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16. Abstract
This report seeks to reach conclusions over the role that electric vehicles (EVs) and public charging infrastructure should play in the future U.S. transportation system As demonstrated in this report, electric vehicles are neither new nor technologically infeasible. Current circumstances have initiated what appears to be a revival of the EV – these circumstances include high oil prices, geopolitical instability, and growing awareness of environmental concerns resulting from conventional vehicles (CV) usage. Nevertheless, impediments remain. One of the most important is the prospect of building public charging infrastructure to allow drivers to use an EV like their conventional vehicle, for both long and short distances. Public charging infrastructure, however, cannot be built without some critical mass of EVs on the road to use them – otherwise they are not economically feasible. This report analyzes various facets of both EVs and public charging infrastructure to give the reader a clear understanding of the complex criteria that must be understood to assess EVs in the United States. Texas is given special consideration as a case study in this report, particularly the Austin area where public charging infrastructure for EVs is currently being implemented.

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ELECTRIC VEHICLES AND PUBLIC CHARGING INFRASTRUCTURE: IMPEDIMENTS AND OPPORTUNITIES FOR SUCCESS IN THE UNITED STATES

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“Local Infrastructure to Support the Widespread Use of Hybrid/All Electric Vehicles: What Programs and Public Policies are Likely to Work to Promote Environmental Sustainability and Livable Communities”

Performed in cooperation with the
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EXECUTIVE SUMMARY

Today’s debate regarding the United States (U.S.) transportation sector has never been more important. As similar discussions embroil electricity generation, one can see the powerful forces of the status-quo pitted against growing momentum behind alternatives. The electric vehicle (EV) finds itself somewhere in the middle of the debate, as a possible alternative to the conventional vehicle (CV).

Electric vehicles are neither new nor technologically infeasible. Current circumstances have initiated what appears to be a revival of the EV – this includes years of high oil prices, geopolitical instability, and growing awareness of environmental concerns resulting from CV usage. Due to these concerns demand has risen for alternatives and governments around the developed world are thinking about ways to curb the use of petroleum, where transportation is often a large user. Among several others, one alternative “fuel” that would diminish environmental damage while curbing use of petroleum is electricity.

Nevertheless, impediments remain. One of the most important is the prospect of building public charging infrastructure to allow drivers to use an EV like their conventional vehicle, for both long and short distances. Public charging infrastructure, however, cannot be built without some critical mass of EVs on the road to use them – otherwise they are not economically feasible.

This report analyzes various facets of both EVs and public charging infrastructure to give the reader a clear understanding of the complex criteria that must be understood to assess EVs in the United States. Texas is given special consideration as a case study in this report, particularly the Austin area where public charging infrastructure for EVs is currently being implemented. Through a detailed analysis of electric vehicles and charging infrastructure, as well as the United States transportation system, this report seeks to reach conclusions over the role EVs and public charging infrastructure should play in the future U.S. transportation system.

Despite a historical general acceptance with the public, EVs faced several drawbacks still largely present today, including relatively short range and lack of knowledge over how to maintain the vehicles. A lack of cost-effective and convenient charging stations across a large network of roads has remained an issue for EVs since their introduction into the system. Higher quality and quantity of road systems has encouraged the use of long-range conventional vehicles. Additionally, large quantities of domestic oil reserves have made gasoline cheap and plentiful and spurred infrastructure in the form of gasoline fuel shops. In contrast, most rural locations were not hooked into the electrical grid and could not provide charging for electric vehicles. Also, the cost of CVs compared to EVs has proven advantageous over time.

Currently, there are several forms of electric vehicles, each with varying degrees of “electrification.” This report does not consider the traditional “hybrid” vehicle, or “mild hybrid” as an electric vehicle, as these vehicles contain larger-than-normal batteries which operate in conjunction with an internal combustion engine (ICE) engine; they are not charged by the electric grid, but by the ICE engine and regenerative braking technologies. The types of vehicles

this report refers to as “electric” are the plug-in hybrid electric vehicle (PHEV), and fully electric vehicle (EV). Plug-in hybrids have a large battery that can be charged with the grid, and also contain an ICE for longer trips. A fully electric vehicle is charged solely from the grid with electricity likely to be stored in a lithium-ion battery – the cost of this battery accounts for most of the cost differential between EVs and ICEs.

Incentives at the federal level are targeted to consumer purchasing behavior, in the form of consumer tax credits. However, at the federal level, the primary incentives for EV charging infrastructure recently expired at the end of 2011. Advocacy groups, including Plug In America are currently advocating for the return of this previous incentive, with modifications for increased credit. In the meantime, state incentives for infrastructure development will become increasingly important.

There are several state-level incentives in Texas that affect the implementation of electric vehicle infrastructure as well as the purchase of electric vehicles at this time including: Alternative Fueling Infrastructure Grants, Clean Vehicle and Infrastructure Grants, Alternative Fuel and Advanced Vehicle Research and Development Grants, Clean Fleet Grants, Clean Vehicle Replacement Vouchers, and State Agency Fleet Acquisition Requirements. In addition to state incentives, various utility and private initiatives are also spurring investment in Texas: Electric Vehicle Supply Equipment (EVSE) Incentive through Coulomb Technologies, EVSE Incentive through ECOtality, EVSE Incentive through Austin Energy, and EVSE Incentive through CPS Energy.

Within this report, a case study was performed with Austin Energy (AE). Initiatives for EV adoption through Austin Energy focus on integrating and effectively providing locations for charging to customers taking advantage of EV technology. The initiatives include Plug in Partners for home charging equipment, the Pecan Street Project, focusing on testing and implementation of clean-energy technologies in the Austin area, and Plug in EVerywhere for a public charging network. This report focuses on AE’s public charging and home charging initiatives. All of the projects discussed above are complementary to each other, and seek to provide early-stage information that has the ability to advance United States’ adoption of electric vehicles and charging infrastructure. The “Plug in Everywhere” initiative with AE is a part of the ChargePoint America program, working to integrate and extend the ultimate range of charging networks between large urban areas.

Electric vehicles and public charging infrastructure are often thought of as two sides of the same coin – without public charging infrastructure, EVs cannot be adopted due to consumer “range anxiety,” and without EVs, charging infrastructure cannot be efficiently implemented. This “chicken or egg” dilemma misunderstands the role that public charging infrastructure is meant to play in the short to medium-term.

Thus, this report finds little merit in the idea that lack of public charging infrastructure limits the adoption of EVs, at least for the type of charging stations currently employed. What currently limits EV and PHEV adoption is primarily high upfront cost compared to conventional vehicles (due largely to battery cost) and the limited range of batteries. While cities and utilities should continue to adopt plans to implement convenient public charging infrastructure for consumers to top off their battery, a better alternative to limit range anxiety is currently the plug-in hybrid electric vehicle (PHEV), which eliminates range anxiety for long trips and provides the advantages of an EV for most commutes.

DISCLAIMER

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CHAPTER 1. INTRODUCTION

Today's debate regarding the United States (U.S.) transportation sector has never been more important. As similar discussions embroil electricity generation, one can see the powerful forces of the status-quo pitted against growing momentum behind alternatives. The electric vehicle (EV) finds itself somewhere in the middle of the debate, as a possible alternative to the conventional vehicle (CV). As demonstrated in this report, electric vehicles are neither new nor technologically infeasible. Current circumstances have initiated what appears to be a revival of the EV – this includes years of high oil prices, geopolitical instability, and growing awareness of environmental concerns resulting from CV usage. Due to these concerns demand has risen for alternatives and governments around the developed world are thinking about ways to curb the use of petroleum, where transportation is often a large user. Among several others, one alternative "fuel" that would diminish environmental damage while curbing use of petroleum is electricity.

Nevertheless, impediments remain. One of the most important is the prospect of building public charging infrastructure to allow drivers to use an EV like their conventional vehicle, for both long and short distances. Public charging infrastructure, however, cannot be built without some critical mass of EVs on the road to use them – otherwise they are not economically feasible. This report analyzes various facets of both EVs and public charging infrastructure to give the reader a clear understanding of the complex criteria that must be understood to assess EVs in the United States. Texas is given special consideration as a case study in this report, particularly the Austin area where public charging infrastructure for EVs is currently being implemented. Through a detailed analysis of electric vehicles and charging infrastructure, as well as the United States transportation system, this report seeks to reach conclusions over the role EVs and public charging infrastructure should play in the future U.S. transportation system. The following sections discuss the history of electric vehicles and the United States transportation sector.

1.1 History of Electric Vehicles

At the turn of the 20th century the automobile began to dominate transportation, with three types of vehicles vying for market share: steam powered engines, internal combustion engines (ICEs) and electric vehicles (EVs). Initially, electric vehicles fared well in comparison to competitors, with a smooth, quiet ride, no tailpipe emissions, and relatively reliable starting compensating for higher expense. In 1904, EVs held about one-third of the market share in New York, Chicago, and Boston (Anderson and Anderson, 2010). One of the other main competitors, the horse-drawn carriage, was prevalent at the time in large cities but residents were increasingly critical of drawbacks such as manure that dirtied streets and was unpleasant for obvious reasons. Further, the ICE's loud, polluting engine seemed to be an unsatisfactory alternative next to the EV's relatively quiet, smog-free ride.

A core market was created for EVs when in 1896 New York City began turning to electrics to replace horse-drawn carriages to be used as taxis (Anderson and Anderson, 2010).The Electric Vehicle Company in New York began producing electric vehicles, called the "Electrobat," and they were, by-and-large, a success. About sixty Electrobats were in service by 1899, by then a second version, the Electrobat II. These vehicles would replace their battery with a fully charged one at designated switching stations every four hours (Anderson and Anderson, 2010). An article in an 1899 Scientific American edition stated that "undoubtedly the most important development in transportation has been the remarkable success of the [electric] automobile carriage in this country….The electric cabs of New York are standing the test of winter work, and, during the recent snowstorms, they ran under conditions which discouraged even [horse] drawn time" (Anderson and Anderson, 2010).

Despite a general acceptance with the public, EVs faced several drawbacks still largely present today, including relatively short range and lack of knowledge over how to maintain the vehicles. Further, "convenient, cost-effective charging stations beyond the major population centers had been an issue from the beginning for electrics" (Anderson and Anderson, 2010). Because of these drawbacks, ICEs became much more attractive in comparison when an electric starter was invented in 1912, replacing a difficult to operate and often dangerous crank starter (Anderson and Anderson, 2010). "With ICEs…easy to start and EVs limited distance per battery charge, the EV was fast becoming a niche market" (Anderson and Anderson, 2010).

The decline that began in 1912 would only be exacerbated in years to come. Anderson and Anderson find, in retrospect, the success of the ICE and corresponding decline of EVs and steam-powered cars were primarily due to four factors:

- Higher quality and quantity of road systems by 1920, encouraging the use of long-range vehicles.
- Large quantities of oil reserves discovered in Texas in 1901.This made gasoline cheap and plentiful and spurred infrastructure in the form of gasoline fuel shops. In contrast, most rural locations were not hooked into the electrical grid and could not provide charging for electric vehicles.
- The development of the electric starter in 1912 for ICEs. The "crank starter" previously used was dangerous and difficult to operate and became instantly obsolete while eliminating one of the primary concerns for ICEs.
- Henry Ford's mass production of ICE-powered vehicles. By 1912, "electric roadsters were selling in the $1,750 to $3,000 range, while a gasoline car built by new the new production processes sold for $650" (Anderson and Anderson, 2010). Cost advantages were amplified by cheap fuel (Anderson and Anderson, 2010).

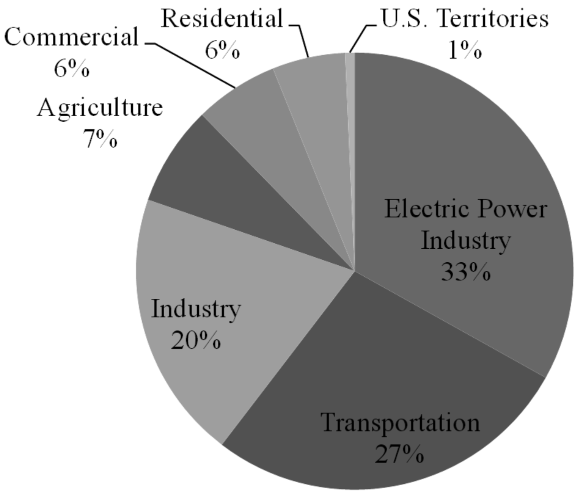
Thus, while electric cars began on an equal footing with the now omnipresent ICE, higher cost (largely due to cost of the vehicle's battery), limited range, lack of charging infrastructure, and cheap fuel for ICEs led to the EV's demise. Though interest in the technology often peaks during time of environmental crisis or high oil prices, it has yet to become a true alternative for the ICE. The following section discusses the United States transportation sector with an emphasis on where EVs may play an important role as this sector evolves in coming years.

