enabled vehicles, ultimately proved too costly to run a profitable business.

3.3.3.3 Car Charging Group

Company Overview

Car Charging Group (CCG) was founded in 2009. Headquartered in Miami, USA, CCG installs, manages and maintains a large network of electric vehicle charging stations throughout the United States.

Key Business Information

- Car Charging Group works with commercial property owners for EV charging services. CCG owns and operates the EV charging equipment. It manages the installation, maintenance, and related services.[9]

[9] http://www.carcharging.com/about/

- CCG covers all the costs of installing and maintaining the charging station. As a result, they own the charging equipment outright. The capital costs for the commercial property owner are close to zero.
- CCG partners with the property owner to share the revenue generated from the charging.
- Car Charging focuses its efforts on placing EV charging stations at multi-family residential properties and other commercially-owned properties such as public parking facilities, grocery stores, shopping malls and retail locations.
- Instead of manufacturing its own brand of EV chargers and selling them to its strategic partners, Car Charging purchases EV chargers from whichever manufacturer is offering the best product at the time and retains ownership of them.[10]
    - CCG purchased the Blink network of chargers in October 2013.
- Car Charging is responsible for maintenance and repair of the charging stations and enters long-term service contracts with the property owners.[11]
- CCG also has capability to charge by Kw/h (instead of by hour), making charging more attractive to certain customers.

<u>Summary</u>

Car Charging Group operates on a "Network Operator-Site Host" model. It does not manufacture the chargers, but simply purchases whichever is the best on the market at the time. CCG retains ownership of the chargers, installs and maintains them for free in strategic commercially owned properties. CCG then shares the revenue created from charging with property owner. CCG does not rely on gov't subsidies, however has yet to turn a profit (in 2012 Car Charging Group had revenue of $258,000 and a loss of $5.3 million). This raises the question, is revenue from a portion of, not even all, the charging profit enough to sustain the company.

3.3.3.4 Chargepoint

<u>Company Overview</u>

Chargepoint was founded in 2007 under the name Coulomb Technologies. It is headquartered in the Bay Area, CA. Chargepoint is the largest manufacturer and network operator of electric vehicle charging stations in the USA.

<u>Key Business Information</u>

- Revenue is generated through the sale of Chargepoint charging stations to a commercial customer base; as well as an annual subscription for its service plan software.
- Chargepoint uses the "Manufacturer – Network Operator" model, as the charging stations are all independently owned. Thus, Chargepoint's business model does not involve any retention of the proceeds created from optional charging fees to the users. All site host responsibilities are assumed by the purchaser/leaser of the stations.
- Chargepoint offers a unique financing option for its clients, through a partnership with partner Key Equipment Finance. This offers a virtually no cost option for owners to install charging stations, and pay for them via monthly lease payments. However, for

[10] ibid

[11] ibid

Chargepoint the revenue is generated in full at time of sale, as Key Equipment Finance pays for the charger and then acts as the lender to the client.
- The annual subscription service is an important revenue generator, as Chargepoint does not receive revenue from the charging stations. The subscription service will provide significant revenue as the network of charging stations grows.
- Chargepoint chargers are also used in other networks of charging stations. For example, Chargepoint manufactures a large amount of the chargers in the Car Charging Group network.

Summary

Chargepoint adopted a similar model to that of Ecotality. While manufacturing the chargers and operating the network, the chargers remain entirely independently owned. What has made Chargepoint so successful to date is the financing options that are available to their clients. Providing electric charger stations at close to no up-front cost has solved the barrier for what are otherwise expensive investments for property owners. Chargepoint's service plans, software, and mobile integration have provided it with additional revenue streams. Chargepoint has taken a distinctly different approach than Car Charging Group, by passing all potential profit from charging to the property owner, and generating revenue from the equipment and service plans.

3.3.3.5 NRG eVgo

Company Overview

EVgo is a division of the large energy company NRG. Started in 2010, the eVgo charging network targets both residential and commercial charging. Based out of Texas, USA, eVgo operates in Texas, California, and Washington DC.

Key Business Information
- EVgo operates on a "Manufacturer-Network Operator-Owner" model. This means they maintain full control and ownership of their network and equipment at all times. Nothing is ever sold to the customer, except a subscription service to use eVgo's chargers and service.
- NRG eVgo targets both residential and commercial charging. EVgo charges its customers a flat monthly rate for one of its subscription plans. Plans include monthly fees which cover the installation of charging equipment at the users home, and the use of the eVgo's network chargers set up around major cities in their networks.
- EVgo's network of away-from-home chargers is entiresly made up of DC fast charging stations. This is different than most other chargers, which are predominatnyl Level 2. EVgo has separate plans for the unlimited use, and per-use basis, of their DC fast chargers.
- EVgo's network is still small, focused mainly on Houston and Dallas, but they are expanding into CA and DC.

Summary

EVgo provides charging services for both residential and commercial charging. With binding subscription services, eVgo provides affordable financing for home charger installations. For their commercial chargers, revenue is generated primarily through subscription plans, as well as per charge fees at the charging stations. EVgo's decision not to sell their charging equipment, but to charge a monthly fee to chargers is an interesting one. Whether they will be able to compete with charging offered by other charging stations, which are operated often not-for profit, remains to be seen.

