



Puerto Rico Electric Vehicle Introduction Study



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Puerto Rico Electric Vehicle Introduction Study

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Abstract

As part of its effort to address Puerto Rico's heavy dependence on fossil fuels for transportation, the Government of Puerto Rico plans to introduce electric vehicles on the island. This project, sponsored by the Energy Affairs Administration, studied various factors that would influence electric vehicle introduction to Puerto Rico. Our findings revealed that electric vehicles are viable in Puerto Rico; they are also supported by the general public. Prior to the deployment of electric vehicles, however, more charging stations must be installed. Additionally, financial incentives and educational campaigns are necessary to create an electric vehicle market in Puerto Rico.



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Authorship

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Results and Discussion: Survey Analysis	All
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Executive Summary

The rapid increase in the world's population growth and economic activities, particularly in countries like China, India, and Brazil has resulted in elevated levels of energy demand. The concomitant higher energy consumption is currently met largely by reliance on fossil fuels, which are limited in supply, expensive, and polluting to the environment. The rise in transportation needs has had adverse effects on the environment and has also intensified the world's dependence on fossil fuels. As transportation is a vital part of our modern way of life, society must seek ways to diminish its negative effects.

Electric vehicles (EVs) produce no harmful emissions; therefore, they would contribute to alleviating the world's dependence on fossil fuels. There are, however, important factors that must be considered before EVs can successfully be introduced into our mobile society. Particular aspects include the need for proper infrastructure as well as strong acceptance by the population and supported by the local government. The Government of Puerto Rico has expressed interest in introducing EVs to the island. However, in-depth local analysis must be performed before EVs can be successfully deployed in Puerto Rico.

The goal of this project is to facilitate the introduction of EVs to Puerto Rico by providing recommendations to our sponsor, the Energy Affairs Administration (EAA). In order to meet this goal, we achieved each of the following objectives. First, we researched the required infrastructure to support EVs and determined its current status in Puerto Rico. Second, we assessed the public knowledge and opinion of EVs on the island. Third, we determined the economic viability of EVs for the citizens and the Government of Puerto Rico. Finally, we researched existing domestic and international legislation and incentives aimed at stimulating the



EV market and assessed their applicability in Puerto Rico.

Our objectives were accomplished through archival research, case studies, face-to-face surveys, and personal interviews. Extensive research and case studies on EV infrastructure provided us with detailed information about the requirements for EV charging, electric grid support, and current and upcoming EV technologies. Comparative case studies between Puerto Rico and other locations already working on the implementation of EVs helped in identifying the economic viability of the project and any required changes to the existing legislation on the island. The survey responses aided us in suggesting marketing strategies for EVs.

Based on our research for the Energy Affairs Administration, we concluded that Puerto Rico is lacking some of the major infrastructural aspects necessary to support EV operation. While the road network and the electric grid on the island will be able to support the introduction of EVs, the lack of charging stations is currently detrimental to the widespread EV deployment. Although Puerto Ricans are supportive of EVs, cost is a limiting factor for their purchase. Based on the current prices of electricity and gasoline, it is economically viable to operate an EV in Puerto Rico. Despite the fact that some “early adopters” exist in Puerto Rico, supportive legislation and government incentives will need to be enacted to decrease the initial cost of EVs for the general public.

As a culmination of our research, data collection, and analysis, we propose the following recommendations to facilitate the introduction of EVs in Puerto Rico:

- We recommend the initial introduction of EVs to the metropolitan area of San Juan with the primary focus on development of public charging station infrastructure



- We recommend that the Government of Puerto Rico allocates reserved parking spaces for EVs
- We recommend that the Government of Puerto Rico reaches agreements with other car manufacturers similar to the memorandum of understanding with Nissan
- We recommend that the Government of Puerto Rico initially waives the vehicles excise tax for EVs until they gain acceptance on the island
- We recommend that the Government of Puerto Rico negotiates with PREPA in order to provide discounted electricity rates for EV charging during off-peak hours
- We recommend that the Government of Puerto Rico enacts community based EV adoption legislation
- We recommend that EVs are first marketed to the well-educated sector of the Puerto Rican society
- We recommend that the Government of Puerto Rico works with auto manufacturers to develop a joint educational strategy for the marketing of EVs
- We recommend that the EAA develop a marketing campaign to emphasize the long-term savings and environmental benefits of EVs

CHAPTER 1: INTRODUCTION

As the world population and its economic needs continue to increase, demand for energy is bound to increase as well. High energy consumption has become a major problem throughout the industrialized world. This energy demand is largely being met by fossil fuels, which are limited in supply, expensive, and polluting to the environment. With increasing globalization, transportation has become essential for a wide variety of activities ranging from everyday commutes to international commerce. Thus, people have become dependent on fossil fuels for nearly every facet of their lives. One promising approach to alleviate environmental problems is to utilize alternative energy sources to power automobiles. Vehicles powered by electricity have emerged as a potential solution, as they can release zero tailpipe emissions provided that the electricity they use is produced from select renewable sources (Garthwaite, 2009).

On the island of Puerto Rico, transportation powered by internal combustion engines (ICEs) has become a growing problem (Marquez, 2005). The increasing number of vehicles has produced high pollution volumes, which has led to adverse effects for the environment and human health. Introducing electric vehicles (EVs) to Puerto Rico could help reduce both the island's high dependence on fossil fuel imports and the elevated level of pollution. EVs also have the inherent capability to stimulate the local economy by generating new employment opportunities. There are many important factors to consider with the introduction of EVs in Puerto Rico, including the need for proper infrastructure, governmental support and marketing, and social approval.

The large-scale introduction of EVs requires specific infrastructure. While traffic and road conditions can affect the performance of EVs, the most important factor to consider is the



installation of a network of charging stations. As a case in point, Israel, has vowed to implement EVs nationwide by the end of 2011 and as a part of this effort, charging stations are to be strategically placed throughout its territory along with the installation of home and parking lot chargers (Roth, 2008). Additionally, EVs can also have a significant effect on the electric grid; studies have shown that charging of EVs can possibly increase electricity demand by more than 50% (Hartmann & Odzemir, 2011). Governmental support is another essential factor in the successful introduction of EVs. In Japan, the government has allotted free parking spaces in its major cities for EV drivers and has permitted EVs to travel in designated highway carpool lanes (Nansai et al., 2001). Moreover, tax credits have already been provided in many countries for EV buyers (Yeshayahou, 2011). In an effort to reduce indirect EV emissions, the governments of Ireland and Denmark have enacted laws which require the production of up to one fifth of their total electricity output from renewable sources (Schwartz, 2009; Travers, 2010). In Puerto Rico, the Energy Affairs Administration (EAA) is also already providing credits for the production of energy from renewable sources (Pabón, 2010). Perhaps the most important factor in the successful implementation of any new technology is societal support. Studies have shown that while the public is generally interested in the purchase of EVs, their advantages are still not fully understood (Kuo, 2010).

As observed in the popular media, EVs are gradually being introduced in many nations. However, the details of bringing EVs to Puerto Rico have not yet been properly researched and will need to be assessed before EVs can become competitors with fossil fuel powered cars. In order to ensure that EVs can operate in Puerto Rico, the local electric grid must be able to support the increased electricity demand. Public charging stations will also need to be installed at strategic locations. Additionally, the Government of Puerto Rico would need to provide financial



incentives to potential buyers of EVs in order to assist them with the increased initial investment. To decrease the indirect emissions of EVs, laws must be passed to encourage the development of alternative energy sources. Social factors like public opinion and environmental awareness will likely have a strong effect on the success of EVs.

The goal of this project is to study the introduction of EVs to Puerto Rico through a variety of research methods. In order to address the issues outlined above, we determined the opinion of Puerto Ricans towards EVs through face-to-face surveys. As part of the survey, we also assessed the knowledge base of Puerto Ricans regarding EVs and determined their ability to purchase EVs. Additionally, to meet the objectives of this project, we performed extensive research and case studies on other regions where EVs are currently being implemented and gauged the ability of Puerto Rico to take similar actions. Upon completion of this project, we provided recommendations to the EAA to help facilitate the introduction of EVs in Puerto Rico and thus reduce the dependence of the Puerto Rican transportation sector on fossil fuels.

The organization of our report is as follows: Chapter 2 provides background research, Chapter 3 states our objectives, Chapter 4 describes our methodology for completing these objectives, Chapter 5 presents our results and a discussion of these results, Chapter 6 includes the conclusions, and Chapter 7 describes the recommendations that we have proposed to the EAA. Following these chapters, a complete list of our references and several appendices containing additional information and figures are included.



CHAPTER 2: BACKGROUND

The island of Puerto Rico is dependent on fossil fuels for all of its transportation needs. However, the supply of oil is limited and its importation is extremely expensive. Additionally, fossil fuel consumption results in harmful pollution to the environment. EVs present a potentially viable alternative to traditional ICE cars in Puerto Rico. EVs could produce zero emissions provided that the electricity is generated from non-polluting, renewable sources (Garthwaite, 2009). There are, however, many important factors associated with the implementation of EVs including environmental considerations, required infrastructure, governmental support, and preferences of the general public. In order to better understand how to facilitate the introduction of EVs to the transportation sector of Puerto Rico, we will discuss all of these important factors in this chapter.

2.1 Environmental Considerations

The energy needs of the world today are largely being met by fossil fuels, e.g. coal, oil, petroleum. Fossil fuels are derived from the carbon rich deposits below the surface of the Earth. Around 85% of the energy required by the United States is provided by the combustion of these resources (U.S. Department of Energy [DOE], 2011a). Since fossil fuels have been the most economically favorable source of energy since the 18th century, a large number of countries around the world are becoming increasingly dependent on them. Their unsustainable use for hundreds of years has led to a limited availability, making imports and extensive use very expensive. However, with the increasing awareness of sustainability and environmental health, the use of coal and petroleum to provide power for electricity and transportation has been reconsidered in the past few decades.

2.1.1 Environmental Impact of Fossil Fuels

As more and more research is being done on the economic and environmental impact of fossil fuels, a large number of countries have consciously tried to control and monitor their use nationwide and develop less polluting alternative resources (DOE, 2011b, Fossil Fuels). The energy stored in carbon-based fuels is released through burning in the ample presence of oxygen – a process called combustion. This leads to the release of ash and potentially harmful gases like carbon dioxide, carbon monoxide, sulfur dioxide, and nitrogen oxides. Once released to the environment, these gases may combine with the water vapor present in the atmosphere and lead to the degradation of air quality and acid rain, which is destructive to forests as well as metal structures. Carbon dioxide plays a major role in the greenhouse effect. Excessive accumulation of carbon dioxide in the atmosphere is believed to be the driving factor for global warming, an issue of crucial concern all over the world (DOE, 2011b, Fossil Fuels).

2.1.2 Dependence of the Transportation Industry on Fossil Fuels

Extensive research and studies on the consumption patterns of fossil fuels have shown that one of their major uses has been to provide energy for the transportation sector (DOE, 2011b, Fossil Fuels). Also, unlike most consumer products, oil and petroleum are not affected by fluctuation in prices since many businesses and economic entities depend on them. Thus, these products are untouched by market and economic changes of demand and supply. According to the U.S. Energy Information Administration (2011, Oil) most of the transportation sector of the United States is in fact powered by petroleum, as is depicted in Figure 1.

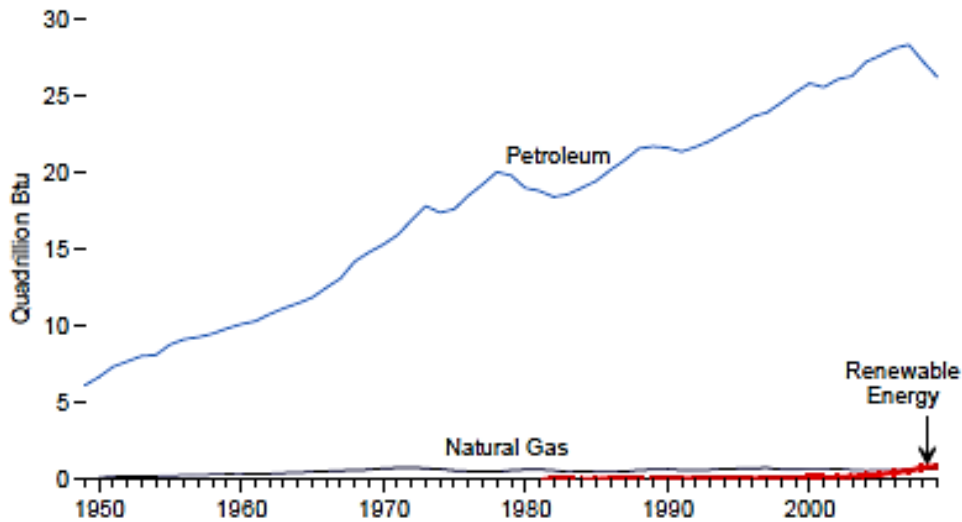


Figure 1: Fuel sources for transportation in the US by the major sources of energy from 1949-2009 (US EIA, 2011, Oil).

As can be seen from Figure 1, petroleum has been the major source of energy supply to the transportation industry, with renewable energy sources and natural gas lagging far behind. It can be seen that by the early 21st century 25 quadrillion (2.5×10^{16}) British Thermal Units (BTUs) of petroleum were being used versus about only 1 quadrillion BTU of renewable energy. These statistics are worrisome because such extensive use of petroleum and oil are very hazardous to the environment. For example, drilling for oil on land may cause saltwater from the neighboring water bodies to rise to the surface, which if left untreated may damage the ecosystems (DOE, 2011b, Fossil Fuels). Drilling practices are also often dangerous for the involved personnel due to the unstable nature of drilling on the surrounding hills and surfaces. The combustion of any petroleum based fuel releases carbon dioxide, which further contributes to global warming. Respiratory irritants like soot, smoke, dust, and sulfur dioxide, are also generated. Many of these pollutants are also known to be carcinogenic and as a result pose a serious danger to human health.

2.1.3 Risks Associated with the Transportation of Petroleum

Transportation of oil can sometimes result in oil spills, which are very difficult to manage and result in immediate and disastrous effects. For example, “the April explosion that destroyed the BP-leased Deepwater Horizon rig killed 11 workers and, according to government estimates, led to more than 200 million gallons of oil spewing from a hole a mile beneath the Gulf of Mexico” (The Associated Press, 2011, p. 3). Oil in the form of tar finds its way into the food chain through infected fish, weeds, and grass; which could be potentially fatal if the infected seafood is consumed by humans and animals.

2.1.4 Sustainable Energy and Electric Vehicles

Due to the adverse effects of the use of fossil fuels, the dependence of the transportation sector on petroleum products appears unsustainable. This paves the path for the development of sustainable energy sources. In the transportation sector, efforts are being concentrated on the development of plug-in hybrid vehicles and on battery-run EVs. Plug-in hybrid vehicles are vehicles that are powered by a battery (which supplies electricity) but also have an ICE to provide an extended range. By contrast, EVs, as defined by the US Department of Energy use solely “a battery to store the electrical energy that powers the vehicle” (DOE, 2011d, Vehicle technologies program). Light duty vehicles (low powered) are at the core of sustainable vehicle research since this is the most widely driven class of vehicles worldwide. Because light duty vehicles are the largest in number and consume the greatest quantity of petroleum, the introduction of EVs in this sector is likely to have a profound impact on the shift of dependence from fossil fuels to renewable energy resources (Trailer Body Builders, 2011).

2.1.5 Environmental Impact of Electric Vehicles versus Internal Combustion Engine Cars

While EVs do not emit any sort of pollutants directly, it needs to be noted that the various sources of production of electricity for charging EVs may produce some pollutants. Numerous studies have been done on this topic and the most popular approach has been the Well to Wheels (WTW) analysis (Wang, 2003). A WTW analysis is a specific form of the life cycle assessment analysis of a given product. In particular, a WTW evaluates the environmental impact of a given car by analyzing the amount of greenhouse gas (GHG) emissions released during the operation and use of the car. Vehicle technologies are compared by tracing the extraction of the fuel used in the vehicles of interest up to the point where it is actually used to power the car. Such an analysis is often completed in two parts, first is the well to pump evaluation and the second is the pump to wheels analysis. Figure 2 above summarizes and compares the GHG emissions for various vehicle technologies, including the conventional gasoline vehicle and the battery powered EV.

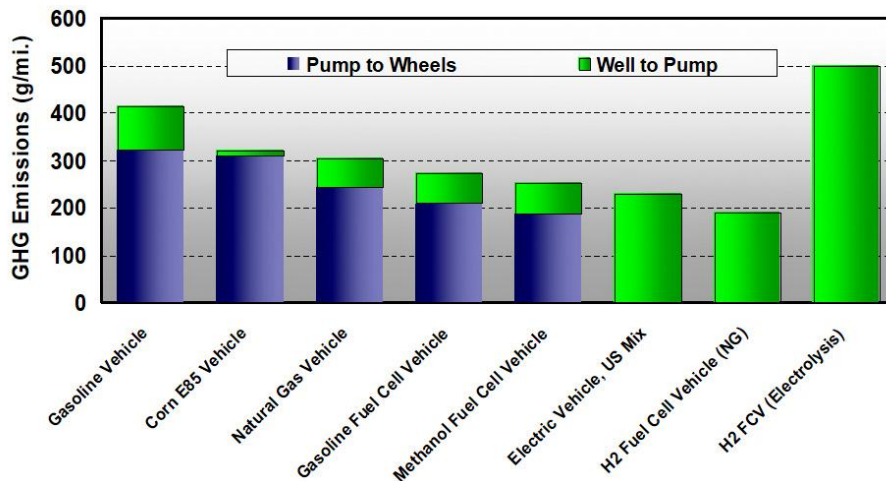


Figure 2: Greenhouse gas emissions for a “Well to Wheels Analysis” for various vehicle technologies (Wang, 2003)

A well to pump analysis focuses on the environmental impact in terms of CO₂ released

into the environment in the process of extracting the fuel and transporting it to the fuel supply station (for example, a gasoline pump station). A pump to wheel analysis, on the other hand, focuses on the greenhouse emissions released during the supply of energy to the engine of the car through the usage of the fuel obtained at a fueling station. It has been assumed that the fuel sources used to provide the electricity for charging the battery of an electric vehicle are a mix of coal, petroleum, natural gas and other similar resources used in the United States. While a gasoline vehicle produces a little over 400 grams/mile (g/mi) of CO₂ emissions during the well to pump stage, an EV produces only around 200 g/mi (Figure 2). Additionally, an EV produces no tailpipe emissions during the pump to wheels stage while a gasoline vehicle produces over 300 g/mi. Thus, an EV does not only have zero tailpipe emissions, but also reduces the carbon footprint of the well to pump stage by almost 50%.

2.1.6 Environmental Impact of Electric Vehicles Batteries

EVs are directly powered by rechargeable batteries. These batteries can be charged at charging stations by connecting them to an electric power source like a custom wall socket (through the electric grid) or by exchanging the used battery for a new, fully charged one. While the use of batteries for the production of electric power does not cause any pollution, improper disposal of these batteries is an issue of environmental concern (Professor Fred J. Looft, personal communication, February 10, 2011). Lead acid, lithium-ion, lithium polymer, and Ultra-capacitors are the known energy storage battery technologies used in EVs. The most favored battery in EV research is the lithium-ion battery, chosen because of its high energy density (Campanari, Manzolini, and de la Iglesia, 2009). The lithium-ion battery is layered with lithium Cobalt dioxide (LiCoO₂). Cobalt (Co), if not recycled, can lead to environmental poisoning. However, extensive research on the LiCoO₂ has proved that the recycle process is easy and

economical to perform and has a minimal effect on the battery discharge capacity (Liu, Hu, Li, Wang, and Guo, 2006). While the current market for battery recycling is small and mainly limited to smaller lithium-ion batteries, the U.S. DOE (2011d), through the Sandia National Laboratory predicts that the battery recycling market will grow with the increase in the number of EVs. Since this procedure is economically viable, a supporting infrastructure can easily develop with the growth of the EV market.

2.2. Electric Vehicle Infrastructure

In order for EVs to be successful at a particular location, specific infrastructure must be installed and maintained. Many areas of the world today, such as Israel, Germany, China and Japan, have all begun establishing appropriate infrastructure with the goal of facilitating EV purchases and use. The geography and climate of Puerto Rico appear particularly favorable for the use of EVs. Travel distances on the island are limited and year-round summer-like conditions promote long battery life time. Thus, Puerto Rico could follow similar approaches to establish the necessary EV infrastructure.

The types of infrastructure needed for EV introduction present some formidable installation and maintenance challenges. Infrastructure such as mobile charging stations as well as home chargers are options for EVs (John Gilbrook, personal communication, February 8, 2011). Along with charging technologies, the need will arise for roadside assistance programs and driver's education classes to inform people about how to effectively and safely operate EVs. In addition, road conditions and transportation infrastructure must be well maintained and suitable for the operation of EVs. Battery replacement and charging times are other vital factors that must be considered.

Another important aspect of infrastructure that must be considered is the electric power grid availability in the region. The strain on the electric power grid from EVs could potentially be substantial. Not only will this raise the electricity costs for people living in such locations, it could also potentially cause problems in the electricity supply system (e.g., power shortages, blackouts, etc.). According to Mr. John Gilbrook, an engineer at National Grid, battery disposal methods must be developed in order to efficiently recycle old batteries in an environmentally friendly and cost effective manner. Despite its short lifetime, there already exists a plethora of EV infrastructure technology on the market today, which must be analyzed by the Government of Puerto Rico in order to effectively support the introduction of EVs. Figure 3 shows the three distinct categories that form the basis of the EV infrastructure.

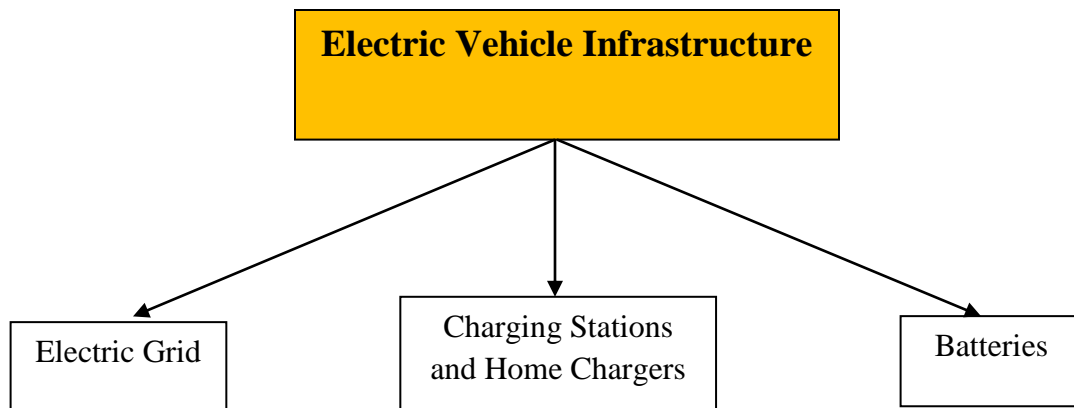


Figure 3: Three components that form the basis of the required electric vehicle infrastructure

2.2.1 Grid Support for Electric Vehicles

For the successful adoption and expansion of the EV industry, the electric grid of the island must be able to provide sufficient electric energy. Brady and O’Mahoney (2011) have shown that a typical EV requires 0.25 kilowatt hours per kilometer (kWh/km) of electricity under real driving

conditions. Using computer software, Hartmann and Ozdemir (2011) have analytically modeled the potential toll of EVs on the electric grid in Germany. They calculated that the average distance driven in one day is around 41 kilometers and the maximum charging power for one EV battery is 3.6 kilowatts (kW). Through their mathematical modeling, they estimated that the introduction of 1 million EVs into the German transportation sector would only increase the overall impact on the electric grid of the country by 1.5%. However, if the entire vehicle fleet in Germany were replaced with EVs (42 million vehicles), then the overall electric grid impact would virtually double, increasing by 92% (Hartmann & Ozdemir, 2011). These data suggest that Puerto Rico would initially experience no problems with the addition of EVs onto the island, but the electric grid output would need to be significantly increased if EVs are to become extremely common. The authors ultimately concluded that although there are several available options for charging EVs, a region must create a uniform charging method in order to most effectively utilize the electric grid. It has also been shown that strategic timing in charging can decrease electricity costs by up to 200 euros per hour (Kiviluoma & Meibom, 2011). For example, if different charging rates are provided, charging at night is usually significantly cheaper than charging during the day because there is a much lower demand for electricity.

One way to combat the problem of the high energy toll on the grid is to produce electricity from renewable resources such as wind and solar energy. For example, Ireland currently generates 14.4% of its electricity from renewable sources, mainly from wind energy (Brady, 2011). Ireland also vows to produce 40% of its electricity from renewable sources by the year 2020. As Hable et al. (2011) point out, implementation of up to 5 million EVs would lead to a 10% increase in the overall electricity demand in Germany. However, this increase in demand

could easily be met with the establishment of a small number of renewable energy power plants.

2.2.2 Electric Vehicle Charging Stations

EV charging stations are most often placed in easy access and high volume traffic areas, such as rest areas of freeways or on busy streets. A program called “Quick Charge” was implemented in California beginning in 1996 and resulted in the installation of 356 EV charging stations at 111 locations (Nansai, et. al, 2001). Most of these charging stations took an average of 3 hours to recharge the vehicles. This could potentially be a problem as most people would prefer to get their car batteries recharged as soon as possible. Considering the environmental aspect, however, Nansai, et al. (2001) have found that the manufacturing and installation of charging stations combined with the driving of EVs releases significantly less greenhouse pollutants than driving and manufacturing gasoline powered vehicles.

Another option in the development of charging stations is to encourage a program similar to that currently being used in Israel. Lead by an organization called *Better Place*, Israel is beginning a nationwide program to shift from combustion engine cars to zero emission EVs (Friedman, 2010). In order to do so, Israel has installed charging stations throughout the country. An advantage of the *Better Place* charging station program is that it also provides replacement stations. At these stations, depleted batteries are replaced with fully charged ones. The exhausted batteries are then recharged and given to another customer. This process significantly reduces waiting times as it can be completed in a few minutes. *Better Place's* charging stations are also currently being employed in Denmark and Tokyo (Friedman, 2010). However, according to Mr. Gilbrook (personal communication, February 8, 2011), the US would never be able to implement a system of such replacement stations as a result of the competitiveness of car manufacturers.