CHAPTER 2. UNITED STATES TRANSPORTATION SECTOR

There are several reasons why the transportation system in America needs an overhaul – perhaps a re-invention. Primary concerns include environmental issues at the local and global level and geopolitical considerations due to U.S. reliance on oil, which is priced and traded in a global market. Environmental damage includes contribution to global warming, whereby the United States is currently one the highest carbon dioxide emitters in the world on a per capita basis (UN, 2012). Additionally, local emissions cause health problems and damage to local environments from combustion of fuel in cars and trucks. There are also negative environmental externalities from the drilling and refining of oil, which is primarily used in the U.S. transportation sector. In 2007, 72% of petroleum was used in the transportation sector (OECD, 2009).

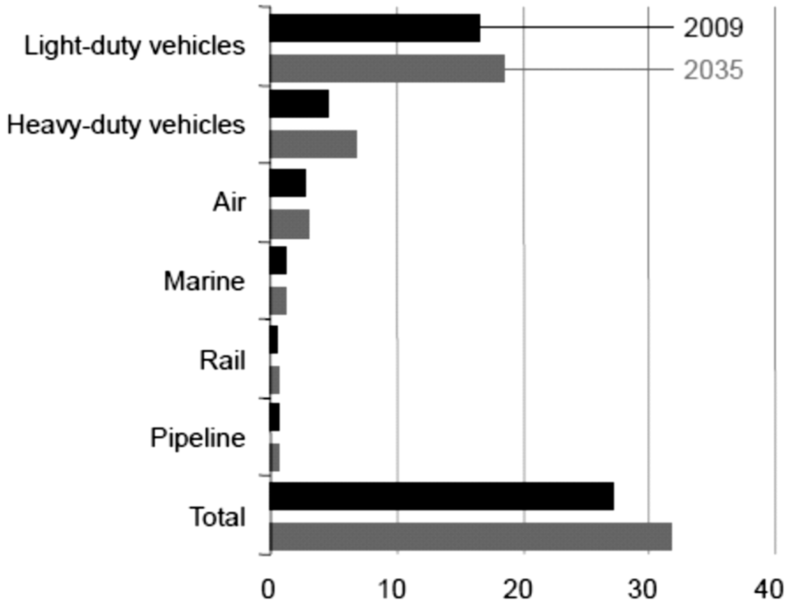
The transportation sector's emissions in the U.S. are primarily in the form of carbon dioxide (95% of the transportation sector's emissions) from combustion of fossil fuels, mainly conventional gasoline (60%) (U.S. DOT, 2010, U.S. EIA, 2009). The transportation sector was responsible for about 27% of U.S. emissions in 2009, the second largest sector behind the production of electricity.

Figure 1. 2009 Greenhouse Gas Emissions by Sector (Source: U.S. EPA, 2011).



Consumption of energy in the transportation sector comes primarily from light-duty vehicles, further emphasizing the impact consumer consumption has on total emissions and the role alternative fuels like electricity for every-day use could play in a re-invention of America's transportation sector:

Figure 2. 2009 Energy Consumption in Transportation by Mode, 2009 and 2035 (quadrillion BTU) (Source: U.S. EIA, 2011).



The figure above also demonstrates higher use of cars for transportation instead of bus, passenger rail, or other forms of public transportation. If the relative share of emissions from these sources of emissions were to increase, overall emissions would likely decrease due to public transportation's more modest emissions on a per-capita basis. Over time, emissions from transportation have flattened in terms of growth: Overall transportation emissions are up 16% from 1990 levels, but down around 5% from 2000 (U.S. EIA, 2011). Between 2009 and 2035, the U.S. Energy Information Administration expects transportation emissions of carbon dioxide to grow annually by .4% (Administration, 2011).

In addition to large emissions of CO2 from the transportation sector, mobile sources in the United States are the largest contributor to "air toxics," at the local level, described as "pollutants known or suspected to cause cancer or other serious health or environmental effects" (U.S. EPA, 2011). While programs to limit air toxics have been instituted by the U.S. Environmental Protection Agency (EPA), such as the removal of lead from gasoline completed in the 1990's,the incomplete combustion of gasoline remains a health issue, especially in urban areas with high concentrations of mobile sources (U.S. EPA, 1994).

Drilling for oil in and around the United States is prone to environmental damage and increasingly sophisticated methods, such as deep-water drilling, pose a high risk for environmental disasters – the oil transported internationally is also quite prone to spills and environmental damage. Between 1996 and 2009, in the Gulf of Mexico alone, there were 79 reported accidents wherein oil flowed uncontrollably from a leak either deep under water or on the surface (U.S. National Commission, 2011). In total off the coast of the U.S., there were 194 spills of fluids (crude oil, refined petroleum, synthetic-based fuels, and chemicals) greater than or equal to 50 barrels between 1996 and 2009 on the Federal Outer Continental Shelf, according to the Regulation and Enforcement Bureau of Ocean Energy Management (BOEM, 2011). The most damaging environmental spill occurred recently on April 20, 2010, where 11 men also died in the accident (U.S National Commission, 2011). This catastrophe has illuminated various holes in U.S. regulation of deep water drilling, as well as safety cultures of individual companies; one hopes that in light of this disaster, regulatory oversight and company cultures' toward safety will improve. Nevertheless, in such dangerous and technically difficult environments, accidents will continue to occur even if every precaution is taken, and oil will continue to cause damage to local eco-systems. Further, drilling for offshore, deep- water oil will become an increasing portion of U.S. domestic production in years to come:

> The area of federal jurisdiction, the outer continental shelf, contains an estimated 85 billion barrels of oil in technically recoverable resources —more than all onshore resources and those in the shallower state waters combined. The future of domestic oil production will rely to a substantial extent on current outer continental shelf sources and further development of deposits there—in progressively deeper, more distant waters, and perhaps in such challenging environs as the Alaskan Arctic (U.S. National Commission, 2011).

2.1 United States Oil Consumption

On a global basis, the U.S. is the largest consumer of oil in the world, consuming around 19 million barrels a day in 2010 (British Petroleum Company, 2011). Given that, until recently, the U.S. produces around 8 million barrels per day, the majority of this oil (just over 11 million barrels a day) is imported (British Petroleum Company, 2011). Figure 3 below demonstrates typical consumption and production of oil of the top 10 oil consuming countries.

Figure 3. 2010 International Consumption and Production of Oil (thousand barrels, daily) (Source: British Petroleum Company, 2011).

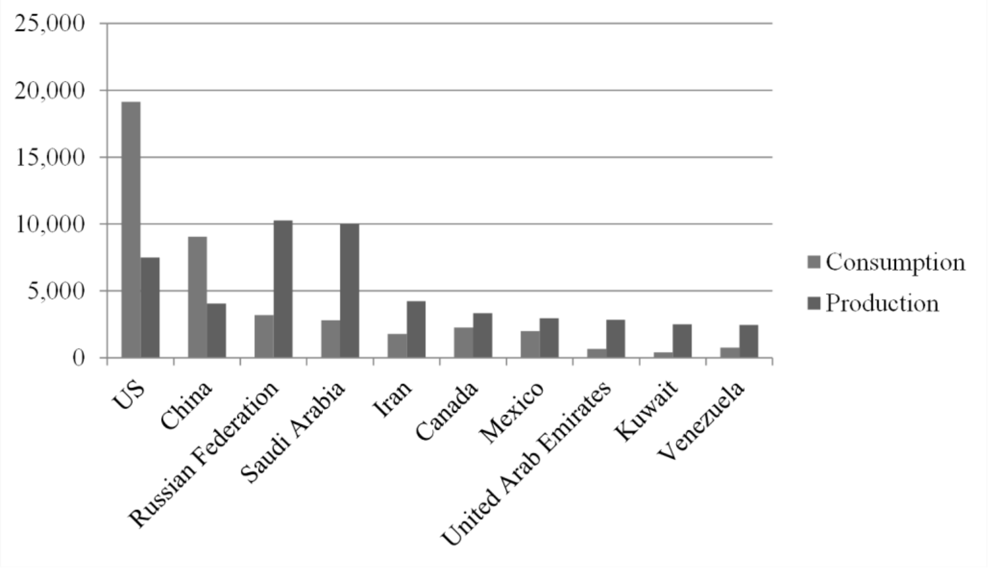
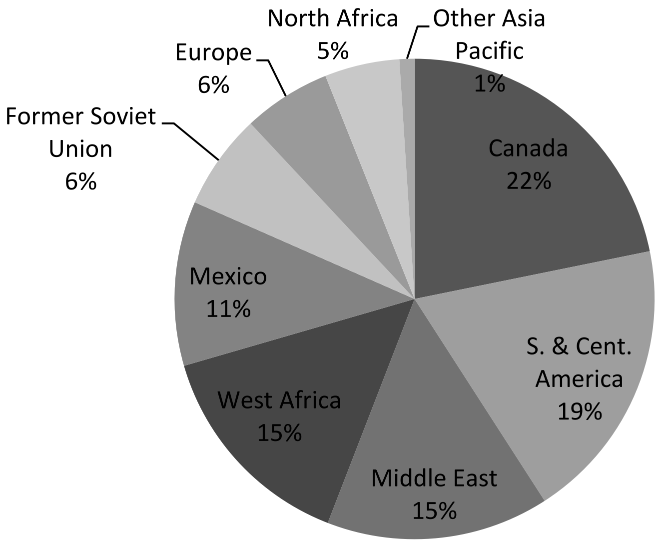


Figure 4. 2010 United States Oil Imports By Country/Region (Source: British Petroleum Company, 2011).



In past years, imported oil has primarily come from Canada, South and Central America, and the Middle East, as seen above. This trend is likely to continue in future years; nevertheless, the year 2011 saw large growth in U.S. domestic production, and the U.S. only imported around 4 billion barrels of oil from abroad (U.S. EIA, 1994). However, given that oil is priced and traded in an international market, whether oil is produced domestically or imported from abroad has little relation to the geopolitical consequences of U.S. consumption of oil. Supply shocks abroad will still affect prices of oil produced domestically. Along these lines, a report by the RAND corporation had the following major findings:

- An abrupt and extended fall in the global oil supply and the resulting higher prices would seriously disrupt U.S. economic activity, no matter how much or how little oil the United States imports.
- Oil-export embargoes have been ineffective in advancing the foreign policy goals of oil exporters.
- Oil-export revenues have enhanced the ability of rogue states, such as Iran and Venezuela, to pursue policies contrary to U.S. interests.
- Terrorist attacks cost so little to perpetrate that attempting to curtail terrorist financing through measures affecting the oil market will not be effective.
- The United States might be able to save an amount equal to between 12 and 15 percent of the fiscal year 2008 U.S. defense budget if all concerns for securing oil from the Persian Gulf were to disappear (RAND, 2009).

The findings show that dependence on oil costs a significant amount of money, and past actions to mitigate this have been ineffective (the report does not mention how many lives have been lost, most likely as motives for action in the Middle East and elsewhere cannot easily be tied to U.S. protection of oil supply). Further, oil revenues fund states and groups that work against the interests of the United States. The last bullet demonstrates an important point in the context of today's political environment, namely the burdensome costs that accrue to protect oil supply, particularly in the Persian Gulf. The report summarizes the links between U.S. oil imports and national security:

Figure 5. Summary of Potential Links between Imported Oil and National Security (Source: RAND, 2009).

Potential Link	Risk or Cost
Economic	
Large disruption in global supplies of oil	Major
Increases in payments by U.S. consumers due to reductions in supply by oil exporters	Major
Political	
Use of energy exports to coerce or influence other countries in ways detrimental to U.S. interests	Minimal
Competition for oil supplies among consuming nations	Minimal
Increased incomes for rogue oil exporters	Moderate
Oil-export revenues that finance small terrorist groups	Minimal
Oil-export revenues that finance Hamas or Hizballah	Moderate
Military	
U.S. budgetary costs of protecting oil from the Persian Gulf	Moderate

Due to these concerns, the RAND report recommends three policy actions, namely to cushion supply disruptions, increase domestic production of oil through exploration of all possible oil discoveries (along with unbiased assessment of environmental costs with corresponding benefits), and to reduce domestic consumption of oil, chiefly through an excise tax on consumption of oil (RAND, 2009). An excise tax on oil would make the use of electricity to fuel vehicles far more cost competitive, in addition to other alternative forms of fuel that do not rely heavily on oil in their production process.