Table 16: Major Charging Network providers

Charging Company	Manufacturer	Network Operator	Site Host	Still in Busi-ness	Residential	Commercial
Ecotality (Blink)	X	X		No	Yes	Yes
Car Charging Group		X	X	Yes	No	Yes
Charge-point	X	X		Yes	No	Yes
Better Place	X	X	X	No	No	Yes
eVgo	X	X	X	Yes	Yes	Yes

3.3.4 Business models and mobility concepts

While there is likely plenty of academic research ongoing regarding new business models and mobility concepts around electric vehicles, perhaps the most relevant are the real-world projects and mobility solutions being conducted in the US, particularly in large, dense urban areas such as New York City and San Francisco. DriveNow, an effort launched by BMW, exclusively operates with electric vehicles, and car2go features a mix of electric and conventional vehicles in select cities. Many of the other mobility solutions listed below include hybrid vehicles, but are not limited to just electric drive vehicles.

Table 17: New Mobility Solutions offered in the US

Connected Service	Web Address	Description
DriveNow	https://us.drive-now.com	Electric vehicle car sharing program. It has no annual or monthly fees, all electricity is free and 100% renewable.
car2go	https://www.car2go.com/	Car2go is a car sharing service that offers Smart Fortwo "car2go edition" vehicles and features one-way point-to-point rentals, which are charged by the minute (with hourly and daily rates available).
Uber	https://www.uber.com/	Uber is a mobile app that connects passengers with drivers of vehicles for hire and ridesharing services.
Zipcar	http://www.zipcar.com	Car sharing program that works by online and mobile reservations. No gas or insurance fees, but a $6 monthly subscription is required.
Lyft	https://www.lyft.me	On demand ride-sharing community. Individuals offer to give rides in an area and using mobile phone connects them with people asking for rides.
Getaround	http://www.getaround.com/	Getaround is an online car sharing or peer-to-peer carsharing service that allows drivers to rent cars from private car owners, and owners to rent out their cars for payment.
Relay Rides	https://relayrides.com	$1 million liability insurance policy, strict renter screening, 24/7 roadside assistance & support, free parking and car washes at various airports.
Ridejoy	http://ridejoy.com/	Ridejoy is a community-driven marketplace for sharing rides. Drivers can list extra seat space in their cars, and people needing a ride can find it using the service.
sidecar	http://www.side.cr	The new Sidecar allows riders to choose the vehicle, the driver and the price, tailoring every ride for any occasion. Sidecar is the only ride sharing app that shows you the exact price of your ride
Driving Alliance	http://drivingalliance.org/	Driving Alliance is a non-profit, tax-exempt public charitable group that aims at reducing the amount of drunk drivers by providing a Free designated ride to and from selected establishments, thus encouraging individuals not to drink and drive.

3.3.4.1 The Tesla Story

Headquartered in Palo Alto CA, in the heart of the Silicon Valley, Tesla launched the two-seater Tesla Roadster in 2008, and by 2012 had sold more than 2,250 Roadsters in 31 countries. The base price of the Roadster was US$109,000, and the new luxury sedan, launched in 2012, came with a base price of US$57,400. The Model S is manufactured in Fremont, CA, and has sold approximately 21,270 models in the US since its 2012 launch. Tesla's approach to selling electric vehicles is unique in that they have several goals for increasing EV availability to customers. They sell through company-owned showrooms and online, not through dealerships, they sell powertrain components to other manufacturers, and hoped to act as a catalyst to encourage other automakers to join the EV market.

While Tesla has stated that they plan to bring an all-electric sedan to market at US$30,000, their current offerings are well above the average purchase price for most new-car buyers, and they have maintained a certain brand exclusivity through the introduction and installation of Tesla-specific Superchargers, which are not compatible with either the ChaDeMo or SAE combo Quick Charging connectors. Their home charger is a Tesla-specific connector and charges at a significantly higher current than the standard 220V home charger used by other BEVs or PHEVs.

Their Supercharger network is a unique experiment for a company to undertake, allowing users unlimited use of the Superchargers as part of the purchase of their Tesla vehicle. In California, for example, Tesla built six Supercharger stations in secret, and revealed the locations in late 2012. These chargers are capable of charging the Model S at 90 kW, allowing for approximately 150 miles of driving in 30 minutes of charge time, and are positioned to link Northern and Southern CA along the major Interstate freeway.

- **Folsom, CA** US Route 50
  Folsom Boulevard Exit 23 *Folsom Premium Outlets*
  Folsom, CA 95630
- **Harris Ranch** I-5 Exit 334 *Harris Ranch Inn and Restaurant*
  Coalinga, CA 93210
- **Gilroy, CA** 101 at Leavesley Road *Gilroy Premium Outlets*
  Gilroy, CA 95020
- **Barstow, CA** I-15 Exit 178 *Country Inn and Suites*
  Barstow, CA 92311
- **Tejon Ranch** I-5 Exit 219B *Petro Shopping Center*
  5602 Dennis McCarthy Dr
  Lebec, CA 93243
- **Los Angeles, CA** I-105 Exit 5 Hawthorne Municipal Airport
  3203 Jack Northrop Ave
  Hawthorne, CA 90250

