

Electric Vehicles

Exploring the Options for Electric Vehicles on
Nantucket
Nantucket, MA

An Interactive Qualifying Report submitted to faculty of
Worcester Polytechnic Institute
in partial requirements for the Degree of Bachelor of Science.

By Matt Gilzinger, Zachary Lorch, and Dustin Vinci

Dated December 15, 2010

Submitted to:
Dr. Dominic Golding
Project Advisor
Worcester Polytechnic Institute

Nantucket Project Center

Mike Burns
Gregg Tivnan
Sponsor Liaisons

Abstract

Given the growing interest in electric vehicles (EV's) and the possible role they might play in a 'smart' electric grid, the Town of Nantucket asked us to examine the desirability of encouraging EV's on the Island. Accordingly, we surveyed residents, interviewed key stakeholders, and assessed the costs and benefits of EV's on Nantucket. We conclude: there is significant public interest in EV's; the potential for adopting municipal EV's is limited; the Nissan Leaf is the most viable EV at present; and, the present grid can accommodate the increased electricity demand from charging EV's. We recommend the Town adopt three EV's and consider installing public charging stations at the airport, Wannacomet Water Company, and the proposed Wilkes Square garage.

Acknowledgements

Our project would not have been possible without the help and generosity of the WPI IGSD department and of the residents of Nantucket. In particular we would like to thank:

- The entire MMA staff, especially Janet Schulte and Andrew McKenna Foster for providing us a place to reside in on Nantucket.
- Our advisor, Dominic Golding for his endless help with this report
- Our sponsor liaisons, Gregg Tivnan and Mike Burns for their support on our project.
- Harvey Young for lending us bicycles which proved to be essential numerous times for travelling across the island.

Executive Summary

Introduction

Climate change is a growing concern among policy makers around the world due to the wide range of adverse impacts, from rising sea levels to declining crop yields. Anthropogenic sources of carbon emissions are believed to be a primary factor in global warming and the burning of fossil fuels is one of the major carbon sources. According to the Environmental Protection Agency (EPA), in 2006 41% of the carbon dioxide emissions in the United States came from electricity generation and about 33% came from transportation (Climate Change - Greenhouse Gas Emissions, 2010). Technological advances have helped to reduce toxic emissions from power plants and have made renewable energy options like wind turbines less expensive, but much remains to be done as emissions of CO₂ and other greenhouse gases continue their upward trend. Similarly, much remains to be done to reduce emissions in the transportation sector. Recent advances in battery and electric motor technology now allow for alternative fuel vehicles, such as hybrids and electric vehicles (EV's), to be viable alternatives to conventional gasoline powered vehicles.

International companies including Coulomb Technologies, BetterPlace, GE WattStation, Nissan and other organizations have been assisting communities to develop the necessary infrastructure for electric cars (BetterPlace, 2009; Nissan, 2010; Popular Science, 2010). Necessary infrastructure changes include repair shops that are able to fix electric cars, electrical charging stations for cars and possibly battery swap stations that will make owning an electric car convenient.

Pilot trials of different types of charging stations are underway in several countries, but no definitive answer has been reached about what system is best. There are also many questions about how to encourage greater public use and acceptance of the technology. As part of its larger effort to promote environmental sustainability, the town of Nantucket is interested in what policy options are available to encourage greater use of electric vehicles on the island, and what would be the costs and benefits of increased use. In particular, the island is interested in what role electric vehicles might play as part of a smart grid system that integrates the alternative energy supplies (photovoltaic farms and wind turbines) that will be installed in the next several years.

The goal of this project was to assist the Town of Nantucket to determine if it is desirable and feasible to expand the use of electric vehicles on the island. An electric car program implemented on the island would entail slowly replacing the population's gasoline engine cars with electric cars while encouraging electric vehicle purchases through incentives and regulations. The project had three objectives:

- to identify the range of policies and programs that have been proposed or implemented in order to encourage greater use of electric vehicles through a review of the background literature and interviews with key individuals and institutions;
- to characterize the knowledge, attitudes, and perspectives of key stakeholders on the island with regard to electric vehicles through surveys of the public and interviews with other stakeholders; and,
- to conduct scenario analyses to gauge the costs and benefits of encouraging greater use of electric vehicles within different segments of the vehicle fleet, including municipal and privately-owned vehicles, as well as taxis, and courtesy vehicles used by local hotels.

Findings

Our data collection methods consisted of surveys with the public, interviews with key stakeholders and department heads, and scenario analyses to gauge the benefits and drawbacks to various levels of adoption with regards to ownership costs of the vehicles. The public surveys that were conducted revealed information about public attitudes and opinions, the interviews revealed some of the complexity of trying to encourage greater adoption of electric vehicles, and the scenario analyses indicated that the costs of EV's are high in the short term, but pay back in the long term, even given the high cost of electricity on the island.

Public Survey

Understanding public opinion is vital in the effort to encourage greater adoption and use of electric vehicles, and our survey was intended to provide a baseline understanding of the knowledge and perceptions of electric vehicles among Nantucket residents. The survey also provided key information that was used in our cost analyses.

We found that the most common model driven by those surveyed was a Ford Explorer, a sport utility vehicle. Due to rough terrain and recreation opportunities on the island such as driving on the beach, people often find having a sport utility vehicle beneficial. Not only do residents use their vehicles for running errands, but twenty-four residents surveyed also use their vehicle for work. From all of the residents that we surveyed, 86% owned their own car. When asked if they considered buying a hybrid or electric vehicle the last time they purchased a vehicle, 75% of those surveyed said they did not, while 65% said they *would* consider buying an electric vehicle in the future. The responses here may be misleading, however, since the average age of vehicles among those surveyed was 8 years, and in 2002, hybrid and electric vehicles were not widely available.