2.2 Oil Alternatives to Fuel Transportation

There are various alternative fuels for transportation, in addition to electricity, each with its own costs and benefits. These are namely biodiesel, compressed natural gas (CNG), ethanol (E85), hydrogen (HY), liquefied natural gas (LNG), and propane (LPG) (U.S. DOE "Alternative", 2011). Biodiesel is "a domestically produced, renewable fuel that can be manufactured from vegetable oils, animal fats, or recycled restaurant grease. It is a cleaner-burning replacement for petroleum diesel fuel. It is nontoxic and biodegradable" (U.S. DOE "Biodiesel"). The most common form is a blend of 20% biodiesel and 80% petroleum diesel, known as B20 (U.S. DOE "Biodiesel"). Ethanol "is a renewable fuel made from various plant materials" (U.S. DOE "Ethanol"). E85 is "a gasoline-ethanol blend containing 51% to 83% ethanol, depending on geography and season" (U.S. DOE "Ethanol"). Most gasoline in the U.S. now contains some amount of ethanol, with 95% of U.S. gasoline currently containing up to 10% ethanol. (U.S. DOE "Ethanol Blends"). The figure below displays the relative maturity of vehicle technologies that could use these alternative fuels.

Figure 6. Developmental Stage of Engine Technologies (Source: Indiana University, 2011).

Technology	***Development Stage***
Internal Combustion Engine Vehicles	Mature
Conventional Hybrid Electric Vehicles	Approaching maturity
Hydrogen Fuel Cell Vehicles	Demonstration phase
E85* Vehicles	Mature, except for cellulosic ethanol
Compressed Natural Gas Vehicles	Early adopter phase
Liquefied Natual Gas Vehicles	Early adopter phase

The costs and benefits of each of these alternatives will not be discussed in this paper. However, a well (better)-functioning market that prices externalities explained above would pick the lowest-cost, most efficient, and most beneficial of these fuels. Pricing externalities in the form of a tax has proven politically unpalatable in the U.S., and in lieu of such market-oriented measures subsidies have been carved out (discussed below for electric charging stations) with limited success for the implementation of a higher percentage of alternative fuels, with the large exception of ethanol.

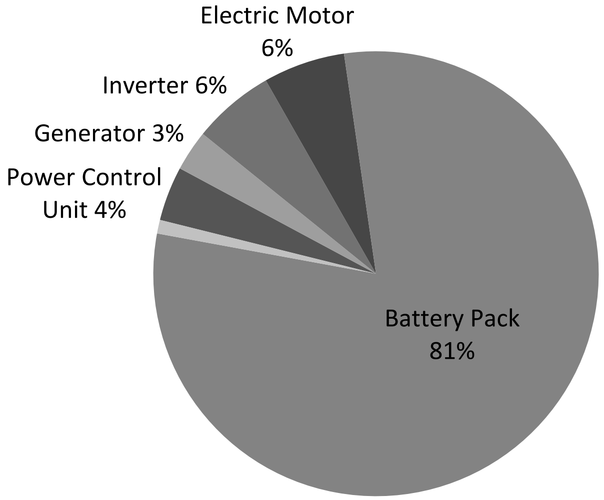
CHAPTER 3. ELECTRIC VEHICLES

There are several forms of electric vehicles, each with varying degrees of "electrification." This report does not consider the traditional "hybrid" vehicle, or "mild hybrid" as an electric vehicle, as these vehicles contain larger-than-normal batteries which operate in conjunction with an ICE engine; they are not charged by the electric grid, but by the ICE engine and regenerative braking technologies. The types of vehicles this report refers to as "electric" are the plug-in hybrid electric vehicle (PHEV), and fully electric vehicle (EV). Plug-in hybrids have a large battery that can be charged with the grid, and also contain an ICE for longer trips. "In the absence of charging infrastructure, this option can combine the benefits of the electric vehicle for city driving with the capability for longer trips" (Boston Consulting Group, 2009). A fully electric vehicle is charged solely from the grid with electricity likely to be stored in a lithium-ion battery – the cost of this battery accounts for most of the cost differential between EVs and ICEs, discussed in the following section.

3.1 Electric Vehicle Costs

The cost of an electric vehicle is considerably higher than traditional vehicles. The majority of incremental cost is due to the battery pack, demonstrated by figure 7 below which shows the percentage of cost by drive component for a PHEV:

Figure 7. Cost of PHEV Drive System, by Component (Source: Cheah and Heywood, 2010).



According to a report out of the University of Indiana, current unit costs of batteries are "$680/kWh for the Tesla Roadster, $500–600/kWh for the Chevrolet Volt, and $375–750/kWh for the Nissan LEAF" (Indiana University, 2011). This represents improvement, but is still above the generally accepted cost goal for batteries, which is $250 per kwh in the medium term (Indiana University, 2011). Much of the cost discrepancy lies with economies of scale that can be achieved with mass production of batteries, wherein "70 percent of cell costs and 75 percent of battery pack costs are volume dependent" (Bonston Consulting Group, 2010). With economies of scale, many experts hope to reach the $250/kwh goal to minimize the cost differential between

EVs and CVs. While Boston Consulting Group sees “substantial challenges” to reaching this goal by 2020, initial cost estimates and reductions sited above seem promising given sufficient demand for electric vehicles and continued policy supports (particularly on the consumer side), along with continued high gasoline prices.

Consumer surveys “suggest that purchasers want to break even on the higher purchase price of electric vehicles in three years” (Boston Consulting Group, 2010). At current prices and even with rebates, the three-year break-even mark is not met. The following compares the Chevrolet Volt, a PHEV, with a traditional vehicle comparison, the Chevrolet Cruze:

Table 1. Annual Gasoline Savings for a PHEV Chevrolet Volt vs. Chevrolet Cruze (Source: Khan and Kockelman, 2011).

	Annual Savings				
Electricity price (ct/kWh)	**Gas Price**				
	$2.50/gallon	**$3.50/gallon**	**$4.50/gallon**	**$5.50/gallon**	**$6.50/gallon**
	Vehicle is driven on average ≤ 15 miles/day, and 4,315 miles/year				
6.0	$252.0	$383.2	$514.0	$645.0	$776.0
11.2	$188.0	$318.6	$449.3	$580.0	$711.0
16.0	$128.0	$258.9	$389.7	$520.0	$651.0
	Vehicle is driven on average between 15 and 30 miles/day, and 8,056 miles/year				
6.0	$252.0	$383.2	$514.0	$645.0	$776.0
11.2	$188.0	$318.6	$449.3	$580.0	$711.0
16.0	$128.0	$258.9	$389.7	$520.0	$651.0
	Vehicle is driven on average more than 30 miles/day, and 14,886 miles/year				
6.0	$252.0	$383.2	$514.0	$645.0	$776.0
11.2	$188.0	$318.6	$449.3	$580.0	$711.0
16.0	$128.0	$258.9	$389.7	$520.0	$651.0

The Chevrolet Cruze gets 28 miles per gallon (mpg) on average, and the Volt 37 mpg when running on gasoline. The Volt was assumed to consume 36kwh per 100 miles of electricity (Khan and Kockelman, 2011).

The average gasoline price for regular conventional fuel across the United States in 2011 was $3.48 per gallon, and the average retail price for electricity to residents in 2010 was 11.4 cents per kwh (U.S. EIA “Electricity”). Thus, someone who drives around 15,000 miles per year saves about $1,000 a year at 2011 price levels from buying a PHEV over a conventional vehicle from substituting electricity for gasoline. Still, given the more than $10,000 price differential (including government-funded rebates) between the two vehicles, this implies a more than ten year payback period at 2011 price levels (not taking into account time value of money) (Kockelman, 2011).

However, as with many new technologies battery costs are expected to decrease with economies of scale through mass-production. A break-even point of one to five years is possible by 2020, given the continuation of government consumer incentives at current levels and relatively high gas prices (at least $100 per barrel) through 2020 (Boston Consulting Group, 2010).

3.2 Electric Vehicle Emissions

Emissions due to electric vehicles are often disputed, given the complexity of electricity modeling and the variation in country and inter-country energy production mixes:

> There has been some confusion about the degree to which electric vehicles actually reduce CO2 emissions. The answer is more complex than for other technologies. Although the electric systems in these vehicles don't themselves emit CO2, the generation of the electricity that charges their batteries does. An analysis of the worldwide power-generation market shows that, for example, in China and India, the substitution of electric vehicles for ICE vehicles would hardly reduce CO2 emissions, either today or in 2020.
>
> On the other hand, in Europe, where the power generation mix is much cleaner, thanks to the use of renewable and nuclear energy, an electric vehicle generates 55 to 60 percent less in CO2 emissions than conventional ICE car. In the next decade, CO2 emissions from electricity generation will be reduced even further as a higher percentage of electricity is generated from renewable generation capacity…and as new technologies…come into increasing use [technologies which limit the output of CO2] (Boston Consulting Group, 2009).

The analogies to China and India above can be to some extent extended to the U.S., where some regions are relatively 'cleaner' and other parts 'dirtier.' An EV's emissions in one part of the country are not equal to emissions in another, and fluctuate based on time of day and type of generation.

The Electric Power Research Institute (EPRI) and National Resource Defense Council (NRDC) examined the effects across the U.S. of varying scenarios of carbon intensity and PHEV fleet penetration. The results are profound in that they show that across the United States, greenhouse gases (GHG's) would be reduced even in the scenario of high GHG intensity electricity generation:

Figure 8. Cumulative 2010 – 2050 GHG reductions from PHEVs (billion tons GHG) (Source: Electric Power Research Institute, 2007).

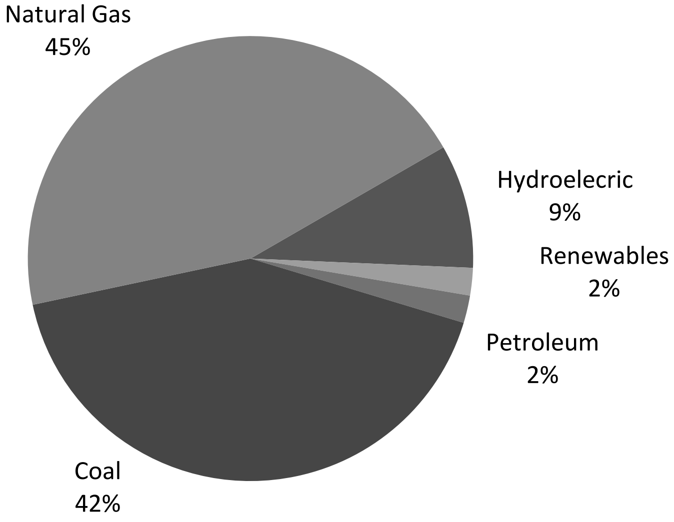
2010-2050 Total GHG Reduction (billion metric tons)		Electric Sector CO_2 Intensity		
		High	**Medium**	**Low**
PHEV Fleet Penetration	**Low**	3.4	3.4	3.4
	Medium	7.9	8.9	8.0
	High	9.8	10.1	10.3

Part of the reduction in GHG's also occur because PHEVs use gasoline more efficiently than electric vehicles. However, much of the emissions benefits come from using electricity instead of conventional gasoline: "The three electric sector carbon emission scenarios assumed in this study each would result in an electric sector that will deliver marginal electricity to PHEVs at a low enough carbon intensity to achieve significant reductions from scenarios where gasoline or diesel fuel is used instead of electricity to provide energy for VMT [vehicle miles traveled]" (Electric Power Research Institute, 2007).

It behooves each area of the country to conduct its own analysis on the effect of PHEVs or EVs on emissions, but overall a nationwide system of vehicles charged by electricity would improve the emissions characteristics of light-duty transportation. One factor that has a significant effect on EV or PHEV emissions is how and when the car charges. In the study above, the majority of car charging (74%) was assumed to occur at off-peak times (10:00pm to 6:00am) (Electric Power Research Institute, 2007). This assumption has implications not only for emissions, but also for capacity constraints that may occur with large influxes of EVs and PHEVs, as well as the cost of charging: charging during periods of high demand is more costly.

In another study of the Xcel Energy service territory in Colorado, different charging scenarios were modeled for PHEVs that could travel 20 miles on electricity and the effect on emissions for each scenario was ascertained (Parks *et al.,* 2007). It is important to note that the energy mix at the time of the study in the Colorado area was overall more fossil-fuel heavy than the U.S. as a whole:

Figure 9. Generation Capacity in Colorado by Fuel Type (Source: Parks *et al.*, 2007).