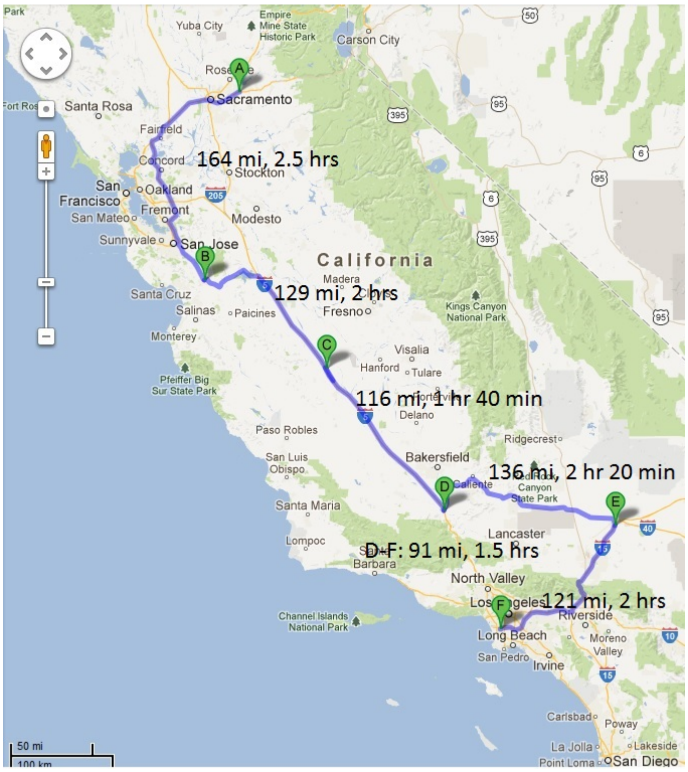


Figure 7: Tesla Supercharger network in CA

3.3.6 Results of the interviews with stakeholders: opinions on EV Industry and Economy

Vehicle concepts

Two different strategies for EV concepts were discussed among the interview partners. Either the so called purpose design (vehicle concept based on a new vehicle platform, e.g. the BMW i3) or the conversion design (vehicle concept based on existing vehicle platform, e.g. the Ford Focus Electric) were mentioned by manufacturers as the most promising and efficient strategy for OEMs to produce EVs. Those in favour of a purpose design approach mentioned that such a concept brings the possibility to design the car fully after the user's needs. The new car would thus be a "completely new experience of mobility". Also, a vehicle designed and based on a new concept is more individual and distinguishable from other vehicles. The advantage of conversion design is the cheaper production process. The new assembly line is very cost intensive and not feasible yet with uncertain market estimates. Costumers used to a certain model also tend to stick to this specific type, rather than switching to another model type or brand say those in favour of conversion design. Expert quote: *the electric drive is just another drive train; the vehicle around it must not be re-invented*. For the coming 10 to 15 years there will probably coexist different types of drivetrains for a single model type.

Components technology

Work place

A high visibility of charging facilities at work places influences the opinion of potential EV users strongly. Co-workers receive a first-hand impression about the vehicle and how it can be arranged to charge it during working hours. A growing number of companies is introducing EVs in their company fleet. The experts state that many employees have been convinced about an EV purchase through their company which is running electric vehicles. The experts mention that the government should take the necessary steps to improve the visibility of charging facilities at work places.

3.4 Consumer and market

The world market for light duty vehicles in 2013 was around 100 million units. The 2013 new car market in the United States was 15.6 million, the highest in many years (Edmunds.com). California accounted for 12.5% of 2013 new car sales (CNDA). Electric vehicles are a very small percentage of the market so far, less than 1%, and less than 0.1% of the fleet.

3.4.1 Market development of electric vehicles up to now

Sales of mass-produced electric vehicles for the world and USA market began in earnest in Dec 2010 with sales of the mass produced Chevy Volt (in Europe is called Ampera) and the PHEV Nissan Leaf. Those two vehicles still lead world sales, although there are a number of new vehicles in the markets. We show last December and last years sales for 27 models.