Many car manufacturers use slight variations in their battery design and are reluctant to share this information. Therefore, it would be nearly impossible to have each EV run by a uniformly designed battery. It is much more likely that home charging will be the “fueling” method of choice in the US. That being said, standardization can lead to increased efficiency. For example, the nations of the European Union have standardized cell phone chargers, so that the same charger can be used on any phone (“Europe Standardizes Cell Phone Chargers”, 2010). If EV batteries were standardized, this could result in increased efficiency and even increased employment, as battery swap stations could be opened.

The Beautiful Earth group (BE) recently installed solar powered charging stations for EVs in conjunction with the Brooklyn Bridge Park Corporation. This project was completed on March 15, 2011 and is spread over 5 acres. By using the energy of the sun to power and operate its EVs, New York City aims to reduce its CO₂ emissions by 30% by the end of 2030 (Beautiful Earth Group, 2011). The use of solar energy to power EVs is not only purely environmentally friendly, it will also reduce the expenditure related to gasoline use by \$200,000 and eliminate electricity costs by tens of thousands of dollars over the span of 25 years. The charging station installed in Brooklyn is completely off the grid and is supported by 24 photovoltaic panels and has the capacity to store this energy in battery packs and provide on demand electric power for EV charging. This charging station also has the added bonus of being modular, i.e. it can easily be deconstructed and rearranged. “To build the station, BE purchased photovoltaic panels made at a Sharp Electronics plant in Tennessee; a racking system from Unirac in New Mexico; recycled containers from a local New York vendor; batteries, which are 97 percent recyclable, from the Trojan Battery Company in Georgia; inverters from OutBack Power Systems in Washington; and the solar arrays frame from U.S. Fence Systems in Brooklyn” (Beautiful Earth Group, 2011).



Although charging stations, like the one in New York are rare, the increase in the number of EVs will stimulate the growth of this technology. For example, Nissan is already working on constructing solar powered charging stations in the US while Honda has already began the construction and testing of such charging stations in Japan.

2.2.3 Electric Car Models

The *Better Place* program is currently using Renault's Fluence ZE models, which are manufactured in France (Friedman, 2010). For drivers who prefer minivans or Sport Utility Vehicles (SUVs), Renault is in the process of developing 9 new EV models. The current EV models are able to travel up to 124 miles on a single charge. In the US, General Motors is currently producing the Chevrolet Volt, which is considered an extended range EV. The Volt, unlike other EVs has an electricity generator powered by an ICE. For the first 40 miles, the Volt is solely battery powered and after this distance, the generator supplies electricity to the battery, thus extending the car's range. Japanese car maker Nissan has developed the Leaf, a pure EV that is now on the market for purchase. Some of the EV models available on the market today can be seen in Figure 4. After the applicable federal tax credits, the Nissan Leaf can be purchased for approximately \$26,000, but the cost for consumers could drop to \$21,000 (Ramirez, 2011). In the near future, many other car manufacturers plan to develop EVs.



Figure 4: Some electric vehicles on the market today (from left: Renault Fluence ZE, Nissan Leaf, and Chevrolet Volt)

2.2.4 Electric Vehicle Batteries

The main type of battery utilized to power EVs is the lithium-ion battery, “which will hold more of a charge for a longer time” than the typical nickel metal hydride battery used in most hybrids (Miel, 2009). However, one main obstacle in the electric energy storage technology is that these lithium-ion batteries are manufactured almost exclusively in Japan and China.

A new technology on the market has recently greatly reduced charging times. However “[despite the name], rapid charging is still rather slow compared to fuelling a conventional petrol car ... and may require almost half an hour (assuming that there is no need to wait in a queue)” (Carlsson, 2003, p.13). The batteries used in the *Better Place* program are expected to last up to 7,000 charges. Even if they were to last for only 1,500 charges, this would amount to over 150,000 miles of vehicle travel, which is equivalent to the full life of many ICEs (Erlanger, 2008).

Several studies have been carried on the performance and specifications of EV batteries. The lithium-ion batteries can be up to 94% efficient and the electric drive train can be up to 89% efficient (Eaves, 2010). From 79 kWh of energy provided by a renewable source (wind, solar, hydropower), a total of 60 kWh of energy can be delivered to the wheels of the vehicle. This process of energy conversion occurs in a total of two distinct steps, which can be overall 77% efficient (Eaves, 2010). This is much more efficient than an ICE, which usually is about 25% efficient in its energy conversion. The lithium-ion batteries that power EVs have a minimum weight requirement of 504 kg and they must also allow for 143 Watt-hours of energy to deliver per kilogram (Eaves, 2010). Battery powered EVs (BEVs) have been studied in comparison to other zero emissions vehicles, such as fuel cell vehicles (FCVs). In one study, BEVs were shown

to be both more efficient and cost effective than FCVs. Overall, the entire BEV energy pathway was found to be 8% more efficient than the pathway provided by FCVs (Eaves, 2010).

2.2.5 Electric Vehicle Home Charging

Another method for charging EVs is to have a home-charger installed in one's garage, enabling people to charge their EVs overnight from the comfort of their own home. According to Mr. John Gilbrook (personal communication, February 8, 2011), home charging will most likely be the preferred method of charging in the US, and is a viable option for use in Puerto Rico as well. There are two main types of home charging readily available: Level I and Level II. Level I charging requires 120 Volts in alternating current (VAC) and at this level, cars can be connected in to a standard electrical outlet (Los Angeles Department of Water and Power, 2011). However, Level I charging can take from 12-24 hours to completely charge an EV.

Level II home charging stations require 240 VAC and cannot come from connecting into a standard outlet (Los Angeles Department of Water and Power, 2011). In fact, Level II chargers use the same type of outlets required for operating a home dryer. Level II charging allows for EVs to be fully charged in 3 to 8 hours, making them ideal for an overnight charge. However, they need to be installed by a professional electrician, ideally in a garage. Home charging is extremely convenient, especially for individuals who do not travel very long distances for their daily activities. As more EVs are purchased, home charging use and installation will become more prevalent and efficient. Level III charging stations are powerful stations that can fully charge an EV in under a half hour. However, these charging stations are currently not available for installation in the home and can only be utilized in public charging areas. These stations use a 480 volt, 3 phase electrical service. ("Fast Charging Stations Announced," 2010).

Additionally, roads must be in good condition and ample roadside assistance programs must be provided for all drivers of EVs (John Gilbrook, personal communication, February 8, 2011). According to Mr. Gilbrook, the overall repair and maintenance of EVs is very different from that of ICE vehicles. Thus, according to him, roadside assistance programs can simply be extended and increased in size from preexisting ones. This would require more employees, potentially creating new jobs and stimulating the economy.

2.3. Electric Vehicle Financial Aspects

Introducing EVs in a particular city or nationwide is a complex sequence of events requiring both substantial private investment and government incentives. The process needs to be well coordinated among car manufacturers, public agencies and companies operating the network of charging stations. Production of EVs is already underway, and companies such as Nissan and Chevrolet are distributing limited emission cars on the market. Such battery operated vehicles, however, can currently travel about 100 miles on a single charge and thus need to “refuel” frequently in order to overcome their limited range. Last but not least, in order for electric drive vehicles to be competitive, the government may need to provide incentives for their purchase.

2.3.1 Electric Vehicle Manufacturing

EVs have long been an alternative to conventional automobiles. As discussed by PBS (2009), their history begins in the 1830s with the invention of a crude electric carriage by Robert Anderson, followed by the building of the first successful electric automobile in 1897 by William Morrison. The EV industry reached its prime in the early 1900s followed by a rapid decline in the 1920s when EVs become easily outperformed by gasoline-powered cars.

At the beginning of the 21st century, problems related to climate change raised people’s

awareness about environmental issues and in particular the high levels of carbon dioxide emissions. In recent years, many governments have introduced new policies stimulating the development of energy from renewable sources and the reduction of greenhouse gases (Lee, 2008). EVs once again have become an attractive, but not necessarily a viable alternative to gasoline powered cars. It has only been through substantial government support that they have become economically feasible in certain countries (Lettice, 2008; Schwartz, 2009; Bradsher, 2009). Electric cars currently in production include the Nissan Leaf, Renault Fluence ZE, Chevrolet Volt, Mitsubishi i MiEV, Th!nk City and others. By the end of 2011, on the streets of Israel there will be approximately 100,000 EVs (Roth, 2008). Renault will deliver another 100,000 electric cars to Denmark by 2016 (Bergman, 2010), and Hawaii is planning to accommodate about 10,000 more EVs by 2014 (Shapira, 2009). According to Mulliken (2010), a projected 1.3 million electric cars will be sold by 2020; this will, however, still represent only about 1% of the total number of automobiles worldwide.

2.3.2 Financial Aspects of Charging Stations

The battery life of an EV is sufficient for about 100 miles of driving on average (Garthwaite, 2010). When the battery is exhausted, it will need to be recharged or replaced. Available options for this include home charging, parking lot charging posts or on-the-go battery replacement stations (*Better Place*, 2011). Home charging is most efficient during the night when the electric grid is operating at lower demand, while parking lot charging posts are suitable for recharging while the owner of the vehicle is at work, for example (Greenemeier, 2011). Battery replacement stations can exchange an empty battery for a fully charged one in minutes and are perfect for when the vehicles are needed for longer trips (Nagarajan, 2009). The price for a home charging device depends on the location and the condition of the electric system, but on average

it is estimated to be \$1500 (Roth, 2008), while the capital investment of a public battery replacement station is approximately \$500,000 (Bergman, 2010).

One company facilitating the introduction of EVs throughout the world is called *Better Place* (“Better Place, 2011). Established in 2007, the company is valued at \$1.25 billion and has set as its mission to end fossil fuel dependence (Associated Press, 2010; Roth, 2008). Founder of the company, Shai Agassi, is the visionary who has brought together governments throughout the world with electric car manufacturers to achieve a common goal. With an initial capital of \$200 million and a recent investment of \$350 million from HSBC, *Better Place* has managed to arrange for the introduction of EVs to many countries including Israel, Denmark, China and the United States. With the cost of batteries contributing to roughly half of the price of an EV, *Better Place* decided to separate the car from its primary energy source. Thus, an EV buyer might only lease the battery, which would be owned by the distributing company. This significantly reduces the price of EVs and also facilitates exchanging batteries in recharging stations. *Better Place* installs and maintains the network of charging stations. It also offers several charging plans, which are all at least a third of the price of an equivalent amount of gasoline (Oare, 2010). The company has also invested in on-board software which can estimate energy consumption based on travel destination and suggest available recharging stations.

2.3.3 Government support

With the increased problem of environmental pollution, many countries have attempted to implement policies leading to the development of sources of alternative energy and the reduction of harmful gas emissions. EVs are an optimal solution to the problems within the commercial transportation sector as they could lead to zero emissions, provided that the electricity is derived

from renewable sources. Many governments have taken steps towards the introduction of EVs by providing different incentives for their purchase. Additionally, the recently established Electric Vehicle Initiative is promoting cooperation in research and development, sharing of experience and exploring the possibility for universal standards among involved nations (Clean Energy Ministerial, 2010). The participating governments of China, France, Germany, Japan, South Africa, Spain, Sweden and USA have agreed to launch pilot city EV programs and share information.

The country to first implement a nationwide system of EVs is Israel (Gingichashvili, 2008). *Better Place* decided to use Israel as a test country for the project, which is to be completed by the end of 2011. According to Roth (2008), Israel is a perfect “island” location for the experimental introduction of EVs, since it is surrounded by sea on one side and by enemies on the other sides. Besides its appropriate location and warm climate, the country’s dense population and supportive government were also major factors contributing to the final decision. With a gas price in Israel of \$6.30 per gallon, 90% of the population drives fewer than 45 miles a day. Additionally, all major urban centers are situated within 100 miles of each other (Associated Press, 2010). After a presentation by Shai Agassi, a native of the country, the President of Israel at that time, Shimon Peres, decided that the idea was viable, and in the following years the country modified its tax codes to offer incentives for the purchase of EVs (Roth, 2008). The 78% tax on petroleum fueled cars was reduced to only 10% for zero emission vehicles for four years. Even though this might at first seem like an unwise decision, any losses that the tax reduction might entail are insignificant compared to foreign oil costs. A network of charging stations has already been installed throughout the country, and the first electric cars are soon to appear on the

streets of Tel Aviv.

The other big project of *Better Place* is in Denmark, which so far leads Europe's electric car race. The country plans to introduce EVs by 2012, which will be a test for EV technology because of the cold climate there (Bergman, 2010). Denmark has arranged for the distribution of 100,000 cars from Renault, and it is already providing incentives for potential customers. The country has waived the 180% vehicles registration tax for zero emission cars, which can amount to savings of \$40,000 for early buyers. There will be also free parking for EVs in downtown Copenhagen (Bergman, 2010). *Better Place* is planning to install a total of 25,000 charging posts and stations in Denmark, and its partner in this undertaking, DONG Energy, has promised an increased share of wind power, which currently accounts for 20% of the electricity produced there (Schwartz, 2009).

The United States is the greatest challenge for *Better Place*, as Americans are responsible for the most pollution per capita. President Obama has provided \$2.4 billion for the development of the next generation of EVs and a total of \$4 billion for the establishment of facilities for batteries, battery components and electric drive components (Oare, 2010; Recovery.gov, 2009). This includes a tax credit of up to \$7,500 for EV buyers. In the United States, however, it has been impossible to arrange nationwide tax reforms similar to those in Israel and Denmark. In 2007, a number of cities including Los Angeles, New York, and San Francisco showed interest in the local introduction of EVs, but the respective mayors did not have enough power to positively influence this endeavor (Roth, 2008). Instead, another place was chosen as the starting point – Hawaii. The Hawaiian Islands, with their limited imports and exports of cars, provided the perfect location for another pilot plan. Governor Linda Lingle was also supportive of the idea,



and a project was developed for the statewide introduction of EVs by 2012. Bills were passed ensuring at least one charging station per parking lot and also reserved parking spaces for EV drivers. One billion USD was invested for the statewide charging system, and the tax on a barrel of oil was increased by \$1 to stimulate alternative energy production (Shapira, 2009). This provided up to a \$4,500 rebate towards the purchase of an EV and also a \$500 refund for installation of a home charging station. Together with the federal tax credit, this amounts to a price reduction of up to \$12,500. As part of the program, the state has set a goal of creating a 40% renewable energy share by 2040.

2.3.4 Cost-benefit Analysis

An accurate cost-benefit analysis of driving an EV is difficult to establish as it depends on a number of factors. Several of these include, but are not limited to, the initial price of an EV and the battery, its rate of usage, and the cost of electricity and gasoline. These factors can be greatly influenced by technological developments, local and foreign investments, and government policies, which can be difficult to predict. A simplified cost comparison can, however, be performed. If we assume that the typical US driver gets 20 mpg and travels around 15,000 miles per year, then this would account for an annual gas bill of \$2,250 at \$3 per gallon (Petersen, 2011). The average annual cost of operating an EV would be about \$560 assuming energy consumption of 25 kWh per 100 miles and electricity price of \$0.15/kWh. This is equivalent to 750 gallons of gasoline saved and an annual CO₂ abatement of over 4,000 kilograms (Petersen, 2011).

2.3.5 Technical Support and Training

EVs, compared to ICE-powered cars, contain fewer moving components, which are

vulnerable to wearing out (van den Bulk, 2010). This generally results in lower annual maintenance costs in the long term (Alternative Energy – Alternative Fuels, 2010). EVs require no oil change nor oil or gasoline filter replacement (Sponte, 2011). Air filters of electric cars will need to be changed every 40,000 miles (compared to every 5,000 miles for conventional ICE automobiles) and engine brushes will need to be replaced every 80,000 miles (Alternative Energy – Alternative Fuels, 2010; Sponte, 2011). Additionally, breaking pads will also need to be serviced less often, because part of the mechanical energy released when slowing down could be converted into electric energy and transferred to the battery. This is the result of the regenerative breaking technology (Alternative Energy – Alternative Fuels, 2010). An on-board battery condition analyzer will track battery capacity and signal the driver when replacement is necessary. This will amount to an annual maintenance cost of about \$240 for EVs, which is significantly less than the average \$600 per year for ICE-powered cars (van den Bulk, 2010). In fact, as suggested by Sponte (2011), the most difficult part of taking care of an EV might be to remember to “do it at all”.

Currently, however, maintenance of EVs is an area of specialized knowledge. In January 2010, Ford partnered with the University of Detroit Mercy to establish a program aimed at retraining automotive engineers for work on electric cars (Richard, 2009). As part of this Advanced Electric Vehicle Program, 125 Ford engineers will receive internal training. According to Ingram (2011), car dealerships will provide initial service of EVs for their customers. There, customers will have to access to highly trained personnel and all of the specialized tools. Independent car mechanics will take time to acquire the skills needed to service an EV. Additionally, drivers will no longer be able to repair their own cars (John Gilbrook, personal communication, February 8, 2011). Buyers of EVs will need to be advised against such self-



service activities, as they can pose safety risks.

2.4. Societal Factors Associated with Electric Vehicle Introduction

Society is a factor of prime importance when considering the introduction of EVs to a certain location, as people are the potential buyers and end users of the product. Important issues such as safety, public opinion and social class of potential buyers must be considered before EVs are implemented on the island of Puerto Rico. Resolving major societal problems and addressing customers' concerns will help guarantee a successful market for EVs.

2.4.1 Safety Risks and Management

Driving an EV entails some risks that are different from those associated with operating a conventional ICE-powered vehicle; drivers and safety personnel must be aware of these additional hazards in order to prevent and be able to manage any accidents. EVs operate at high voltages reaching up to 500 V, which poses a potential risk of electric shocks (Coyle, 2010). Additionally, an operating electric car does not provide noticeable engine sound (Motavalli, 2009). This can lead to unwanted moving of the vehicle. Also, unlike ICE-powered cars, EVs can deliver their full power instantly (Roth, 2008). This represents another risk for untrained drivers and pedestrians.

In March 2010, more than fifty countries, in addition to EV manufacturers and consumers, met in Geneva to discuss safety issues associated with the rapidly emerging EVs (Electric Car News, 2010). As a result of the meeting, forty-one countries agreed on international safety standards for EVs. Among the mandated regulations were an indicator for engine operation and a safeguard mechanism against vehicle movement when charging.

Another safety training project has received \$4.4 million funding from the US DOE



(Carli, 2010). As part of the initiative, the National Fire Protection Association organized a nationwide tour where more than 1,600 fire and emergency service leaders received training on handling accidents involving electric cars. Target cities were initial launch markets for the Chevrolet Volt. First responders received training on emergency power shut-off, in addition to information about lithium-ion batteries, location of high strength steel and cut points for extrication procedures (Carli, 2010). Car manufacturers are also working to provide enhanced safety features, such as labeled high voltage cables, an easily accessible 12 V cable, which can be disconnected to terminate power supply, battery seals to eliminate shock risks if the vehicle is immersed in water, and up to 80% more high strength steel (Brooks, 2011).

2.4.2 Public Opinion Regarding Electric Vehicles

Several surveys have been performed in the United States to assess public opinion on electric cars as well as people's reasons for and against the purchase of an EV. Studies have identified that 48% of surveyed Americans are interested in purchasing an alternative-fuel car (Kuo, 2010). According to IBM's Institute for Business Value, in 2011 "nineteen percent of drivers surveyed said that they are either "very likely" or "likely" to consider purchasing an electric-only vehicle when shopping for a new car" (Buscemi, 2011, para. 3). A separate study indicated that 37% of respondents are at least "somewhat likely" to purchase an EV within the next two years (Coxworth, 2011, para. 2). Sixty-three percent of drivers have indicated that they travel less than 40 miles a day, and 30% are ready to switch to an EV that has 100 miles per charge or less (Evarts, 2010b; Michalik, 2011). When it comes to costs, 40% of the interviewed persons were ready to pay up to 20% more for an EV, but only 13% were willing to spend more than \$1,000 to install charging stations at their residence (Michalik, 2011). Eighty percent of Americans would support the government in a national goal to reduce oil consumption, and 14%

were ready for a tax on miles driven or an increase in the gasoline tax (Evarts, 2010a).

Americans have indicated that the most important factors when shopping for a new car are quality (88%), price (86%), and safety (86%). A little more than half of the people surveyed also considered “environmental friendliness” as important feature of a new vehicle (Evarts, 2010b). As part of the same survey, respondents have pointed to the reduction of oil dependency (26%), lowering emissions (21%) and fuel efficiency (14%) as reasons to “go green”. Out of all alternative fuel-powered cars, twenty-five percent consider EVs to be the most environmentally friendly solution. The study conducted by IBM also indicated the top reasons why people will convert from an ICE to an EV. Fifty-one percent of the public pointed to higher oil prices, 48% suggested sustainability concerns, 41% government incentives, and 26% mentioned access to priority driving lanes as reasons to buy an EV (Buscemi, 2011). Currently, the most popular EVs are the Chevrolet Volt (53%), Ford Focus EV (49%), Nissan Leaf (31%), and the Tesla Roadster (17%) (Coxworth, 2011).

Despite the public’s general interest in EVs and the intent of some to purchase an EV in the future, educational programs will have to be offered in order to better inform potential buyers. According to Michalik (2011), 42% of poll respondents know little about EVs or have “only heard of them” (para. 1). In a different survey, 75% said that they do not know the difference among alternative “green” vehicles (Kuo, 2010). Currently, deterrents for the purchase of an EV include the high purchase price (66%), inadequate charging infrastructure (60%) and limited driving range (58%) (Evarts, 2010b).

The car market in Puerto Rico additionally presents some unique challenges. The aesthetics of EVs will be an important aspect to consider when marketing and advertising EVs. According to Dr. Ingrid Matos-Nin (personal communication, January 28, 2011), Puerto Ricans

prefer SUVs as they are considered a symbol of power and offer additional safety over smaller cars. This is a result of dangerous driving conditions in major cities like San Juan, where traffic is extremely congested during rush hours. Additionally, Dr. Matos-Nin emphasized the risky behavior of Puerto Rican drivers. According to her, SUV drivers do not always follow traffic rules, do not respect the drivers of smaller cars, and will often attempt to overtake them illegally.

Another important consideration that must be taken into account is the environmental awareness of Puerto Ricans. According to Dr. Matos-Nin (personal communication, January 28, 2011), even though the public in Puerto Rico is nature-loving, people there are not very environmentally conscious. This is a result of people's ignorance of important environmental issues and partly due to inadequate governmental actions. Dr. Matos-Nin gave the following example:

Even though you might be able to find trash cans in a park in Puerto Rico, you will notice that they are always full and are rarely cleaned or emptied by the government. As a result, people find it easier to just leave the trash on the park grounds. This also leads to an inactive attempt on behalf of Puerto Ricans to sustain their environmental resources.

2.4.3 Socioeconomic Status of Potential Buyers

When introducing EVs to Puerto Rico, it will be necessary to identify potential customers. Dr. Matos-Nin (personal communication, January 28, 2011) suggested that Puerto Ricans are often impulsive buyers, and if a few well-off individuals begin purchasing EVs, a trend is likely to begin. According to her, Puerto Ricans are always willing to invest in technologies that will help them reduce expenditure on gasoline. Dr. Matos-Nin suggested that the introduction of EVs should be marketed by targeting the elite of the society, since they are not only wealthy, but also have the educational background to understand the future of EVs. Due to the driving habits of

citizens, another major problem is commuting, even though the roads are in good condition. Even if people can find ways to avoid waiting in traffic, they often have to put up with long lines for parking spots. Hence, providing reserved parking for EV owners may be a good marketing strategy.

2.4.4 Societal Barriers for Electric Vehicle Purchase

The Clean Cities group at the US DOE under the Vehicles Technology program sponsored a workshop on “Plug-in Vehicles and Infrastructural and Community Readiness” in July, 2010. The corresponding report outlines the scope of community preparedness and the barriers to the deployment of EVs. It also asserts DOE to be the primary supporter of the community in the introduction of EVs. Since societal barriers can hinder and obstruct the success of EVs in the world, it’s important to thoughtfully consider their implications and possible ways to overcome these problems.

One of the major problems for EV usage in general is the limited distance that can be travelled on a single charge. In order to counter this problem, charging stations need to be installed not only in the homes of EV owners but also externally in a large number. Also, in the first few years of EV deployment, consumers as well as providers may be hesitant to invest in this technology. This is because providers will not have enough information about EVs and necessitate further knowledge. Additional costs would include the installation of charging stations, acquiring private permits for the same, technician and emergency responder training, and expensive replacement parts. This high initial costs and lack of information about EVs can only be countered by partnerships between all involved partners – the government, electricity providers, and car manufacturers as well as dealers. With the replacement of oil and petroleum

with renewable energy sources in mind, it is important to understand that purely electricity driven vehicles are an ultimate goal.

2.5 Summary

This literature review aids the understanding of the various factors necessary for the introduction of EVs into a new region. We first explored the environmental benefits of EV engines over ICEs, mainly in terms of greenhouse gas emissions. We then discussed the necessary infrastructure options for the support and success of EVs in the transportation sector. We also covered specific case studies from regions where EVs are already being implemented, including Israel and Japan. Review of financing and marketing of EVs is provided, including some of the most up-to-date EV models and technologies. Lastly, societal factors, such as public opinion, environmental awareness, and potential target groups were reviewed as important factors to consider in EV introduction to Puerto Rico. The collected information identifies many efforts towards the widespread adoption of EVs throughout the world. However, more research and analysis is necessary to further facilitate the introduction of EVs to the island of Puerto Rico.

CHAPTER 3: OBJECTIVES

The transportation sector of Puerto Rico overwhelmingly depends on fossil fuels which are limited, expensive, and harmful to the environment. The administration of Puerto Rico has no experience with the deployment and use of EVs, which could serve as a solution to this problem. The goal of our project is to facilitate the introduction of EVs to Puerto Rico by providing recommendations to the EAA regarding required infrastructure, relevant legislation and marketing strategies. Based on the guidelines provided by our sponsors, we pursued our project goal through completing the following four objectives:

- Research the infrastructure required to support EVs and determine its current status in Puerto Rico.
- Assess the public knowledge and opinion of EVs on the island.
- Determine the economic viability of EVs for the citizens and the Government of Puerto Rico.
- Research existing domestic and international legislation and incentives aimed at stimulating the EV market and assess their applicability to Puerto Rico.

In order to meet our objectives, we developed a detailed methodology which is described in the following chapter.

CHAPTER 4: METHODOLOGY

The goal of our project was to facilitate the introduction of EVs to Puerto Rico by providing the EAA with recommendations on how to best address infrastructural, financial and societal issues throughout the process of EV deployment. To accomplish this goal, we needed to better understand the strategies undertaken by other countries and obstacles that Puerto Rico might face with the implementation of a successful EV market. We used the following methodology in order to obtain specific data and construct our analysis.