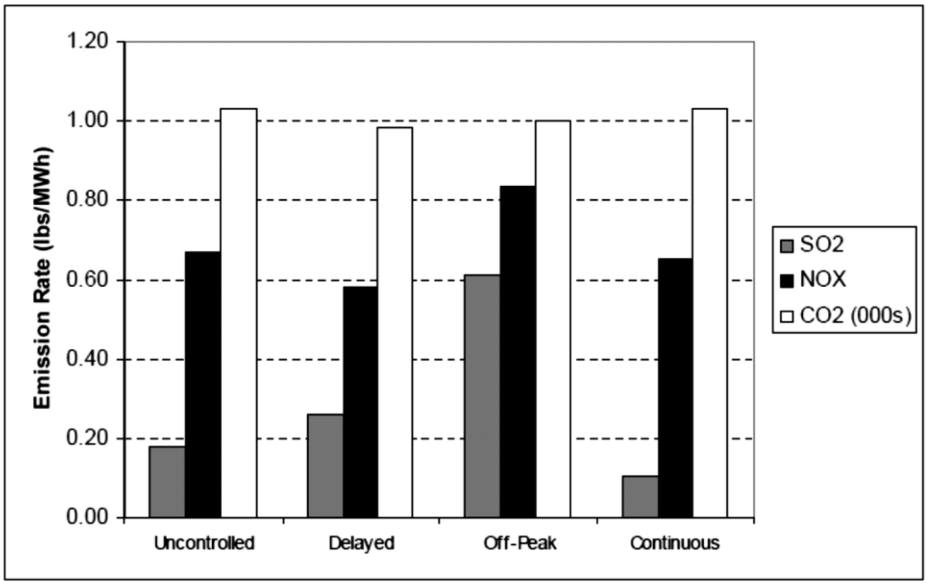
The actual generation of electricity tends to be even more coal-based than the preceding figure displays (71%). This is likely due to the fact that natural gas power plants are utilized more heavily during periods of high demand (as marginal power peaking plants), with coal power generally cheaper on a variable cost basis and utilized for relatively higher output of electricity.

The study identified four types of charging which may occur and modeled each scenario:

- *Case 1, Uncontrolled Charging:* This is a "simple" case, where vehicles are charged immediately when they are plugged in at home – there is no control either by the owner or utility to utilize cheaper, off-peak electricity. This scenario implies a "business-as-usual" case for infrastructure whereby all charging occurs at the home.
- *Case 2, Delayed Charging:* In this case, all charging also occurs at home, but differs from case 1 in that charging utilizes off-peak electricity (beginning at 10p.m.). This case was considered "most likely" considering the modest investment in infrastructure a utility would need to make (a timer) and the benefits from the utility perspective it would receive.
- *Case 3, Off-Peak Charging:* Case 3 is similar to case 2, in that charging occurs at off-peak hours. However, this case gives more control to the utility to match periods of low-demand and low prices through utility control of charging. "Indirect control" in which a vehicle was automatically matched with periods of low prices would have the same result. This matching achieves maximum economies for the utility.
- *Case 4, Continuous Charging:* Similar to case 1, charging cannot be controlled in this scenario but vehicles are assumed to be charged whenever they are parked through public charging infrastructure. "The advantage of this scenario is that it maximizes electric operation, and minimizes both petroleum use and vehicle emissions" (Parks *et al.,* 2007).

The following results were obtained in comparing the four scenarios:

Figure 10. Comparison of Emissions from Four Charging Scenarios of PHEVs (Source: Parks *et al.,* 2007).



SO2 and NOX emissions were greatest when charging occurred at off-peak times due to the heavier utilization of coal during these periods. The graphic emphasizes how types of charging schemes in an area affect emissions.

The following figures demonstrate the studies' findings on emissions when compared to conventional vehicles (26mpg) and hybrid electric vehicles (36mpg). When running on gasoline PHEVs were assumed to have mile per gallon efficiency of 37mpg (Parks *et al.,* 2007).

Figure 11. Annual NOX Emissions Rate Comparison by Vehicle and Charging Scenario (Source: Parks *et al.,* 2007).

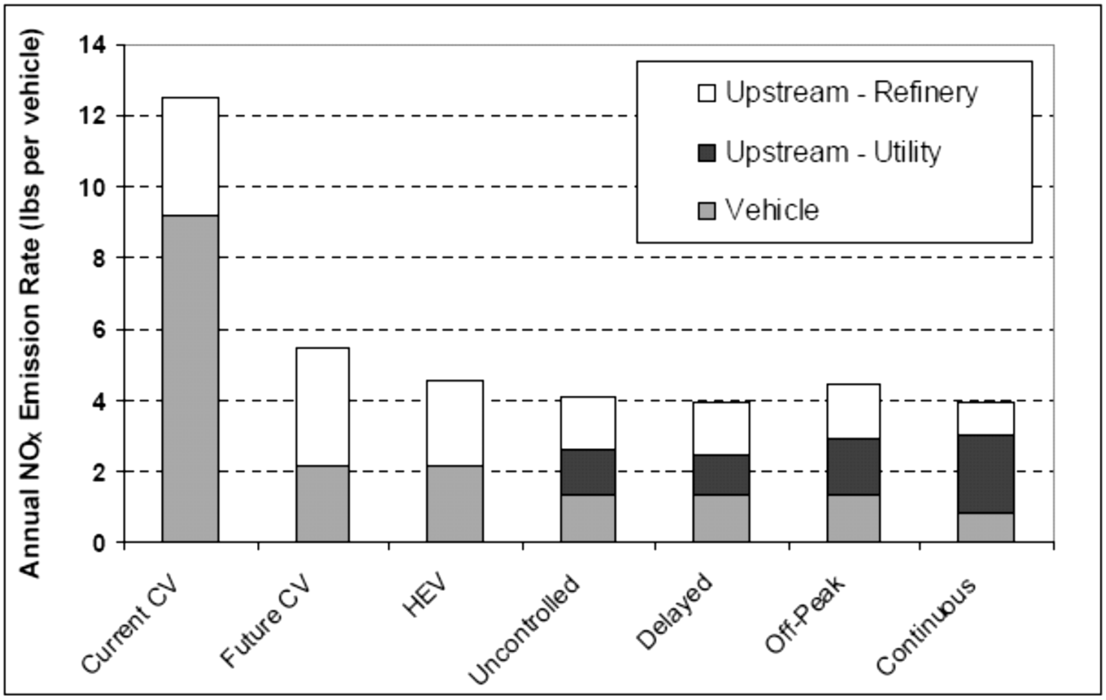


Figure 12. Annual SO2 Emissions Rate by Vehicle and Charging Scenario (Source: Parks *et al.,* 2007).

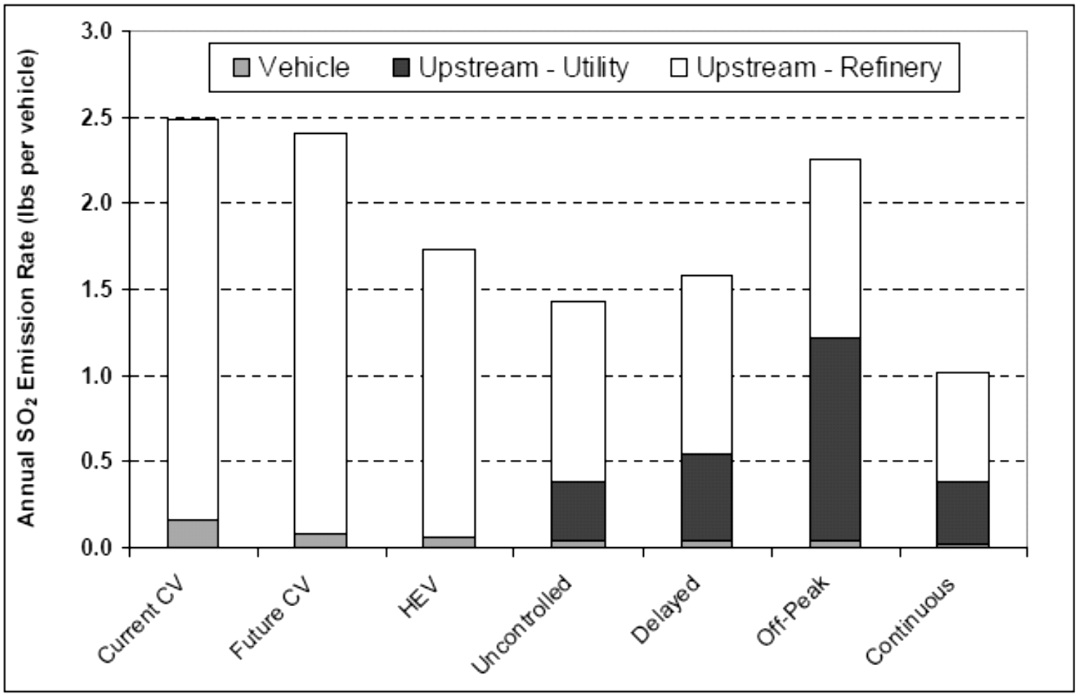
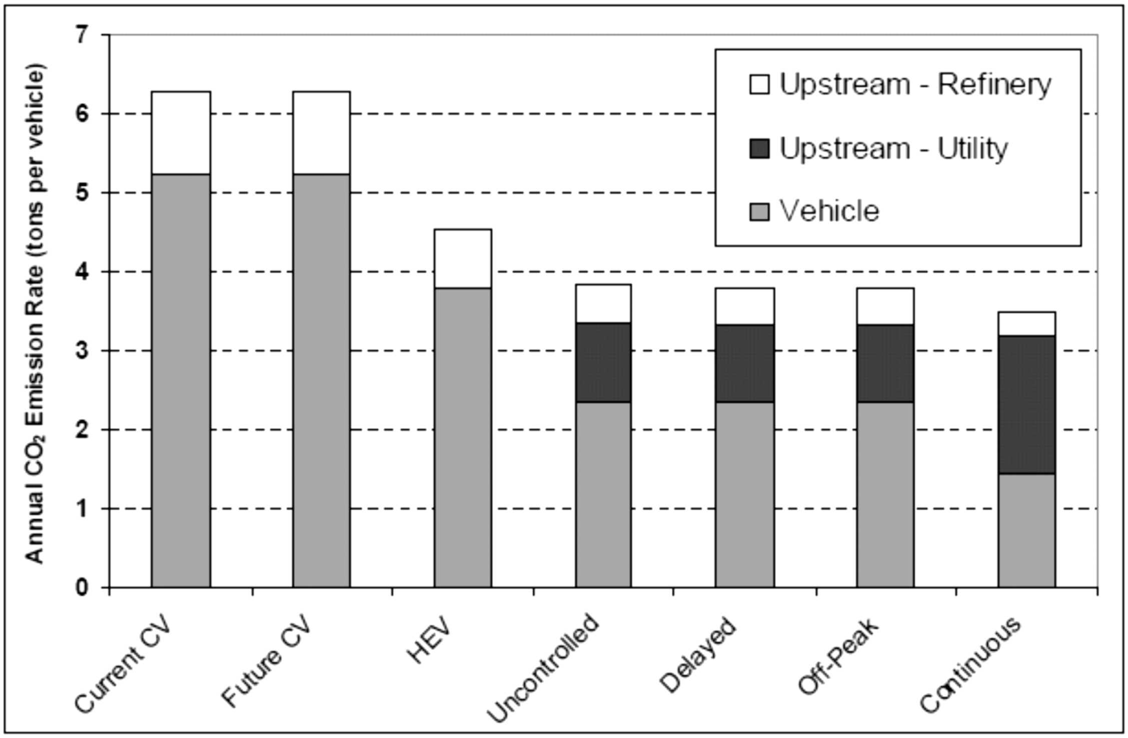


Figure 13. Annual CO2 Emissions Rate by Vehicle and Charging Scenario (Source: Parks *et al.,* 2007).



This study further supports the conclusions of the EPRI study discussed previously, in that even with carbon-intensive generation of electricity, major emissions reductions, particularly of CO2, are achieved through the use of electric vehicles. The only case in which this was not true was emissions of SO2, particularly in the case of off-peak charging (due to the higher use of coal plants at this time). However, the nation's cap and trade program on SO2 would come into effect, causing no net increase in SO2 nationally. "As a result, any increase in SO2 emissions resulting from additional load created by PHEV charging must be offset by a decrease in emissions elsewhere" (Parks *et al.,* 2007).