The survey revealed that the public actually has a reasonable knowledge of some of the major aspects of the current technology. People surveyed on average thought that electric cars take seven hours to charge and can travel 150 miles on a single charge. The majority of the residents surveyed also correctly indicated that electric cars cost more to purchase and maintain but less to fuel than equivalent gasoline powered cars. Most people were unaware that the government offered incentives to purchase electric cars, however.

Interviews

Aside from some basic information on fleet composition and so forth, the interviews were designed to identify some of the more complex issues associated with the adoption of electric vehicles on the island according to some of the key stakeholders and decision makers, such as municipal workers, taxi drivers, rental agencies, and car dealer and repair shops.

One organization that was especially interested in EV's is the Wannacomet Water Company. The head of the company, Robert Gardener, indicated that he would be in support of installing charging stations at his facility. When asked about his fleet he said that he could replace three or four of his vehicles with electric vehicles if they saved him money and were equivalent to his current vehicles. His interest in alternative technology and cost savings is also evident in his plans to install solar panels at his facilities. Using such solar energy to charge the cars would reduce his overall electricity charges. It may also be possible to put a park and ride in the gravel parking lot by the office with a few charging stations for residents to park their car and take a bus. A bus stop already exists down the street for residents and tourists. The primary

concern of the planning department was where the charging stations should be placed. In an interview the Senior Planner indicated that the beach, water department and somewhere downtown, maybe Wilkes Square, would be best the best options for electric car charging stations. A shuttle to the water department would encourage people to charge their cars while also relieving traffic. Downtown would also be an appropriate place to put charging stations but there is likely to be opposition to such locations on several fronts.

Conclusions and Recommendations

The results from our surveys and interviews showed that the residents of Nantucket were very interested in the prospect of greater use of electric vehicles on Nantucket. In fact:

- Two thirds of the residents surveyed said that they would consider an electric vehicle when they next purchase a car
- The owner of Don Allen Ford received neighborhood electric vehicles to sell and was approached by several people looking to buy them.

We also found that the island can support moderate adoption of electric vehicles if it took measures to encourage charging during off peak hours (nighttime) and discourage charging during peak hours (daytime).

- Using our high estimate of electric vehicle adoption, the power cables would not be able to support all of the vehicles charging at once. However, if charging was spread throughout the off peak hours, the island would be able to support the increased demand in electricity.

Based on our findings from the scenario analyses, our interviews with key stakeholders, and our public survey, we identified several recommendations:

- **We recommend that the town does not adopt electric trucks at this time but wait until the electric truck technology improves to the point where 4x4 electric trucks become reliable and economically viable alternatives to conventional gasoline vehicles.**
- **We recommend that the town adopts a small number of electric cars in the near future on a trial basis.** We estimate the town can save money over the life of the car by choosing

an electric car over a comparable gasoline powered car if the car is driven more than 8,000 miles a year.

- **Based on our findings from the scenario analysis and through interviews with taxi company owners we cannot recommend that they adopt electric vehicles at this time.** Most models of electric vehicles available at this time fail to meet the requirements of taxi drivers on Nantucket. Only the Ford Transit Connect EV is remotely suitable in functionality, but is cost prohibitive. Furthermore, even with the fastest charging options available in the United States, the relatively long charging times and short range of an electric car battery makes electric vehicles impractical for taxis. While battery swapping has been used for taxi operations in other countries, battery swapping stations are prohibitively expensive and unlikely to be feasible given the likely future size of the electric vehicle fleet on Nantucket. If taxi companies are extremely interested in using EV's in their vehicle fleet, then we recommend they look into the company BetterPlace and their battery swapping system.
- **We recommend that the town consider installing public charging stations at the Nantucket Memorial Airport.** The excess power from the solar farm that is planned for the airport could be used to power the electric cars at the airport, and numerous residents leave their cars at the airport for extended periods during which full charging would be feasible. We also found through our public survey that more people were in favor of placing charging stations at the airport than anywhere else.
- **We recommend the town consider installing public charging stations in the proposed Wilkes Square parking garage.** Two thirds of the respondents to the public survey were in favor of the town installing charging stations downtown. Installing the charging stations in the proposed parking garage would mitigate some of the concerns raised by other stakeholders, such as the HDC. The Wilkes Square parking garage would allow charging stations to be in the downtown area without being on Main Street.
- **We recommend that the town consider installing public charging stations at the Wannacomet Water Company in combination with the development of a shuttle bus service, as proposed by the Planning Department.** Residents from the east of the island would be able to charge their cars at the facility and take the shuttle bus to town, thus relieving downtown of some congestion.

- **Finally, we recommend that the town continue to monitor the development of electric vehicles and reevaluate the suitability of electric vehicles for the municipal fleet in the future.** It is likely that as more manufacturers develop electric vehicles, electric cars and trucks that are better suited to the needs of the different municipal departments may become economically viable. Economic viability would be greatly enhanced with ‘behind the meter’ charging associated with the town’s proposed alternative energy facilities.