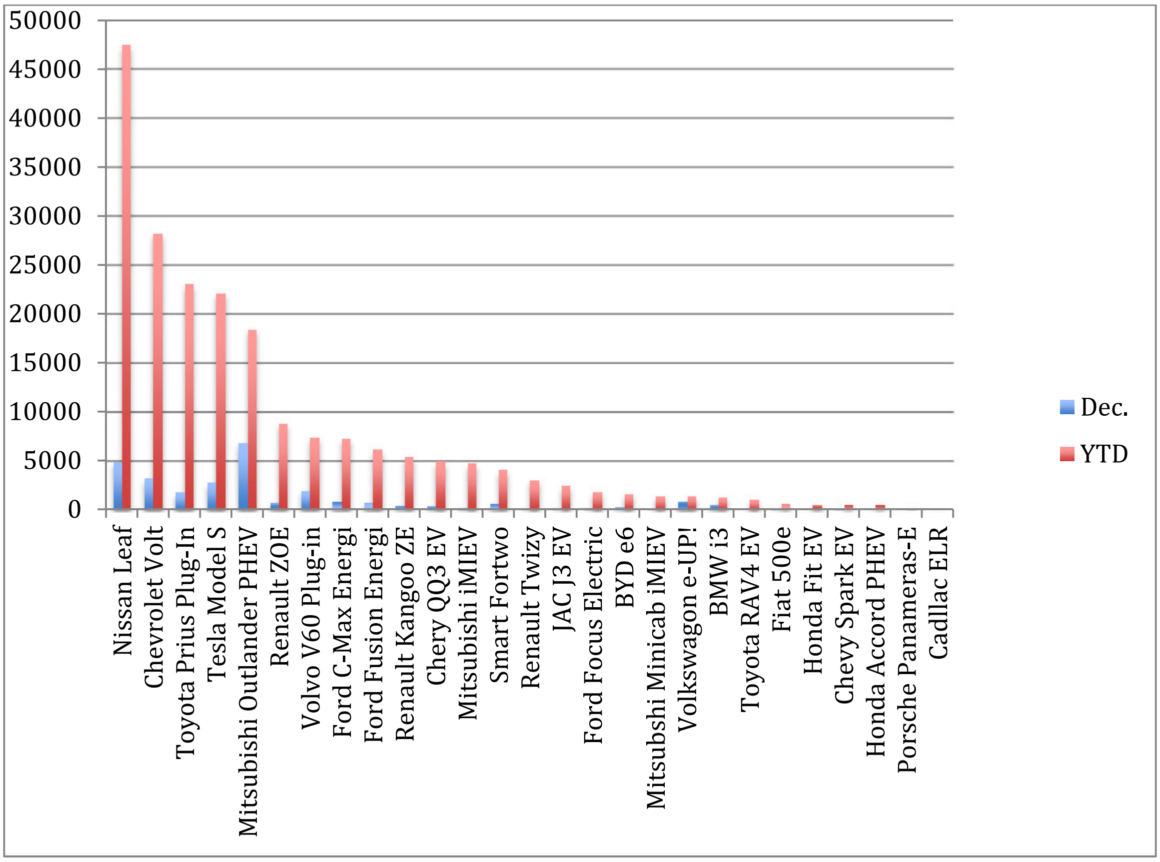


Figure 8: 2013 PEV sales data gathered from http://ev-sales.blogspot.com & http://insideevs.com

The world sales of plug in electric vehicles in Dec 2013 were 27,544 units and around 215,000 total units for 2013, there were about 400,000 PEVs registered in the world. United States accounts for almost one half of this market. There were about 96,000 PEVs sold in the United States in 2013 and as of January 2014, there were about 170,000 PEVs registered in the United States. If you combine BEV and PHEV sales (PEV) the rate of market growth from 2010-2012 is faster than the two year period of market introduction of HEVs in the United States (2000-2002). If you separate PHEVs and BEVs, the rate of growth is similar. Of course the incentives for PEVs have been considerably higher.