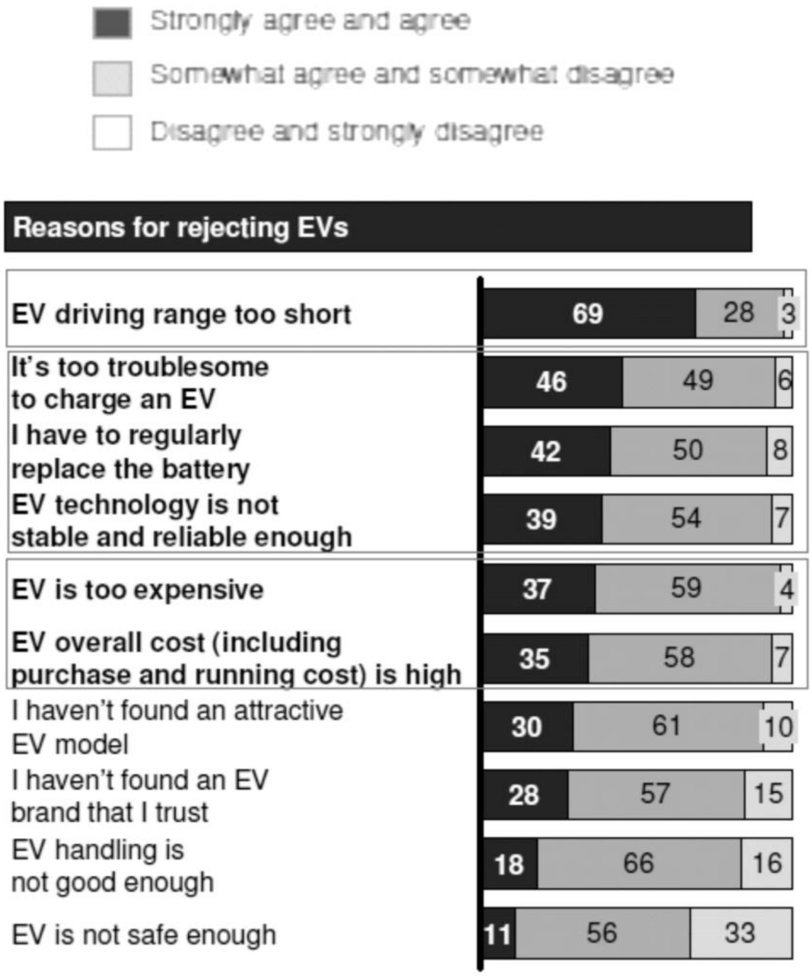
Important implications were also derived from this study with regard to potential capacity constraints imposed by the influx of electric vehicles on the electricity grid, as well as cost. If uncontrolled charging is used, the study found there would be increased pressure on marginal peaking units during times of high demand. However, "[n]o additional capacity would be required for even a massive penetration of PHEV if even modest attempts were made to optimize system charging" (Parks *et al.,* 2007).

In terms of cost, the study found that in the near-term, much of the charging for PHEVs would come from natural gas units – therefore, the price of charging would fluctuate with the price of natural gas. "This translates to an equivalent production cost of gasoline of about 60 cents to 90 cents per gallon" (Parks *et al.,* 2007).

3.3 Electric Vehicles and Consumer Behavior

What ultimately will drive purchases of electric vehicles, and thus the need for charging infrastructure, are consumer purchasing decisions. Mckinsey conducted a study to understand consumer perceptions and decision-making with regard to electric vehicles, and found that concerns about range, battery charging, and reliability were the largest reasons consumers would reject an EV:

Figure 14. Consumer Perceptions and Electric Vehicle Purchasing Decisions (Source: McKinsey & Company, 2010).



The findings highlight the importance the EV's limited range plays in consumer purchases, often referred to as "range anxiety." Mckinsey (2010) concludes that "in the long term, public charging will be needed to make EVs attractive for consumers that do not have private parking (i.e., charging facilities)." For most drivers, electric vehicles will have sufficient range without charging, as "half of all drivers log 25 miles or less [per day]" (Electric Power Research Institute, 2011). Current vehicles on the market, the Chevy Volt (a PHEV) and the Nissan Leaf (all-electric vehicle), would easily cover most daily trips without a charge (and without using gasoline for the Volt), given that their batteries support around 35 mile and 73 mile trips, respectively (Electric Power Research Institute, 2011). PHEVs like the Chevy Volt eliminate “range anxiety” by also having a traditional ICE gas-powered engine for longer trips.

CHAPTER 4. OVERVIEW OF ELECTRIC VEHICLE CHARGING STATIONS

4.1 Electric Vehicle Charging Stations

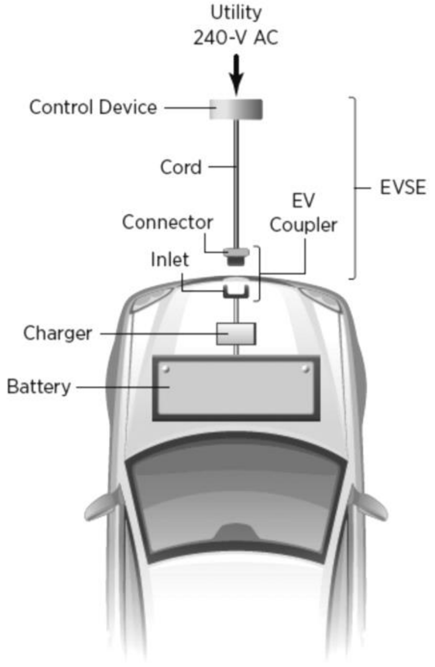
The stations that will need to be built to charge electric vehicles are a critical component of introducing electric vehicles to the United States market. Essentially, there are three places where charging may take place – at home, at the office, and through public infrastructure, which can include all public spaces as well as convenience stores and restaurants. There are three categories of charging, delineated by the amount of electricity and speed by which the car can be charged.

Figure 15. Types of Charging for Electric Vehicles (source: Indiana University, 2011).

Level	*Volts/Amps*	*Electricity Delivered*	*Time to Charge 24kWh Battery to 80%*	*Available for At Home Charging?*
Level 1	120/15	-1.8 kW	20 hours	Yes
Level 2	240/80	Up to 19.2 kW	7 hours	Yes
DC-DC	480	50kW	30 minutes	No

While a level 2 charger adds about 10 to 20 miles of range in an hour of charging, DC fast chargers can add 60 to 80 miles in 20 minutes, but are much more expensive as seen below and require more electricity flow for use. There is also no standard connector for the DC fast charging system, as there is for level 1 and 2 charging (SAE J1772) (NREL, 2011).

Figure 16. Level 2 Charging Diagram (source: NREL, 2011).



4.2 Barriers to Adoption

For public infrastructure to be adopted, there are several barriers that must be overcome. The primary reason for public infrastructure is to allay range anxiety and give EV owners an alternative to the home and office to charge their vehicle. These chargers would need to be faster than the "slow" charging described above, and require cooperation with the local utility and government to be built, as well as non-public sites such as retail to locate charging stations. As identified by a Harvard Kennedy School of Government report, there are several types of barriers to public charging infrastructure.

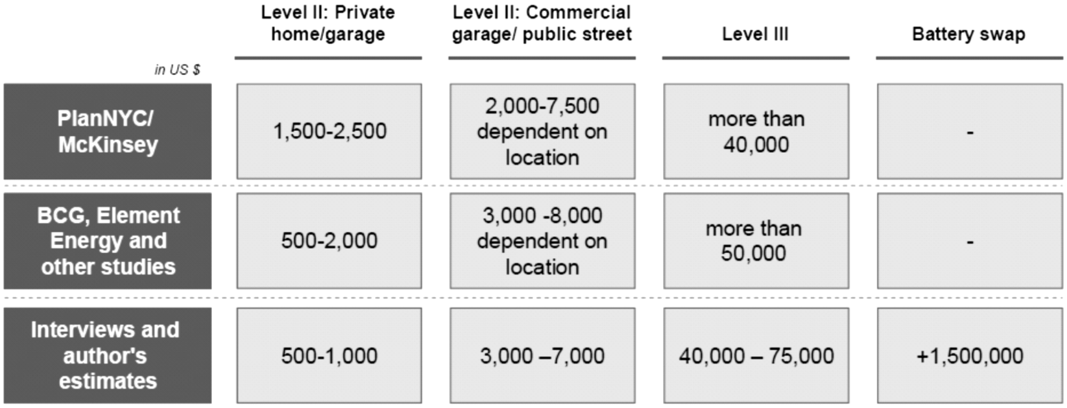
4.2.1 Regulatory Barriers

The Harvard report identifies the lack of standardization for charging infrastructure, particularly connectors and types of charging as a barrier. This is likely not a concern any longer for level 1 and 2 charging stations. Additional regulatory impediments include uncertainty over the sale of electricity due to how various locales will regulate the sale of electricity for electric vehicle charging infrastructure, the extent to which government (or regulated utilities) will invest in public infrastructure which would make the business case more difficult for private entities, and uncertainty over the permitting process for homes and public charging infrastructure.

4.2.2 Economic Barriers

Economic barriers to charging infrastructure primarily surround the uncertainty of how many vehicles will use the infrastructure, and can thus be charged for it. This is linked to consumer behavior and adaptation of EVs, also examined in this paper. For a single charging outlet, the following cost estimates were summarized by the report from Harvard:

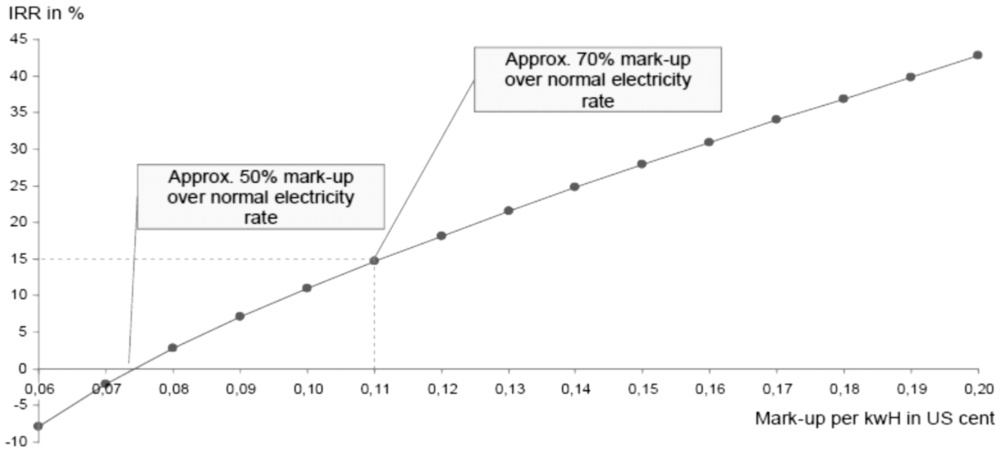
Figure 17. Cost Summary for EV Charging Infrastructure (in U.S. $) (source: Wiederer and Philip, 2010).



in US $	Level II: Private home/garage	Level II: Commercial garage/ public street	Level III	Battery swap
PlanNYC/ McKinsey	1,500-2,500	2,000-7,500 dependent on location	more than 40,000	-
BCG, Element Energy and other studies	500-2,000	3,000 -8,000 dependent on location	more than 50,000	-
Interviews and author's estimates	500-1,000	3,000 –7,000	40,000 – 75,000	+1,500,000

The economic feasibility of building these stations vary by use and business model. Business models for EV charging stations are discussed in a subsequent section of this report. The business case also depends on the life-span of the station, which is uncertain at this time given that most charging stations are close to brand-new, as well as maintenance and operation costs, estimated to be around 10% annually of original installation costs (Wiederer and Philip, 2010). Another "cost" is the required profitability margin for a private entity to enter the market and build public charging infrastructure (Wiederer and Philip, 2010). This cost would be over and above what an EV owner would pay for a home charge.

Figure 18. Estimated Mark-Up for EV Charging Stations (Level 2 (source: (Wiederer and Philip, 2010).**)**



The preceding figure shows that the owner of a public charging station would need to mark up electricity prices by at least 50% to break even. The figure also shows that even a 70% mark-up results in a relatively modest price increase for the consumer, about 11 cents per kwh (in addition to the base price). Level 3 charging, however, is much costlier, with at least a 125% mark-up over standard electricity prices to break even (Wiederer and Philip, 2010).

4.2.3 Technology Barriers

The technology to charge electric vehicles is known and commercially tested and does not form a significant barrier at this time. Most of the technological uncertainty with regard to charging lies in "smart grid" technologies, which allow the utility to charge the car at different times with varying rates of control. Smart grid technology that could most benefit utilities and rate-payers would be the ability to use EVs as a form of electricity storage, which "would require bi-directional flow of electricity through charging equipment" (Wiederer and Philip, 2010). The large-scale application of this type of technology is still many years away, and concerns over the deteriorating effects of frequent charging and discharging on an EV battery, as well as the possibility of incorrect frequencies from EV batteries to the grid, are not yet fully solved (Wiederer and Philip, 2010). The application of these smart-charging functionalities would provide utilities additional opportunities to maximize benefits from electricity in EV batteries to minimize cost and maximize efficiency. Research and development of better and more sophisticated technology for grid management must continue to be invested in for large-scale integration in the future.