Authorship

Section	Primary	Secondary	Editor
Executive Summary	DV	MG	ZL
Abstract	MG	DV	ZL
Introduction	DV		MG
Literature Review:	MG		DV
- Introduction			
- Electric Vehicles as Part of the Solution	MG	ZL	DV
- State of the Market	DV		ZL
- Policies to Promote the Adoption of Electric Vehicles	MG		DV
- Infrastructure	DV	ZL	MG
- Conclusion	DV		MG
Methods:	DV		MG
- Introduction			
- Surveys and Interviews	DV	ZL	MG
- Scenario Analysis	MG		DV
Findings:	ZL		DV
- Public Survey			
- Interviews	ZL		DV
- Scenario Analysis	MG		DV
Conclusions and Recommendations:	MG	ZL	DV
- Public Survey			
- Interviews	MG	ZL	DV
- Scenario Analysis	MG		ZL
- Recommendations	DV		ZL

Table of Contents

Abstract	i
Acknowledgements	ii
Executive Summary	iii
Introduction	iii
Findings.....	iv
Public Survey	iv
Interviews.....	v
Conclusions and Recommendations	vi
Authorship.....	ix
Table of Contents	x
List of Tables	xiii
List of Figures	xiii
Introduction.....	1
Literature Review.....	3
Introduction.....	3
Electric Vehicles as Part of the Solution.....	4
State of the Market.....	5
Alternative Fuel Vehicles.....	5
Consumer Studies	8
Policies to Promote the Adoption of Electric Vehicles.....	10
Monetary Incentives.....	10
Non-Monetary Incentives	12
Overall Effectiveness of Incentives	13

Current Governmental Incentives	13
Infrastructure	15
Batteries	16
Charging.....	18
Battery Swapping Stations	22
Smart Grid Technology.....	23
Conclusion	24
Methods.....	26
Introduction.....	26
Surveys and Interviews	26
Public Survey	26
Interviews.....	28
Scenario Analysis.....	34
Cost Analysis	34
General Public Fleet.....	36
Municipal Fleet	37
Taxi	38
Rental	39
Findings.....	39
Public Survey	39
Interviews.....	47
Town Departments.....	47
Electricity Usage	49
Transportation	50
Rental and Taxi	52

Repair and Sales.....	53
Scenario Analysis.....	54
Cost Analysis	54
Municipal Fleet	55
General Public.....	57
Rental Fleet	58
Taxi Fleet	58
Conclusions and Recommendations	60
Conclusions.....	60
Recommendations.....	62
Works Cited	65
Appendix A: Public Survey	69
Appendix B: Infrastructure Cost Table.....	71

List of Tables

Table 1 : Electric Vehicles Available	8
Table 2 : Evaluation of Policies Adopted in Europe.....	11
Table 3 : Incentives offered by State	15
Table 4 : Public Survey Response.....	27
Table 5 : Municipal EV Replacement Candidates	56
Table 6 : Selected General Public Scenario Analysis Results	57
Table 7 : Selected Rental Fleet Scenario Analysis Results.....	58
Table 8 : Selected Taxi Fleet Scenario Analysis Results.....	59

List of Figures

Figure 1 : Electrification Path for Power Train Technologies	6
Figure 2 : Battery Cost	18
Figure 3 : Small Electric Car Charging in Holland.....	21
Figure 4 : Better Place Charging Stations in California.....	21
Figure 5 : Survey Results - Car Make.....	40
Figure 6 : Survey Results - Type of Vehicle.....	41
Figure 7 : Survey Results - Annual Mileage Histogram.....	41
Figure 8 : Survey Results - Car Year	42
Figure 9 : Survey Results - Considered a Hybrid or EV at Time of Last Vehicle Purchase	43
Figure 10 : Survey Results - Would Consider Purchasing an Electric Vehicle	43
Figure 11 : Survey Results - Reasons For and Against Purchasing an EV	44
Figure 12 : Survey Results - Do EV's Cost More to Purchase / Fuel / Maintain	45
Figure 13 : Survey Results - Percent of Residents Aware of Government Incentives	45
Figure 14 : Survey Results - What the Town Should Do.....	46
Figure 15 : Survey Results - Where to Install Public Charging Stations.....	46
Figure 16 : Time for Different Electric Vehicles to Break Even for Different Scenarios	55
Figure 17 : Time for Selected Municipal Fleet EV Adoption to Break Even.....	56

Introduction

Climate change is a growing concern among policy makers around the world due to the wide range of adverse impacts, from rising sea levels to declining crop yields. Anthropogenic sources of carbon emissions are believed to be a primary factor in global warming and the burning of fossil fuels is one of the major carbon sources. According to the Environmental Protection Agency (EPA), in 2006, 41% of the carbon dioxide emissions in the United States came from electricity generation and about 33% came from transportation (Climate Change - Greenhouse Gas Emissions, 2010). Technological advances have helped to reduce toxic emissions from power plants and have made renewable energy options like wind turbines less expensive, but much remains to be done as emissions of CO₂ and other greenhouse gases continue their upward trend. Similarly, much remains to be done to reduce emissions in the transportation sector. Recent advances in battery and electric motor technology now allow for alternative fuel vehicles, such as hybrids and electric vehicles (EV's), to be viable alternatives to conventional gasoline powered vehicles.

International companies including Coulomb Technologies, BetterPlace, GE Wattstation, Nissan and other organizations have been assisting communities to develop the necessary infrastructure for electric cars (BetterPlace, 2009; Nissan, 2010; Popular Science, 2010). Necessary infrastructure changes include repair shops that are able to fix electric vehicles, electrical charging stations in convenient, accessible locations and battery swap stations that will make owning an electric car convenient.