4.1 Survey of the general public

In order to determine the economic viability of EVs and the public sentiment of Puerto Ricans towards the introduction of EVs, we conducted a survey (See Appendix D). This survey was targeted at the general public of Puerto Rico and consisted of a variety of questions regarding EV deployment. These questions were aimed at determining the public knowledge of EVs, people's preference towards specific types of incentives and the purchasing power on the island. After some questions, interesting facts were provided for educational purposes. The survey was conducted through face-to-face interviews in Spanish at numerous locations, including in front of Departamento de Hacienda (The Treasury Department), La Plaza Las Americas Mall, on Ashford Avenue in Condado, and around the area of Old San Juan. Interviewees were selected through convenience sampling and 200 face-to-face responses were obtained. Survey responses were optional and completely anonymous. After the data were collected, the obtained information was compiled in Sigma Plot and Microsoft Excel spreadsheets, and the results were visually represented using graphs and tables. Such an analysis allowed us to identify the building blocks of EV marketing and enabled us to identify the most viable forms of incentives for EV purchase

in Puerto Rico. This information can be used as a basis for developing strategies aimed at stimulating EV sales on the island.

4.2 Interviews with select resource personnel

Interviews with select resource persons were used as a method of choice for collecting information about EV infrastructure, financing and legislation in Puerto Rico. Interviewees were selected based on their area of expertise and questions were tailored to obtain as much information as possible. Interview protocols were developed before each meeting (See Appendix C, Parts I – V), although additional questions were asked in order to seek more information on unforeseen discussion topics. All of the interviews were conducted in English; we did not encounter any major language barriers that could have prevented clear understanding of the questions or the provided answers. Whenever possible, all three team members were present for each interview. A lead interviewer was designated and the other team members were responsible for taking notes, although they too participated in the conversation. At the end of each interview, the interviewees were asked to provide consent for being cited in this report. Such was obtained in all cases. After the completion of every interview, an interview summary was written (See Appendix C, Parts VI – XV).

4.2.1 Academic Experts

In order to gain further insight into social and technical aspects of EV implementation, we interviewed two Worcester Polytechnic Institute (WPI) professors before arriving to Puerto Rico. The first interview we conducted was with Dr. Ingrid Matos-Nin (See Appendix C, Part VI). She discussed with us the buying behavior of Puerto Ricans and their concern for the environment of the island. She also informed us about the driving conditions in Puerto Rico and people's



preferred choice of car types. Next, we interviewed with Professor Fred Looft, the department head for the Electrical and Computer Engineering at WPI (See Appendix C-VIII). Prof. Looft discussed with us technical aspects of lithium-ion batteries and also provided useful information about battery recycling.

4.2.2 Car Dealerships

We interviewed car dealerships in San Juan to determine how willing the car dealers are to import and sell EVs. We spoke with Mr. Christain Calderon, internet sales manager of the GMC dealership in San Juan, for more in depth information about which car models sell best on the island (See Appendix C, Part IX). Ms. Neredia Ortiz, the fleet manger of Royal Motors GM dealership in San Juan, was able to provide a lot of information about the introduction of the Chevrolet Volt and the typical car buying trends of Puerto Ricans (See Appendix C, Part XI). We were also able to gather important information on Nissan’s private incentives and the expected arrival and distribution of the Leaf by interviewing Mr. Ismael Medina, the head of the Sales Department at Triangle Nissan in Mayaguez, Puerto Rico (See Appendix C, Part XV).

4.2.3 Government Officials

We interviewed Ms. Genevieve Cullen, Vice President of the Electric Drive Transportation Association to inquire about legislation and incentives currently used in the US to influence EV sales (See Appendix C, Part X). We also spoke with Mr. Luis Osorio, attorney for the EAA, to gain knowledge on the current status of the Puerto Rican government and the potential of Puerto Rico to adopt EV legislation and incentives (See Appendix C, Part XII). In our next interview, Mr. José Palou from the municipality of Bayamón provided us with information on the three charging stations which have been installed in Bayamón (See Appendix

C, Part XIV). The installation of the charging stations is part of a bigger project of the Municipality of Bayamón, named Solar Zone, which is aimed at developing renewable energy sources. Additionally, our team was able to attend the press conference and the launch event for Puerto Rico's first EV and to meet with Governor Fortuño, which further verified all the information on governmental incentives that we had collected.

4.2.4 Local Power Providers

Our interview with Mr. John Gilbrook, associate engineer at National Grid, provided us with information regarding EV infrastructure, marketing strategies and relevant legislation (See Appendix C, Part VII). He highly stressed the importance of assessing the condition of the grid as the introduction of EVs can significantly increase the load on the electric grid network. We also interviewed Mr. Francisco Ortiz, operational technology director at the Puerto Rico Electric Power Authority (PREPA), in order to obtain his input on the feasibility of installing charging stations in Puerto Rico, and assess the possible strain that EVs might put on the local electric grid (See Appendix C, Part XIV). Mr. Ortiz provided us with valuable information about the generation, distribution and use of electricity in Puerto Rico. We also discussed PREPA's involvement in charging station installation.

4.3 Case Studies and Comparative Studies

We performed comparative and case studies on relevant EV legislation in the US, current and upcoming EV models, EV charging station prices and technical specifications, and the economic viability of driving an EV. Additionally, we analyzed the Vieques Verde program. A detailed methodology for each of these studies is presented below.

4.3.1 Analysis of US State Electric Vehicle Legislation and Incentives

EV legislation and incentives offered by several states in the US were researched from government documents and reports. States receiving primary focus were California, Oregon and Hawaii as they are at the forefront of EV deployment and thus have developed programs to stimulate EV sales. The Plug-In America website provided an extensive list of legislation and incentives for the development of EV infrastructure throughout the US. The Electric Vehicle Deployment Act was used to obtain information about community based EV programs in Oregon. Information was also obtained from the interview with Ms. Genevieve Cullen from the Electric Drive Transportation Association (EDTA). Based on our findings, a comparative study between Hawaii and Puerto Rico in terms of demographics, geographic features and fuel costs was constructed. The information gathered aided us in formulating recommendations relating EV government legislation and incentives.

4.3.2 Analysis of Current and Upcoming Electric Vehicle Models and Charging Stations

The Nissan Leaf, Chevrolet Volt, Renault Fluence ZE, Tesla Roadster and Ford Focus EV were researched in terms of their cost, range, battery capacity, energy density and warranty, top speed, motor power, charging ports, weight and passenger capacity. Information was obtained from company websites and published documents.

Home, public and fast charging stations from AeroVironment, Coulomb Technologies and General Electric were researched in terms of their power rating, availability and cost. Company sales representatives were contacted in order to obtain the required information.

4.3.3 Economic Analysis of Operating an Electric Vehicle

One of the main focuses of our project was to determine the economic viability of EVs for the people of Puerto Rico. In order to meet this objective, we performed research and case studies to collect as much household income data as possible through government websites and documentation.

To conduct an economic comparison of driving an EV as opposed to driving a conventional car, the costs of operating the two per 100 miles were plotted as a function of electricity and gasoline prices, respectively. For the analysis, several ICE car models were chosen to represent four of the major car types on the market: sedan (Nissan Altima), SUV (Toyota RAV4), sports car (Chevrolet Corvette), and hybrid (Toyota Prius). These were compared to the Nissan Leaf (EV sedan) and Tesla Roadster (EV sports car). For all computations we used \$0.24/kWh and \$3.67/gal as the cost of electricity and gasoline in Puerto Rico, respectively; additionally, gasoline and electricity prices were assumed to be independent. The graphing software used was SigmaPlot and Maple.

The cost of operating each of the gasoline powered cars was first plotted as a function of the price of gasoline and the graph was overlaid with the cost of operating both of the EVs at the current price of electricity in Puerto Rico. To compute the cost of vehicle operation per 100 miles, the following formulae were used:

$$C_{Corvette} = 100 \text{ mi} * \frac{1 \text{ gal}}{18 \text{ mi}} * G \quad (1)$$

$$C_{Altima} = 100 \text{ mi} * \frac{1 \text{ gal}}{27 \text{ mi}} * G \quad (2)$$

$$C_{RAV4} = 100 \text{ mi} * 1 \text{ gal}/22 \text{ mi} * G \quad (3)$$

$$C_{Prius} = 100 \text{ mi} * 1 \text{ gal}/50 \text{ mi} * G \quad (4)$$

$$C_{Leaf} = 100 \text{ mi} * 0.24 \text{ kWh}/\text{mi} * E \quad (5)$$

$$C_{Roadster} = 100 \text{ mi} * 0.22 \text{ kWh}/\text{mi} * E \quad (6)$$

where E represents the cost of electricity and G stands for the price of gasoline. The respective mpg ratings were obtained from the US Environmental Protection Agency (EPA) and EV energy per mile ratings can be found in Table 3 of this report.

For more in-depth analysis, Nissan Leaf and Nissan Altima were chosen as representatives of EVs and gasoline powered automobiles. The Nissan Altima is a good fit for comparison with the Nissan Leaf due to similar specifications of the two cars. The cost of driving a Nissan Altima was plotted as a function of gasoline price. The graph was overlaid with the cost of driving a Nissan Leaf at the current electricity price and after a $\pm 80\%$ change. In a similar manner, the cost of driving a Nissan Leaf was plotted as a function of electricity price and the graph was overlaid with the cost of driving a Nissan Altima at the current gasoline price, as well as after a $\pm 80\%$ change. Further, in order to better depict the relationship between vehicle operation costs and prices of electricity and gasoline, a three dimensional graph was constructed using Equations 2 and 5.

One additional factor that must be considered in determining the economic viability of EVs for the Puerto Rican people is the typical EV buyer profile. It is important to identify the

socioeconomic section of the population that would be likely to purchase EVs. This allows both car manufacturers and the Puerto Rican government to market the EVs brought to the island to an accurate and responsive target market. After conducting research and utilizing case studies of other areas in the world where EVs have been introduced, we compiled and used this information to make comparative studies with respect to Puerto Rico. This research, combined with the results obtained from the survey of potential buyers (Appendix D, Part I), helped us determine the best market for EVs.

4.3.4 Analysis of the Vieques Verde Program

The Vieques Verde program will be used as a pilot project for the introduction of EVs in Puerto Rico. Unpublished documents, meeting minutes, correspondence and copies of the Vieques 2000 Census were provided to us by the EAA. These files included several important fact sheets and statistics regarding income and buying power on the island of Vieques. This information was used to gain a better understanding of the programs being currently undertaken by the Government of Puerto Rico to facilitate EV introduction.

4.4 Summary

To achieve the objectives of this project, we surveyed potential buyers and the general public in order to determine the public sentiment of Puerto Ricans towards the introduction of EVs. Comparative studies of Puerto Rico and countries which have already begun the process of implementing EVs were used to determine the need for financial stimuli, appropriate infrastructure and legislative changes. As a result of this research, we prepared a list of recommendations to the EAA which can be used as a guide towards the successful introduction of EVs on the island.

CHAPTER 5: RESULTS AND DISCUSSION

We conducted surveys and interviews, and performed case studies in order to collect data about public opinion of EVs in Puerto Rico, the state of required EV infrastructure on the island and possible legislation and incentives to support the introduction of EVs. This research was used to make recommendations to the EAA in order to facilitate the large scale deployment of EVs in Puerto Rico.

5.1. Survey of the general public

Our 200 face-to-face surveys yielded data on the public opinion of Puerto Ricans regarding several different factors of EV introduction. We divided our survey results into the following categories: demographic information, EV knowledge, factors for purchasing an EV, and environmental awareness. Some of the survey results may have been influenced by certain societal factors and these will be discussed in this chapter. Additionally, while taking the survey, many individuals carried on conversations with us and gave us insight about their opinion of EVs. The survey results helped us formulate conclusions about the public opinion of EVs and EV marketing strategies. Our complete survey data can be found in Appendix E.

5.1.1 Demographic Analysis

Several questions about demographics were asked in order to better understand how some socioeconomic factors influence the willingness to purchase an EV. Questions about annual income, vehicle preference, number of vehicles per household and daily distance traveled, were asked to better understand the most typical Puerto Rican buyer profile. Results have been summarized in Figure 5.

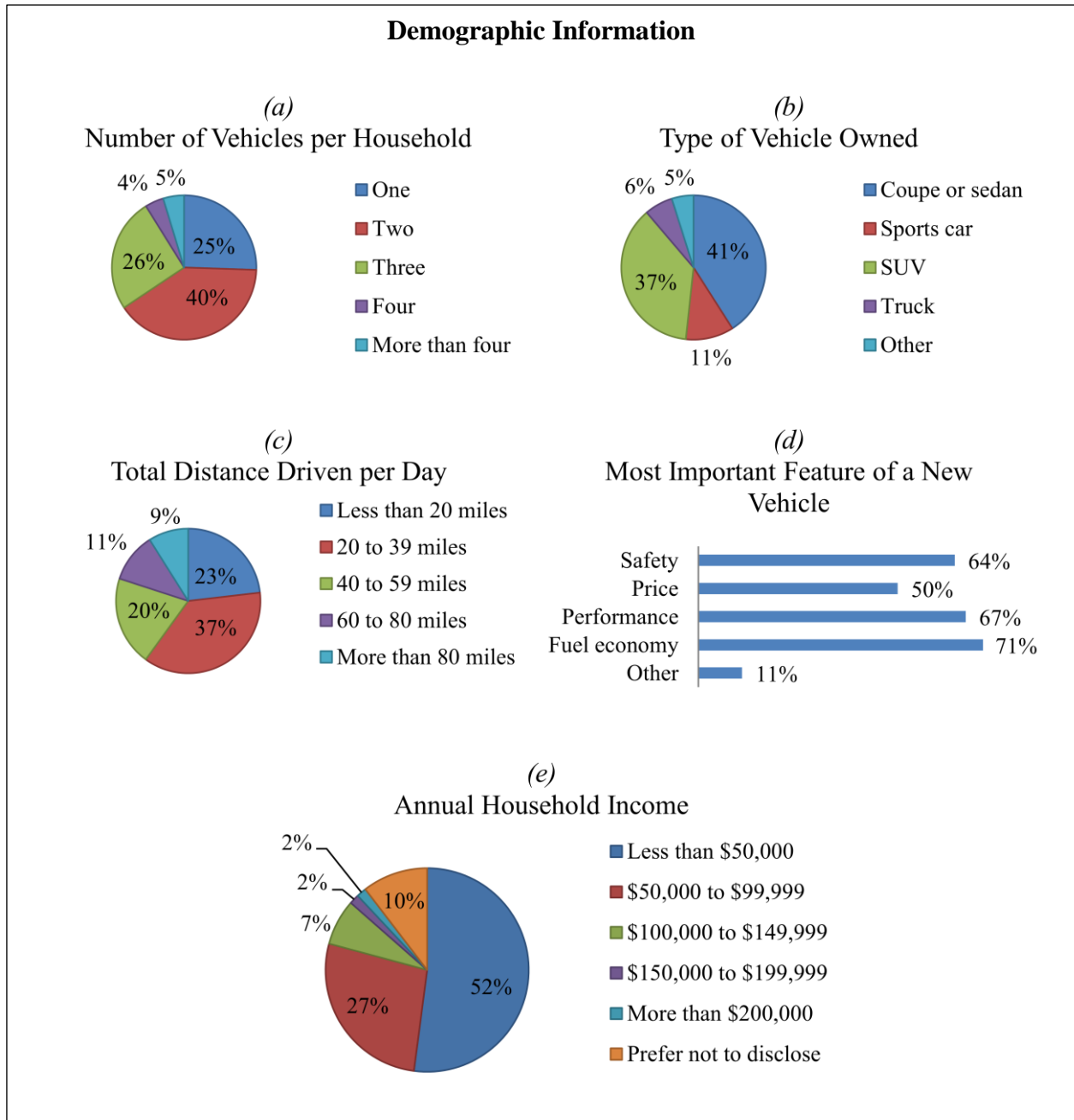


Figure 5: Demographic analysis of survey questions

Results showed that 40% of survey participants had two vehicles in their household. Based on our research, we had hypothesized that this would be the most popular response to this question. About a quarter of interviewees owned either one or three vehicles, and only 9% owned 4 or more vehicles. Due to the short commutes on the island, EVs have the potential to serve as a

vehicle for everyday travel. Since many Puerto Ricans own more than one vehicle, an option would be to purchase an EV for shorter trips and to use a gasoline vehicle for lengthier ones.

Forty-one percent of the people surveyed owned a coupé or sedan. This shows that the Nissan Leaf or Chevy Volt have the potential to become popular in Puerto Rico, as both of these vehicles fall under this category. The second most common car type driven on the island is SUV. From our case studies and interviews with car dealers, we had expected that this would be the case. This could pose a potential problem, as EVs are often designed as more compact vehicles. However, in the near future several car manufacturers will be developing electric SUV models. Sports cars were driven by 11% of the participants, corroborating our hypothesis that a part of the population on the island prefers elegant and high performance vehicles. This fact is encouraging as EV models are increasingly designed to appeal to these target customers.

Another question on our survey gauged the total distance (in miles) driven per day. These data helped us further assess the feasibility of EVs on the island, as people who travel relatively less each day would probably be more apt to purchase an EV. Eighty percent of Puerto Ricans drive less than 60 miles each day; this is encouraging, as currently this distance is within the typical EV range per single charge. In fact, only 9% of people surveyed said that they drive more than 80 miles per day, which could pose a challenge for EV battery capacity. Many people commented on the interesting fact following this question, as they were surprised to learn that 63% of Americans commute less than 40 miles each day. Some simply did not believe this fact.

We were also interested in determining which factors of a new vehicle were most important to the Puerto Rican population. Safety, price, performance and fuel economy were all very important to more than 50% of respondents. Additionally, more than 10% indicated

environmental impact as another important factor to consider when purchasing a new vehicle.

In order to gauge the buying power of our sample population, we inquired about the annual income in their household. A little more than half of the respondents indicated that they earn less than \$50,000 per year. These data are of some concern, as low income is preventative of EV purchase, at least initially. Thus, EVs at first must be targeted to the wealthier sector of Puerto Rican society. Only 2% of the survey population earned more \$200,000 annually. However, this is still an encouraging fact, as it indicates the presence of an “early adopters” population on the island. These findings supported the need for some financial incentives from both the Puerto Rican government and from private car dealers. Interestingly, some individuals who had an annual household income of less than \$50,000 owned three or more car. This led us to speculate that used cars are popular on the island, and as supported by our research, Puerto Ricans often like to perform maintenance on their own vehicles rather than bringing them to repair shops.

5.1.2 Analysis of Electric Vehicle Knowledge

Another main objective of our survey was to determine the current public knowledge of EVs on the island. Results obtained from the relevant survey questions are summarized in Figure 6. As proper educational programs are a key factor in the success of any new technology, these data helped us determine the need for further EV awareness.

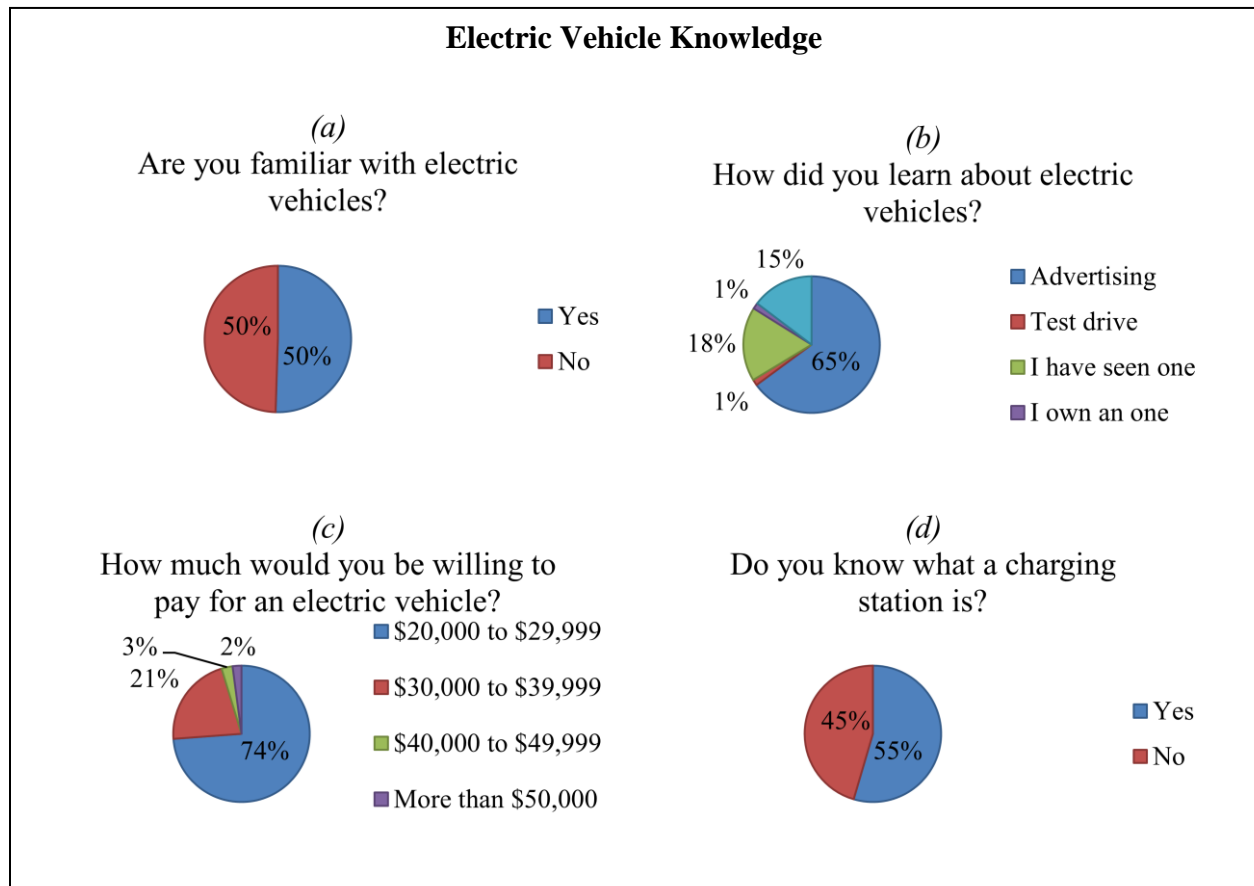


Figure 6: Analysis of electric vehicle knowledge amongst Puerto Ricans

Our survey results show that only half of the sample population was familiar with EVs. Additionally, 55% of the people surveyed knew what a charging station is. These data make it evident that a large amount of the Puerto Rican public is not well informed or educated about EV technology. Thus, a sound and informative marketing campaign is necessary to increase awareness and knowledge of EVs in Puerto Rico.

We also inquired of the way people have learned about EVs. The majority of the respondents had heard of EV through advertisement such as TV commercials, newspapers, radio, etc. Surprisingly, a relatively large number (18%) of people answered that they had seen EVs on the street. These data led us to deduce that many people mistook hybrid cars for EVs.

Another question was aimed at determining the amount people are willing to pay for an EV. The most common answer to this question was the lowest amount provided, \$20,000 to \$29,999, with 74% of the population responding with this amount. Only 2% of the survey participants responded that they would pay more than \$50,000 for an EV. This further highlights the need for government aid in terms of incentives, as the willingness to purchase an EV declined greatly as the cost increased.

5.1.3 Factors for Electric Vehicle Purchase

Several of our survey questions dealt with factors that influence EV purchasing. We found that 73% of survey participants would consider buying an EV that would bring them savings in the long run, even though its purchase will be associated with a higher initial investment. To the remaining 27%, initial cost is clearly a concern and limiting factor for EV purchase. Further, 69% of survey takers responded that they would consider buying an EV based on the fact that it can travel 100 miles on a single charge and can be charged in about 6 hours. From this information, it appears that a smaller number of people suffer from “range anxiety” than we initially anticipated. However, while talking to individuals during the course of this survey, many Puerto Ricans were concerned about the fact that there currently exist no charging stations in the area. As a result, they would be very concerned about the limiting range of EVs unless adequate infrastructure was already in place. The above results have been summarized in Figure 7.

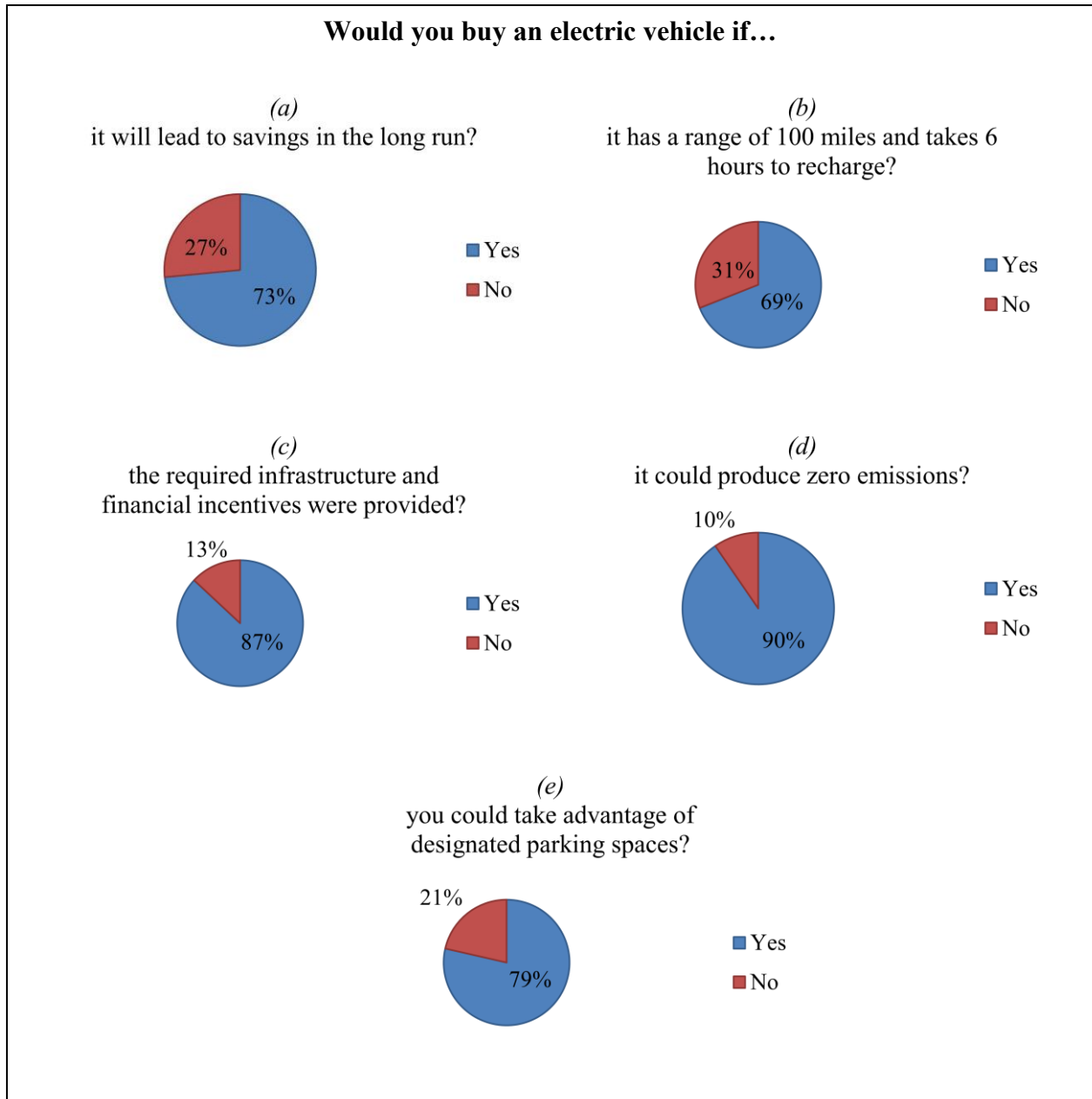


Figure 7: Willingness to buy an electric vehicle in accordance with various factors

The cost of EVs is a very important factor and government incentives serve as a powerful tool to facilitate the introduction of EVs. Eighty-seven percent of survey takers said that they would be interested in purchasing an EV if the government were to offer incentives to lower the cost of the cars. Only 13% of participants would not be interested in EVs even after incentives,

and many of these individuals made it clear that they were afraid that the vehicles would still be too expensive.