4.3 Business Models for Charging Infrastructure

One business model which would supplement EV charging infrastructure is to switch-out batteries when they are low with freshly charged ones. In an electric transportation system with switchable batteries, network operators offer electric car drivers pay-per-mile service contracts that finance the cost of the battery, the charging infrastructure, and the charging electricity. The vehicles, developed and sold by existing manufacturers, will have removable, rechargeable batteries with a range of approximately 100 miles. Network operators will install home and office-based charging stations as well as charge spots in public locations to allow customers to recharge their batteries between short trips and commutes. In order to extend electric vehicles range to exceed the 100 mile battery range, the system will rely on the demonstrated technology known as battery switching stations. By installing these switching stations along highways, the overall range of electric cars will eventually rival that of gasoline powered vehicles. An electric transportation system centered on a network operator business model offers drivers an attractive value proposition while also overcoming the range and convenience shortcomings of previous iterations of electric cars (Becker and Sidhu, 2009).

According to a University of California report, this model would mitigate the upfront costs of the batteries (essentially making the price of an EV the same as a conventional vehicle at time of purchase), and allow car companies to outsource battery manufacturing (Becker and Sidhu, 2009). However, this business model, embodied by a company called Better Place (Better Place), has been met with some skepticism. The Harvard report finds “strong evidence that battery exchange is unlikely to become widespread within the mass market – if it materializes at all it will most probably be a niche application for fleets” (Wiederer and Philip, 2010). The report attributes its assessment to high costs (between $1 million and $1.5 million), the fact that the concept requires more than one battery to be made per car, the inability of such a system to adapt to improvements in battery technology quickly, and the assessment that “OEMs seem to see battery performance to be a factor they can potentially compete on;” this competition would be eliminated under such a coordinated system (Wiederer and Philip, 2010).

In addition to switchable batteries, there are now several companies that offer EV charging stations (the focus of this report), the early-stage implementation of which are supported by the Department of Energy (Chambers, 2010 and ECOtality, 2012). There are essentially two types of business models that will support the purchase of EV charging infrastructure:

- *Pay Per Use Model:* Users may be charged in accordance to how many kilowatt-hours they use at a station, or once per use, marked up to make the station profitable over a period of time.
- *Subscription-based Model:* Users are charged a subscription fee, which can be a flat fee or monthly charge in addition to nominal charges for usage of a station.

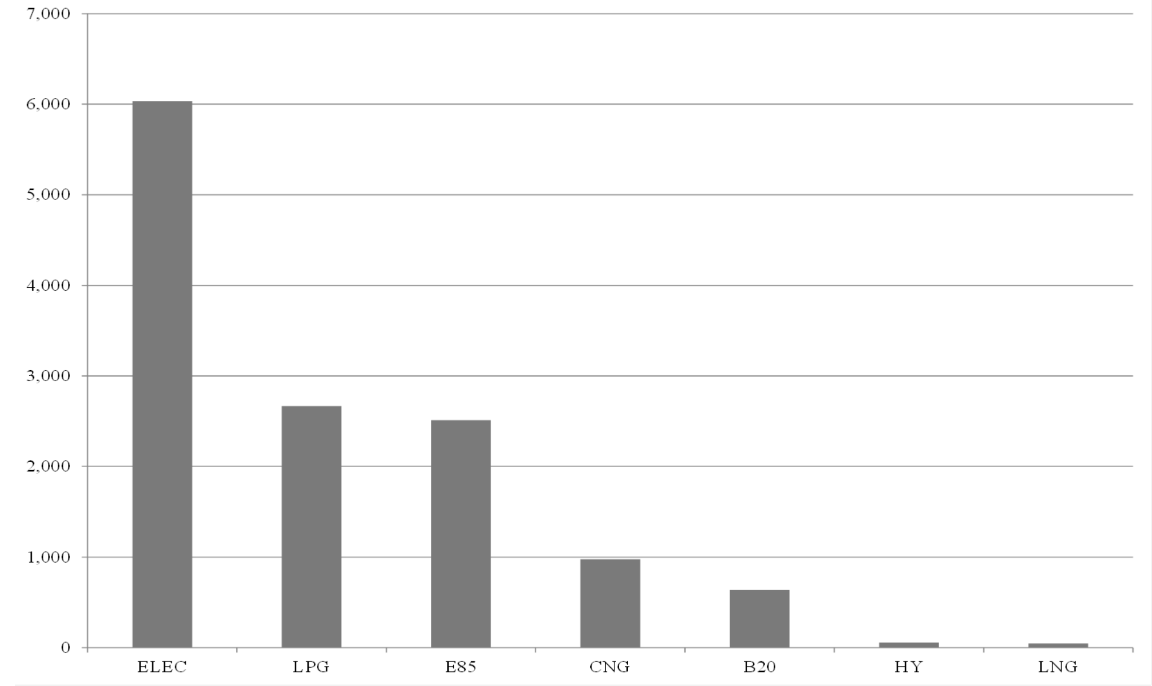
For instance, the ChargePoint network (Coulomb technologies), which builds EV infrastructure across several states, sells its charging infrastructure to an owner (i.e. Walgreens), and then the owner of the station charges the users’ ChargePoint access card for each use of one of their station. Each station may be different, and some are listed as "free" at this time most likely as a trial period for this new technology (ChargePoint, "Find Charging Stations). This appears very similar to how traditional gasoline stations work – one can imagine that if prices are transparent across stations, there will be a convergence of price in the long-run that reflects the underlying price of electricity, plus a standard mark-up.

The "eVgo" network, operated by a subsidiary of NRG Energy, offers several subscription plans, and is "one of the first private companies to invest significant capital in PEV deployment without public subsidy" (Nigro, 2011). For the $89 per month "unlimited plan," a subscriber receives installation of the home charging dock, a three-year service agreement, unlimited charging at eVgo's stations, and unlimited charging at home "with no additional electricity cost during non-peak hours." The most basic plan is $49 per month, where the subscriber receives installation of a home charge, pays for his charging via the normal utility bill, and the plan does not include use of the public network of charging stations. According to the Wall Street Journal, "experts say subscription plans offering flat monthly rates, like those of cellphone providers, are the model that is likely to prevail" (Ramsey, 2011).

4.4 Electric Vehicle Charging Stations in the United States

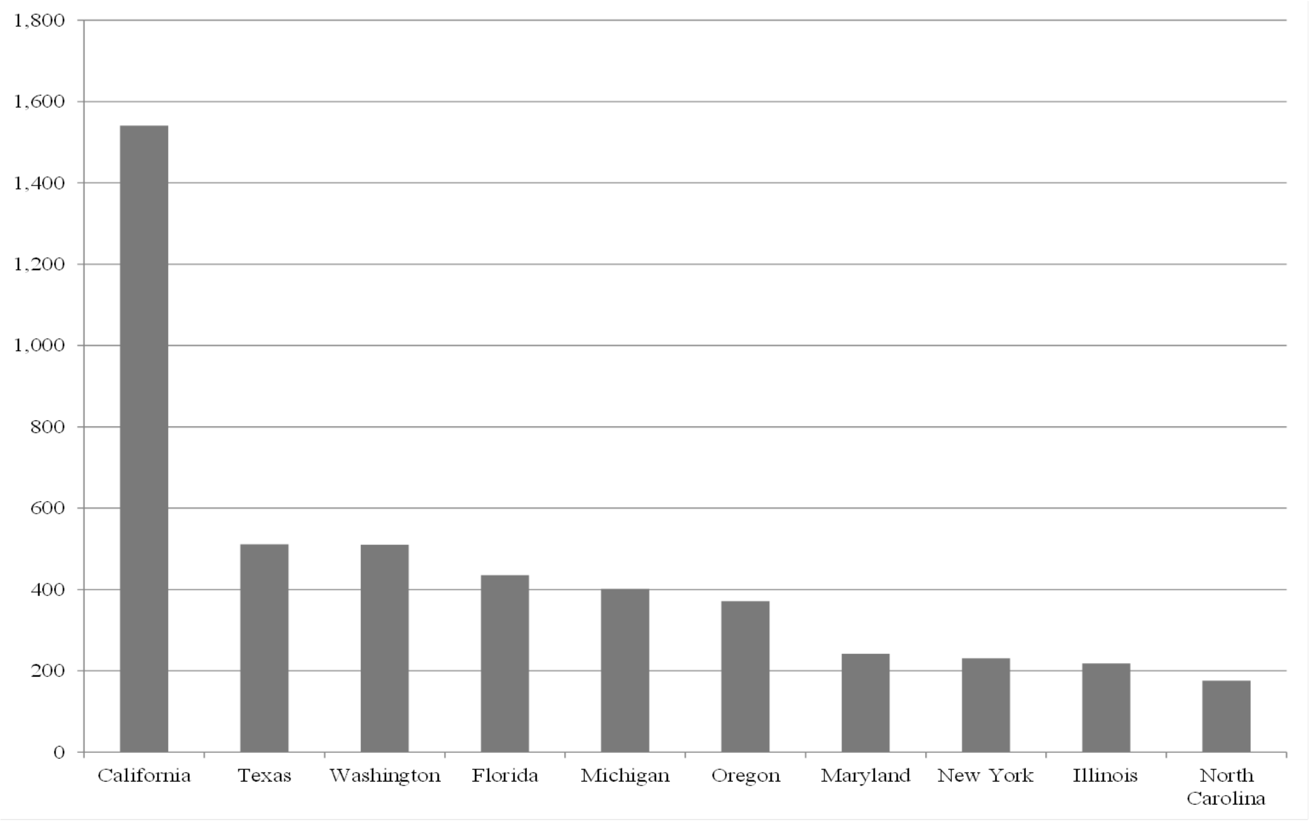
The United States government and private investors have begun investing in alternative fuels, described above. Each is governed by its own policy incentives and financial criteria. In terms of infrastructure for the fuels, there are more electric vehicle charging stations than other alternative fuel infrastructure thus far in the United States, with 6,033 charging stations as of the end of January, 2012 (this does not include private charging stations at residences):

Figure 19. Alternative Fueling Station Count, As of January 31, 2012(U.S. DOE, "Alternative").



This is quite small overall compared to the amount of gasoline stations in the U.S., over 100,000 (U.S. DOE, "Number of Gasoline Stations"). When examining electric vehicle charging infrastructure on a state basis, California leads the way with around 25% of the infrastructure or 1,541 charging stations, followed by Texas with less than half this number, 511, as of the end of January 2012.

Figure 20. Electric Vehicle Charging Stations by State, As of January 31, 2012 (U.S. DOT, "Alternative Fueling Station Total Counts"). Electric charging units, or EVSE, are counted once for each outlet available and does not include residential electric charging infrastructure.



CHAPTER 5. PUBLIC POLICY ENVIRONMENT – ELECTRIC VEHICLES AND CHARGING INFRASTRUCTURE

At the federal level, the primary incentives for EV charging infrastructure recently expired at the end of 2011. This was in the form of an alternative fuel infrastructure tax credit, which comprised, in addition to hydrogen tax credit, provisions for:

> …equipment for natural gas, liquefied petroleum gas (propane), electricity, E85, or diesel fuel blends containing a minimum of 20% biodiesel installed through December 31, 2011, is eligible for a tax credit of 30% of the cost, not to exceed $30,000. Consumers who purchase qualified residential fueling equipment prior to December 31, 2011, may receive a tax credit of up to $1,000 (U.S. DOE, "Federal & State Incentives").

Advocacy groups, including Plug In America are "working to renew and raise this important tax credit" (Plug In America). In the meantime, state incentives for infrastructure development will become increasingly important.

Other incentives at the federal level are targeted to consumer purchasing behavior, in the form of consumer tax credits. For instance, tax credits have been issued for the purchase of plug-in electric vehicles meeting certain specifications:

> The minimum credit amount is $2,500, and the credit may be up to $7,500, based on each vehicle's traction battery capacity and the gross vehicle weight rating. The credit will begin to be phased out for each manufacturer in the second quarter following the calendar quarter in which a minimum of 200,000 qualified plug-in electric drive vehicles have been sold by that manufacturer for use in the United States (U.S. DOE, "Federal & State Incetives").

This incentive was put in place with the passing of the American Recovery and Reinvestment Act of 2009 (Plug In America). Other incentives which may directly or indirectly affect electric vehicles are advanced energy research projects grants, energy technology loans, and federal and state fleet acquisition of alternative fuel vehicles and use of alternative fuels.

5.1 State and Local Policies Regarding Electric Vehicles

Many states have also introduced policy instruments to promote the use of electric vehicles. These have primarily come in the form of consumer incentives to buy electric vehicles, in the form of rebates, income tax credits, or a sales tax exemption (Indiana University, 2011).

California, Colorado, Georgia, Illinois, Louisiana, Maryland, New Jersey, Oregon, Oklahoma, South Carolina, Utah, and Washington have incentives that range from a $750 income tax credit (Utah) to a rebate of up to $20,000 for commercial PEVs (California). Recently, Tennessee also announced a rebate of $2,500 on the first 1,000 PEVs (plug-in electric vehicles) sold in the state. New Jersey and Washington offer state sales tax exemptions for BEVs (battery electric vehicles), a policy that DOE models suggest is quite effective at stimulating sales of vehicles. Washington offers PHEVs a more modest exemption from its 0.3% motor vehicle tax (Indiana University, 2011).