Pilot trials of different types of charging stations are underway in several countries, but no definitive answer has been reached about what system is best. There are also many questions about how to encourage greater public use and acceptance of the technology. As part of its larger effort to promote environmental sustainability, the town of Nantucket is interested in what policy options are available to encourage greater use of electric vehicles on the island, and what would be the costs and benefits of increased use. In particular, the Island is interested in what role electric vehicles might play as part of a smart grid system that integrates the alternative energy supplies (photovoltaic farms and wind turbines) that will be installed in the next several years.

The goal of this project was to assist the Town of Nantucket to determine if it is desirable and feasible to expand the use of electric vehicles on the island. Any electric car program implemented on the Island would necessarily entail slowly replacing the population's gasoline engine cars with electric cars while encouraging electric vehicle purchases through incentives and in response to other regulations (e.g., carbon taxes). The project had three objectives:

- to identify the range of policies and programs that have been proposed or implemented in order to encourage greater use of electric vehicles through a review of the background literature and interviews with key individuals and institutions;
- to characterize the knowledge, attitudes, and perspectives of keys stakeholders on the island with regard to electric vehicles through surveys of the public and interviews with other stakeholders; and,
- to conduct scenario analyses to gauge the costs and benefits of encouraging greater use of electric vehicles within different segments of the vehicle fleet, including municipal and privately-owned vehicles, as well as taxis, buses, and courtesy vehicles used by local hotels.

This report begins with a literature review that summarizes the current state of electric vehicle technology and presents an overview of the different programs and incentives that are designed to promote the adoption of electric vehicles as well as the infrastructure options for EV's. Following the literature review, we describe the methods used to conduct the surveys, interviews, and our scenario analysis. The final chapter presents our overall findings and conclusions, as well as a set of recommendations about how the Town of Nantucket may proceed in the future.

Literature Review

Introduction

Around the world, many governments are promoting the development and adoption of electric cars as an effective way to improve sustainability, to reduce oil consumption, and to reduce the emissions of several pollutants, especially carbon dioxide which has been shown to affect global warming. In response to these government programs and in anticipation of expected consumer demand, the private sector has been pushing to develop the battery technologies and infrastructural elements necessary to support the general introduction of electric cars. At this time, several car manufacturers are about to release electric car models (e.g., the Chevy Volt, the Tesla Model S, and the Nissan Leaf), but there are still many obstacles preventing widespread adoption by the public. Consumers are concerned about the cost (e.g., Are electric vehicles more expensive to own and operate than conventional cars?), the readiness of the technology (e.g., How far and fast can I go? Will the batteries last long enough?), the availability of infrastructure (e.g., How and where can I charge my car away from home? What if I forget to charge my car at home?), as well as other issues. To overcome these consumer concerns and other remaining obstacles, government agencies, corporations, and non-governmental organizations worldwide are offering various incentives to consumers to adopt electric vehicles and beginning to build the infrastructure to support them.

In this section of the report we summarize the nature of these obstacles and the status of efforts to overcome them. We will examine:

- The status of electric vehicle development;
- The available options for infrastructure to support the adoption of electric vehicles;
- Public concerns about and attitudes towards electric vehicles; and,
- Varying incentives to encourage greater adoption.

In the final portion of the literature review, we examine the unique situation in Nantucket. To improve its sustainability and reduce pollution, the Town of Nantucket is interested in knowing what the advantages and disadvantages of promoting the wider use of electric vehicles might be. Nantucket is an island separated from the mainland this leads it to having one of the highest electricity rates in the US as well as one of the highest gasoline prices in the US.

Nantucket is exploring the possibility of integrating renewable energy projects into the grid, to reduce peak loads and to decrease the overall consumption of electricity on the island. The Town of Nantucket is also interested in the possibility of installing a smart electric grid on the island to better manage the use of electricity, encourage greater conservation, and allow the seamless integration of various alternative energy sources, including photovoltaic farms and wind turbines. The Town is interested in exploring how electric vehicles would fit in a smart grid as a battery storage system. Many experts see electric cars as an important part of smart grid systems (John Edwards, Principal of Optimized Energy Networks, September 24, 2010), and we review the current status of thinking on this topic.

Electric Vehicles as Part of the Solution

Electric vehicles (EV's) offer many benefits to the consumer as well as the environment. EV's do not use an internal combustion engine for locomotion, but instead use an electric motor. As a result, EV's do not have any direct emissions. EV's however, have indirect emissions depending on how the power grid generates the electricity used to charge them. In fact, according to Johnston,

“The electricity needed for charging vehicle batteries, however, is mostly generated from power plants burning oil, natural gas, or coal. ... In this sense, electric vehicles are not emission-free (unless the electricity for recharges is generated by nuclear plants)” (Johnston, 1997, p. 171).

By using power from external sources the energy can be produced more efficiently, however, and maybe cleaner than using gasoline. In a world that is continually seeing the effects of global warming the reduced emissions of EV's serves as a potential way to solve the problem. In addition when looking at cost, electric vehicles are cheaper to run than regular gas powered vehicles, however, the higher purchase price of an electric vehicle can negate the savings (INL, 2010). Since electricity is produced on such a large scale, the cost of the power generated to charge an electric vehicle's battery is less than paying for gas. Also, controlling emissions of CO₂ and other greenhouse gases from power plants may be easier than controlling similar emissions from gasoline-powered cars.