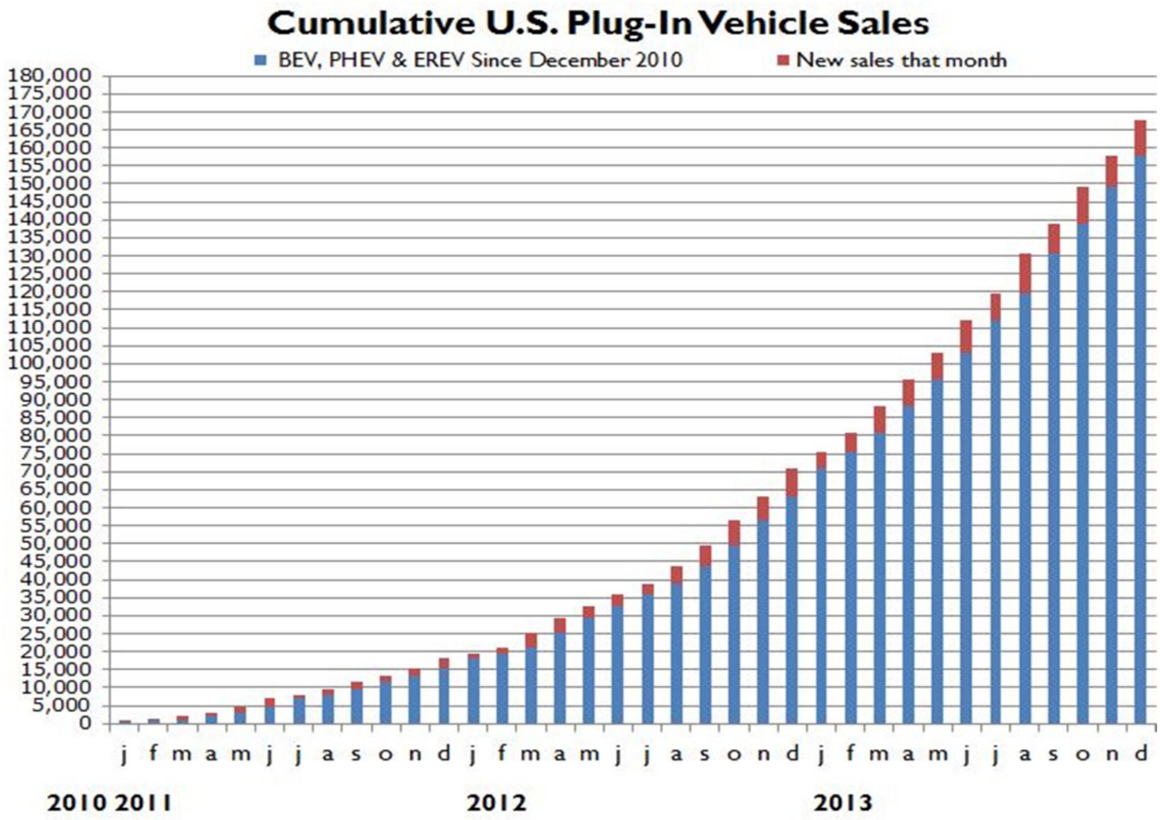


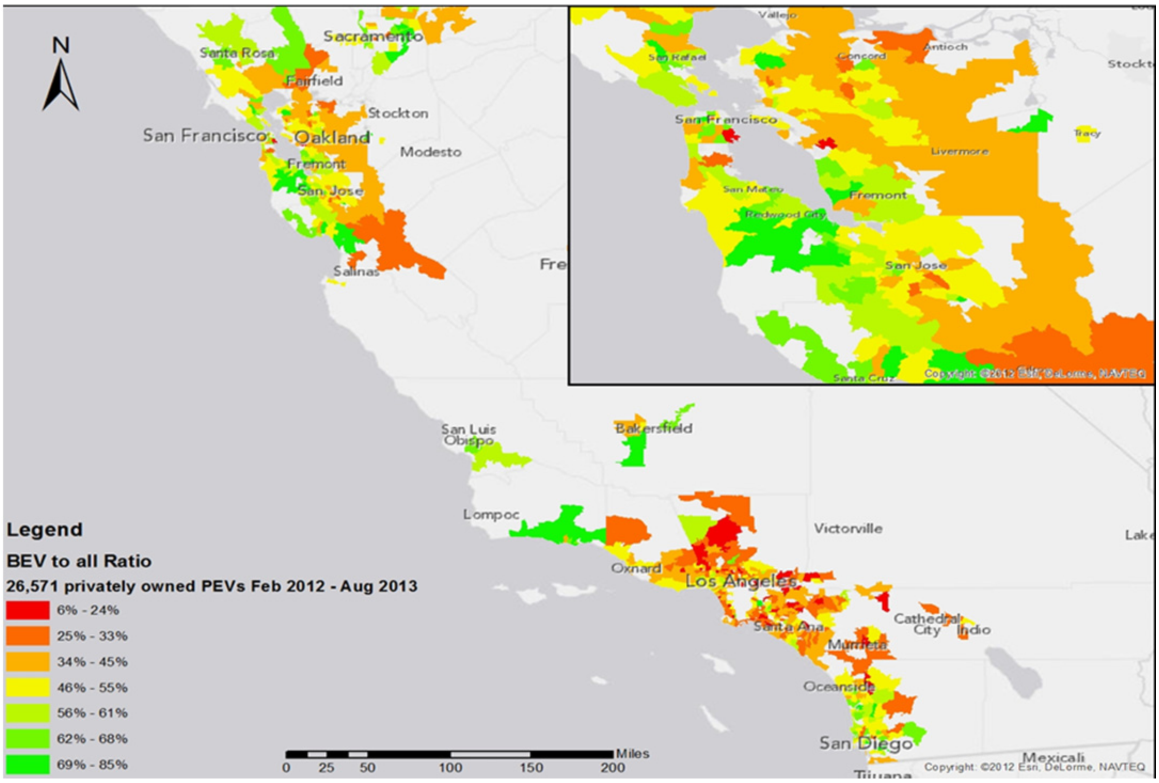
Figure 9: Cumulative US Plug-In vehicle sales. 2010 – 2013 (from EDTA)

Sales of these vehicles have been concentrated in a few regions, in particular city regions on the west coast (San Diego, Los Angeles, San Francisco Bay Area, Portland Oregon, and Seattle Washington). In particular, California, accounts for about 1/3rd of national PEV sales, although it accounts for about 12% of all new vehicle sales in the United States. Within California, sales are strongest in coastal cities, where most of the wealth and technical industries reside, and car purchases tend towards cars instead of trucks. Overall, in the last couple of quarters, sales have been nearing 2% of all sales.

Additionally, there are even more specific market trends within these coast zones with some neighborhoods and zip codes. Acceptance of PEVs has been primarily in the technology hubs and politically liberal areas - San Francisco Bay Area, North Carolina Research triangle, Boston, Boulder Colorado, Austin Texas, San Diego California, Seattle Washington, Portland Oregon. Additionally, sales have predominated among well educated, and relatively wealthy households. Additionally, so far sales have been in those households that live in detached single-family homes, which have a practical location to park and charge the vehicle during the night. The general population averages 2.1 vehicles per household (Transport Energy Data Book, 2011), whereas recent survey results show the average PEV buyer has 2.7 vehicles in their household (Tal and Nicholas, 2013).

The following map shows the distribution ratios of all battery electrics and all PEVs in California, showing the heavy concentration of PEVs in the Coastal cities, and the emphasis on BEVs in care urban, with a greater concentration of PHEVs on the peripheral suburbs.

Ratio of BEVs to all PEVs by California zipcodes



The recent market for plug in vehicles began in the United States in 2008 with limited sales of the Mitsubishi iMIEV and the Tesla Roadster. In December 2010, Nissan began sales of the mass produced Leaf and GM also began sales of the Chevy Volt. The following two charts show quarterly sales of BEVs seperated from PHEVs. Sales of the PHEVs are dominated by the Chevy Volt, with small markets of the Toyota Plug in Prius and growing sales of the Ford Fusion Energi and Ford C-Max Energi. Sales of BEVs are dominated by the Nissan Leaf and Tesla S.

It is unclear yet how much competition exists between these brands for market share. It is evident each time a new model is brought to the market, such as the Ford PHEVs or the Tesla S, the market grows considerably. The addition of each new type of vehicle, whether from a new body style, new functionality, or new performance attribute, likely will continue to increase the market share of PEVs rather than compete with existing brands until there are many more options available on the market for consumers.