Other states have offered incentives for batteries or manufacturing of EVs in their states. Indiana, Michigan, Louisiana, New Mexico, Oklahoma, South Carolina, and Pennsylvania, have implemented property tax exemptions, tax credits for the purchase of equipment, and specific tax credits linked to the quantity and volume of batteries produced. States have also given credits for the installation of home recharging stations (Indiana University, 2011).

In addition, states have attempted to mitigate some inconveniences of buying an EV. Arizona has lessened prices for some PHEVs, and Florida exempts EV owners from many additional insurance charges. One interesting development that could provide additional incentives to consumers is the use of high occupancy vehicle (HOV) lanes for single drivers of EVs: Virginia, Maryland, and California (among others) have adopted this policy. Also, states have supported local governments with grants and loans for various activities including municipal fleet purchases, installation of recharging infrastructure, and others (Indiana University, 2011).

According to a report by Senetech, Inc. for the Department of Energy, initial vehicle cost is currently the "most significant market barrier for PHEVs (Senetech, 2010)." The Senetech report finds that "incentives that greatly reduce the incremental vehicle cost between PHEVs and HEVs appear to have a strong impact." Further, state sales tax exemptions, if extended through 2020 would have the greatest impact on PHEV sales compared to other policies:

Figure 21. Incremental Sales and Investment of Various Public Policies if Extended through 2020 (Senetech, 2010).

Incremental Values through 2020	Totale Federal Invesement above CPC (in millions)	Total PHEV Sales Above CPC	Cost to Achieve Incremental Sales (per PHEV sold)
Current Policy Case (CPC)			
CPC + Additional Vehicle Subsidies	$200	$3,425	$58,400
CPC + PHEV Federal Fleet Mandates	$260	$88,750	$2,900
CPC + Increased Chargint Infra. - City and Suburb	$1,600	$370,650	$4,300
CPC + Federall-Backed Battery Warranety	$0 - $60,000	$392,525	$0 - $15,000
CPC + Plug-in Vehicle Tax Credit Extension	$18,000	$6,011,175	$3,000
CPC + Annual Operating Cost Allowance - $150	$9,000	$3,225,125	$2,800
CPC + 'Progressive Feebate' Option - All Vehicles	-	$1,475,275	-
CPC + State Sales Tax Exemption	$18,000	$10,340,425	$1,750

It is important to note that while the state sales tax exemption was the most powerful element of public policy in the study to spur adoption, it was also one of the most expensive, $18 billion over 10 years if extended through 2020.

The following section examines the policies of Texas, specifically, to give the reader an in-depth examination of one state and to support the case study found at the end of this report on Austin Energy's initiatives regarding electric vehicles and charging infrastructure.

5.2 Texas Policy Regarding Electric Vehicles

There are several state-level incentives in Texas that affect the implementation of electric vehicle infrastructure as well as the purchase of electric vehicles at this time:

- *Alternative Fueling Infrastructure Grants:* These grants, administered by the Texas Commission on Environmental Quality (TCEQ), provides grants for 50% of eligible costs up to $500,000 for the construction, reconstruction, or acquisition to store, compress, or dispense alternative fuels in Texas air quality nonattainment areas. Alternative fuels include electricity and several other forms listed above. The program is scheduled to expire in August, 2018.
- *Clean Vehicle and Infrastructure Grants:* Administered by TCEQ, this legislation provides grants for multiple types of projects under the Emissions Reduction Incentive Grants Programs. Alternative fuel use falls under this legislation.
- *Alternative Fuel and Advanced Vehicle Research and Development Grants*: Administered by TCEQ under the New Technology Research and Development Program, this legislation provides grants for alternative fuel and advanced technology demonstration and infrastructure projects to encourage and support research, development, and commercialization of technologies to reduce pollution.
- *Clean Fleet Grants*: Administered by TCEQ under the Texas Clean Fleet Program, this grant encourages fleet owners with diesel vehicles to remove them from the road and replace with alternative fuel vehicles or hybrid electric vehicles. A fleet must be at least 100 vehicles and replace at least 25 vehicles, resulting in diminished (at least 25%) reduction of pollutants. The program is in effect until August, 2017.
- *Clean Vehicle Replacement Vouchers*: Administered by TCEQ under the AirCheckTexas Drive a Clean Machine program, qualified individuals in certain counties may receive a voucher of $3,500 towards a hybrid electric, battery electric, or natural gas vehicle up to three model years old.
- *State Agency Fleet Acquisition Requirements:* State agency fleets with more than 15 vehicles (not including emergency or police vehicles) may not purchase or lease a motor vehicle unless the vehicle utilizes natural gas, propane, ethanol (E85), methanol (M85), biodiesel (B20), or electricity, including PHEVs. Some exceptions may be granted if there is inadequate infrastructure to support vehicles or infrastructure cannot be acquired at a cost commensurate with using conventional fuel (U.S. DOE, “Texas Incentives and Laws”).

In addition to state incentives, various utility and private initiatives are also spurring investment in Texas:

- *Electric Vehicle Supply Equipment (EVSE) Incentive* – Coulomb Technologies: Under the Chargepoint America program, Coulomb Technologies offers EVSE installation at no cost to individuals in the Austin area. The charging system must be able to be accessed by the public and be in a “high use” area. Home charging stations are also available for residents in a specified area and having purchased a qualified electric vehicle or plug-in hybrid.

- *Electric Vehicle Supply Equipment (EVSE) Incentive* – ECOtality: ECOtality covers the Dallas, Fort Woth, and Houston areas, offering EVSE at no cost to individuals. Qualified EVs or PHEVs must be purchased to be eligible, and covers most to all of the installation costs.
- *Electric Vehicle Supply Equipment (EVSE) Incentive* – Austin Energy: EV owners in the Austin Energy service area are eligible for a 50% rebate of the cost to purchase and install a "level 2" charging station, up to $1,500.
- *Electric Vehicle Supply Equipment (EVSE)* Incentive – CPS Energy: CPS Energy and the City of San Antonio offer CPS customers a rebate of 50% of the cost of level 2 charging infrastructure at a customers' home, up to $1,000 for a single family. Limited funds have the ability to curtail the program.

Next, Austin Energy initiatives will be examined, whereupon conclusions can be formulated to supplement background information found in previous sections. Austin Energy initiatives regarding home and public charging infrastructure are given particular attention in the forthcoming analysis.

CHAPTER 6. CASE STUDY: AUSTIN ENERGY

6.1 Initiatives Related to Electric Vehicles and Charging Infrastructure

Austin Energy (AE) is involved in four initiatives related to electric vehicle charging, making it one of the most forward-looking utilities in the United States. The initiatives are pursuant to Austin city council's resolution 050301-48, passed in July 2004, which among other directives "directed Austin Energy to investigate the feasibility of the future integration of the electric and transportation sectors" (Austin Energy, 2005). The initiatives are:

- *Plug In EVerywhere* – This public charging initiative has installed around 50 public charging stations around the city of Austin, and is "the first charging station network of its kind in the country to be powered completely by renewable energy through Austin Energy's GreenChoice® program" (Austin Energy, Getting Ready").
- *Plug-in Partners* – Austin Energy provides a home charging equipment rebate for installation costs of a home charging unit up to $1,500 (Austin Energy, "Texas Incentives and Laws). This has been taken advantage of in around 60 homes in the Austin area (Austin Energy Employees, 2012).
- *Pecan Street Project* – This project tests and conducts pilot projects over various clean-energy technologies in the Austin area. It is funded through a grant from the Department of Energy. One of the key initiatives is a smart grid demonstration in Austin's Mueller community, which is also the basis for an electric vehicle charging initiative which provides a $7,500 rebate (in addition to federal consumer incentives discussed above) for the purchase of a Chevy Volt (Pecan Street Inc., "Q&A"). Further, Pecan Street plans on providing level 2 chargers to Mueller residents at no cost, once an agreement is come to with charging suppliers.
- *Electric Vehicles North Texas* – This initiative compels cooperation between various entities in the region for knowledge-sharing on how to prepare for electric vehicle integration. It has fostered cooperation among "utility companies, regional governments, school districts, transit authorities and local businesses in an effort to develop a plan that prepares the region for the transition to plug-in electric vehicles. This plan will be used as a guide to progress and overcome initial barriers in order to implement necessary infrastructure and incentives to ensure vehicle support throughout the region" (NCTCOG).

This report focuses on AE's public charging and home charging initiatives. All of the projects discussed above are complementary to each other, and seek to provide early-stage information that has the ability to advance United States' adoption of electric vehicles and charging infrastructure.

6.2 Austin Energy Initiative "Plug-In EVerywhere"

Austin Energy (AE) estimates that about 192,000 plug-in electric vehicles will be in Austin Energy's service territory by 2020 (City of Austin, 2010). AE's pilot program for public charging infrastructure, called "Plug-In EVerywhere" is part of the ChargePoint America program, administered through Coulomb Technologies. Coulomb Technologies was awarded a grant from the Department of Energy through the American Recovery and Reinvestment Act and the Transportation Electrification Initiative (ChargePoint America). "The objective [of the program] is to accelerate the development and production of electric vehicles to substantially reduce petroleum consumption, reduce greenhouse gas production, and create jobs" (ChargePoint America). Austin was chosen as one of ten regions in the United States to participate in the nationwide program (Charge Point America, "Program Info"). As mentioned, the program couples electricity delivered by public charging stations with its GreenChoice program, which is "Austin Energy's renewable energy program that provides customers with a fixed GreenChoice charge instead of a traditional fuel charge during the term of the subscription (Austin Energy, "Greenchoice Program"). GreenChoice charges are linked with various renewable energy power purchase agreements, allowing Austin Energy to fund renewable commitments. The electricity provided to vehicles via public charging stations in Austin are also funded through this program. This exemplifies a novel approach to ensuring electric vehicles are as "clean" as possible; however, given that most charging of electric vehicles is expected to occur at home, it is likely to have a nominal impact on the overall emission profile of electric vehicles in Austin. Early adopters of EVs have likely entered the program of their own accord, given a "green" purchasing decision for an EV (or PHEV) often extends to other types of consumer decisions, particularly for early adopters. Also, given that the GreenChoice program was established in 2001, (Austin Energy, "Greenchoice – Answers") residents have had ample time to sign up for the program.

Charging stations are given free through this program to businesses and retail locations, which must then pay installation costs for the system and meet program criteria (Austin Energy, Charge on the Road"). Program criteria ensure that stations:

- Must be within Austin Energy's service territory;
- Must have a well-lit, safe location for a charging station and meet other Austin Energy location criteria designed to ensure a widespread and diverse station network;
- Must be accessible to the general public (residential and employee parking are not permissible unless they are in locations freely open to the general public);
- Must contract with an authorized Coulomb installer and pay installation costs;
- Must agree to a three-year commitment to the program;
- Must sign a Station Host agreement that provides Austin Energy access to repair and maintain the charging station (Austin Energy, "Station Host").

The responsibility for installation logistics and costs lie with the station host, while other responsibilities, including maintenance, network fees, and advertising, lie with Austin Energy.

The stations are level 2 charging stations (240 volts) which can deliver 7.2 kwh of electricity per hour (Austin Energy, "Station Host"). DC charging was considered too expensive by the utility, and the lack of a standard plug for "fast" DC charging was a barrier to adoption. Further, DC charging, due to the large flow of electricity to a vehicle, may cause retailers to hit their demand charge (an extra charge by the utility relative to the maximum amount of electricity over a specified period of time) (Austin Energy Employees, 2012). Customers would be wary of such charges, which would impede adoption of the stations and constrain coverage.

Users are charged an initial cost of $25 for six months of unlimited charging (Everywhere, “Station Host”). This has been widely ascribed to by EV and PHEV users (Austin Energy Employees, 2012). AE admits that these prices “are established for the pilot program. After Austin Energy gathers data on the cost and usage of public charging stations in its network, prices will change” (Everywhere, “Station Host”).

AE’s program seeks to establish enough charging stations in its service area such that drivers are no more than 5 miles from a charging station at any point in time. By putting stations at retail sites and restaurants, consumers can partake in other activities while allowing their EV time to charge. However, it is important to note that AE does not expect home charging and public charging to be interchangeable – home charging is expected to be the primary place where customers charge their vehicles (Austin Energy Employees, 2012). Instead, public charging infrastructure is meant as a supplemental convenience feature – somewhat like cell phone charging stations at airports or other public places. This is quite different than the gasoline station model and will require a level of mental adjustment for consumers. Nevertheless, such stations may still have the ability to limit “range anxiety” inherent to EVs.