Electric vehicles have many disadvantages as well as many advantages and depending on the situation they may or may not be a viable option for transportation. Some of the limitations of the adoption of alternative fuel vehicles are that they are expensive, their driving range is less than comparable internal combustion engine vehicles (ICEV's), the time it takes to recharge the vehicle, and having the ability of four-wheel drive electric vehicles. Phoenix Motor Company has come out with an all-wheel drive electric sport utility truck (Phoenix Motorcars, 2001). However, since the company is small, not a major car company, and cannot mass produce this vehicle, the cost of this vehicle is more than a traditional gasoline all-wheel drive truck. Ford recently came out with the electric version of the Transit Connect which is a light duty commercial vehicle that does not have the option of four wheel drive (Silvermen, 2010). Navistar is coming out with an electric delivery truck called the eStar which has already been incorporated into some of FedEx's fleet (Hobbs, 2010). eBus is another company that is building electric busses and states that their buss can charge all night and run all day (eBus, 2008). As an alternative fuel vehicle, EV's prove to be a cleaner, more sustainable option than traditional internal combustion engine vehicles, but they have some drawbacks not present in ICEV's.

State of the Market

Alternative Fuel Vehicles

There are many different types of alternative fuel vehicles on the market today. These consist of advanced internal combustion engine vehicles, advanced diesel vehicles, hydrogen fuel cell vehicles, hybrid vehicles, plug-in hybrid vehicles, extended range electric vehicles, and battery electric vehicles. Figure 1 is chart which shows a transition of gasoline vehicles to electric vehicles.

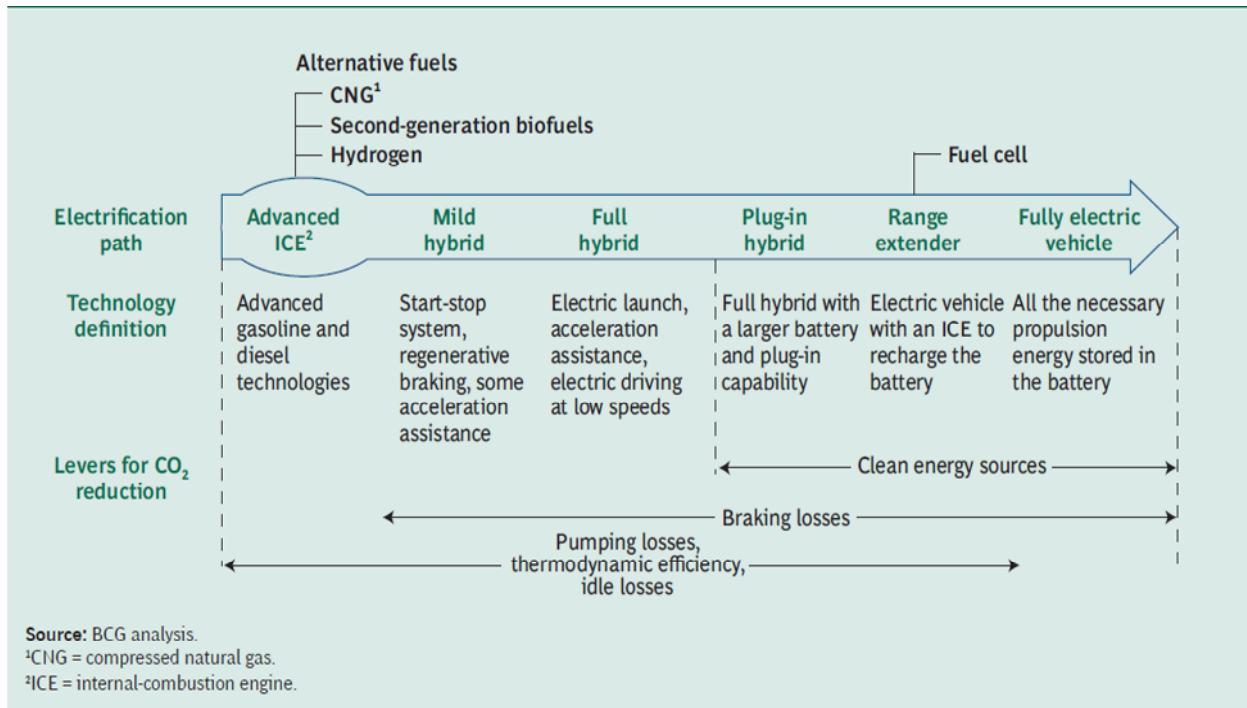


Figure 1 : Electrification Path for Power Train Technologies

(Boston Consulting Group, 2009)

The advanced internal combustion engine vehicle (AICEV) technology consists of compressed natural gas vehicles, second-generation biofuels, and hydrogen. “Second-generation biofuels offer significant potential for CO₂ reduction.” (Boston Consulting Group, 2009). According to the Boston Consulting Group, second-generation biofuel vehicles have the potential to reduce carbon emissions by up to 90%, while compressed natural gas can reduce carbon emissions by up to 25%. The most concerning elements of compressed natural gas vehicles to the public are the costly investments needed for the infrastructure and the costly elements in the vehicle (Boston Consulting Group, 2009). Hydrogen vehicles are different than hydrogen fuel cell vehicles because they actually burn hydrogen as a fuel. Hydrogen-based vehicles are not likely to be as successful in the coming years because of the low efficiency and the costly investments. Overall the most likely transition from traditional ICEV’s will be towards biofuels in the next few years (Boston Consulting Group, 2009).