Perhaps more importantly, the growth of sales in the last half of 2013 reflects the shift from purchase to leasing. In 2012, the majority of PEV purchases were sales, while in the last half of 2013, the majority of purchases were leases. These leases were successful because the manufacturers were able to roll the sizable tax credit into the the three years of a lease. Together with regional incentives, these leases are much more attractive than purchase. Presumably, buyers might be more interested in leasing given the uncertainty about the performance and reliability of PEVs; leases allow for less commitment.

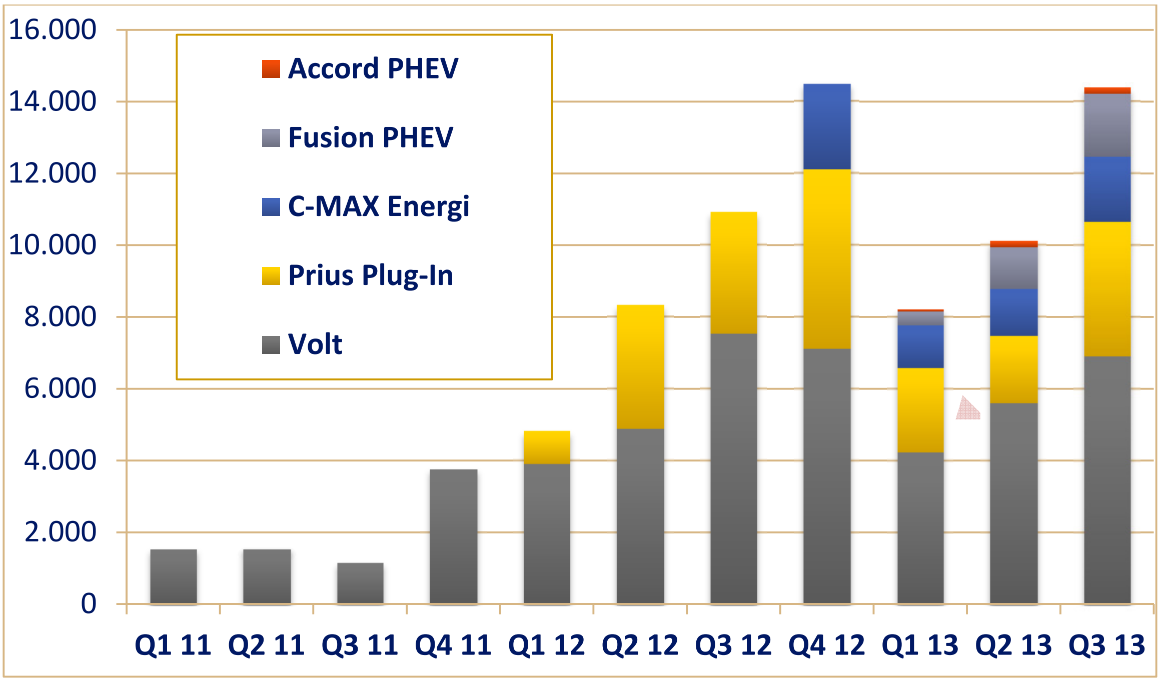


Figure 10: PHEV Sales through 3rd quarter, 2013

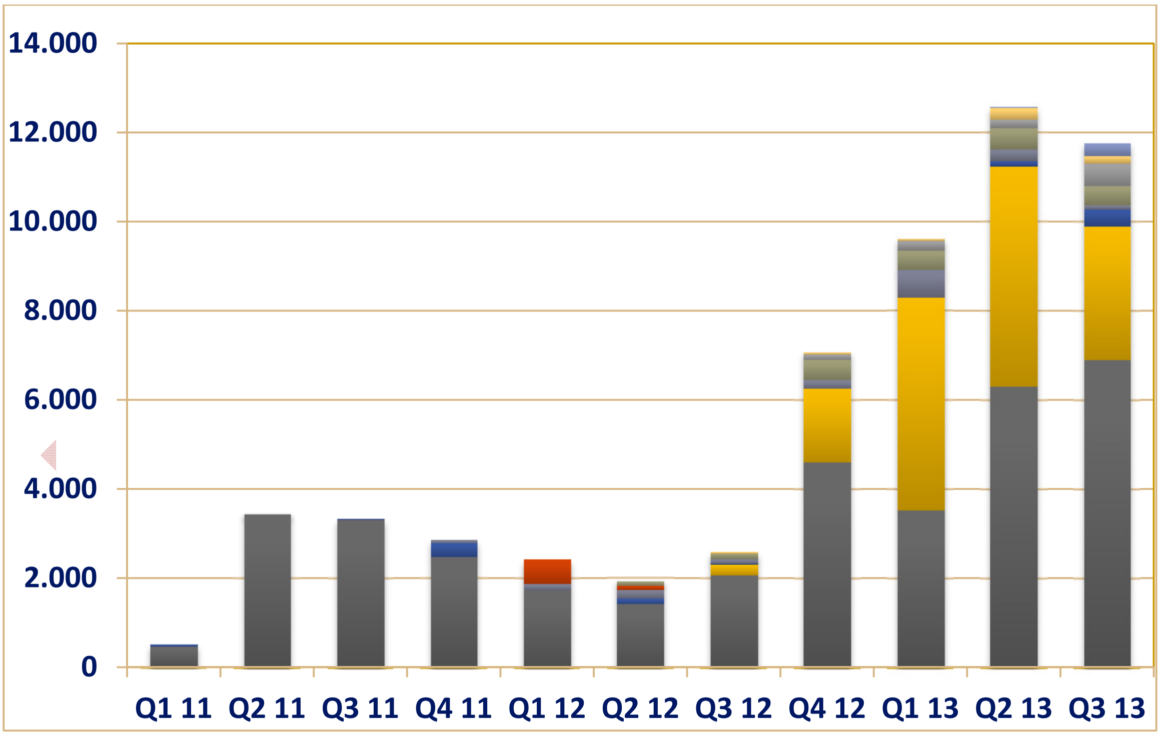


Figure 11: BEV sales through 3rd quarter 2013

3.4.2 Market perspectives on development up through 2025

As mentioned above, in the sections on USA, and California,

- The market in the next ten years is shaped by several factors:

- Lack of manufacturing infrastructure, especially batteries
- Lack of consumer knowledge of the vehicles
- An incipient infrastructure, which also involves grid integration
- Cost of batteries, which are expensive but currently reducing in cost through mass production at around 7% per year.
- Lack availability in many market segments – importantly truck like vehicles in the US.

We can view the development of the PEV market in the United State in part through mapping several tends on to the next ten years of the market:

- Regulations requiring OEMS to meet PEVs:
  - California and Section 177 States (about 30% of the US market requiring ZEVs by 2025);
  - Sub-markets with favourable conditions for PEVs, including federal, state and local government fleets; and,
  - Several non-Section 177 states, including Colorado, Texas, Florida, Georgia, Washington, Hawaii, and Tennessee which have special conditions or social institutions that favour EVs.