Additionally, analysis of the survey data showed that 90% of the Puerto Ricans would be interested in purchasing an EV knowing that it would produce zero emissions. These data suggest that Puerto Ricans are environmentally conscious and willing to live sustainably. Many survey takers expressed their concern for the pollution in the San Juan area and the carbon emissions that are contributing to global warming.

In order to gauge another buying factor, survey takers were asked if they would be willing to buy an EV provided that they could take advantage of designated parking spaces. A total of 79% of participants would be interested in buying an EV given this information. People were very concerned about the traffic congestion and the lack of adequate parking in the San Juan metropolitan area. Many Puerto Ricans were unaware of this type of incentive, but were very interested in the prospect of having a reserved parking space for their EV.

5.1.4 Environmental Awareness

Our survey also included a question aimed at determining the level of environmental consciousness on the island. Results can be found in Figure 8. Overall, 63% of our sample population responded that they were “very concerned” about environmental affairs and an additional 25% responded that they were “concerned” about the current state of the environment.

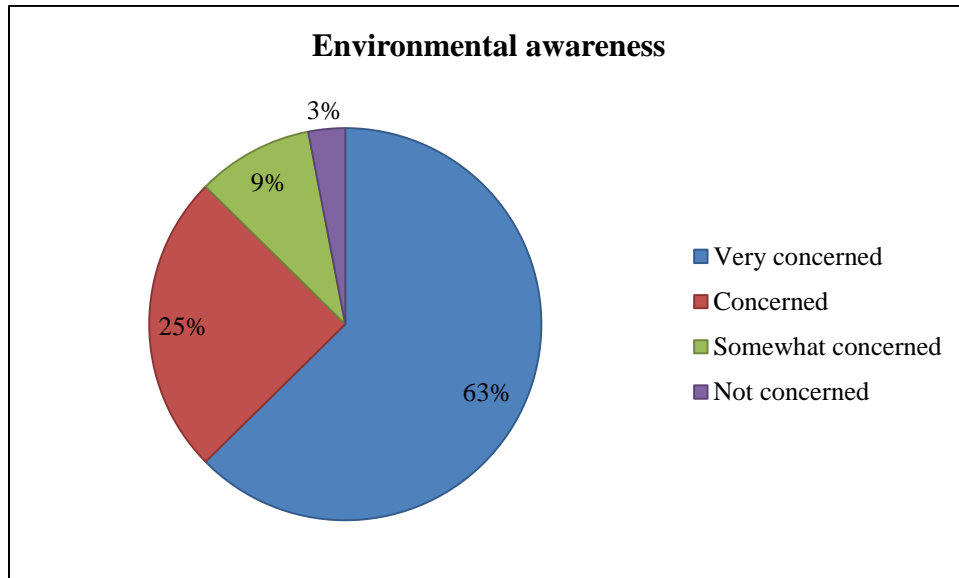


Figure 8: Analysis of environmental awareness

These data displayed the strong concern amongst the Puerto Rican population regarding environmental affairs. Only 3% of survey participants responded that they were “not concerned” about environmental affairs. These data help emphasize the strategy of marketing EVs as environmentally friendly to the general public.

5.1.5 Cross-tabulation Analysis

Our sample population consisted of 200 individuals from a wide socioeconomic background, giving us an accurate representation of the different classes on the island. In order to further assess our survey data, cross-tabulation analysis was performed. Interrelations between various survey responses were established and results can be found in Figures 9, 10 and 11.

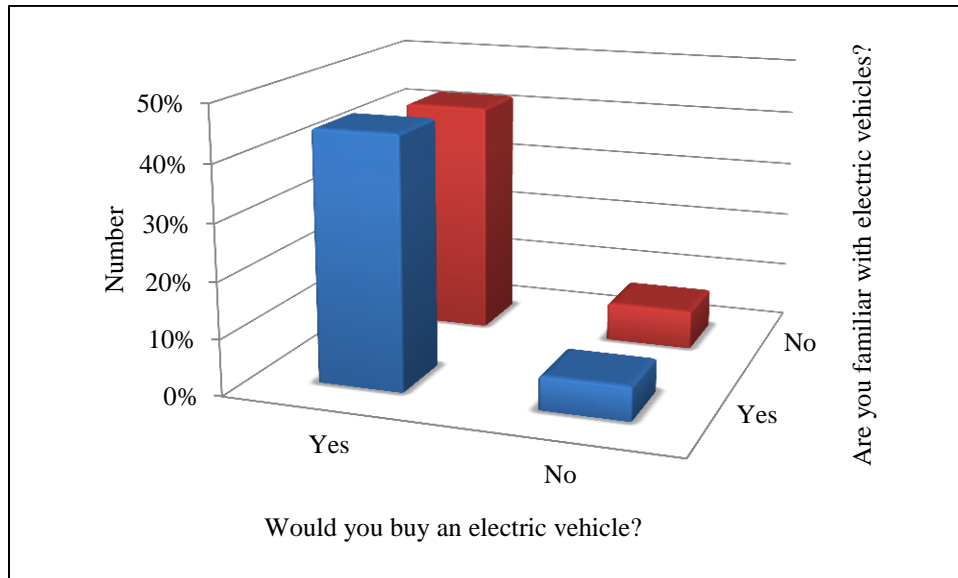


Figure 9: Relationship between EV knowledge and willingness to purchase an EV

We were able to develop a relationship between the people who were aware of EVs and those who would purchase an EV. Approximately 45% of survey respondents, who were familiar with EVs, expressed an interest in buying an EV as well. However, 7% of those who were not already familiar with EVs said they would not be interested in buying an EV. This interrelation is a direct indicator of the importance of educating and familiarizing the general public with EVs for their successful marketing and sales in Puerto Rico.

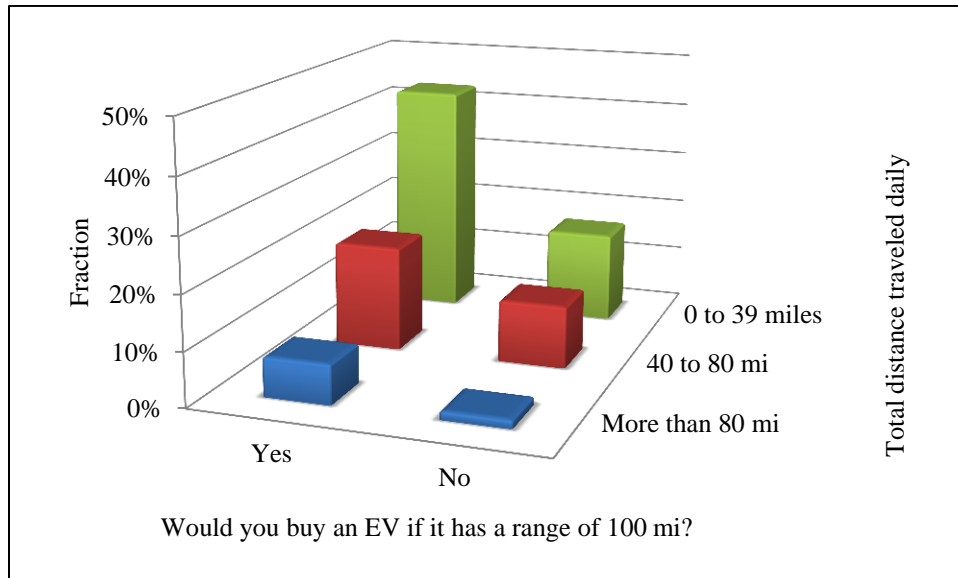


Figure 10: Relationship between willingness to purchase an EV and daily distance travelled

Another interesting result is that people who travel a relatively short distance are more likely to purchase an EV based on the fact that it has a range of 100 miles on a single charge. Forty percent of those who travelled less than 40 miles per day would be interested in purchasing an EV. Furthermore, even of those who travelled more than 80 miles daily, 5% would be interested in purchasing an EV. These data strongly suggest that range anxiety is not a major obstacle for EV purchase in Puerto Rico.

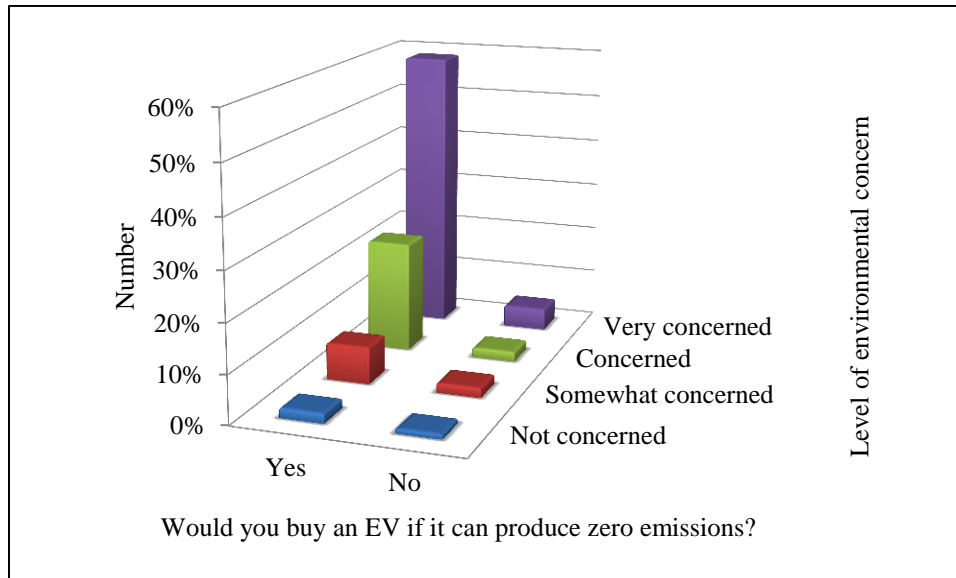


Figure 11: Relationship between willingness to purchase an EV and level of environmental concern

We had expected that people who are more concerned about the environment are more likely to invest in sustainable technologies. This assumption was confirmed by our survey results, which showed that 60% of the people who were “very concerned” about the environment would buy an EV knowing that it can produce zero emissions. Conversely, only about 5% of the people who said they were “not concerned” about the environment would be interested in buying an EV. This trend was observed to remain constant with the amount of people interested in purchasing EVs declining with the decrease in their personal concern regarding the environment.

5.2. Interviews with select resource personnel

Interviews with select resource persons were used to collect information about EV infrastructure, financing and legislation. All interviews were conducted using previously developed protocols (See Appendix C, Parts I – V); complete interview summaries can be found in Appendix C, Parts VI to XV.

5.2.1 Prof. Ingrid Matos-Nin, WPI, Worcester, MA

The interview with Prof. Matos-Nin, professor of Hispanic studies at WPI, provided us with information about driving conditions in Puerto Rico and potential marketing strategies for EVs. From this interview we gathered that drivers in Puerto Rico prefer larger cars like SUVs as opposed to smaller cars as a result of the dangerous driving conditions in the metropolitan area which additionally aggravates the traffic. Even though the roads on the island are in good condition, the large number of vehicles compared to the island size results in shortage of available parking. This makes daily commute on the island difficult, and thus, Puerto Ricans are willing to invest in vehicle technologies that will help them save money on gasoline. Since the elite of Puerto Rico are the richest and the most educated ones, they should be the initial targeted buyers of EVs.

5.2.2 Mr. John Gilbrook, National Grid, Waltham, MA

The interview with Mr. Gilbrook, associate engineer at National Grid, provided us with information regarding EV infrastructure, marketing strategies and relevant legislation. The condition of the grid is an important factor to take into consideration when assessing the introduction of EVs as they can significantly increase the load on the electric grid network. A single EV uses as much power as a conventional dryer or a refrigerator when charging but an increased number of EVs can cause problems at the distribution sector of the grid. If necessary, transformers would be the first component that would need to be upgraded. However, it is expected that the adoption of EVs will be gradual and will not result in immediate grid-related issues. Smart grids could offer advantages over conventional grids as they can allow direct monitoring of grid usage and thus allow for charging during off peak hours. They can additionally prevent blackouts and increase the life of grid components and stimulate the



development of vehicle to grid technologies. Uniform battery standards, geographical features such as plain areas and short distances between cities will further facilitate the deployment of EVs. According to Mr. Gilbrook, marketing strategies should be targeted at early adopters and should mainly focus on vehicle performance. While the provision of allotted parking spots for EVs is an appropriate incentive, it should be used carefully and not be overdone.

5.2.3 Prof. Fred Looft, WPI, Worcester, MA

The interview with Prof. Looft, chair of the electrical and computer engineering department at WPI, provided us with information about recycling issues related to Li-ion batteries. A significant number of countries export their exhausted batteries for recycling to developing nations due to the availability of cheap labor. However, not only is the exportation very expensive, it also contributes to environmental degradation of the countries that actually recycle these batteries.

5.2.4 Mr. Christian Calderon, Royal Motors GMC, San Juan, Puerto Rico

The interview with Mr. Calderon, internet sales manager at Royal Motors GMC, provided us with information on the most popular car models in Puerto Rico. Also, we gathered that Puerto Ricans strongly associate their vehicles with their social status.

5.2.5 Ms. Genevieve Cullen, EDTA, Washington, DC

The interview with Ms. Cullen, vice president of the EDTA, provided us with useful information about EV incentives and legislation. The most popular strategy to promote the sales for hybrid vehicles has been allowing hybrids access to High Occupancy Vehicle (HOV) lanes and designated parking spaces. Similar strategies could be applied to EVs. Also, in addition to the federal tax credit, some states provide further discount to their residents for the purchase of an



EV. Funding the research and development of new EV technologies will accelerate the deployment of EVs. The federal credit provided by the American Recovery and Reinvestment Act (ARRA) will expire soon and additional funding will be required. In Oregon, targeting specific communities for the development of EV infrastructure has worked particularly well. An organization that does promote such endeavors is the Clean Cities Coalition.

5.2.6 Ms. Nereida Ortiz, Royal Motors GMC, San Juan, Puerto Rico

The interview with Ms. Ortiz, fleet manager at Royal Motors GMC, provided us with information on marketing strategies that will be adopted by GMC in Puerto Rico. Aesthetics are a major determinant in the process of choosing a new car. In Puerto Rico, the lack of engine sound in EVs would offer an additional advantage as Puerto Ricans are fond of the radio and enjoy loud music. The best way to market EVs in Puerto Rico would be to ensure that buyers are well informed by developing appropriate educational strategies. GMC and other car dealerships in the area will provide the necessary support system for the successful sales of EVs.

5.2.7 Mr. Luis Osorio, EAA, San Juan, Puerto Rico

The interview with Mr. Osorio, legal counselor at the EAA, provided us with information regarding legislation that may promote or deter the popularity of EVs in Puerto Rico. The biggest source of funding for developing supporting infrastructure for EVs has been ARRA. However, most of the funding provided by ARRA for 2010-2011 has been already spent and additional funding will be required to continue working on strategies for the sale of EVs. This funding is also supplemented through DOE funds since Puerto Rico is considered a state by this department for monetary purposes but not by the federal government since Puerto Rico does not pay federal taxes. The Government of Puerto Rico has signed a contract with Nissan for providing discounts

for the purchase of the Nissan Leaf. The Government of Puerto Rico will require 4-5 years before it is able to allocate sufficient resources for the development of EV projects. Laws 128, 83 and 73 can be particularly helpful during the process of EV introduction. However, PREPA has been given monopoly in power generation and distribution on the island, which could lead to potential obstacles. Additionally, even though the recycling rates in Puerto Rico are low, the government has been making efforts towards sustainability.

5.2.8 Mr. Francisco Ramos, PREPA, San Juan, Puerto Rico

The interview with Mr. Ramos, operational technology director at PREPA, provided us with information on infrastructural requirements and marketing strategies that will be necessary to successfully introduce EVs on the island. The electric grid in Puerto Rico has the capacity to produce up to 6000 MW of electricity but is only producing about 3600 MW and can thus, support EV charging. Since EVs are new to the island, it is difficult to predict the impact and success of EVs in Puerto Rico. As a result, PREPA will be installing charging stations by the end of April, 2011 and performing initial testing of different EV models. Rural areas of Puerto Rico do not have a steady electric supply and also lack a well-developed roadway. Thus, such areas will pose a challenge for the island-wide deployment of EVs. Extensive testing of different EV models, including EREVs such as the Chevrolet Volt will be performed. The current cost of electricity in Puerto Rico is \$0.24/kWh and as a result, Puerto Rico is investing in alternative energy resources. So far, PREPA has signed eighteen contracts for the development of renewable energy sources. Currently, the predominant part of energy generation in Puerto Rico is located in the south part of the island, while 75% of the energy consumption is within the metropolitan area of the northern part. This can be a potential problem since the transportation of electricity is expensive. Additionally, in order to ensure a reliable and continuous supply of electricity,

renewable energy will need to be supported by a back-up system. The maintenance of this support system is costly even if it is not being used. Thus, electricity cost could potentially rise to around \$0.60/kWh. PREPA is developing smart grid technologies. This is a costly initiative but is receiving strong support by the government. This will enable PREPA to monitor energy usage and to offer different rates for peak and off-peak usage. Additionally, a smart grid would enable the future development of V2G technology. Hybrid vehicles faced difficulties with their initial introduction as a result of the lack of sound educational and marketing strategies.

5.2.9 Mr. José Palou, Municipality of Bayamón, Bayamón, Puerto Rico

The municipality of Bayamón has installed three charging stations which are powered by photovoltaic cells. The charging stations are ChargePoint model supplied by Coulomb Technologies and provide outlets for Level I (120 V) and Level II (208 V) charging. The installation of the charging stations is part of a bigger project of the Municipality of Bayamón, named Solar Zone, which is aiming to develop renewable energy sources. In addition to harvesting renewable energy, the Project Solar Zone also aims to raise the public's awareness of sustainable development. The installation of a total of 2553 photovoltaic panels had a total cost of \$3.7 million and 65% of it was supplied from ARRA funding. The project had to go through a competitive selection process to receive financial support. A company named Aireko was hired for the construction of the solar panels which began on March 1st, 2010 and was completed on May 29th of the same year. The system of photovoltaic panels has an average energy production of 585 kW per hour. The solar cells have 14 – 17% efficiency and each contributes about 230 W per hour. In total, the Solar Zone Project is generating an average of 2.2 MW per day, which leads to an estimated 25% savings in energy consumption. As part of the project, two residential type inverters were also installed for educational purposes. Currently the generation of electricity

does not exceed the needs, but any excess power could be sold to PREPA. The three charging stations are currently in testing phase and are so far not being used for charging of EVs. Their maintenance is provided by the construction company Aireko.

5.2.10 Mr. Ismael Medina, Triangle Motors Nissan, Mayagüez, Puerto Rico

The interview with Mr. Medina, head of sales department at Triangle Motors Nissan, provided us with details of the expected arrival of the Nissan Leaf and several issues regarding its sales. The Nissan Leaf is expected to arrive to the Puerto Rican market in September 2011. However, since there are currently no charging stations on the west side of the island, appropriate infrastructure will need to be developed before EVs can be sold. A stimulus for the purchase of EVs can be the high gasoline prices in Puerto Rico. Nissan is willing to support EV sales on the island by providing incentives as well as training for its technicians and sales representatives.

5.3 Case Studies

Case studies were performed in order to investigate the relevant EV legislation and incentives in the US, current and upcoming EV model specifications, charging station costs and technical specifications as well as a detailed analysis of the Vieques Verde program, undertaken by the Government of Puerto Rico. Additionally, a comparative economic analysis of ICE cars and EVs was performed in terms of cost of operation.

5.3.1 Study of Relevant Legislation and Incentives in the United States

States in the US are most applicable to conduct legislative analysis in order to make a sound comparison with Puerto Rico. Being a United States territory, Puerto Rico has a very similar government structure and lawmaking body as the individual states. Thus, studies of legislation and incentives currently employed in the US will provide a basis for similar laws in

Puerto Rico.

Arguably, the state at the forefront of EV introduction is California. California passed Assembly Bill 32 (AB 32), which is also known as the California Global Warming Solutions Act of 2006. AB 32 calls for the elimination and retrofitting of all diesel equipment. This act was passed mainly as a result of California's unsatisfactory air quality ("Global Warming Solutions Act", 2011). The EPA is the main enforcement agency of this law, along with the California Air Resources Board (CARB) ("Global Warming Solutions Act", 2011). The main goal of this bill is to reduce the greenhouse gas levels by the year 2020 to the levels they were at in 1990. This bill also provides several incentives for the conversion to renewable energy fuels. Additionally, it also offers incentives to "offset buyers", i.e. those willing to transition to renewable energy vehicles (Sullivan, 2010). Thus far, the elimination of all diesel equipment has yet to be enforced, but actions will be taken by CARB in 2012. Enforcement will include fines for missing refrigerant gas inventory and for other items such as missing tracking records. The majority of the funding for these projects will be implemented through special fund borrowing (Sullivan, 2010). Also, a lack of compliance to the rules of this bill will result in penalties such as a failure to pass yearly inspection.

In California, a total of \$12,500 can be received as a tax credit for the purchase of an EV. ARRA provides a federal \$7,500 tax credit to EV buyers in the US and the California Clean Vehicle Rebate Project (2007) offers an additional \$5000 tax credit ("Clean Vehicle Rebate Project", 2011). ARRA also provides a 10% tax credit for conversion of fossil fuel powered vehicles to "green" vehicles and up to a 30% tax credit on the installation of charging stations for both private buyers and large businesses.



Another state at the forefront of EV introduction is Oregon. The main legislation Oregon has used to introduce EVs is the Electric Vehicle Deployment Act (2010). This act requires local regions to introduce 700,000 EVs within the next five years (Electrification Coalition, 2011). This legislation has led to the funding of EV projects and installation of infrastructure throughout the state.

Hawaii has established a \$1 billion statewide charging network and signed a contract with *Better Place*, the same company establishing an electric car network in Israel (Shapira, 2009). Hawaii plans to have over 10,000 EVs statewide by the year 2014. In order to increase the popularity of EVs, the Hawaiian state government has proposed legislation to increase the tax on all oil imports. However, this may have negative impacts on other areas of society, even if it provides a positive impact of the transportation sector (“EV Ready Grants,” 2010). The EVs adopted in Hawaii must have batteries of a minimum capacity of 5 kWh that must be certified by the EPA. The Hawaii Department of Business, Economic Development and Tourism (DBEDT) has received \$3 million in EV grants from ARRA to install infrastructure and commercially available charging equipment (“EV Ready Grants”, 2010). Hawaii has also implemented the EV rebate program, allowing for a credit of up to \$4,500 towards the vehicle cost and up to \$500 for the installation of charging stations (“Hawaii’s Electric Vehicle Rebate Program”, 2011). This program has funding until September 30, 2011 and represents one example of a strong incentive to encourage people to buy EVs and to install the necessary EV infrastructure. This is an exemplary effort in terms of legislation to accelerate EV adoption.

Hawaii is comparable to Puerto Rico in terms of geographical location and area. Both of these regions are islands that depend heavily on the import of oil and cars. The virtually identical

climatic conditions would result in similar battery performance. Additionally, the cost of charging an EV in Hawaii and Puerto Rico would be very similar, providing for another point of comparison. All of these similarities can be used to draw parallels in order to facilitate EV introduction in Puerto Rico.

However, it should be kept in mind that some important differences exist between these two locations. Puerto Rico has almost three times the population of Hawaii, leading to many more vehicles on the road, which could potential have a higher impact on the electric grid. Further, the per capita income in Puerto Rico is much lower than that in Hawaii. Perhaps the largest difference between these two regions is that Puerto Rico currently has no legislation or incentives regarding EVs. This results from the fact that Hawaii is a state while Puerto Rico is a US territory. Puerto Ricans do not pay federal income tax to the US government, and consequently do not receive federal tax credit for EV purchases. Furthermore, vehicle importation additionally increases the cost of cars. In Puerto Rico, the vehicle excise tax can range from 12 – 40% (See Appendix F). These factors make the current cost of buying an EV in Puerto Rico much higher than in Hawaii. Data used for this analysis can be found in Table 1.