Hybrid technology is seen as the next likely vehicle in the transition to full electric vehicles. Hybrids break down into two main categories: full hybrids such as the Ford Escape

Hybrid, and plug-in hybrids such as the new Toyota Prius Plug-in Hybrid. According to the Boston Consulting Group, full hybrids consist of electric launch, acceleration assistance, and electric driving at low speeds while the plug-in hybrids consist of a full hybrid with a larger battery and plug-in capability. These are seen as the next transition because the plug-in hybrid brings in the first stage of all-electric vehicles which is the ability to travel a certain distance on a single charge as well as the need to be plugged in and charged overnight.

The next phase in the transition to all electric vehicles is the range extended electric vehicle. A good example of this is the Chevy Volt. This car can travel up to 40 miles on the battery alone before the gasoline engine turns on to recharge the battery. This transition will be easier for people because they still have the same range as a traditional gasoline vehicle as well as the “peace of mind” of the gasoline engine in knowing that if they run low on gas then they can pull into any gas station and be refilled in a few short minutes. The next step after this type of vehicle will be the electric vehicle and will be discussed more throughout this report.

Table 1 shown below describes the current market of electric vehicles and some of the future electric vehicles to come. It is shown that electric vehicle technology is emerging and many electric vehicles have yet to be released. It is also seen that many of these electric vehicles have a range close to 100 miles.

Vehicle	Release Date	MSRP	Battery Type	Range	Capacity
Nissan Leaf (BEV)	Late 2010 to early 2011	\$32,780	Lithium Ion	100 miles	24 KWh
Tesla Roadster (BEV)	Available since 2008	\$101,500	Lithium Ion	244 miles	53 KWh
Ford Focus (BEV)	2012	Unknown	Lithium Polymer	Unknown	Unknown
Phoenix Sport Utility Truck (BEV)	2009	~\$45,000	Lithium Titanate	100 miles	35 KWh
Ford Transit Connect (BEV)	Late 2010 to 2011	\$58,200	Lithium Ion	80 miles	28 KWh
Chevy Volt (ER-EV) Extended Range	November 2010	\$41,000	Lithium Ion	40 miles (all electric) 310 miles (with gas)	16 KWh
Toyota RAV-4 (BEV)	1997-2003	\$42,000	Nickel Metal Hydride	110 Miles	27 KWh
	2012	Unknown	Lithium Ion	Unknown	Unknown

Table 1 : Electric Vehicles Available

Consumer Studies

In May 2010, the Electric Power Research Institute (EPRI) released a report of the findings in their comprehensive survey of Southern California residents about their interest in

battery electric vehicles (BEV's) and plug-in hybrid electric vehicles (PHEV's) (Electric Power Research Institute, 2010). The survey covered several topics from the preferred charging locations for BEV's to the effect of gas prices on the demand for battery electric vehicles (BEV's), plug-in hybrid electric vehicles (PHEV), internal combustion engine vehicles (ICEV's), and hybrid electric vehicles (HEV's). EPRI also separated the opinions of hybrid owners and those who didn't own hybrid cars. The study found that:

- Non Hybrid owners liked having charging stations at gas stations;
- Opinions differed significantly between men and women;
- PHEV interest drops after gas prices reach \$4 per gallon and BEV interest increases exponentially;
- Respondents have misconceptions about BEV safety, such as the possibility of electrocution on rainy days;
- Hybrid owners and non-hybrid owners have different expectations;
- BEV's are seen inferior in horsepower and speed to ICEV's;
- Free parking is "nice-to-have" but not a real incentive to buy;
- Monetary incentives are the most promising; and,
- 95% of people will charge an electric car at home.

The Consumer Electronics Association (Consumer Electronics Association, 2010) has also conducted a similar survey entitled *Electric Vehicles: The Future of Driving* and found that:

- 40% of consumers report that they are likely to test drive an EV;
- 32% of those surveyed are familiar with hybrids;
- 25% of those surveyed are familiar with EV's;
- 78% of those surveyed said that the fact that there is no gasoline used in an EV is the greatest advantage;
- The two biggest concerns in order of importance are range and the life of the battery; and,
- The survey supports the belief that BEV's will be cheaper to maintain.

The research on the opinions of consumers shows that consumers are interested in BEV's but they also have concerns about the battery technology. Consumers are worried about the safety, lifespan, range and cost of the batteries (Consumer Electronics Association, 2010).

Policies to Promote the Adoption of Electric Vehicles

Because of societal, political, and economic benefits of switching to alternative fuel vehicles, several government agencies at the federal, state and local levels, as well as various, organizations and companies have enacted policies and incentives to promote the transition to Alternative Fuel Vehicles, including EV's. Most of the policies can be grouped into one of a few categories and are very similar with the primary differences being eligibility requirements and to a lesser extent, the dollar value of the incentive (e.g. \$5000 vs. \$7500).

Monetary Incentives

A common type of incentive offered by organizations and government agencies is a monetary incentive. Various organizations have different reasons for offering these incentives ranging from pursuing sustainability to curbing global warming. Monetary incentives can vary in forms such as rebates for purchasing an alternative fuel vehicle, tax exemptions or other similar incentives that apply immediately at the time and point of purchase, and tax credits which are applied at a later point in time. As Fabian et al. found in Europe, these different monetary incentives have varying levels of effectiveness as shown in Table 2 (Fabian, Wietschel, & Dallinger, 2010).