- Vehicle generations onto the next 10 years, using hybrid vehicles as a historical model of vehicle rollouts for innovative drivetrains that require sustained cost reductions
- Consumer markets, primarily diffusion of innovation models which show how new products spread through market segments over time (and across geography as well)

  The following chart, developed at UC Davis, is based on the rollout of HEVs in Japan. It combines typical percentages for market development of new products in the automotive industry, time periods for product cycles, and regulatory goals into a single graphic.

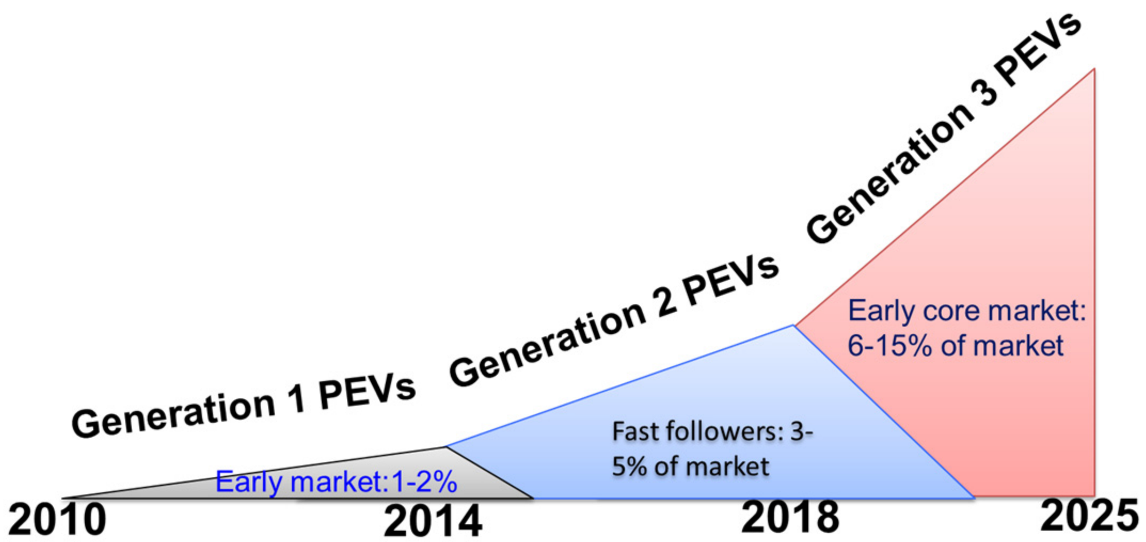


Figure 12: Potential Market Growth through Vehicle and Consumer Generations

3.4.3 Results of the interviews with stakeholders: opinions on the EV market

Today EVs are mostly found in the vehicle segments of small and medium sized vehicles in North America. The experts agreed that the share of large cars in the overall vehicle fleet in the United States will decrease in the future and demand for small sized vehicles will increase. Today's EV concepts are thus becoming more and more attractive to customers. The Nissan Leaf for instance is today the most often sold car in the city of Atlanta. Nevertheless, there exists still a large demand for pick-ups and SUVs on the vehicle market. Several manufacturers have announced plans to introduce SUVs and sports cars as electric vehicles (plug-in hybrid versions). CAFE (Corporate Average Fuel Economy) standards which OEMs have to fulfil are one major reason why manufacturers are focusing on alternative fuels and new engine types. The objective is to reduce their fleet average fuel consumption with an increasing share of electric vehicles.

Today's sales numbers are generally seen as satisfying. The trend of sales goes towards a higher share of plug-in hybrid models and a certain point there will be only a few number of hybrid electric vehicles anymore. The battery price per kWh can drop as low as 125 US-$ in the near future, which is however not possible with current battery technology.