Table 1: Comparison of Hawaii and Puerto Rico

	<i>Puerto Rico</i>	<i>Hawaii</i>
Population	3,967,288 ¹	1,295,178 ²
Land Area	3435 square miles ¹	6423 square miles ²
Per Capita Income	\$17,400 ¹	\$42,055 ²
Average Temperature	80°F ¹	80°F ³
Average Rainfall	52.9 inches ¹	25-30 inches ³
Gas Prices (April 2011)	\$3.67/ gallon ⁴	\$4.29/gallon ⁵
Electricity Prices (April 2011)	\$0.24/ kWh ⁴	\$0.24/kWh ⁵
Tax Incentives for EVs	None ⁴	\$7,500 federal, up to \$4,500 state, up to \$500 state infrastructure ⁶

1 Puerto Rico (2011). Retrieved from the CIA World Factbook on April 7, 2011 at <https://www.cia.gov/library/publications/the-world-factbook/geos/rq.html>

2 Hawaii. (2010). Retrieved from U.S. Census Bureau on April 7, 2011 at <http://quickfacts.census.gov/qfd/states/15000.html>

³ Climate of Hawaii. (2010). Retrieved from the National Weather Service Forecast Office on April 7, 2011 at http://www.prh.noaa.gov/hnl/pages/climate_summary.php

⁴ Ramos, Francisco. Personal Communication. March 31, 2011

⁵ Hawaii Gas Prices. (2011). Retrieved on April 7, 2011 from http://www.hawaiiigasprices.com/Prices_Nationally.aspx

⁶ State and Federal Incentives. (2011). Retrieved March 21, 2011 from <http://www.pluginamerica.org/why-plug-vehicles/state-federal-incentives#federal>

An increasing number of states in the US are also taking steps toward accelerating the introduction of EVs. For example, Washington and New Jersey have waived sales taxes on the purchase of an EV (“State & Federal Incentives”, 2011). In total, over 22 states have some type of incentive at the state level for the purchase of EVs, and for the installation of commercial EV infrastructure. Other states have proposed legislation for EV adoption incentives and plan to vote on them in the near future (“State & Federal Incentives”, 2011). Table 2 provides an overview of some of the various incentives offered by states in the US today. Additionally, Figure 12 depicts the distribution of incentives offered in the US. President Obama has often emphasized EVs and EV technology as a priority for his administration. Thus, tax credits may be revisited in Congress this year, especially if gasoline and oil prices continue to rise (Colleen Newman, personal communication, March 23, 2011).

Table 2: Current and proposed statewide incentive options¹

<i>State</i>	<i>HOV lane access</i>	<i>State Tax Credit</i>	<i>Infrastructure Incentives</i>	<i>Purchase Rebate</i>	<i>Sales Tax Exemption</i>
California	Yes	Yes, up to \$5,000	Yes	No	No
Oregon	No	Yes, up to \$5,000	Yes	Yes (including conversion from ICEs)	No
Hawaii	Proposed for the future	Yes, up to \$4,500	Yes	Yes	No
Massachusetts	Proposed for the future	No	No	No	Proposed for the future
Illinois	No	No	Yes	Yes (including conversion from ICEs)	No
Texas	No	Proposed for the future	No	No	Proposed for the future

¹ Adapted from: State and Federal Incentives. (2011). Retrieved March 21, 2011 from <http://www.pluginamerica.org/why-plug-vehicles/state-federal-incentives#federal>

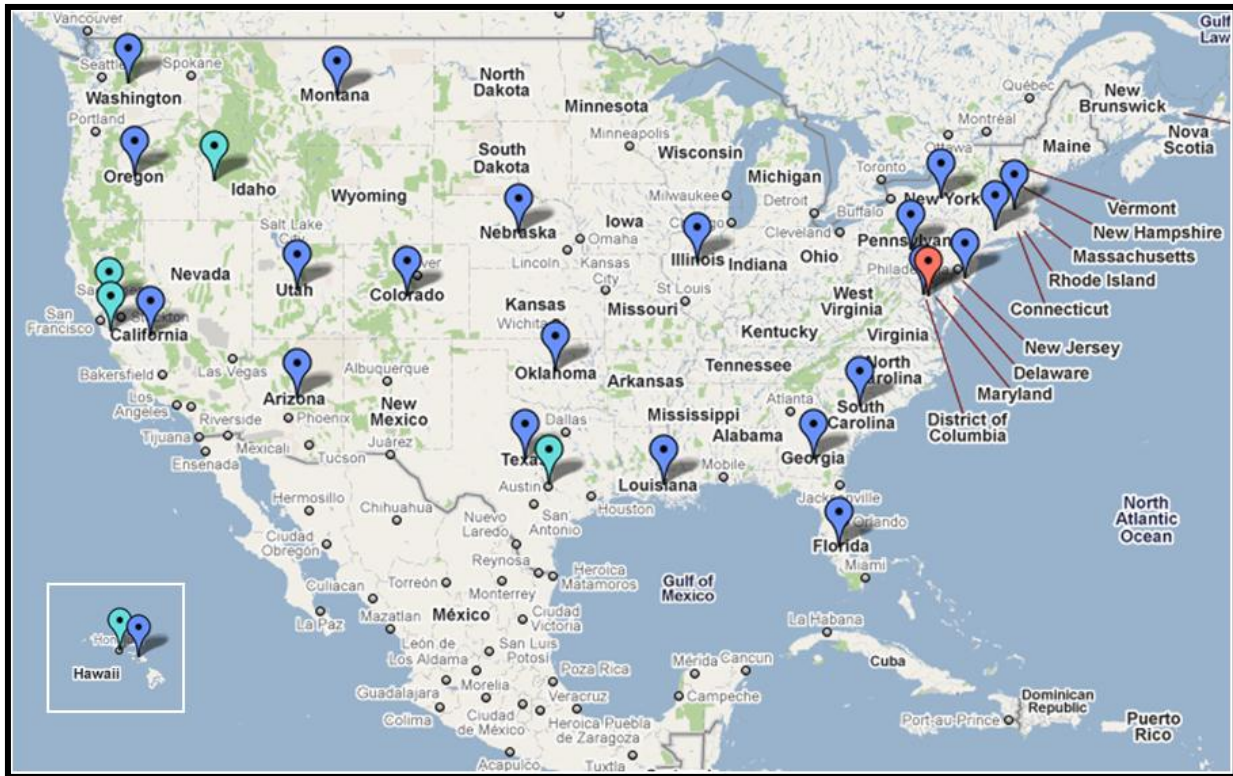


Figure 12: Distribution of EV incentives in the US (red – federal, dark blue – state, light blue – city or community)¹

The most powerful incentive for hybrid vehicles thus far has been access to HOV lanes. Additional consumer credits and preferential parking spots for drivers of hybrid vehicles have also been successful in many states (Genevieve Cullen, personal communication, March 22, 2011). Due to the success of these programs, it appears that the same types of incentives could be used for EVs. Although many bills for incentives and additional funding have been proposed, it can be challenging and time consuming to pass these bills through Congress. However, some grants like the EV Deployment Act are already in place. The funding from ARRA for both EV and infrastructure tax credits will be depleted by the end of 2011, so a new form of legislation is necessary to continue providing support for EV implementation.

¹ Adapted from: State and Federal Incentives. (2011). Retrieved March 21, 2011 from <http://www.pluginamerica.org/why-plug-vehicles/state-federal-incentives#federal>

Puerto Rico is highly dependent on imported oil, and its government has already taken steps towards reducing the use of fossil fuels. Act No. 82, passed on July 19, 2010, establishes a “compulsory goal” for renewable energy share of 12% by 2015 and ultimately 20% by 2035 (Puerto Rico Department of Economic Development and Commerce, 2010a). Additionally, the government has decided to invest a total of \$290 million in alternative energy projects within the next 10 years (Puerto Rico Department of Economic Development and Commerce, 2010b).

5.3.2 Comparative Analysis of Current and Upcoming Electric Vehicle Models

Based on background research of several EV models offered by leading car manufacturers, we compiled comparative data, including cost, vehicle range, and battery capacity, among several others. This information can be found in Table 3.

The Nissan Leaf, the Renault Fluence ZE and the Ford Focus EV are similar in terms of their technical specifications. All three car models have a range of about 100 miles on a single charge and a top speed of approximately 90 miles per hour (mph). Additionally, all three vehicles have a similar battery capacity of about 23 kWh. Out of the three vehicles, however, the Nissan Leaf is the only one currently available on the US market. It is also the most economical EV with an initial cost of \$32,780. As an upcoming competitor, the Ford Focus EV will have a greater battery energy density and motor power.

Even though the majority of EV models are compact and economical by design, EVs are also capable of delivering high performance. The Tesla Roadster, for example, is a sports car designed for high speed driving, reaching 125 mph, and maneuverability. The Roadster has by far the greatest range on a single battery charge (245 mi) and also the highest battery capacity (53 kWh). Additionally, the Tesla Roadster has the most powerful motor, rated at 212 kW. However, these features certainly come at a cost, as the Roadster is offered on the US market for \$108,000.

The Ford Focus EV model is unique in that it only allows for a 240 V charging port. This eliminates the slow charging that comes from a 120 V outlet. However, this vehicle cannot be used as an “early adoption” car because it would require the installation of a home charging station, leading to increased cost. The Tesla Roadster is clearly the most powerful EV, but its cost is a major deterring factor for the general population. The Renault Fluence ZE includes the unique QuickDrop battery technology, which can allow for battery replacement in as little as 3 minutes (“Renault Quick Drop System”, 2009). However, battery swap stations must be constructed for the use of the QuickDrop technology. The Chevrolet Volt is unique in the EV category, as it contains both an electric motor and a gasoline powered generator. The Volt allows for a top speed of 100 mph and runs on 100% electricity for the first 35 miles of driving. Although the Volt consumes gasoline, its generator eliminates the range anxiety that can arise in some EV drivers.

Table 3: Technical specifications of various electric vehicle models

<i>Car Model</i>	<i>Cost (without incentives)</i>	<i>Range (miles)</i>	<i>Battery Warranty (years)</i>	<i>Battery Energy Density (Wh/kg)</i>	<i>Top Speed (mph)</i>	<i>Passenger Capacity</i>	<i>Battery Capacity (kWh)</i>	<i>Energy per Mile rating (kWh/mi)</i>	<i>Motor Power (kW)</i>	<i>Charging Ports</i>	<i>Weight (pounds)</i>
Chevrolet Volt^{1*}	\$40,280	35 (solely electric)	8 years/ 100,000 mi	50	100	4	16	0.46	110	120 V and 240 V	3,140
Nissan Leaf²	\$32,780	100	10 years/ 100,000 mi, 70% efficiency	140	90	5	24	0.24	80	120 V and 240 V	3,354
Renault Fluence ZE³	\$37,170	99	N/A	100	84	5	22	0.22	70	220 V or 440 V, QuickDrop	3,400
Tesla Roadster⁴	\$108,000	245	3 years/ 36,000 mi, 80% efficiency	117	125	2	53	0.22	212	120 V and 220 V	2,723
Ford Focus EV^{5†}	\$37,000	100	N/A	170	85	5	23	0.23	105	240 V	3,691

* Not a 100% EV

† Available on the market in 2012

¹ 2011 Chevrolet Volt. (2011). Retrieved April 8, 2011 from <http://www.chevrolet.com/volt/features-specs/>

² Zero Emission Nissan Leaf. (2011). Retrieved April 8, 2011 from <http://www.nissan-zeroemission.com/EN/LEAF/specs.html>

³ 2011 Renault Fluence Z.E. (2011). Retrieved April 8, 2011 from http://www.auto-power-girl.com/cars-2011/renault-specifications/renault_fluence_z_e_-4106

⁴ 2011 Tesla Roadster 2.5 (2011). Retrieved April 8, 2011 from <http://www.leftlanenews.com/tesla-roadster.html>

⁵ 2012 Focus Electric. (2011). Retrieved April 8, 2011 from <http://www.ford.com/electric/focuselectric/2012/>



5.3.3 Comparative Analysis of Electric Vehicle Charging Stations

Currently, there are several companies which provide charging station options (See Table 4). Level II home chargers have a rating of 7.2 kW and are currently available on the market for an affordable price. Level II public charging stations are also available on the market by Coulomb Technologies and General Electric. Even though Level III charging stations have power ratings reaching 250 kW and can thus provide the fastest EV charging, they are not currently available on the market and will come at a considerably higher price. Currently, General Electric is not offering Level III chargers because of concerns on their effect on the EV battery life. Most of the charging station models which are not presently on the market will become available by the end of 2011.

Table 4: Specification of various charging station models

<i>Model</i>	<i>Type</i>	<i>Power</i>	<i>Charging Level</i>	<i>Availability</i>	<i>List Price*</i>
AeroVironment Charging Dock (EVSE-RS, Wall Mount)¹	Home Charging	7.2 kW	Level II	Now	\$1,140
AeroVironment Commercial AC Charging Station (EVSE-CS)1	Public Charging	7.2 kW	Level II	May 2011	\$6,000
AeroVironment DC Fast Charging Station (EV50-PS)1	DC Fast Charging	50 kW	Level III	May 2011	\$50,000
Coulomb Technologies ChargePoint CT500²	Home Charging	7.2 kW	Level II	Now	\$3,500
Coulomb Technologies ChargePoint CT20002	Public Charging	7.2 kW	Level II	Now	\$6,500
Coulomb Technologies ChargePoint CT30002	DC Fast Charging	50 kW	Level III	Now	\$40,000
General Electric Wall Mount EVWN3³	Home Charging	7.2 kW	Level II	Now	\$4,500
General Electric Single Pedestal EVSRN33	Public Charging	7.2 kW	Level II	Now	\$7,188
General Electric Residential Use WattStation³	Home Charging	7.68 kW	Level II	3 rd Quarter of 2011	N/A
General Electric Commercial Use WattStation³	Public Charging	7.68 kW	Level II	3 rd Quarter of 2011	N/A

* List prices are approximate

¹ Bill Koenig, Sr. Dealer/Fleet Sales Manager, AeroVironment

² Jerry Reich, CEO, Green Power Technology

³ Julio De Jesus Soto, Account Manager, GE Energy – Industrial Solutions



5.3.4 Economic Analysis of Conventional and Electric Vehicles

The current price of gasoline in Puerto Rico is \$3.67/gal, while the cost of electricity is \$0.24/kWh. As oil reserves around the world continue to deplete, the price of gasoline will likely continue to increase. Meanwhile, the use of renewable energy to produce electricity will enable Puerto Rico to decrease electricity costs by reducing on expenditures related to coal and petroleum imports. As such, a simple informed analysis can be used to depict the cost trend line of operating a conventional vehicle compared to an EV.

Figure 13 depicts the cost of operating a gasoline powered car compared to an EV.

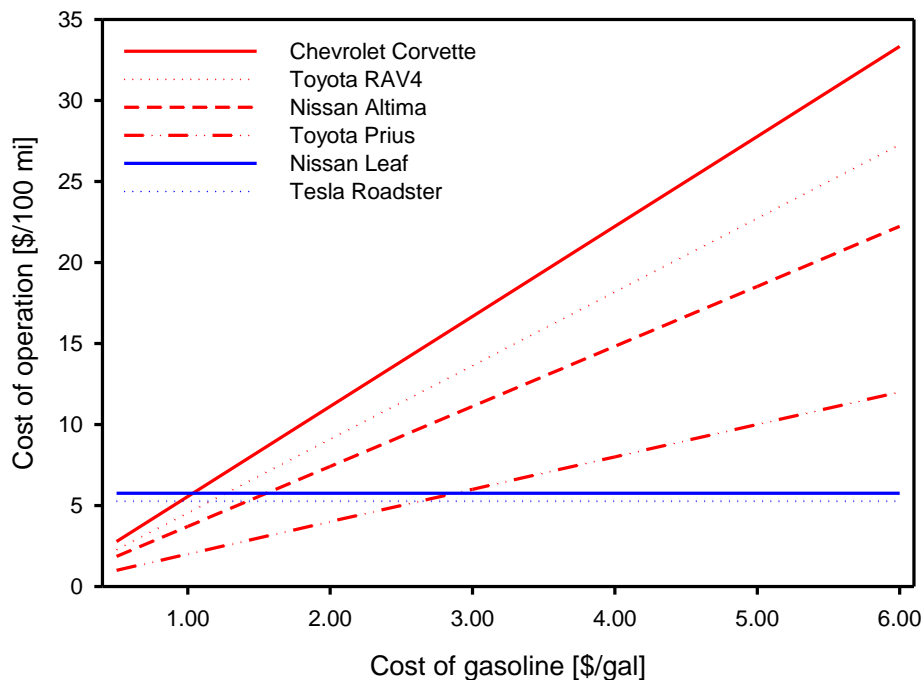


Figure 13: Cost of operating an ICE powered car compared to an EV

Several ICE car models were chosen to represent four of the major car types on the market: sedan (Nissan Altima), SUV (Toyota RAV4), sports car (Chevrolet Corvette), and hybrid

(Toyota Prius). The cost of operating an EV was calculated at the current electricity prices in Puerto Rico. The area to the right of the intersection point of any of the red lines (gasoline powered vehicles) and either of the blue lines (EVs) represents the range of gasoline prices at which operating an EV would be more economical than operating an ICE car. For example, driving a Nissan Leaf will be less expensive than driving a Chevrolet Corvette, Nissan Altima or Toyota Prius as long as gasoline prices are above \$1.04/gal, \$1.56/gal and \$2.88/gal, respectively. Similar results can be obtained for the Tesla Roadster, which is comparable to the Nissan Leaf in terms of energy used per mile.

For further analysis, Nissan Leaf and Nissan Altima were chosen as representative EV and gasoline powered automobile, respectively. Analysis was performed to evaluate how changes in gasoline and electricity prices can affect the economic viability of driving an EV.

Figure 14 compares the cost of driving a Nissan Altima as a function of gasoline price to the cost of operating a Nissan Leaf at various electricity prices.

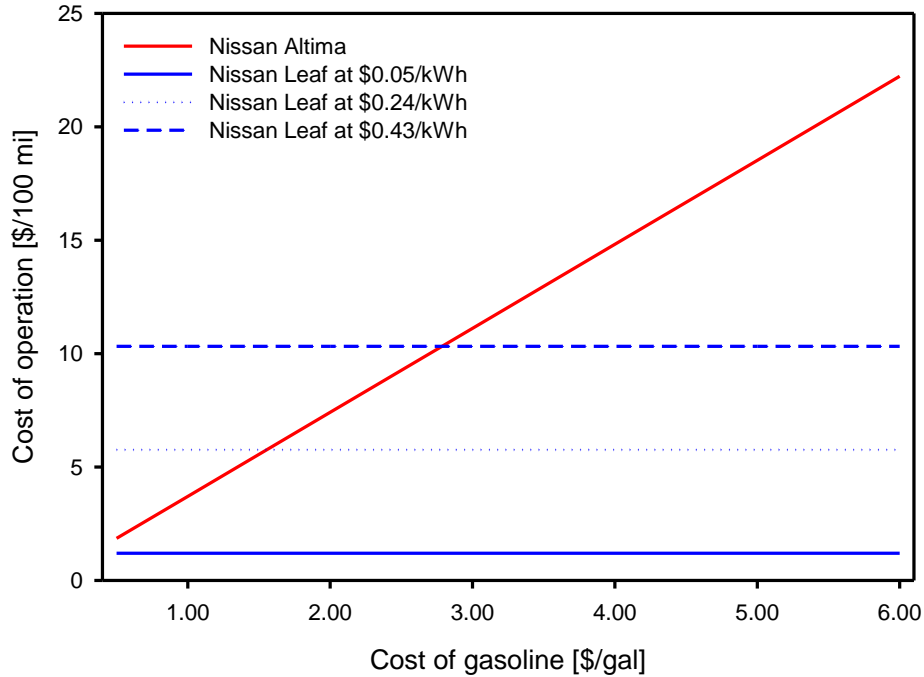


Figure 14: Economic viability of driving an EV with respect to changes in electricity prices

As can be seen, a decrease in electricity cost will greatly increase the profits of driving an EV. Interestingly, even after an 80% increase in the cost of electricity, driving a Nissan Leaf will still be cheaper than driving a Nissan Altima by \$3.27 per 100 miles.

In a similar fashion, Figure 15 compares the cost of driving a Nissan Leaf as a function of electricity price to the cost of operating a Nissan Altima at various gasoline prices.

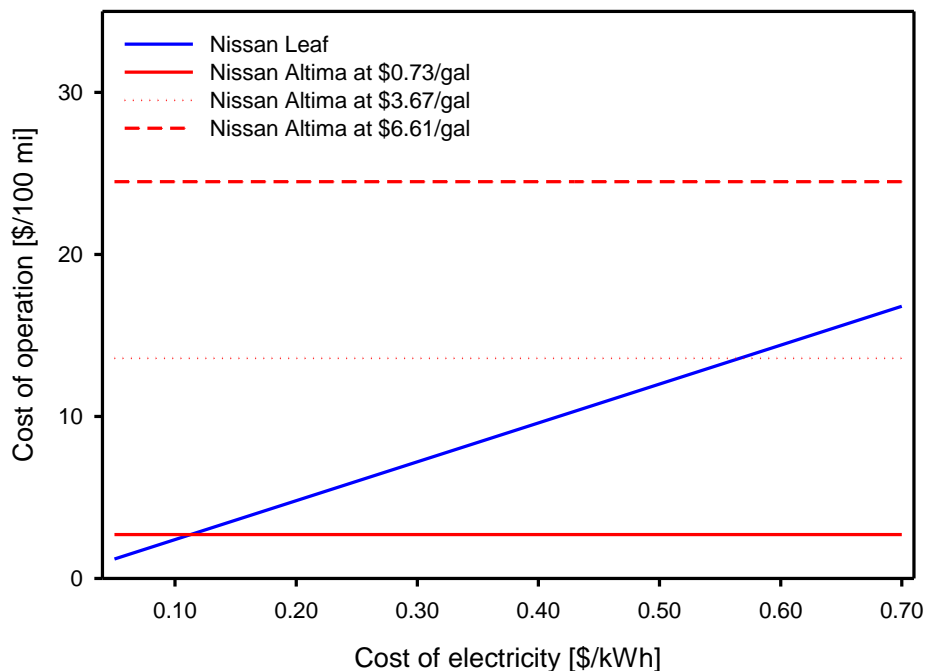


Figure 15: Economic viability of driving an EV with respect to changes in gasoline prices

If prices of gasoline were to significantly increase, benefits of driving an EV will only rise. If the price of gasoline were to decrease by 80%, operating a Nissan Leaf will only be more economical than driving a Nissan Altima if electricity prices are below \$0.11/kWh. Such an event is however highly unlikely.

At the current prices of electricity and gasoline, operating a Nissan Leaf is approximately a third cheaper than operating a Nissan Altima. In fact, operating a Nissan Leaf will be cheaper than driving a Nissan Altima as long as the price of gasoline is more than 5.52 times the price of electricity. That is to say that at the current price of electricity in Puerto Rico, operating a Nissan Leaf will be cheaper than driving a Nissan Altima provided that the price of gasoline is at least \$1.32/gal. Similarly, keeping the gasoline price at its current rate, driving a Nissan Leaf will be

cheaper than driving a Nissan Altima as long as the electricity price is below \$0.57/kWh.

The above results can be represented in a more complex, three dimensional relationship between the cost of electricity, the cost of gasoline, and the cost of operating a vehicle per 100 miles (see Figure 16).

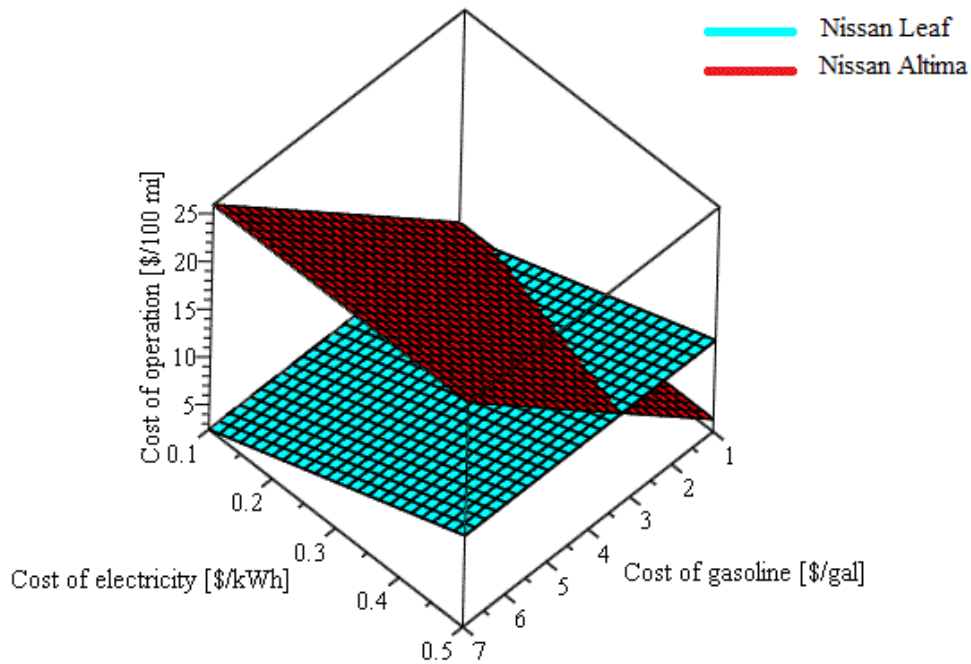


Figure 16: A 3-Dimensional view of the comparative analysis of operating an EV versus a conventional vehicle

The prices of electricity and gasoline were assumed to be independent, thus creating planar regions for the cost of operation of an EV and a gasoline automobile. Again, the cost of operating a Nissan Leaf will be less than that of driving an Altima as long as the gasoline and electricity prices are such that the blue plane is under the red plane.

5.3.5 The Vieques Verde Program

The Government of Puerto Rico is developing a project aimed at transforming the island of Vieques into a completely “green” zone. This will include the development of recycling programs, alternative energy resources, “green” jobs and environmentally friendly utilities. As part of this project, EVs will also be introduced to the island.

The introduction of EVs on the island of Vieques is considered the starting point for the implementation of EVs in Puerto Rico (EAA, 2010a). Vieques, with its small territory of 51 mi² and well developed infrastructure and tourism industry, is a viable site for the pilot project. According to Mr. André Mesa, the first EVs in Vieques will be introduced through car rental companies (personal communication, March 17, 2011). This will help increase the popularity of EVs among the locals and minimize the needed federal investment for the developing of extensive EV infrastructure. Initially, as a result of the small size of the island, the vehicles can be charged solely by the car rental companies and only a small number of charging stations will be required. Also, since only a small number of EVs will be introduced, they will represent a negligible increase on the electricity needs of the island. However, this pilot project will greatly facilitate the development of a broader EV infrastructure on the main island and also educate the Puerto Ricans about the benefits of EVs.

Following the deployment of EVs in car rental companies, electric cars will be introduced into municipal fleets (EAA, 2010b). A greater number of EVs will stimulate the development of a more efficient energy system, minimizing the large differences in energy needs between periods of high and low demand, and also facilitate the introduction of renewable energy sources (EAA, 2010a). Additionally, EVs will stimulate the gradual improvement of the road network in

Vieques, which currently consists of secondary and tertiary roads. The short term goal of the Vieques Verde project is to achieve a 5% share of EVs in Vieques by 2012. As evidenced, the introduction of EVs as part of the Vieques Verde project can help the Government of Puerto Rico gain experience with the new technology. However, there are still some issues to consider before the project can be successfully executed. Thus, the EAA has recommended the creation of an interdepartmental committee of key organizations in Puerto Rico which will address any unresolved problems (EAA, 2010a).