		Effectiveness	Efficiency	Practicability	Public Acceptance
Tax Exemptions	One-Time	●	●	+	+
Tax Credits		-	-	+	●
Subsidies		●	+	n/a	+
Scrapping Scheme		●	-	n/a	+
Feebate Systems	Recurring	+	●	-	+
Annual Fee Reduction		+	+	+	+
Increased Fuel Taxes		+	+	+	-
Parking Fees		●	n/a	-	●

Table 2 : Evaluation of Policies Adopted in Europe

+Above Average

●Average

-Below Average

(Fabian, Wietschel, & Dallinger, 2010)

Tax Credits and Other Delayed Incentives

There are many monetary incentives available that come into effect at varying times after the purchase of a new EV. Corporate and employee incentives often fall into this category; some insurance companies offer discounts on auto insurance for owners of hybrid electric vehicles (HEV's) and other alternative fuel vehicles. Some state and local governments and some corporations and companies offer rebates to buyers of EV's and HEV's (Diamond, 2008) (HybridCars.com, 2009). These rebates fall in between tax exemptions and tax credits in immediacy and are more easily implemented as employee benefits than the other two options.

Sales Tax and Other Immediate Incentives

Unlike tax credits, sales tax exemptions are effective immediately at the purchase of an EV rather than delayed monetary incentives which are effective some time later. When considering tax exemptions and tax credits of the same value, the tax exemptions are more

effective primarily due to the reduction of the upfront cost of the EV (Diamond, 2008, p. 140). Fabian et al. also note that tax exemptions are not only more effective, but more efficient, better received and much more practical (Fabian, Wietschel, & Dallinger, 2010). Fabian et al. also observed that subsidies, a variation of the tax exemption where the buyer is given money at the time of purchase. As noted in Table 2, subsidies are also more effective than tax credits.

Yearly Fees

In the United States, gasoline is often taxed at the federal, state, and sometimes local levels. Fabian et al. state that increasing taxes on fossil fuels is effective and efficient for providing a push to EV's, but it comes at the cost of being very poorly accepted. Fabian et al. also explored the effectiveness of reducing annual fees such as car registration fees and found them to be efficient and effective. The feebate system that Fabian et al. discussed is based on a portmanteau of "fees" and "rebates". The system works by annually charging or crediting car owners for their car based on their car's miles per gallon rating or emissions. Feebate systems were found to be impractical to implement and inefficient compared to other effective policies.

Non-Monetary Incentives

EV use of HOV Lanes

High Occupancy Vehicle (HOV) lanes are traffic lanes that are dedicated to the use of vehicles with more than 2 passengers to promote carpooling and to reduce traffic congestion. The state of California implemented a system where 75,000 (later increased to 85,000) permits were issued allowing HEV's to use HOV lanes in the state. Diamond (2008 p.92) observed that although the permits were quickly grabbed by state residents, the program didn't have a significant effect on the market share of HEV's in California. The rapid depletion of permits and the lack of change in HEV market share suggests that existing HEV owners applied and acquired the permits before customers could buy new HEV's negating the program's usefulness for encouraging the adoption of HEV's. As pointed out by Diamond (2008, p. 119) HEV and EV use of HOV lanes can have several negative drawbacks. Due to increased congestion caused by heavier use of the HOV lanes, use of HEV's in HOV lanes can cause negative perceptions of HEV drivers, possibly driving down demand for them (Diamond, p.121). Another issue with EV use of HOV lanes is that it favors those that are able to afford the price difference between the EV and the ICE model which contributes to the negative feelings towards EV users (Diamond,

p.120). It is to be noted that HOV use policies are of very limited significance on Nantucket because the island has no freeways and no existing HOV infrastructure for commutes.

Preferred Parking

The practice of reserving parking spaces for EV's and HEV's hasn't been focused on much in the past, but lessons from other policies may be used to craft a general overview of how well a Preferred Parking system would work. Because of the very limited nature of parking on Nantucket, it may be inferred that parking is to some degree competitive. The dedication of valuable parking spaces to HEV's or EV's may have a polarizing effect on the public where HEV and EV drivers are given a negative image because of their preferred treatment, as seen in the HOV cases. So preferred parking may have a relatively significant impact on Nantucket, it may have significant negative consequences. The best strategy would likely be to conservatively enact a pilot program and expand it as long as it has a positive impact on the community.

Overall Effectiveness of Incentives

While many types of policies to encourage the adoption of EV's and HEV's have been used in the past, it is important to note the influence of policies as a whole on the market share of HEV's and EV's. Diamond (2008, p. 148) demonstrated that gas prices were the biggest factor in the adoption rates of EV's and that public policies may not have a significant impact. Diamond (2008, p. 145) also warned that some policies may create a group of "entrenched stakeholders" that will fight to keep policies in place that are in their interest but maybe not in the interest of the general public. He warned about HOV use policies specifically although irrelevant to Nantucket which has no freeways, but it can also be applied to preferred parking systems because of the limited nature of parking on Nantucket.

Current Governmental Incentives

The U.S. Federal government offers several incentives for EV's depending on the nature of the vehicle and Massachusetts currently does not have any incentives yet but is reportedly planning to implement HOV exemptions and sales and excise tax credits (Plug In America).

Federal Tax Credits

The only incentive that the Federal government currently offers for purchasing an EV is a tax credit. The government gives out different amounts depending on which of the two following categories the vehicle fits in (U.S. DOE).

- 1 Cars that could replace a standard ICE vehicle (e.g. Nissan Leaf, Tesla Roadster)

“To qualify, vehicles must be newly purchased, have four or more wheels, have a gross vehicle weight rating of less than 14,000 lbs., and draw propulsion using a battery with at least four kilowatt hours that can be recharged from an external source of electricity.”