According to public information, the program currently has over 50 charging stations installed and planned (7 are listed as planned) at the following types of locations:

Table 2. Number of Stations Installed and Planned in Austin Energy’s Service Territory by Type of Location (Austin Energy, “Charging Stations”).

Type of Location	Number of Stations in AE service Territory (Installed and Planned)
Restaurant/Retail	16
Education	10
Community/Library	8
Park/Recreation	8
Government/Office	7
Residential/Retail	5
Hotel	2
Medical	1
Total	57

This data demonstrates a preference towards retailers, which can use EV charging stations as a marketing device and way to lure customers and encourage shopping while charging. Retailers in Austin have been generally very receptive to installing public charging infrastructure, despite the rather bleak economics the station is likely to provide retailers. Adoption is also encouraged due to the fact that the retailer does not need to worry about regular maintenance of the machine or occasional problems which may arise – obligations which lie with Austin Energy. This is an important facet of the program that has helped spur widespread adoption.

Stations can be located by accessing ChargePoint America’s online national directory of stations, as well as through an “app” that can be downloaded at no cost (ChargePoint,

"ChargePoint Network"). This kind of centralized directory will be a key source of information for EV drivers, especially if they are in new cities and do not know where to charge their vehicle.

6.3 Austin Energy Initiative "Plug-In Partners"

In addition to public charging infrastructure, Austin Energy also has a program to incentivize the adoption of private EV charging stations at owners' homes. This program, called "Plug-In Partners" provides a rebate of 50% (up to $1,500) for the installation of a level 2 EV charger (Austin Energy, "About the Pilot Program"). It seems the basic motivation of the home charging incentives is to collect information on how consumers charge their vehicles, for economic and environmental considerations:

> Most of the electricity that Austin Energy provides comes from our own generating plants. When demand is high, however, we have to buy electricity from the wholesale market. We pay more for this electricity, which can raise our overall costs. By charging PEVs when demand is lower, we can reduce the amount of electricity we have to buy and keep rates lower.
>
> Additionally, the type of energy we provide changes throughout the day. For example, wind power is more abundant at night. As we develop smart charging tools, PEV owners can maximize their clean energy use (Austin Energy, "Plug-in Partners").

Thus, Austin Energy's goals are primarily focused with collecting information on charging patterns and how this may affect pricing, stress on the grid, and overall demand. These concerns are intricately linked with smart-charging, whereby a utility (and/or consumer) has the ability to control charging of individual devices with the use of technology: "The goal of the pilot program is to develop this ability [implement smart-charging]. We may test smart charging tools as part of the pilot program. In any smart charging program, PEV drivers will maintain final control over their charging" (Austin Energy, "Plug-in Partners").

The Austin Energy programs are novel in their approach, and represent an important initial step to EV adoption at a wider level. The projects identified above will allow AE to collect data and serves as an important model from which other cities can learn and adopt best-practices. The key findings from this study are as follows:

- Public charging infrastructure is not meant to follow a "gasoline station" model. Rather, they are intended to top-off vehicles at convenient locations; the primary place for vehicles to be charged is at the home.
- Retailers have largely accepted public charging infrastructure as a way to lure customers to the store and for marketing purposes, regardless of the financial prospects inherent to public charging infrastructure. Retail adoption has been significantly aided by the fact that maintenance and service is the responsibility of the utility, AE.
- AE's method of linking renewable energy and public charging is a novel approach to keeping public charging "green."
- Widespread use of public charging infrastructure is predicated upon greater adoption of electric vehicles.

- EVs provide an opportunity for utilities to test smart charging projects. Smart charging will be an important element of how and when EVs are charged at the home, which is a significant source of concern (as well as revenue potential) for utilities.
- It may be inferred that multi-family units and apartment complexes remain a challenge for the adoption of charging infrastructure. This is seen through AE projects' focus on home charging (primarily in garages) and public places. Lack of charging infrastructure at these locations may, alternatively, reflect a belief that dwellers of these units will not adopt EVs in the short to medium-term.

The conclusion section of this report draws upon lessons learned from the Austin Energy case study as well as the wider context and variables discussed previously in this report.

CHAPTER 7. CONCLUSION

Electric vehicles and public charging infrastructure are often thought of as two sides of the same coin – without public charging infrastructure, EVs cannot be adopted due to consumer "range anxiety," and without EVs, charging infrastructure cannot be efficiently implemented. This "chicken or egg" dilemma misunderstands the role that public charging infrastructure is meant to play in the short to medium-term. Considering the level 2 charger is the most likely, at this time, to be universally adopted, and given the amount of time and expense it would take to "fill up" an EV battery, public charging stations cannot, alone, eliminate "range anxiety." Level 2 public charging stations are not an equivalent to the ubiquitous gasoline station – they are more akin to the cell phone charging stations one might find at an airport or coffee shop. We charge our cell phones primarily at home, and find convenience in public places to charge – but they are not expected to replace home charging. This could be done with higher utilization of DC "fast" charging, but it does not seem reasonable that DC charging will be widely accessible in the short term. Thus, this report finds little merit in the idea that lack of public charging infrastructure limits the adoption of EVs, at least for the type of charging stations currently employed. What currently limits EV and PHEV adoption is primarily high upfront cost compared to conventional vehicles (due largely to battery cost) and the limited range of batteries. While cities and utilities should continue to adopt plans to implement convenient public charging infrastructure for consumers to top off their battery, a better alternative to limit range anxiety is currently the plug-in hybrid electric vehicle (PHEV), which eliminates range anxiety for long trips and provides the advantages of an EV for most commutes. Consumers will often be surprised how little they will need to use gasoline, and have incentive to use electricity as their primary fuel whenever possible given that electricity is far cheaper to fuel their car than gasoline (about 60 cents to 90 cents per gallon of gasoline equivalent). This assumes the cost of gasoline stays sufficiently above this mark, an extremely conservative assumption given that the current cost of gasoline in the U.S. is, on average, over $3.90 per gallon.

In addition to the PHEV as a viable "bridge" technology to EVs, enabling EV charging at work places would allow for charging for many hours during the day, and if implemented to a greater degree could become an important alternative to the singular focus on home charging. For many people, the majority of their car's time resides at the home and the workplace – thus, workplace charging could provide an important alternative to home charging, and time spent at the workplace is significant enough that range anxiety would be mitigated.

It is important to note that assessment of EVs is a fluid, non-static picture that depends on a variety factors. Chief among these are energy prices (primarily the cost of gasoline), the cost and range ability of batteries, public policy incentives and research grants related to EVs, efficiency of the traditional internal combustion engine, the cost, efficiencies, and externalities of other alternative fuels, and the availability, convenience, and accessibility of public transportation.

Further, energy prices, alternatives, public policy, and batteries interact with each other in various ways. For instance, a dramatic drop in the price of natural gas may propel that alternative fuel to accelerate in deployment which could highlight its potential to policy-makers, resulting in investments or credits targeted at natural gas. Car companies might then drop investment in battery technology. While this is a hypothetical scenario simply to illustrate the multidimensional nature of this market, it appears the price of natural gas will continue to drop due to projection of large quantities of natural gas now technically and economically recoverable in the United States. This is significant for electricity production, but could also serve as an important driver to propel natural gas as an alternative to petroleum in transportation. Given the limitations for electricity-fueled vehicles over long distances, natural gas may play a significant role for long-haul shipping and driving (discussed later in this section).

This report finds that within a certain context, namely for drivers in urban environments with a light-duty vehicle, where short commutes are the norm, EVs provide a powerful alternative to lessen overall emissions compared to conventional vehicles while drastically reducing local emissions that often have negative effects on air quality and the ozone. EVs can also mitigate significant negative geopolitical consequences of U.S. reliance on oil and environmental consequences of drilling for oil off the coast of the United States. It is important to note that EVs overall environmental impact depends upon what is used to fuel production of electricity, which varies by region. The evolution of the electricity sector is an important factor for the overall emissions impact of EVs.

Electricity to fuel a vehicle is not suitable for long-haul trucks or some rural long-distance driving, nor for other forms of transportation, such as air travel. However, within the niche of urban driving, EVs can have a powerful impact, given that vehicle miles traveled (VMT) in urban environments comprises the majority (over 62%) of driving today, and is expected to reach 80% by 2050 as the U.S. population becomes increasingly urbanized. Further, the environmental impact of EVs can continue to improve if the electricity grid of the United States becomes cleaner. As seen in this report, even electricity produced largely by coal produces less overall emissions for an EV than CV. Further, the cheap price of natural gas caused by an increase in U.S. domestic supply due to previously unconventional recovery methods, as well as the dropping price of renewable energy and increase in its growth portends a cleaner future electric grid in the U.S. than is currently in place today.

The targeting of public and private charging infrastructure to urban environments in the short-term has important consequences. While single family homes often have garages where charging stations can easily be installed, many people live in multi-family dwellings or apartment buildings, and it is unclear how a charging station could be installed in this type of scenario. Given that large cities are often comprised of renters in an urban environment, this is likely to be an important barrier to overcome:

Table 3. Rental Market in 10 Largest United States' Cities (Source: National Multi Housing Council).

City Name	Population	Total Occupied Housing Units	Total Occupied Rental Units	Percentage of Housing Units Occupied by Renters
New York, NY	8,184,899	3,039,467	2,063,173	67.90%
Los Angeles, CA	3,797,144	1,310,259	817,231	62.40%
Chicago, IL	2,698,831	1,014,576	549,328	54.10%
Houston, TX	2,107,208	762,309	409,935	53.80%
Philadelphia, PA	1,528,306	575,413	264,129	45.90%
Phoenix, AZ	1,449,481	511,432	226,250	44.20%
San Antonio, TX	1,334,359	470,223	207,419	44.10%
San Diego, CA	1,311,886	469,635	244,761	52.10%
Dallas, TX	1,202,797	447,680	253,449	56.60%
San Jose, CA	949,197	297,637	124,357	41.80%

A report out of the University of Indiana agrees with this report's assessment:

> The biggest barriers to residential recharging are faced by those consumers who would otherwise find PEVs most attractive: urban dwellers with short commutes, who often lack garages or convenient access to an electrical outlet. Additionally, most municipal regulations and permitting processes are not yet designed with PEVs in mind and present a bureaucratic obstacle to the timely and efficient installation of residential recharging units (Indiana University, 2011).

While this issue is a concern, it will likely not significantly impede early adoption of the EV or PHEV, particularly if consumer incentives are kept in place, the cost of batteries come down, and the public becomes more educated and comfortable with the concept of PHEVs and EVs.

Important in the discussion is the role of public policy to encourage the development of alternatives. Many economists and policy analysts prefer technology-neutral taxes or measures to price conventional fuels' negative externalities and allow market measures to move to alternatives. One relatively simple policy measure would be to tax gasoline at a rate commensurate with its negative externalities, thus allowing alternative fuels to vie on their merit for market share and growth. It would be no easy task to correctly price the negative externalities imposed by petroleum. This market-oriented measure is extremely unlikely given the political climate in the United States. In the meantime, primary policy levers at the national level that have affected battery and EV development have been funded through the American Recovery and Reinvestment Act (the so-called "stimulus" bill), and state-level incentives, which have taken on a variety of forms. However, if tax incentives for consumers and other incentives to help with the technological development and cost of batteries were to be discontinued, adoption of the EV may be significantly impeded. The particular form and level of government support can be debated, but this report finds merit in supporting the early-stage development of these technologies. "[I]n the case of [plug-in electric vehicles], some government action is warranted due to the negative environmental and security impacts of conventional vehicles, as well as the private sector's consistent underinvestment in R&D [Research and Development] caused by the inability of firms to capture all the benefits generated by their R&D efforts" (Indiana University, 2011). The government has historically played an important role in the development of new technology for these reasons, and should continue to do so for EVs and other viable alternatives.

It is often the case that policy-makers and business executives praise or denounce a technology based on the potential for that technology to singularly transform the playing field. In energy policy, often no single technology provides a sufficient "solution" to change the status-quo, and the transportation arena is no exception. This report finds that given the EVs advantages over alternative and conventional technologies, it should be regarded as an important alternative to the conventional vehicle in urban and short-distance commute environments. Charging infrastructure will have a secondary role in encouraging adoption and limiting "range anxiety," but is still an important aspect for utilities and cities to begin planning and implementing. Public policy must continue to help foster alternatives given the significant negative environmental and geopolitical externalities from oil use, discussed at length in this report.

It is hard to imagine a world without the internal combustion engine. At the turn of the 20th century, when the EV and ICE rivaled for market share, technological progress and fortuitous discovery of large quantities of domestic oil favored the ICE, transforming the landscape and creating an automobile market that continues to favor oil in the transportation sector. Now in the 21st century, the EV has been revived. As the technology becomes cheaper and better understood by policymakers and consumers, it will provide an important avenue for the oil-dominant transportation sector to evolve.

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