CHAPTER 6: CONCLUSIONS

Our research indicated that EVs provide a viable and sustainable alternative to the use of fossil fuels for transportation in Puerto Rico. We have concluded that facilitation of EV introduction in Puerto Rico requires a combination of the installation of the required infrastructure, public education programs, government support, incentives, and legislation. These conclusions are based on the results discussed in the previous chapter and are described below.

6.1 Required Infrastructure and Its Current Status in Puerto Rico

From our face-to-face interviews and case studies, we arrived at the conclusion that Puerto Rico currently does not have the infrastructure needed to support the widespread introduction of EVs. Presently, the only three public charging stations in the greater San Juan area are located in the municipality of Bayamón. It is evident from our findings that there are many options for charging station models and locations. We concluded that public charging stations would be the best initial option for installation in the greater San Juan area. Also, more technical expertise is needed for the proper installation and maintenance of these charging stations. We expect that car dealers will take the lead in providing trained experts on EV maintenance and service. Additionally, charging stations should be installed in busy metropolitan areas, such as parking lots and near main roads. More charging stations should aim to emulate the Bayamón Solar Zone, where the charging stations are powered by solar energy. We have concluded that the roads and highways are in an adequate condition to support EV operation. Furthermore, the electric grid in Puerto Rico has the ability to support the introduction of EVs to the island, especially if the deployment is gradual. As such, there are no major upgrades or modifications currently needed to electric grid.

6.2 General Knowledge and Public Opinion of Electric Vehicles in Puerto Rico

Our survey data suggested that Puerto Ricans have relative short daily commutes, have strong environmental concerns and regard safety, performance and fuel economy as more important factors than price when purchasing a new vehicle. This suggests that public opinion is in favor of EVs, as these factors embody some of the major features of an electric car. We also found that the majority of the population in Puerto Rico prefers either coupes, sedans, SUVs or sports cars, which are also all available as EV models. This further supports the conclusion that EVs have the potential to thrive on the island. Additionally, since Puerto Ricans have more than one car per household and relative short daily commutes, EVs can be used for everyday activities, while owning a gasoline car can serve for longer trips.

From our survey data we concluded that educational programs are needed in order to familiarize the general public with EVs and increase their sales on the island. Financial incentives for EV purchase are essential for the successful market of EVs, but a sound marketing campaign for the same will also be necessary.

From our data, it is evident that there exists a population of “early adopters” on the island who seem to be willing to pay more than \$30,000 for an EV. Initially, marketing campaign should be targeted towards these “early adopters”. The survey data also indicated that successful marketing campaigns should highlight EVs as environmentally friendly as well as providing significant savings in the long run.

6.3 Economic Viability of Electric Vehicles for the Citizens and Government of Puerto Rico

From our detailed data analysis, we have concluded that EVs are economically viable for widespread adoption in Puerto Rico. The initial cost of owning an EV is substantial, but its

operation will lead to savings in the long term. In our opinion, government incentives need to be employed in order to drive the initial cost down and make EVs more affordable for car buyers. Through a mathematical model, we are able to conclude that the cost of operating a Nissan Leaf would be lower than the cost of operating a Nissan Altima provided that the price of gasoline is at least 5.52 times the cost of electricity. We determined that EVs will best be introduced if marketed towards the professional and more educated sector of Puerto Rican society. Also, Puerto Ricans must be well informed about their electricity costs and understand that they can save money by charging their EVs at night. From our interviews, it is evident that PREPA would be willing to lower their electricity charges at night.

6.4 Applicability of Electric Vehicle Legislation and Incentives in Puerto Rico

From our research, it can be deduced that local incentives are needed to facilitate the introduction of EVs. Since Puerto Rico is a US territory, Puerto Ricans are not required to pay federal income tax and thus do not receive the federal tax exemption for purchasing an EV. This increases the need for the Government of Puerto Rico to create supportive legislation and provide financial incentives to cover a portion of the initial cost of EVs. The San Juan metropolitan area would be the best area to initially implement local incentives, similar to the community based legislation currently used in some areas of the US. Areas with heavy traffic volume, such as Plaza Las Americas, Condado, and Old San Juan could be potential locations for the introduction of EV parking spots. Additionally, we concluded that the contract with Nissan should be imitated in order to provide financial support for the purchase of other EV models. This would prevent a monopoly of a single car manufacturer.

CHAPTER 7: RECOMMENDATIONS

The following recommendations were developed based on our data collection and analysis. These recommendations can be used by the EAA to guide the Government of Puerto Rico in its effort to facilitate the introduction of EVs into the transportation sector of the island.

1. We recommend the initial introduction of EVs to the metropolitan area of San Juan with the primary focus on development of public charging station infrastructure

Parallel to the Vieques Verde pilot program, EVs should be introduced to the greater San Juan area, because of its advanced development. From our interviews and case studies, it appears that this region would greatly benefit from the positive environmental impact of EVs. Our case studies revealed that EVs are most feasible and economical for everyday city commuters, and our surveys have shown that many Puerto Ricans do not drive more than 40 miles per day. This makes the greater San Juan region the ideal area for the initial introduction of EVs. Further, our research has shown that the condition of the electric grid and the road network in Puerto Rico is adequate to support initial deployment of EVs. Thus, the Government of Puerto Rico should primarily focus its efforts on the development of public charging station infrastructure. These charging stations could be installed in areas with heavy traffic volume and reliable supply from the electric grid. Our calculations show that, initially, seventeen public charging stations will be sufficient to cover the area of metropolitan San Juan, assuming one charging station is installed every ten square miles (See Appendix G). This will translate into an investment of approximately \$120,000. In order to achieve a well-developed charging station infrastructure, a density of one charging station per square mile will be required. Accordingly, around 170 charging stations should be installed in metropolitan San Juan; this will amount to a total cost of \$1,200,000.

However, it needs to be kept in mind that once the government provides an initial basis for the development of the installation of charging stations, private companies will begin investing in this technology and will subsequently share the cost and responsibility of the required infrastructure. Thus, it can be concluded that the development of a charging station infrastructure is affordable for the Government of Puerto Rico.

2. We recommend that the Government of Puerto Rico allocates reserved parking spaces for EVs

From direct observation and interviews, we concluded that the high traffic volume in the metropolitan area leads to insufficient availability of parking spaces. Thus, we expect that preferential parking for EVs will gain instant popularity, similar to the success of reserved hybrid vehicle parking. This strategy can serve as an incentive for EV sales. Similar to strategies used for the promotion of hybrid vehicles, we recommend the initial allotment of 2% reserved parking for EVs in every parking lot consisting of 100 or more parking spaces. In cases where reserved parking is not feasible, reduced parking rates for EVs can serve as an alternative incentive.

3. We recommend that the Government of Puerto Rico reaches agreements with other car manufacturers similar to the memorandum of understanding with Nissan

The memorandum of understanding between Nissan and the Government of Puerto Rico indicates Puerto Rico's strong interest in the Nissan Leaf. Nissan is working towards reducing the cost and providing incentives to local buyers. Our comparative analysis of EV models has shown that the Nissan Leaf is currently the best fit for Puerto Rico due to its range and affordability. However, the government should reach agreements with other car manufacturers, similar to the

memorandum of understanding with Nissan, in order to facilitate the import of more EVs to the island.

4. We recommend that the Government of Puerto Rico initially waives the vehicles excise tax for EVs until they gain acceptance on the island

Our surveys indicated that a major deterrent for EV purchase is the initial cost of the vehicle. Thus, any measures to lower this initial investment would increase the willingness of Puerto Ricans to purchase an EV. Currently the most effective form of financial incentive that the Government of Puerto Rico could provide is to waive the vehicle excise tax for zero emission vehicles until they gain acceptance on the island. Such an initiative will translate to the amount of the federal tax credit offered in the US states. Any financial losses that might result from waiving the vehicle excise tax for EVs will be insignificant compared to the savings resulting from the reduction of petroleum imports. Additionally, from our interviews with several local car dealers, we concluded that many dealerships would be willing to provide additional incentives to buyers of EVs. Incentives at the dealership level will make EV purchase even more economically viable for Puerto Ricans.

5. We recommend that the Government of Puerto Rico negotiates with PREPA to provide discounted electricity rates for EV charging during off-peak hours

Our research has shown that equalizing the electricity demand will reduce the possibility of power outages. Charging EVs during off-peak hours could be used to reduce the difference in power demand during peak and off-peak hours. However, incentives will need to be provided to encourage this behavior. The Government of Puerto Rico could negotiate with PREPA to provide

discounted rates for EV charging during off-peak hours. This will reduce the cost of EV charging and also help PREPA decrease expenditure on power outage reparations.

6. We recommend that the Government of Puerto Rico enacts community based EV adoption legislation

Since Puerto Rico is not eligible to receive federal tax incentives, the Government of Puerto Rico should develop small-scale community based incentive programs, such as those undertaken in Oregon and Hawaii. This type of program would be less costly than an island-wide initiative and could specifically target the greater San Juan area, where development of the required EV infrastructure would be most convenient.

7. We recommend that EVs are first marketed to the well-educated sector of the Puerto Rican society

Our research revealed that in Puerto Rico, the affluent sector of society is more apt to purchase EVs. Our survey results indicated that the professionals in Puerto Rico are better educated and generally have more financial resources. These factors are crucial for the initial adoption of EVs. Additionally, our interviews suggested that if these individuals first purchase EVs, others on the island are likely to follow this trend. For instance, it may serve as a good example if the governor of Puerto Rico purchases an EV; this would likely be followed by other government officials.

8. We recommend that the Government of Puerto Rico works with auto manufacturers to develop a joint educational strategy for the marketing of EVs

After analysis of our survey results, it is evident that many Puerto Ricans are not properly

educated about EVs. Several of our interviews with car dealers revealed that in order for people to purchase a vehicle, they must have an adequate knowledge base. The Government of Puerto Rico should work with car manufacturers to develop a sound marketing campaign for EVs. The collaboration with Nissan can be used as the foundation for the development of relevant educational strategies.

9. We recommend that the EAA develop a marketing campaign to emphasize the long-term savings and environmental benefits of EVs

Although EVs currently have a high initial cost, information from our case studies has revealed that they will lead to long-term savings. Also, our interviews and surveys have allowed us to conclude that a large majority of Puerto Ricans would be willing to buy an EV knowing that it will help the environment. Thus, EVs should be marketed to the Puerto Rican population as environmentally friendly and cost effective in the long term.

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Appendix A: Puerto Rico Energy Affairs Administration Description

The island of Puerto Rico is highly dependent on fossil fuels, which are extensively imported. Due to the non-renewable and polluting nature of fossil fuels, the Puerto Rico Energy Affairs Administration (EAA, Spanish: Administración de Asuntos Energéticos) is making a conscious effort to develop alternative energy resources for its transportation industry. By implementing specific policies and programs, the EAA aims to reduce dependence on the import of fuels and lower the overall cost of energy (Pabón, 2010). The agency is active in informing the public about “green” technologies such as solar power, biodiesel, hybrid automobiles, etc. This would further lead to increased energy security and insure environmental stability. Introducing new technologies to the industry of Puerto Rico will also be advantageous for the economic development of the island.

The EAA is a governmental organization responsible for diversifying the energy sources and providing long-term environmental stability in Puerto Rico. Founded in 1977 as the Office of Energy, the EAA was assigned under the Department of Economic Development and Commerce in 2008 (Energy Affairs Administration, 2011). The current executive director of the EAA is Luis Bernal-Jimenez. He is in charge of the three main divisions of the organization: the Administrative Division (División de Administración), the Division of Education and Energy Support (División de Apoyo Energético y Educación), and the Division of Public Policy and Research (División de Política Pública e Investigación) (Office of Management and Budget [OMB], 2010a). Figure 11 is a schematic representation of the organizational structure of the EAA. In February 2010, EAA consisted of 24 employees and in 2009, the organization earned



revenue of \$230,000 from its State Energy Program (OMB, 2010b; OMB, 2010c).

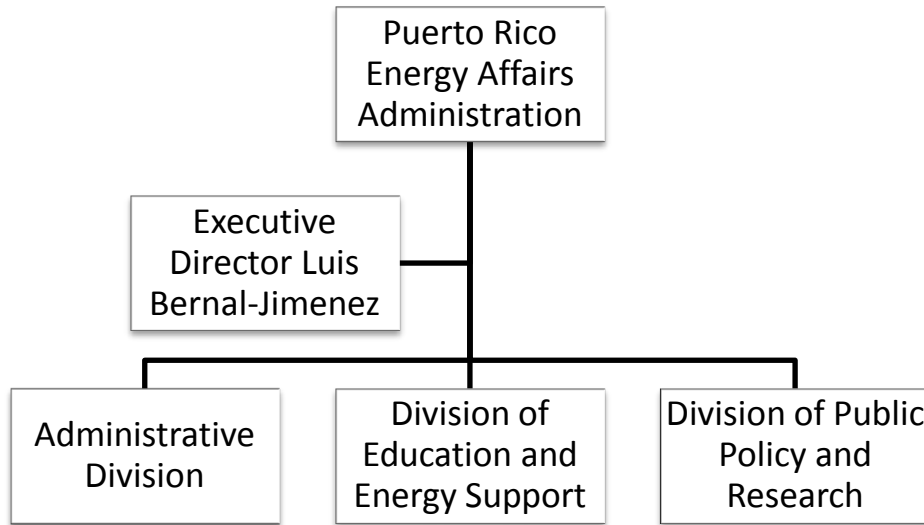


Figure 11: Hierarchal Structure of the EAA

The EAA has several important tasks in aiming to create a more sustainable and environmentally friendly Puerto Rico. As a branch of the Department of Economic Development and Commerce, the EAA was given the authority to “promote and encourage conservation and energy efficiency and thus also the integration of renewable and alternative energy sources” (Maduro, 2010, p. 3). The organization’s power was significantly increased in 2010 with the introduction of Acts 82 and 83, which set “compulsory goals” for the share of renewable energy and provided financial support for green energy projects (Pabón, 2010).

Act 82, also known as the Renewable Portfolio Standard (RPS), gave the EAA the right to distribute Renewable Energy Certificates (RECs) (Puerto Rico Department of Economic Development and Commerce [DEDC], 2010a). Economically, RECs have value and can be marketable in the United States as well as Puerto Rico. Under the RPS, the EAA aims to achieve

a 20% renewable energy share by 2035. Act 82 also mandated the creation of a renewable energy commission. This commission will consist of seven members: five from the government sector (including a representative from the EAA), one from the private sector, and one from academia. According to Miranda (2010), the purpose of this commission will be to monitor the Renewable Portfolio Standard and track the progress of the REC distribution.

Act 83, known as the Green Energy Fund (GEF), allows the collection of funds for the purpose of enhancing the sustainability of the energy producing sectors in Puerto Rico (DEDC, 2010b). Through this act, the Government of Puerto Rico will invest \$20 million for fiscal year 2011-2012 and a total of \$290 million by 2020 in renewable energy projects. Most of the funds will be collected from motor vehicle taxes (Miranda, 2010). In addition to the GEF, Act 83 allows special tax exemptions for companies that use “green” renewable energy as their primary sources of power. This is a strong initiative to make people shift from fossil fuels to renewable energy. The Green Energy Fund increases the power of the EAA to promote a more energy efficient and environmentally friendly Puerto Rico.

The EAA will have to work with many other important agencies and organizations to achieve its goals and missions. For example, all funds received under the GEF will be collected and handled by the Department of the Treasury (DT). The EAA also works with many agencies from the United States, such as the EPA and must follow the standards set by the International Energy Conservation Code (IECC) (Champagne, Evanson, Heath, & North, 2010). The EAA will work in accordance with the North American Renewables Registry (NARR) to keep track of all companies that receive RECs (Maduro, 2010). Overall, the EAA does not have any significant competitors; in contrast, it has several agencies and organizations that aid in its growth and



success.



Appendix B: The Interactive Qualifying Project

An Interactive Qualifying Project (IQP) as defined by the Interdisciplinary and Global Studies Department (IGSD) at WPI is “designed to address the societal impacts of a technological development or the converse” (WPI, Projects Program, 2006). This definition stems from the undeniable fact that the need for scientific development is driven by the needs of society. As society evolves and becomes more sophisticated, its needs also evolve and require a greater degree of sophistication. Science is the tool through which these needs are met. Science and technology are also important tools in training youth to think critically, which is very important in today’s information rich age. Thus, an IQP is a scientific project grounded in the advancement of the society and is based on the inherent relationship of science with the society at large. It is a perfect example of how society acts as a “driving force” for research and development of technology. However, an IQP does not only focus on the impact of society on technology. IQPs more often than not also address the impact of technology on societies. Our current project qualifies all of these criteria, therefore making it an IQP.

Our team’s project is to facilitate the introduction of EV on the island of Puerto Rico by researching and analyzing the various factors of EV introduction. The development and introduction of EV technology is one of the ways to consciously control global warming, by reducing the amount of greenhouse gases being released through the combustion of fuels for transportation purposes. However, this switch from the use of gasoline to the use of electricity for transportation poses several issues that need thorough consideration and research: What type of government support is needed to make the transition from ICE cars to EVs? Does the use of electricity to power vehicles actually reduce pollution? What type of infrastructure is necessary to



facilitate EV introduction? How will people adjust to the daily use of electric cars with respect to home charging and aesthetics? These and many more questions need to be answered before the implementation of EVs is undertaken. By recognizing the requirement of new technology to counteract societal problems, this project will ultimately assess the impact of this technology on society in terms of the environment, infrastructure, finance, and relevant legislation.

By analyzing the impact of the EV technology on the environment, the project fulfills the requirement of addressing societal need. Further, the findings of the project through the assessment of the status of required infrastructure and finance can be used to determine the direct impact of this technology on the society in terms of employment opportunities, tax credits, etc. Assessment of relevant legislation is underlined by the fact that society is governed by certain norms, and this applies to the social aspect of technology as well. No new technology can be implemented without the availability of required provisions. Thus, this project does not only address the needs of society by assessing a new technology, but it also analyzes the impact this technology will have on the society at large.

Appendix C: Interview Protocols and Summaries

Part I: Interview Protocol with Professor Ingrid Matos-Nin

- 1) Please provide us with some information about where you grew up and Puerto Rican culture in general.
- 2) What is level of awareness amongst Puerto Ricans about their environment and environmental issues?
- 3) What are the common cars driven in Puerto Rico (SUVs/smaller cars etc.)?
- 4) What is the condition of the roads in Puerto Rico?
- 5) What is the condition of traffic in Puerto Rico (Especially cities like San Juan)?
- 6) What is your opinion on the concept of Electric Vehicles and their success in Puerto Rico?

Part II: Interview Protocol with Professor Fred Looft

- 1) As a professional in the Electrical Industry field, what factors do you think are necessary for the successful implementation of electric vehicles?
- 2) What is the potential to develop renewable sources of electricity for electric vehicles?
- 3) What are the risks associated with using electricity to power the transportation sector?
- 4) What are the 'hidden' risks associated with operating EVs on a daily basis?
- 5) What is the potential of batteries as a power source for a sector as huge as the transportation sector?
- 6) What are the ways to store electricity in order to optimize the cost of operating and maintaining EVs? What are the costs involved?
- 7) What will be more effective: home chargers or charging stations? Or are both equivalent?
- 8) Do you have any comments on a potential EV industry in Puerto Rico?
- 9) Is there any additional information that you would like to add?

Part III: Interview Protocol with Government Officials

- 1) Are there any programs currently available to provide benefits or incentives for the purchase of EVs? If so, what are they?
- 2) If not, are there any incentives that the government is willing and able to provide, and if so, what are they?
- 3) What does the government need to do to speed up the process of introducing EVs in Puerto Rico in terms of legislation?
- 4) Is a contract with a single car manufacturer an option for Puerto Rico or would the government rather promote a competitive market? Explain why.
- 5) Would it be more beneficial (in terms of sustainability and cost) to install home chargers or to have public charging stations installed? Why?
- 6) Could you give us some more information about the pilot program that is being planned for the island of Vieques?
- 7) What is the current financial ability of the government to provide incentives?
- 8) Would it be possible to allocate further resources in the future to provide incentives?
- 9) Are there currently any laws in Puerto Rico that might hinder the successful introduction of EVs to the island?
- 10) Do you think that any of the current laws in Puerto Rico will be especially helpful in facilitating the introduction of EVs?
- 11) Would the Puerto Rican government be willing to pass laws that will expedite the introduction of EVs on the island?
- 12) In your opinion, would the Government of Puerto Rico be willing to sign a contract with a certain car manufacturer if this would enable the introduction of battery exchange stations?
- 13) Would the government be able to financially support the local power company if substantial upgrades are needed to the power grid?

Part IV: Interview Protocol with Electric Power Providers

- 1) In your opinion, how will the introduction of EVs impact the electric grid of Puerto Rico?
- 2) Is the introduction of EVs feasible throughout the island or just in the metropolitan areas? Why?
- 3) Do you advise the installation of home chargers or public charging stations? or perhaps both? Why?
- 4) How much will it cost to the consumer to have a home charger installed?
- 5) Will the introduction of EVs create a need to hire more employees in your company?
- 6) Would you consider providing discounted rates for users of EVs?
- 7) Do you plan to develop alternative energy (“greener”) resources? If so, what would these be and why?
- 8) Is there any tentative timeline for the development of alternative energy resources? If so, what is it?
- 9) What changes to the electric grid might be needed, and do you have the resources to make these changes?

Part V: Interview Protocol with Nissan and Chevrolet Dealers

- 1) What kinds of incentives are you willing to offer to get people to purchase EVs?
- 2) Would you be willing to market/sell a large number of EVs or just a small number initially? What is your reasoning behind this?
- 3) Would you have to hire additional employees if you brought EVs to your dealership? If so, why?
- 4) Do your employees have the required knowledge to effectively market EVs? If not, are there any means to train them?
- 5) From your knowledge, what car models sell best in Puerto Rico?
- 6) How would you plan to advertise EVs?
- 7) What are some FAQs that people have before purchasing a vehicle?
- 8) From your experiences, what are the most important criteria that consumers use when deciding on a vehicle purchase?

Part VI: Interview Summary with Professor Ingrid Matos-Nin, Humanities and Arts Department, WPI

January 28, 2011

Our team met with Professor Matos-Nin, a Professor of Hispanic Studies at WPI, native of Puerto Rico, and discussed with her some issues of importance to the background research of our project. The interview was informal and included general advice on Puerto Rican culture as well. Prof. Matos-Nin has lived in Puerto Rico for forty years. She lived on the west side of the island, in Mayagüez, for 23 years and on the south side for about 17 years.

We began by discussing the driving conditions in Puerto Rico. Prof. Matos-Nin told us that drivers are generally rash and negligent in Puerto Rico. They do not always follow rules. Also, SUV drivers do not respect the drivers of small cars and will often attempt to overtake them illegally. She mentioned that rush hour is usually very busy in cities like San Juan. Even though the roads are in good condition, due to the driving habits of the citizens, commuting is a major problem. Even if people can find ways to avoid being stuck in traffic, they often have to put up with long waits for a parking spot. Hence, providing EV owners parking preference may be a good marketing strategy.

Prof. Matos-Nin mentioned that people in Puerto Rico are fond of nature but are not that environmentally conscious (for example, they will throw garbage on the road, etc.). This happens because laws are not strictly enforced. For example, even though there are trash cans in the parks in Puerto Rico, they are always full and are rarely emptied. As a result, people find it easier to just leave the trash on the park grounds. This leads to an inactive attempt on the behalf of Puerto Ricans to sustain their environmental resources.

When asked about her opinion on EVs on the Island, Prof. Matos-Nin said that people in



Puerto Rico prefer SUVs as opposed to smaller cars, because of the dangerous driving conditions in the cities. However, Puerto Ricans are always willing to invest in technologies that will help them save money on gasoline. She suggested that the introduction of EVs should be marketed by targeting the elite of the society, since they are not only rich but also have the educational background to understand the future of EVs. However, frequent power shortages and electric company strikes due to variations in the political fabric of Puerto Rico might hinder the charging process of EVs and their popularity.



Part VII: Interview Summary with Mr. John Gilbrook, Associate Engineer, National Grid

February 8, 2011

Mr. Gilbrook is part of the Product Management/Transportation Group and his job entails working with car manufacturers to develop the most up-to-date EV technologies. He also works with auto manufacturers in order to pass the required legislation for the implementation of EVs. Mr. Gilbrook informed us of several useful organizations to obtain information from, including the Clean Cities Coalitions, and the EDTA's National Plug-in Initiative. He also suggested for our team to visit valuable resources provided at www.goelectricdrive.com. Mr. Gilbrook informed us of a program taking place at both Clark University and WPI this upcoming summer. National Grid has partnered with the Institute for Energy and Sustainability (IES) to install 5 charging stations at Clark University and 3 charging stations at WPI. He gave us the contact information for Chris Noonan, a WPI graduate, who now works with the IES, a collaborative effort between Clark University and WPI, in an effort to develop green communities.

Mr. Gilbrook then went on to inform us of areas of the United States where EV implementation has a high chance of success and others where it will take a little more time. For example, California is currently having success in implementing EVs as a result of the EPA stringent emissions standards. Also, Texas has been able to implement EVs because they have a much newer electric grid as well as flat terrain and spread-out roads. However, the infrastructure in greater New England is currently not in the condition for supporting EVs because it is relatively old and the grid is "dumb". A dumb grid simply supplies power to one particular area but does not provide feedback as to where most of the electricity is being consumed. Mr. Gilbrook suggested that a "smart" grid would be advantageous for implementing EVs, because it would allow consumers to monitor where their electricity costs are stemming from. Therefore,



EVs could be charged at night when electricity costs are significantly cheaper. Smart grids could also be extremely effective in preventing blackouts and could one day even allow for vehicle-to-grid (V2G) technologies, where the energy stored in the EVs could be distributed back to the power grid. Additionally, because smart grids allow for the monitoring of energy use, they could increase the life of many of the components of the electric grid, including transformers. Many of the distribution systems in place today are not designed to receive an influx of power, so V2G would not be possible in these areas. Interestingly, Mr. Gilbrook informed our team that this summer National Grid is planning to launch a pilot of their smart grid system in Worcester, MA.