User / Consumer attitude and behaviour

The initial stages have shown that the majority of EV users charge their vehicle at home or at work. There are plans to expand the public charging stations as well, however do most of the experts state that there is a much larger potential in subsidizing charging stations at homes and condos or at work places. The longer idle times at these locations lead to this conclusion. Sudden peaks during charging hours for instance at working hours can be avoided through an intelligent charging management. First experiences have shown that drivers of battery electric vehicles almost exclusively choose the Level 2 charging utility as an upgrade. Drivers of hybrid vehicles are more often satisfied with a Level 1 charging utility because they are more flexible using the range extending combustion engine. An important issue in larger cities is the installation of charging stations at condos where many car owners share parking spots. Here the installation is often decided by the house owner who is not the EV owner. There exist local governments who are targeting this issue with special funds to such house owners to make it more attractive to install the charging facility. The advantage here is that the availability can attract others to purchase EVs which again is of interest to the city.

A special challenge for EV owners is using the vehicles in colder climates. In Canada the pre-heating of cars plays an important role and would be a benefit for EVs in order to save the energy to heat up the inside of the car. For the control of their energy consumption home owners in the U.S. use so called smart meters. One expert mentioned that his electricity consumption grew by 100% since he started using an EV on a regular basis which is an impressive finding.

3.5 Conclusions

The goals of 15% market for ZEVs in California by 2025 and 1 million PEVs in the USA by 2015 are ambitious goals. To transition to plug-in hybrid and all battery electric vehicle requires continuous improvement of batteries, development of an entirely new supply chain, a system of chargers integrated with the electric power grid, and satisfied car owners. The initial challenge in this transition is that the auto-industry is vested in a vast supply chain for internal combustion gasoline and diesel vehicles; shifting to a whole new drivetrain technology disrupts current patterns for making profit, whether you make, sell or repair automobiles. There have already been some significant bankruptcies during this initial phase, including Project Better Place, Fiskar and several battery makers as well.

The second great challenge is to compete in the marketplace with ICE vehicles, a technology to which consumers are accustomed, vehicle and fuel prices are low and for which there is a well-established system to fuel and repair. In the early years of the market, PEVs are more expensive, the charging system is not well developed, and full battery electric vehicles have range limitations imposed by the expensive and limited storage capacity of batteries. Plug-in electric vehicles do have some advantages for consumers, including good driving feel, less expensive electricity for fuel, potentially less repair, and of course they are clean and quiet. The market is developing first among well educated, wealthy technically knowledgeable car buyers. Additionally, the first buyers mostly own a home with predictable, nighttime parking and access to electric circuits. About one half of Americans who buy new cars, have a practical home charging situation.

California, with its history of air pollution, well-paid technical industry, and progressive politics has been a strong first market for PEVs; that market is concentrated in the wealthy neighborhoods and mild climate of the coastal cities. Similar first markets have developed in coastal cities and technical industry regions of other parts of the USA, notably in areas like the Research Triangle of North Carolina, Seattle Washington, or Portland Oregon. The market is currently about .65% in the US on whole, 1.5% in California, and in some high income, highly educated neighborhoods in university dominated and technical industry areas, approaching 3-5%.

The market is heavily incentivized during these first years, with Federal tax credits, State credits and rebates, and local incentives, such as free charging and parking at workplaces and public parking lots. In recent months, inexpensive leases, HOV lanes privileges and free charging and parking have expanded the market, attracting more middle income buyers. These incentives are probably not sustainable; as the market grows, the total cost of such incentives escalates and faces backlash from both tax conservatives and equity minded politicians.

However, there is a developing web of policies in the United States keeping the market afloat, including the CAFE standards, the ZEV program in California, and a network of other states adopting the ZEV standard in the next few years. Industries, such as Tesla, are developing, and gaining political support as well by being successes. Tesla in particular has been a huge success, with its plan to enter the market at the top end, and provide an included charging network to its buyers.

While slow, it is probable that the PEV transition will happen, but will take several decades, with primary market growth accelerating only when battery and component costs drop to compete with ICE vehicles, or fossil fuels cost become prohibitive. The hybrid market has taken at least 15 years to get rooted in the US auto-market, first growing in coastal cities, and served by a limited range of models during the first two generations of vehicle designs. The market in some coastal cities for hybrids has grown to 10 percent, while overall sales in the US have stayed around 3 percent. However, the number of hybrid models in the market is accelerating in recent months, and the market is poised to grow at a faster pace in the next years.

We would expect to see similar growth for PEVs once the costs are leaned out (third generation vehicles) and a practical charging system is established across the US. This will take at least a decade and probably longer. When the market and industry reach this threshold, we can expect the market growth to accelerate into the range of current hybrid growth, which is between 5 and 15% (Japanese hybrid market is around 20% in 2013).

The most important contingencies are fossil fuel and battery prices. If batteries improve dramatically and prices drop to targets of $200 or less per kWh, large battery BEVs, like the Tesla, could expand the market. But if battery costs do not drop, PHEVs will dominate this market and BEVs with modest batteries will result in a smaller share of the PEV market. However, if fossil fuel prices rise dramatically as they have in the last decade in the United States, and or CO_2 taxes are imposed on fossil fuels, PEV markets could grow even faster than the hybrid market experience would predict.

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