Another area where EVs are gaining popularity is Hawaii. Michigan, as a home state of General Motors, has also become a leader in launching EVs. However, areas like the Midwest United States do not show much interest in EVs even though electricity prices are roughly half of those in Massachusetts. It is suggested that the reason for this is a lack of legislative support and long distances between cities and towns. Mr. Gilbrook pointed out that EVs generally work much better in flatter, less mountainous areas of the globe.

Mr. Gilbrook emphasized the importance of what he termed “early adopters”. These are people who are likely to invest in new technologies. Mr. Gilbrook believes it is important to target buyers of hybrid vehicles, as they are likely to want to purchase the latest, environmentally friendly EVs. Early adopters usually include people who are well educated and have an income of at least \$70,000 per year in the United States. Mr. Gilbrook believes that it is important to target people who are fond of science and new technologies.

Mr. Gilbrook explained to us that while the EV advertisers are strongly pushing the environmental impacts and benefits of EVs, he wishes that they would focus more on the power



and performance of the vehicles. According to him, a successful marketing strategy would be to advertise EVs as sleek and as more powerful than ICE cars. He also noted that he would like to see more EVs designed to look like popular automobiles and sports cars, to attract a much larger consumer base.

In terms of the electric grid, Mr. Gilbrook explained that the only problem with the grid would be the distribution section. The generation and the transmission sectors of the electric grid would not have any problem in supporting the influx of EVs. Overall, he informed us that charging an EV does not require much more power than a refrigerator or a dryer. He mentioned that a slow adoption of EVs is expected. It has been almost ten years since hybrid cars were introduced to the United States and today they account for only around 1% of vehicles. This slow adoption of EVs would have a minimal impact on the electric grid. According to him, the first level of upgrade to the grid, if need be, would be the introduction of additional transformers. However, transformers are extremely expensive, often costing more than \$30,000 to install, and they must be strategically placed.

Mr. Gilbrook also informed us of programs being undertaken by the government to help with the implementation of EVs. He explained that the major EV technology development was supported through ARRA funding, totaling \$1.98 billion dollars. For example, the major source of government funding for EV buyers is through incentives, such as the \$7,500 tax credit. Also, he pointed out that providing designated parking spots for EVs as an incentive could possibly be an issue of concern. Parking spots are already so limited in many suburban areas that many do not agree with this incentive. He also explained to us that the electricity to power EVs will first be derived from a mix of sources before it could become solely renewable. Wind energy is

promising, but wind turbines are extremely expensive to install and must be strategically located. He pointed to natural gas as a good alternative to meet at least a portion of the energy consumption. Natural gas has 30% less carbon content than coal and can be burned much more efficiently.

Mr. Gilbrook then provided us with information about lithium-ion batteries that are used to power EVs. He pointed out that they greatly contribute to the initial high price of EVs, costing up to \$1000/kWh. For example, a battery arrangement like the one in Chevrolet Volt could cost roughly \$16,000 and the Nissan Leaf batteries can cost up to \$24,000. He pointed out that the United States will probably never be able to adopt a program like the one *Better Place* developed in Israel, because it would require the manufacturing of uniform batteries. Car manufacturers are simply too competitive, and each manufacturer has a slightly different battery design. He pointed out that lithium-ion batteries are safe, and that people often forget that gasoline powered ICEs can be extremely dangerous with people engaging in activities like smoking while pumping gasoline. He spoke of a new lithium-ion polymer cell that is currently being studied as next generation in battery technology. These batteries could allow for up to a 100% improvement in battery life.

Mr. Gilbrook then showed us a Ford Escape Plug-In Hybrid Electric Vehicle (PHEV), one of only 21 vehicles produced by Ford for research, development, and demonstration. It is important to note that unlike the Nissan Leaf, the Chevrolet Volt is not entirely electric. It is referred to as an extended range electric vehicle (EREV). The Volt has a gasoline generator and the Escape is equipped with a gasoline engine. However, gasoline is only used for climate control or if the car is travelling at a speed of over 40 miles per hour. On the highway these cars can

achieve up to 70 miles per gallon of gasoline. Under 40 miles per hour, the cars are run totally on electric power. Mr. Gilbrook allowed us to test drive the Ford Escape PHEV. He showed us the regenerative braking feature, where the mechanical energy absorbed through braking is used to recharge the lithium-ion battery. The gas engine turned on initially to warm up the vehicle, but was then shut off. This was a strange feeling, as the car was turned on but completely silent. The acceleration of the PHEV was comparable to and even faster than that of an ICE.

**Part VIII: Interview Summary with Professor Fred Looft – Department Chair, Electrical
and Computer Engineering, WPI**

February 10, 2011

The team interviewed Professor Fred Looft, the head of the Electrical and Computer Engineering Department at WPI, in order to receive further insight on the feasibility of EVs. We first talked about the additional strain that EVs could put on the overall electric grid. Prof. Looft seemed to believe that initially, EVs would not have a considerable impact on the electric grid because the introduction of EVs will be gradual. He also believes that it would be beneficial if people charged their vehicles at night when the strain on the electric grid is much less. Prof. Looft also advised the team to research the power capacity and usage of the grid in Puerto Rico.

Prof. Looft also informed us of ISO New England based in Springfield, MA. ISO is a non-governmental group that reviews the electric infrastructure standards in a given area. They advise utility companies of cost reduction strategies, and also analyze the power usage in the region to update electricity suppliers. Prof. Looft advised us to look into whether or not such an organization exists in Puerto Rico. If so, it would be very helpful in analyzing the power capacity remaining on the island to support EVs.

Prof. Looft expressed a strong concern about the lithium-ion batteries used in EVs. More specifically, he was skeptical about recycling of lithium-ion batteries. He said that in the present day, many lithium-ion batteries are sent to third world nations and improperly disposed of, leaking harmful chemicals and carcinogens into the environment. This would be extremely counterproductive, as the main goal of EVs is to prevent environmental damage. Prof. Looft said he would like to see many more companies arise that would properly dispose of batteries



domestically. He informed us that there are currently a few companies that recycle batteries domestically. This strategy needs to be embraced by other companies, rather than shipping old batteries overseas. However, Prof. Looft believed that lithium-ion batteries did not present any major dangers, as he pointed out that ICEs have several dangers associated with them as well.

Prof. Looft then introduced us to Prof. John Orr, an ECE professor and former Provost at WPI. Prof. Orr is the director of the IES program at WPI. He briefly spoke to us about our project and gave us his contact information in case we had any further questions.



**Part XI: Interview Summary with Christian Calderon, Internet Sales Manager, Royal
Motors GMC Dealership**

March 17, 2011

Christian Calderon was able to provide our team with valuable information about popular car models in Puerto Rico and successful advertisement of these cars. The interview was conducted over the phone. Mr. Calderon informed us that some of the most popular vehicles are the Chevrolet Cobalt, the Buick Lacrosse, and the Chevrolet Equinox, a new SUV model. He told us that so far there is not much information on the Chevrolet Volt and that most employees do not know much about EVs or the Volt in particular. However, an important factor to keep in mind is that many Puerto Ricans associate their car with their social status. This often translates in the purchase of attractive and unique cars, meaning EVs could have a good chance of selling well in Puerto Rico.



Part X: Interview Summary with Genevieve Cullen, Vice President, EDTA

March 22, 2011

Genevieve Cullen is the Vice President of the Electric Drive Transportation Association (EDTA), an organization stationed in Washington, DC and dedicated to educating the public about EVs. Ms. Cullen was able to provide some very useful information about current EV legislation and incentives in the United States. According to Ms. Cullen, the most prominent incentives in California and Virginia are HOV highway lanes set apart for drivers of hybrid vehicles. This shortens commutes each day for drivers of hybrid vehicles. Also, preferential parking and additional state tax credits serve as other powerful incentives.

Several bills have been proposed for increasing government funding for EV programs and federal incentives, but often such bills are difficult to pass through Congress. In Ms. Cullen's opinion, the best option would be to optimize the government incentives and grants for specific communities, similar to the programs that have worked well in Oregon thus far. However, the federal tax credit provided by the American Recovery and Reinvestment Act (ARRA) will expire at the end of 2011, so new legislation is needed to continue providing tax credit incentives for EV buyers. Also, there need to be incentives for larger EV trucks and SUVs, as none currently exist. Money for the research and design (R &D) of new EV technologies will help speed up the adoption of EVs.

The Clean Cities Coalition is one of the most powerful organizations that could facilitate the implementation of EV programs. Ms. Cullen also informed us of the Plug-In Readiness Report on societal factors related to the introduction of EVs.



**Part XI: Interview Summary with Nereida Ortiz, Sales Department (Fleet Manager), Royal
Motors GMC Dealership**

March 23, 2011

Ms. Nereida Ortiz was very helpful in providing us with information about the purchasing trends of Puerto Rican buyers. She also had some valuable information about the adoption of EVs into Puerto Rico. Ms. Ortiz said that currently there is no set date or time frame for the introduction of the Chevrolet Volt onto the island. The best selling models in her dealership are the Hyundai Sonata, the Chevrolet Malibu, and the Chevrolet Tahoe hybrids. People like to buy SUVs in Puerto Rico because of safety concerns. However, many city drivers value smaller, economical cars because they get better mileage per gallon.

Also, Ms. Ortiz informed us that Puerto Rican drivers value both a good radio/stereo system and a good engine that allows for high speeds. Puerto Rican drivers will appreciate the silent engine of an EV since they will be able to better enjoy the radio. Ms. Ortiz believes that price is the most important factor that influences the purchase of vehicles. However, another very important factor is the look of the vehicle itself. Puerto Ricans value sleek looking cars. There is currently no advertising campaign developed for the Chevrolet Volt in Puerto Rico. However, Ms. Ortiz believes that it is most important to inform and educate people about the Volt in order to increase sales. Specific numbers and data about the car are necessary.

The overall advertising strategy will come from GMC and the company will send representatives in order to educate dealers about the vehicle and to launch the marketing campaign. Also, they will train dealership employees in EV maintenance. Based on this information, Ms. Ortiz does not believe that her car dealership will have to hire additional

employees in order to properly sell and advertise the Chevrolet Volt.



Part XII: Interview Summary with Luis Osorio, Energy Affairs Attorney, EAA

March, 25, 2011

Luis Osorio is an attorney at law and works for the EAA. Mr. Osorio informed the team that Puerto Rico is allotted funds for the development of ‘green energy’ by the ARRA funding. The last allotment was of about \$4.5 million in July 2010; however these funds are already depleted. While ARRA is very specific in nature, the State Implementation Plan (SIP) is an annual “state” fund. Puerto Rico is considered a state by the DOE for the purposes of funding and is thus eligible for SIPs; however the federal tax credit for EV purchases does not apply in the island.

The Government of Puerto Rico is collaborating with Nissan in order to reduce the price of the Nissan Leaf on the island. Laws that support EV introduction in Puerto Rico include Laws 128, 83, 73, and the Green Energy Fund. Mr. Osorio expressed his opinion that PREPA should not be given the sole responsibility for installing charging stations on the island, because of its monopoly on the island.

He also said that the Government of Puerto Rico is very supportive of sustainability programs and thus will work hard towards recycling car batteries. However, the current rate of recycling in Puerto Rico is only about 11%. This is partially a result of the government’s primary focus in financial savings. An effective way to promote recycling would be to build a competitive base for the commercial sector and give monopoly of recycling to the best bidder. However, currently there is no funding for EV introduction available in Puerto Rico. Money might be set aside for these purposes in about 4 - 5 years and will be based on the supply-demand relationship of EVs at that time. Mr. Osorio said that the best way to market EVs in Puerto Rico would be to

educate people about charging stations and advertise them similar to the Smart cars: cheap, efficient, and visually appealing. The most important factor is money and EVs need to be sold at a low price. Also, charging stations should be installed on a wide scale prior to EV introduction.



**Part XIII: Interview Summary with Francisco Ramos, Operational Technology Director,
Office of Transmission and Distribution, PREPA**

March 31, 2011

Mr. Ramos was an excellent source of information to our team about the electric power in Puerto Rico and the capacity to develop alternative fuel resources. Mr. Ramos told us that currently it is very difficult to predict the impact of EVs on Puerto Rico and how successful they will be because EVs are still a relatively new technology. Even in other areas of the world, the adoption of EVs on a large scale is just currently taking place and there is not a large amount of data available from which to draw conclusions. Therefore, PREPA will be purchasing a few Nissan Leafs and installing charging stations at their facility in the Santurce by the end of April 2011. They will use these EVs and charging stations as a trial, to gather data about the energy requirements and consumption of EVs and the range and reliability of the vehicles.

He voiced some concerns, citing a study that showed that charging an EV can lessen service transformer performance by up to 83%. Also, it is important to note that in Puerto Rico, electricity costs around \$0.24/kWh, totaling around \$6 to fully charge an EV. Thus, charging an EV may not be more cost effective than filling up a car with gasoline. That being said, PREPA is adamant about bringing EVs to Puerto Rico and is willing to invest a lot of money to make the introduction of EVs successful.

PREPA is also conducting a trial with a building of photovoltaic cells used to harvest solar energy and power charging stations. PREPA is looking for the best way to bring EVs to Puerto Rico. Mr. Ramos also mentioned that PREPA is interested in determining the best EV fit for Puerto Rico and will that perform tests with several car models. They would like to acquire



Chevrolet Volts, Nissan Leafs, and Ford Transits. He informed us that a Level II home charging station costs around \$3,000. This means that government funding and tax incentives are especially important. Mr. Ramos was very familiar with the Vieques Verde Program, as PREPA is working with the EAA to make this trial a success. He also informed us of a similar program taking place in the south of the island.

PREPA plans to run their tests on the EVs for at least 6 months in order to obtain a sufficient amount of information. He believes that EVs would initially be best for the San Juan metropolis and about a 23 mile radius outside of the city. This area uses about 75% of the energy on the island, and it will be easier to establish infrastructure in these regions. Mr. Ramos suggested that the Chevrolet Volt may be the best option of an EV, as installing charging stations in rural parts of the island might be challenging. In urban areas, electricity could be used to power the vehicle and reduce emissions, but if a longer distance trip is necessary, the car could be powered by gasoline.

Mr. Ramos informed the team that the power grid in Puerto Rico can support up to 6000 megawatts (MW) of electric power. Currently, about 3600 MW of power are consumed on the island, leaving ample space on the grid to support EVs. The upgrade of the current grid to a smart grid is a large undertaking being conducted by PREPA. It will take a lot of money to update and modernize the electric grid, but Mr. Ramos believes that it is feasible with government support and agreements with other agencies, such as the EAA. Mr. Ramos said that PREPA would not be opposed to charging different rates for electricity during the night time, to encourage night time charging of EVs. He said that vehicle to grid (V2G) technology is still a long way in the future, but that it could one day be a possibility on the island. As of today, about 30% of the project to

convert the electric grid to a smart grid is completed. PREPA hopes to have it almost entirely completed and implemented by 2016.

There is a great effort to switch to renewable energy in Puerto Rico. Unfortunately, a lot of money and negotiation is needed between both public and private companies. Currently, 18 contracts and alliances have been signed on the island to work for renewable energy resources. A large wind farm is currently being implemented in Guanica and there are other wind turbine sites proposed. One of the biggest obstacles for Puerto Rico is that the majority of the renewable energy would come from the south of the island, as this is the ideal spot for wind farms and photovoltaic panels. The install infrastructure for harvesting renewable energy is expensive, even though the energy itself is free. The energy harvested in the south of the island must be transmitted along cables mainly to the San Juan metropolitan area. Also, Mr. Ramos informed us that a backup source of energy is needed for each wind turbine that is installed.

He said that the rapid installation of renewable energy infrastructure without careful planning and consideration could drive the cost of electricity up of \$0.60/kWh. Further, Mr. Ramos informed us that \$2.1 billion dollars is spent annually by PREPA for fuel to generate electricity. Thus, a pipeline of natural gas from the south of the island is currently under negotiation. This could cut costs of fuel in half, and natural gas is a cleaner source of energy than oil. The pipeline construction is facing some harsh opposition from the people of the island who do not want a pipeline running through their towns. Mr. Ramos says that if enough support is received, the pipeline could be completed as early as 2012.

Mr. Ramos believes that the most important aspect for the success of EVs is to show people that there will be economy on the cars and to educate them. He said that hybrids are



starting to become popular on the island, but that the initial introduction of hybrids was not successful because there was no solid marketing campaign for them. Also, many people were not educated about hybrids. Puerto Ricans like to fix their cars themselves, but many people damaged hybrid vehicles in doing so. Mr. Ramos believes that a positive first impression of electric vehicles is an important factor. If people initially are not excited by EVs, then they will simply not sell well. Another vital aspect of EV introduction is government and dealer incentives, as the price must be lowered. The poverty level in Puerto Rico is much higher than in the states, and the initial cost of the vehicle is often the deciding factor in the purchase of the vehicle.



Part XIV: Interview Summary with Mr. José Palou, Engineer, Municipality of Bayamón

April 1, 2011

The municipality of Bayamón has installed three charging stations which are powered by photovoltaic cells. The charging stations are ChargePoint model supplied by Coulomb Technologies and provide outlets for Level I (120 V) and Level II (208 V) charging. The installation of the charging stations is part of a bigger project of the Municipality of Bayamón, named Solar Zone, which aims to develop renewable energy sources.

In addition to harvesting renewable energy, Project Solar Zone also aims to raise public awareness of sustainable development. The installation of a total of 2553 photovoltaic panels had a total cost of \$3.7 million and 65% of it was supplied from ARRA funding. The project had to go through a competitive selection process to receive the financial support. A company named Aireko was hired for the construction of the solar panels which began on March 1st, 2010 and was completed on May 29th of the same year.

The system of photovoltaic panels has an average energy production of 585 kW per hour. The solar cells have 14 – 17% efficiency and each contributes about 230 W per hour. In total, the Solar Zone Project is generating an average of 2.2 MW per day, which leads to an estimated 25% savings in energy consumption. As part of the project, two residential type inverters were also installed for educational purposes. Currently the generation of electricity does not exceed the needs, but any excess power could be sold to PREPA.

The three charging stations are currently in testing phase and are so far not being used for charging of EVs. Their maintenance is provided by the construction company Aireko. The Solar Zone Project is also supplied with a live monitoring system. Information about current environmental conditions and power generation can be accessed online at <http://aireko.kiosk->



view.com/Bayamon.



Part XV: Interview Summary with Mr. Ismael Medina, Sales Department, Triangle Nissan Dealership (Mayagüez)

April 8, 2011

Mr. Ismael Medina is the head of the Sales Department at Triangle Nissan in Mayagüez, Puerto Rico. Via phone conversation, he informed us that their dealership expects to receive some Nissan Leafs within the next 6 months. However, Mayagüez is on the west side of the island and currently no charging stations have been installed in this area. Therefore, the required infrastructure must be installed before the Leaf can be sold. Mr. Medina also informed us that all of the employees in his dealership are excited and enthusiastic about the arrival of the Leaf. Gas prices in Puerto Rico are currently around \$1 per liter, equivalent to about \$3.70 per gallon. This rise in prices, in Mr. Medina's opinion, has increased the public's willingness to embrace EVs.

Mr. Medina informed us that his dealership would provide some incentives to EV buyers. He also was hopeful that the government would come up with some additional local incentives, as the federal tax credit in the United States is not applicable in Puerto Rico. Mr. Medina did not believe that his dealership would need to hire more employees with the introduction of the Leaf, but he did emphasize the importance of educating the employees in the sales department for the successful marketing of the vehicle. He informed us that Nissan would provide the necessary marketing strategy and educational training to the employees of the Triangle Motors dealership.

Mr. Medina referred us to the Nissan website and also the Plug-In America website for more information about the specifications and details of the Nissan Leaf.

Appendix D: Survey

Part I: Electric Vehicles Survey (English Version)



Welcome to the Electric Vehicles Survey!

Please take a few minutes to complete all questions as your opinion matters to us.

Thank you,

The Electric Vehicles Group

Worcester Polytechnic Institute

In association with the Energy Affairs Administration

DISCLAIMER: All information in this survey is confidential, anonymous and fully optional. This survey is to be used for the Electric Vehicles Research Project sponsored by the Puerto Rico Energy Affairs Administration and Worcester Polytechnic Institute in Worcester, Massachusetts.





Electric Vehicles Survey

1. Are you familiar with electric vehicles?

- Yes
- No

Did you know: Electric vehicles, unlike conventional cars, operate on internal batteries charged by electricity instead of running on petroleum fuels!

2. Please explain how you learned about electric vehicles.

- Advertising (e.g. TV commercials, newspaper, radio, etc.)
- Test drive
- I have seen one on the road
- I own an electric vehicle
- Not applicable

3. Electric vehicles will have a higher initial cost, but will lead to savings in the long run, and will also have a lower maintenance and repair price. Would you be willing to buy an electric vehicle based on this fact?

- Yes
- No

4. How much would you be willing to pay for an electric vehicle?

- \$20,000 to \$29,999
- \$30,000 to \$39,999
- \$40,000 to \$49,999
- More than \$50,000

5. Do you know what a charging station is?

- Yes
- No



Did you know: EV charging stations can be installed at your home, at work, in shopping centers, restaurants, etc.

6. Electric vehicles have a driving range of up to 100 miles on a single charge. Recharging their batteries could take up to 6 hours. Based on this fact, would you be willing to buy an electric vehicle?
- Yes
 - No

Did you know: Fast Charging Stations have the capability to fully charge an EV in less than 30 minutes!

7. Would you consider buying an electric vehicle if you could take advantage of designated parking spaces?
- Yes
 - No
8. If the required infrastructure was provided and the government was to give financial incentives for the purchase of an electric vehicle, would you buy an electric vehicle?
- Yes
 - No

Did you know: In the United States and in many countries there is free parking and designated highway lanes for drivers of electric vehicles!

9. How concerned would you say you are with environmental issues?
- Very concerned
 - Concerned
 - Somewhat concerned
 - Not concerned

Did you know: Driving an electric vehicle can save more than four tons of CO₂ emissions a year!

10. Electric vehicles have the potential to produce zero tailpipe emissions. Would you be willing to buy an electric vehicle based on this fact?
- Yes
 - No



11. What do you think is the most important feature of a new vehicle? Please check all that apply.

- Safety
- Price
- Performance
- Fuel economy
- Other (Please specify) _____

12. What type of vehicle do you currently drive?

- Coupé or sedan
- Sports car
- SUV
- Truck
- Other (Please specify) _____

13. What is the total distance that you usually drive per day?

- Less than 20 miles
- 20 to 39 miles
- 40 to 59 miles
- 60 to 80 miles
- More than 80 miles

Did you know: Sixty-three percent of drivers in the US travel less than 40 miles a day!

14. How many vehicles are there in your household?

- One
- Two
- Three
- Four
- More than four

15. What is the yearly income of your household?

- Less than \$50,000
- \$50,000 to \$99,999
- \$100,000 to \$149,999
- \$150,000 to \$199,999
- More than \$200,000
- Prefer not to disclose



Part II: Electric Vehicles Survey (Spanish Version)



¡Bienvenidos a la Encuesta de Vehículos Eléctricos!

Por favor tome unos minutos para completar todas las preguntas ya que su opinión nos interesa.

Gracias,

*Grupo de Vehículos Eléctricos
Worcester Polytechnic Institute
Junto a la Administración de Asuntos Energéticos*

DECLARACIÓN: Toda información completada en este cuestionario es confidencial, anónimo y completamente opcional. Esta encuesta se utilizara para el Proyecto de Investigación de Vehículos Eléctricos auspiciado por la Administración de Asunto Energéticos y por el Worcester Polytechnic Institute localizado en Worcester, Massachusetts.





Cuestionario de Vehículos Eléctricos

1. ¿Estas familiarizado(a) con los vehículos eléctricos?

- Sí
- No

¿Sabías que los vehículos eléctricos operan con baterías internas que se cargan con electricidad en vez de gasolina?

2. ¿Cómo supo de los vehículos eléctricos?

- Propaganda (Ej. Anuncios de televisión, periódico, radio, etc.)
- “Test drive”
- He visto uno en la calle
- Tengo un vehículo eléctrico
- No aplica

3. Los vehículos eléctricos tienen un costo inicial mayor, aunque a largo plazo representa un ahorro debido al mantenimiento mínimo requerido y costo de reparación. ¿Estarías dispuesto(a) en comprar un vehículo eléctrico basado en esta información?

- Sí
- No

4. ¿Cuánto estarías dispuesto(a) pagar por un vehículo eléctrico?

- \$20,000 a \$29,999
- \$30,000 a \$39,999
- \$40,000 a \$49,999
- Más de \$50,000

5. ¿Sabes que es una estación de carga?

- Sí
- No



¿**Sabías que** las estaciones de carga para vehículos eléctricos pueden ser instaladas en el hogar, en el trabajo, restaurantes, centros comerciales, entre otros lugares?

6. Los vehículos eléctricos pueden recorrer hasta 100 millas en una carga completa. Recargar las baterías puede durar hasta 6 horas. ¿Estarías dispuesto(a) en comprar un vehículo eléctrico basado en esta información?

- Sí
 No

¿**Sabías que** las estaciones de carga rápidas tienen la habilidad de cargar un vehículo eléctrico en menos de 30 minutos?

7. ¿Consideraría comprar un vehículo eléctrico si tuviera la ventaja de estacionamiento designado?

- Sí
 No

8. Si existe la infraestructura e incentivos ofrecidos por el gobierno para la compra de vehículos eléctricos, ¿comprarías un vehículo eléctrico?

- Sí
 No

¿**Sabías que** en los Estados Unidos y en otros países hay estacionamientos gratis y carriles destinados para el uso del vehículo eléctrico?

9. ¿Cuán preocupado(a) esta con los asuntos ambientales?

- Muy preocupado(a)
 Preocupado(a)
 Algo preocupado(a)
 No preocupado(a)

¿**Sabías que** conducir un vehículo eléctrico puede ahorrar más de cuatro toneladas de emisiones de gases de invernadero en un año?

10. El vehículo eléctrico tiene potencial de producir cero emisiones. ¿Estarías dispuesto(a) a comprar un vehículo eléctrico basado en esta información?

- Sí
 No

11. ¿Cuál crees que es la característica más importante de un vehículo nuevo? Favor de seleccionar todas las alternativas que apliquen.

- Seguridad
- Precio
- Rendimiento
- Ahorro en gasolina
- Otros (favor de especificar)_____

12. ¿Qué tipo de vehículo usted conduce?

- Coupé o sedan
- Deportivo
- Guagua “SUV”
- Camión “Pick-up”
- Otro (favor de especificar)_____

13. ¿Cuál es la distancia total que usted conduce a diario?

- Menos de 20 millas
- 20 a 39 millas
- 40 a 59 millas
- 60 a 80 millas
- Más de 80 millas

¿Sabías que el 63% de los conductores en los Estados Unidos viajan menos de 40 millas al día?

14. ¿Cuántos vehículos hay en su casa?

- Uno
- Dos
- Tres
- Cuatro
- Más de cuatro

15. ¿Cuál es el ingreso anual en el hogar?

- Menos de \$50,000
- \$50,000 a \$99,999
- \$100,000 a \$149,999
- \$150,000 a \$199,999
- Más de \$200,000
- Prefiero no contestar

Appendix E: Survey Data

Table 5 presents a detailed summary of our survey results. Percentage values are given for all options possible. Table 6 contains the results obtained in response to the “Other (please specify)” option in questions 11 and 12. Responses, when provided in Spanish, have been translated to English.

Table 5: Detailed survey results

	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>
1	50.5%	49.5%				
2	64.9%	1.4%	17.5%	1.4%	14.7%	
3	73.5%	26.5%				
4	73.8%	21.5%	2.6%	2.1%		
5	54.5%	45.5%				
6	69.0%	31.0%				
7	78.6%	21.4%				
8	86.9%	13.1%				
9	62.6%	24.7%	9.6%	3.0%		
10	90.4%	9.6%				
11	63.9%	49.7%	66.7%	71.0%	10.9%	
12	41.0%	10.7%	37.1%	6.3%	4.9%	
13	23.2%	36.8%	20.0%	11.1%	8.9%	
14	25.5%	40.1%	25.5%	4.2%	4.7%	
15	52.1%	27.1%	7.3%	1.6%	1.6%	10.4%

Table 6: Responses of “Other, please specify” options in Questions 11 and 12

<i>Question 11</i>	<i>Question 12</i>
Environment	None at the moment
Environmental concerns	Reventa
Saving time	No car
Technology	Minivan
Environment	Compact
Protecting the environment	Prius
Environmental impact	Guarantee/ warrant
Technical support	No contamination
Maintenance cost	No car
Less contamination	
Environment	
Help the environment	

Save the environment
 Environment
 Save money in the long run
 Care for the environment

Table 7: Cross-tabulation analysis of Questions 1 and 8

		Would you buy an electric vehicle?		
		Yes	No	Total
Are you familiar with electric vehicles?	Yes	89	12	101
	No	84	14	98
	Total	173	26	199

Table 8: Cross-tabulation analysis of Questions 9 and 10

		Would you buy an EV if it can produce zero emissions?		
		Yes	No	Total
Level of environmental concern	Very concerned	115	9	124
	Concerned	45	5	49
	Somewhat concerned	15	5	19
	Not concerned	4	2	6
	Total	179	19	196

Table 9: Cross-tabulation analysis of Questions 6 and 13

		Would you buy an EV if it has a range of 100 mi?		
		Yes	No	Total
Total distance traveled daily	Less than 20 mi	26	18	44
	20 to 39 mi	56	14	70
	40 to 59 mi	23	15	38
	60 to 80 mi	14	7	21
	More than 80 mi	14	3	17
	Total	133	57	190

Appendix F: Puerto Rico Vehicle Excise Tax Information

The following table is used to calculate vehicle importation taxes in Puerto Rico. The information is part of Law Num. 1 of January 31, 2011.

Table 10: Vehicle excise tax in Puerto Rico

<i>Vehicle Price</i>	<i>Tax Amount</i>
Up to \$6,170	\$750
From \$6,170 to \$10, 690	\$750 plus 13% of the difference from \$6,170
From \$10, 690 to \$21,380	\$1,338 plus 25% of the difference from \$10,690
From \$21,380 to \$31,780	\$4,011 plus 30% of the difference from \$21,380
From \$31,780 to \$44,890	\$7,130 plus 35% of the difference from \$31,780
More than \$44,890	40%

Appendix G: Charging Station Distribution in Metropolitan San Juan

The San Juan metropolitan area includes the city of San Juan as well as the municipalities of Bayamón, Trujillo Alto, Cataño, Carolina, and Guaynabo. The region, which can be seen in Figure 17, has a land area of approximately 177 square miles.



Figure 17: Map of the San Juan metropolitan area

The minimum number of charging stations to be introduced to this region was calculated to be 17, assuming a density of one charging station for every 10 square miles. The approximate distribution of these charging stations has been depicted in Figure 18. This will result in a distance of 3.57 miles between any two charging stations. This result was obtained by finding the radius of each circle of 10 square miles area and multiplying it by 2 to obtain the distance between adjacent charging stations.



Figure 18: Model of charging station distribution in metropolitan San Juan

Through background research and personal communication, we have found that the cost of an average Level II public charging station is around \$7,000. Thus, the total cost of installing 17 charging stations will be about \$119,000. However, in order to develop a charging station infrastructure able to support an increased number of EVs, about one charging station should be installed per square mile¹. This would translate to the installation of approximately 170 charging station on the area of metropolitan San Juan.

¹ Retrieved from: <http://www.nissanusa.com/leaf-electric-car/chargingMap?dcp=tqd.leaf.MCR.April11Leafnews.HNR#/leaf-electric-car/chargingMap>

Appendix H: Nissan Leaf Launch Event Summary

On the April 5, 2011, the first Nissan Leaf was introduced to Puerto Rico. Governor Luis Fortuño signed a memorandum of understanding with Kenneth Ramírez, Nissan director for Latin America and the Caribbean. Miguel Cordero, executive director of PREPA also attended the event. Pictures from the event and a transcript of the press conference following the event are provided below.



Part I: Transcript of Event

[Radio WOSO]: Good morning, Governor. I have... it's more like a three part question – first of all, the cost of the vehicle, but number two the initiative that you undertake and the government is taking in putting up these recharging stations at different areas of the island. How would that work and is that something that's 24/7 eventually when it would happen? And the third part is

how quickly is the government going to change its fleet of vehicles to this?

[Gov. Luis Fortuño]: Excellent. First of all, my understanding is the average price range is about \$30,000, but the Nissan team can tell you more about it certainly. Secondly, the idea of entering into a memorandum of understanding with Nissan is precisely to actually work in conjunction with them in the development of those stations. They have the technical expertise that we can use for those purposes. Thirdly, in terms of how quickly, well, Mr. Ramírez was mentioning to me that he has been to other jurisdictions, other states or countries where they don't have not even one charging station, that they, they enter into the MOU. We are at a charging station. So we are ahead of the curve in that sense. Having said that, the Puerto Rico Electric Power Authority is part of the deal, uh, Eng. Miguel Cordero is a co-signer of this memorandum of understanding and it will be, well actually, the most of the responsibility in terms of the development of those stations will actually be on their shoulders. So it will be PREPA that will be in charge of that. I cannot finish answering the question without actually stating that as you may have heard from us in the past and we have Mr. Morton from the Department of Energy, uh, at the federal level, we have a, we want to develop a pilot program in Vieques, which we call Vieques Verde. And part of that project entails not just a 100% renewable energy for the island, but it also entails switching the fleet there towards vehicles that are not producing as much carbon dioxide as ours do nowadays. Uh, so that's the idea. We have been moving aggressively so far on the hybrid side of the equation. Actually you may have seen my car is a hybrid and I can tell you, we pay a lot less in gas than we used to before, uh, the busses of the Metropolitan Bus Authority are, the new ones in the last two years, all of them are hybrid. But now there is the technology for mass production of vehicles. That's a breakthrough that was not available before. We are witnessing



history in the making, really, in that sense and we wanna be part of that history.

[Unidentified]: Mira, ¿quisiera saber cuándo el público va a poder contar con este vehículo en el mercado y en que otras áreas de Puerto Rico se va a estar construyendo plazas para poder recargar?

[Kenneth Ramírez]: So, uh, thank you for the questions. Before I answer the first question in English y la segunda parte en español. To answer your first question about the price of the vehicle, to give you a reference, in the United States, the vehicle is sold retail at \$32,700. And it receives, the user, the customer, receives a federal tax credit in the amount of \$7,500. That brings the price of the vehicle to \$25,000. In some states, there is an additional incentive of \$5,000. That brings the price of the vehicle to \$20,000. So you see, the starting price of the vehicle is competitive by itself, but the incentives of the government make it more accessible and an incentive to bring the technology even faster to the use base. But we are working together with the Government of Puerto Rico and the leadership of the governor is how to translate those incentives in US to other methods in the same or equal amount to the consumers in Puerto Rico. The idea, of course is being part of the United States to the consumer to have a similar benefit as it does the consumer in the United States. In other parts of the world, we have similar situations, where the incentives bring the vehicle to that level. There are several methods, for example the importation tax for zero emission vehicles could be one of the methods. We are discussing that as part of our process.

Y la segunda pregunta, perdón, era sobre el vehículo, ¿cuándo podría llegar a ventas en menudeos a clientes en Puerto Rico? El proyecto que empezamos hoy es un proyecto piloto para traer flotas de vehículos casi inmediatamente. De hecho nos estamos moviendo en un ritmo



mucho más rápido que lo que esperamos realmente. ¿Se recuerda cuando anunciamos hace solo un mes que vamos a tener un acuerdo en 60 días? Lo hemos hecho en más corto plazo, por lo cual creo que nos movemos muy rápido, con el ritmo del Gobierno del Puerto Rico se mueve más rápido que lo que vemos en otros lugares. Así que estamos listos ya para traer vehículos a flotas de gobierno y a través de este proceso, desarrollar el plan para recarga y el plan para cliente dentro de un plazo de un año máximo nos estamos dando para traer el vehículo al mercado. O sea nuestro acuerdo es dentro de un año máximo en conjunto para traer el vehículo al mercado, esperamos que sea un tiempo más corto. Y tenía otra segunda parte no sé si...

[Unidentified] ... ¿y en cuanto a puntos de recarga...?

[Miguel Cordero]: Muchas gracias, buenas días. En cuanto puntos de recarga nosotros, ya el sistema nuestro está preparado para poder instalar puntos de recarga a nivel de todo Puerto Rico. Y algo más, que quizás el consumo de esa recarga, digamos si alguien de San Juan está en Mayagüez y carga su vehículo en Mayagüez, se le puede acreditar a través de la misma cuenta que paga su factura. Y este proyecto va a tener una tarifa incentivada, mucho más baja que la tarifa normal que usted paga en su residencia.

[El Vocero] Partiendo de esa misma premisa, obviamente basado en el costo de kWh, ¿cuánto aproximadamente es el costo mensual de recargar este vehículo y cuántas millas me ofrece?

[Kenneth Ramírez] Si, gracias. La recarga del vehículo total le da una autonomía de 100 millas, cada recarga – 100 millas, esa recarga en el hogar en Puerto Rico a tarifa de carga no incentivada, todavía a 21 centavos por kWh, equivale a 5 dólares. Cinco dólares por 100 millas. Esta misma distancia en un vehículo similar de gasolina son 15 dólares en Puerto Rico. Así que ve el costo

operacional del vehículo aún sin los incentivos ya es mucho más bajo y los incentivos que se van a contemplar le dará aún más economía al usuario por lo cual el costo del vehículo aún baja más por el retorno de inversión en tiempo de la vida del vehículo.

[Telenoticias] Si, buenos días. Al señor gobernador, me gustaría saber cuáles son los... Se ha dicho de manera dispersa... Pero si me puede resumir, cuales son los incentivos de que su administración está contemplando para los compradores de estos vehículos. Sé que hay algo de energía eléctrica y si lo contributivo va a ser factible.

[Gov. Luis Fortuño] Si, claro. Hasta el este momento no había producción en masa de un vehículo cero emisión en el mundo. Punto. Esto no existía. Esto es algo nuevo que acaba de lograrse. O sea, que en ese sentido parte del acuerdo es que Nissan nos va a dejar saber experiencias que están viviendo en otras jurisdicciones, ya sean estados, ciudades o países, para entonces poder lograr un incentivo a nivel local. Aparte de eso hay un incentivo federal. El incentivo federal para vehículos de este tipo no es aplicable en este momento a Puerto Rico. Y parte del fuerza que estamos haciendo es de que el mismo pueda ser aplicable porque ... porque, repito, la firma de un acuerdo como el que acabamos de firmar demuestra el compromiso que tenemos y si miras todos los demás proyectos que estamos llevando a cabo en el área energética y en el área de reducción de emisiones de carbono, encaja perfectamente en nuestro plan de Puerto Rico Verde.

[Nuevo Día] Si, buenos. Quería preguntar, ¿hay algún plan específico de otros municipios que estén haciendo esta iniciativa?, ¿cómo está haciendo el municipio de Bayamón de hacer estas recargas? ¿Cómo se va a hacer esta introducción?

[Gov. Luis Fortuño] Yo no tengo notificación de ello, que sepamos no. Bayamón ha sido realmente en este sentido fue más que pionero. Porque cuando vinimos aquí a la colocación de la primera piedra de las placas solares; en ese momento no se conocía de la capacidad de poder producir en masa para la venta al detal de vehículos 100% eléctricos. Eso es algo que no existía. Estamos hablando más bien de proyectos pilotos, que si querías adquirir uno de esos vehículos realmente no era accesible por el costo. Este es el primer vehículo que está saliendo o que va a estar saliendo de producción en masa, una vez esté totalmente disponible, que va a ser accesible a todos nosotros para poder adquirir.

[Primera hora] Mi pregunta es para Kenneth, quería preguntarle, ¿cuál es la garantía que Nissan está ofreciendo en este vehículo? Me gustaría también saber, ¿cuál es el alcance completo que tiene el vehículo en una carga completa de batería y la velocidad máxima del vehículo?

[Kenneth Ramírez] Gracias. Primero, la primera pregunta creo que fue la inversión de Nissan para este desarrollo de tecnología, no? ... La garantía del vehículo es igual que la garantía de cualquier vehículo de Nissan. O sea, que no es ninguna diferencia, es igual. Pero si tengo un poquito más información sobre la tecnología, el rendimiento de la vida del vehículo se espera que sea muy larga. Las baterías tienen un rendimiento de, por ejemplo, en 10 años de uso diario, de recarga diaria, aún retienen 70% de la recarga, de la capacidad de recarga. Quiere decir que la tecnología de esas baterías tiene una segunda vida. La segunda vida puede ser almacén de energía. Estamos viendo ya como otras autoridades, incluyendo la Autoridad de Energía Eléctrica, para tener almacén de energía con las baterías de uso del vehículo. Después de 5 años, digamos, cambia a otra batería del mismo vehículo con la nueva tecnología que tal vez le da más rendimiento. Le segunda parte creo que fue rendimiento – una recarga total, que son 24 kWh da

un rendimiento de 100 millas de uso típico. Quiere decir que esas 100 millas no es necesario cargar todos los días, depende del tipo de uso que tenga, pero de uso urbano, de “commute” urbano usualmente es mucho menos de 100 millas. El vehículo tiene un desempeño muy ágil porque siendo de propulsión totalmente eléctrica, tiene...el torque de motor eléctrico es inmediato, entonces da una aceleración mucho mayor de un vehículo de gasolina. La velocidad máxima es de 90 millas por hora, la cual hace competitivo. Un espacio para 5 pasajeros, las baterías están debajo de los asientos, lo hace un desempeño de manejo muy competitivo, porque el centro de gravedad es más bajo. Hay otras tecnologías más que podemos compartir, pero le da un poco de información de cómo es el desempeño del vehículo.



Part II: English Translation

[Radio WOSO]: Good morning, Governor. I have... it's more like a three part question – first of all, the cost of the vehicle, but number two the initiative that you undertake and the government is taking in putting up these recharging stations at different areas of the island. How would that work and is that something that's 24/7 eventually when it would happen? And the third part is how quickly is the government going to change it fleet of vehicles to this?

[Gov. Luis Fortuño]: Excellent. First of all, my understanding is the average price range is about \$30,000, but the Nissan team can tell you more about it certainly. Secondly, the idea of entering into a memorandum of understanding with Nissan is precisely to actually work in conjunction with them in the development of those stations. They have the technical expertise that we can use for those purposes. Thirdly, in terms of how quickly, well, Mr. Ramírez was mentioning to me that he has been to other jurisdictions, other states or countries where they don't have not even one charging station, that they, they enter into the MOU. We are at a charging station. So we are ahead of the curve in that sense. Having said that, the Puerto Rico Electric Power Authority is part of the deal, uh, Eng. Miguel Cordero is a co-signer of this memorandum of understanding and it will be, well actually, the most of the responsibility in terms of the development of those stations will actually be on their shoulders. So it will be PREPA that will be in charge of that. I cannot finish answering the question without actually stating that as you may have heard from us in the past and we have Mr. Morton from the Department of Energy, uh, at the federal level, we have a, we want to develop a pilot program in Vieques, which we call Vieques Verde. And part of that project entails not just a 100% renewable energy for the island, but it also entails switching the fleet there towards vehicles that are not producing as much carbon dioxide as ours do nowadays. Uh, so that's the idea. We have been moving aggressively so far on the hybrid side

of the equation. Actually you may have seen my car is a hybrid and I can tell you, we pay a lot less in gas than we used to before, uh, the busses of the Metropolitan Bus Authority are, the new ones in the last two years, all of them are hybrid. But now there is the technology for mass production of vehicles. That's a breakthrough that was not available before. We are witnessing history in the making, really, in that sense and we want to be part of that history.

[Unidentified]: See, I would like to know when these vehicles would be available on the market and in which other areas of Puerto Rico will they construct recharging areas?

[Kenneth Ramírez]: So, uh, thank you for the questions. Before I answer the first question in English and the second part in Spanish. To answer your first question about the price of the vehicle, to give you a reference, in the United States, the vehicle is sold retail at \$32,700. And it receives, the user, the customer, receives a federal tax credit in the amount of \$7,500. That brings the price of the vehicle to \$25,000. In some states, there is an additional incentive of \$5,000. That brings the price of the vehicle to \$20,000. So you see, the starting price of the vehicle is competitive by itself, but the incentives of the government make it more accessible and an incentive to bring the technology even faster to the use base. But we are working together with the Government of Puerto Rico and the leadership of the governor is how to translate those incentives in US to other methods in the same or equal amount to the consumers in Puerto Rico. The idea, of course is being part of the United States to the consumer to have a similar benefit as it does the consumer in the United States. In other parts of the world, we have similar situations, where the incentives bring the vehicle to that level. There are several methods, for example the importation tax for zero emission vehicles could be one of the methods. We are discussing that as part of our process.



And the second part was about the vehicle, when will it arrive for retail sales in Puerto Rico?

The project that is starting today is a pilot project to bring fleets of vehicles here almost immediately. In fact we are moving at a pace much faster than what we really expected. Do you remember when we announced just a month ago that we will have an agreement within 60 days?

We have done it in much shorter time, so I think that we are moving at a very fast pace. The Government of Puerto Rico is moving faster than what we see elsewhere. So we are now ready to bring vehicles to government fleets and through this process, develop a plan for recharging and a plan for customers within the maximal period of one year during which we are planning to bring the vehicles to market. So our agreement is within a maximum year together to bring the vehicles to market, hopefully in a shorter time. And he had another second question I do not know if ...

[Unidentified]: And as for charging stations..?

[Miguel Cordero]: Thank you, good day. As for charging, our system is already prepared to install charging ports at all of Puerto Rico. And something else, about the consumption of this energy, say if someone from San Juan is in Mayaguez and is charging his vehicle in Mayaguez, he will be able to charge this amount to his electricity bill. And this project will have a reduced rate, much lower than the normal rate you pay in your home.

[El Vocero] On that same premise, obviously based on the cost of kWh, approximately how much is the monthly cost of recharging the vehicle and how many miles would it offer me?

[Kenneth Ramírez] Yes, thank you. The total charge of the vehicle gives a range of 100 miles, each recharge - 100 miles, this recharge at home in Puerto Rico at the normal rate, currently at 21 cents per kWh, would equal to \$5. Five dollars per 100 miles. This same distance in a similar



gasoline vehicle is \$ 15 in Puerto Rico. So the operational cost of the vehicle even without incentives is much lower and incentives will further decrease the cost of driving the vehicle and even more for the return of investment in the vehicle lifetime.

[Telenoticias] Yes, good morning. Mr. Governor, I would like to know what the ... It has been so scattered ... But if I can summarize, what the incentives are that your administration is looking for the buyers of these vehicles. I know there is some power and if the tax is going to be feasible.

[Gov. Luis Fortuño] Yes, that is correct. Until now there was no mass production of zero emission vehicles in the world. This did not exist. This is something new that has just been achieved. So, in that sense part of the agreement is that Nissan will let us know of their experiences in other jurisdictions, whether states, cities or countries, then an incentive to achieve locally. Apart from that there is a federal incentive. The federal incentive for such vehicles is not applicable at this time to Puerto Rico. And part of the effort we're making is that the same may be applicable because ... because again, the signing of an agreement as we have just signed demonstrates the commitment we have and if you look at all the other projects we are carrying out in the energy field and in the area of reducing carbon emissions, it fits perfectly into our plan of Green Puerto Rico.

[Nuevo Día] Yes. I wanted to ask, are there any specific plans of other municipalities that are making this initiative, how is making the municipality of Bayamón to do these refills (recharges)? How are you going to do this introduction?

[Gov. Luis Fortuño] I have no notice of it, we do not know. Bayamón was really in this sense more than a pioneer. Because when we came here to lay the first stone of the solar panels, at that



time little was known about the ability to mass produce for the retail sale of 100% electric vehicles. That is something that did not exist. We're talking more of pilot projects, if you wanted to buy one of these vehicles really was not accessible due to cost. This is the first vehicle to be coming out of mass production, once it is fully available, which will be accessible for all of us to acquire.

[Primera hora] My question is for Kenneth, I wanted to ask, what is the guarantee that Nissan is offering this vehicle? I would also like to know, what is the extent that the vehicle has a full battery and what is the speed of the vehicle?

[Kenneth Ramírez] Thanks. First, the first question I think was Nissan's investment in this development of technology, no? ... The vehicle's warranty is the same as security for any Nissan vehicle. So, it's no difference, is the same. But if I have a little more information about the technology, the performance of the life of the vehicle is expected to be very long. Batteries have a yield of, say, 10 years of daily use, daily recharge, even retain 70% of the recharge, the recharge capacity. Technology means that these batteries have a second life, which can be storage of energy. We are already seeing other authorities, including the Power Authority (PREPA), to have vehicle energy storage batteries. After 5 years of use, say, change to another battery of the same vehicle with new technology that may give more performance. I think it was second performance - a total charge, which is 24 kWh yields about 100 miles from typical usage. It means that those 100 miles is not necessary to load every day, depending on the type of use you have, but urban use, "commutes" are usually much less than 100 miles. The vehicle has performed very fast because being all-electric propulsion, is ... the electric motor torque is immediate, and gives a much greater acceleration than a gasoline vehicle. The maximum speed is 90 miles per hour,

which makes it competitive. It has room for 5 passengers; batteries are under the seats, which makes it a very competitive performance management, because the center of gravity is lower. There are other technologies that we can share, but this gives some information on the vehicle's performance.



Appendix I: Glossary of Common Definitions and Abbreviations

Alternating Current (AC) – an electric current that reverses its direction at regular intervals, typically used in power supplies

Battery Capacity – the maximum total electric charge that a battery can deliver to a load under a specific set of conditions, expressed in kWh

Battery Energy Density – the amount of energy stored in a given battery mass, expressed in Watt-hours per kilogram (Wh/kg)

British thermal units (BTU) – the amount of heat needed to raise the temperature of one pound of water by one degree Fahrenheit

kiloWatt (kW) – unit of power equivalent to 1000 Watts

kiloWatt hour (kWh) – a unit of energy equivalent of one kiloWatt of power expended for one hour of time, commonly used in electrical applications

Lithium-ion (Li) battery – a rechargeable battery which has twice the energy capacity of a nickel-cadmium battery and has greater safety and stability

Megawatt (MW) – a unit of energy equivalent to 1 million Watts

Miles per Gallon (mpg) – measurement of fuel economy in vehicles, how many miles a vehicle can travel on one gallon of fuel

Volt (V) – SI unit of electromotive force, the difference of potential that would drive one ampere of current against one ohm of resistance

Watt (W) – SI unit of power, corresponding to the rate of energy in an electric circuit in which the potential difference is one volt and the current is one ampere



Appendix J: Timeline of Progress

Week 1 (March 14-18)

- Reviewed the surveys with sponsors and translated them into Spanish
- Conducted an introductory presentation in order to familiarize the EAA with our project goals and objectives
- Interviewed with Neredia Ortiz and Christian Calderon, of Royal Motors GM, for information about the Chevrolet Volt and purchasing trends of Puerto Ricans
- Interviewed with Luis Osorio of the PREAA about Puerto Rican government structure and renewable energy legislature
- Obtained the Vieques Verde files from the EAA

Week 2 (March 21-25)

- Interviewed with Genevieve Cullen from EDTA regarding legislation and government incentives for EVs
- Completed research on US legislation and incentives in particular states
- Researched documents on the Clean Cities Coalition and the Plug-in Readiness workshop
- Continued research regarding EV car models and specifications

Week 3 (March 28-April 1)

- Conducted face-to-face surveys outside of La Plaza Las Americas Mall, in Condado and in Old San Juan
- Interviewed with Francisco Ramos from PREPA
- Interviewed with Jose Balau, one of the engineers for the Bayamón solar powered parking garage and charging stations
- Researched charging station types and prices

Week 4 (April 4- April 8)

- Revised and proofread executive summary, introduction, background, methodology and appendices
- Attended government event with PREAA for the introduction of the 1st Nissan Leaf to Puerto Rico, met governor Luis Fortuño
- Conducted an interview with Ismael Medina, of Triangle Nissan, about the introduction and sales strategies for the Nissan Leaf
- Began writing the Results and Discussion, Conclusions and References sections of the report

Week 5 (April 11- April 15)

- Conducted face-to-face surveys at the Treasury department and achieved the target quota of 200 responses.
- Compiled and analyzed survey results, case studies and interviews
- Began compiling a final list of recommendations and conclusions
- Completed the first draft of the final report
- Submitted a first draft of our completed report to Professor Ludwig for editing and feedback

Week 6 (April 18- April 22)

- Completed the list of recommendations and conclusions
- Continued analyzing the survey results, looking for relationships between various survey answers
- Completed Appendices F and G and authorship page
- Made all necessary revisions and changes as suggested by Professor Ludwig

Week 7 (April 25- April 29)

- Organized and polished the final list of recommendations
- Completed the final editing of the report
- Translated and transcribed the Spanish audio recording for the Nissan launch press conference into English and added a new appendix for the same

Week 8 (May 2- May 5)

- Updated and Completed Appendix I
- Final presentation and project wrap-up
- Submitted the final report to our sponsors and advisors