- 2 Smaller, low range and low speed vehicles that do not fit in the former category (e.g. Neighborhood Electric Vehicles)

“To qualify, a vehicle must be either a low speed vehicle propelled by an electric motor that draws electricity from a battery with a capacity of 4 kilowatt hours or more or be a 2- or 3-wheeled vehicle propelled by an electric motor that draws electricity from a battery with the capacity of 2.5 kilowatt hours.”

Consumers that purchase vehicles that fall into the first category are eligible for a tax credit between \$2,500 and \$7,500 depending on the battery’s capacity while consumers that buy vehicles in the second category are eligible for a tax credit consisting of 10% of the purchase price up to \$2,500.

State Incentives

Several states offer similar incentives for HEV use as seen in Table 3 below. Most of the policies are the same except for changes in monetary amounts and restrictions applied to the incentive. Utah offers a tax credit for 50% of the difference between the HEV and the ICE versions of a HEV vehicle, but it only applies to the Honda Civic while California has a system where HEV’s can use HOV lanes but there is a limited number of permits. Governor Deval Patrick of Massachusetts recently offered 100 subsidized charging stations for Massachusetts with a preference to Green Communities. This was offered in October 2010, lasted for 60 days,

and ended in December 2010 (Mass.Gov, 2010). A more complete table of incentives offered by other states is shown in Table 3.

State	Tax Exemption?	HOV Lane Use?	Tax Credits
Arizona		Yes	
California		Yes (Capped)	
Colorado	Incremental Rebate		
Connecticut	>40 MPG HEV only		
D.C.	Yes		Registration Discount
Florida		Yes	
Louisiana			Caps at 2% or \$1500
Maryland			Inspection Fee Waived [50+ MPG HEV only]
New Jersey		Yes	
New York		Yes	
Oregon			\$15000 or 35% incremental
Pennsylvania			\$500 rebate
South Carolina			Matches 20% of Fed. Credit
Utah		Yes	50% Incremental Credit for Honda Civic
Virginia		Yes	

Table 3 : Incentives offered by State

(Diamond, 2008)

Infrastructure

In order to encourage greater use of electric vehicles people need to feel secure that they are not going to be stranded when the battery in their electric vehicle runs out. Thus, cities,

states, federal government agencies and various other organizations are beginning to discuss what kind of infrastructure needs to be developed to support EV's in the US. Several different options have been proposed and some are in various stages of development in the US and elsewhere in the world. For example there are plans to develop electric cars in Israel, Australia, Japan and Hawaii, and there are already some electric car infrastructures in place in the UK, Switzerland, and California (Agassi, 2010). Basic infrastructure is composed of charging stations at home, work, and in public venues as well as a network of battery swapping stations that are the electric vehicle equivalents of gas stations. Many factors affect the type and configuration of the infrastructure, and the technology is new and rapidly evolving. One key element in the entire infrastructural planning and design process is the nature of battery technology. In the following sections, we discuss each of these.

Batteries

All EV infrastructure needs stem from one piece of equipment and that is the battery in the EV. The issues with batteries are the charge time, the weight, the cost and the distance the vehicle can travel per charge (Kromer & Heywood, 2007). These factors are related to one another because each one affects the next. If a person would like a vehicle that travels farther per charge, then it will cost more and will weigh more, making the vehicle less efficient (Kromer & Heywood, 2007). The average battery in EV's today is a lithium ion battery. The new technologies in these batteries are safer than previous lithium batteries and they are more easily recycled than previously.

There are many different types of electric vehicle batteries. The lead acid battery is standard in most ICEV's but holds the least amount of charge per unit and is not suited for all electric vehicles. In increasing order of energy storage, there are also nickel cadmium batteries, nickel metal hydride, lithium ion (Li-ion), lithium titanate, and lithium ion polymer batteries. Battery technology continues to evolve at a rapid pace, with improvements in energy storage, charging times, and other key attributes, including safety. For example, the current lithium ion polymers are much safer than the early Li-ion batteries and are more resistant to shock damage. Lithium titanate batteries have a revolutionary composition that allows them to be charged and discharged much faster than other lithium batteries but they have less capacity and operate at lower voltages. A typical lithium ion battery works by sending electrons to charge the battery

cells through carbon anodes which only have about 3 square meters per gram for carbon for contact point for these anodes. A typical lithium titanate battery works in the same general way but instead of having carbon anodes it uses lithium titanate nanocrystals which gives the anodes about 100 square meters per gram of surface contact (Graham-Rowe, 2005).

In order to charge the battery pack in an electric vehicle, alternating current (AC) power from the grid must first be converted to direct current (DC). The majority of proposed and existing charging stations have this converter in place already. The charging station then distributes the power to the battery pack. Unfortunately, it takes 8 hours to fully charge an electric car such as the Nissan Leaf using a conventional at-home charging station (Nissan, 2010). The average EV can travel about 100 miles per charge, but some special battery packs are now available that can deliver as much as 400 miles per charge. Unfortunately, such batteries are much heavier and more expensive (Kromer & Heywood, 2007). The graph below compares the cost and the range of two different types of batteries (\$200/kWh versus \$250/kWh). Generally, the \$250/kWh can store more energy than the \$200/kWh battery but is more expensive. The graph shows the increasing the mileage per charge from 100 to 400 miles increases the cost of the \$200/kWh battery from about \$4,000 to \$20,000, and the cost for the \$250/kWh battery increases from \$5000 to more than \$30,000.

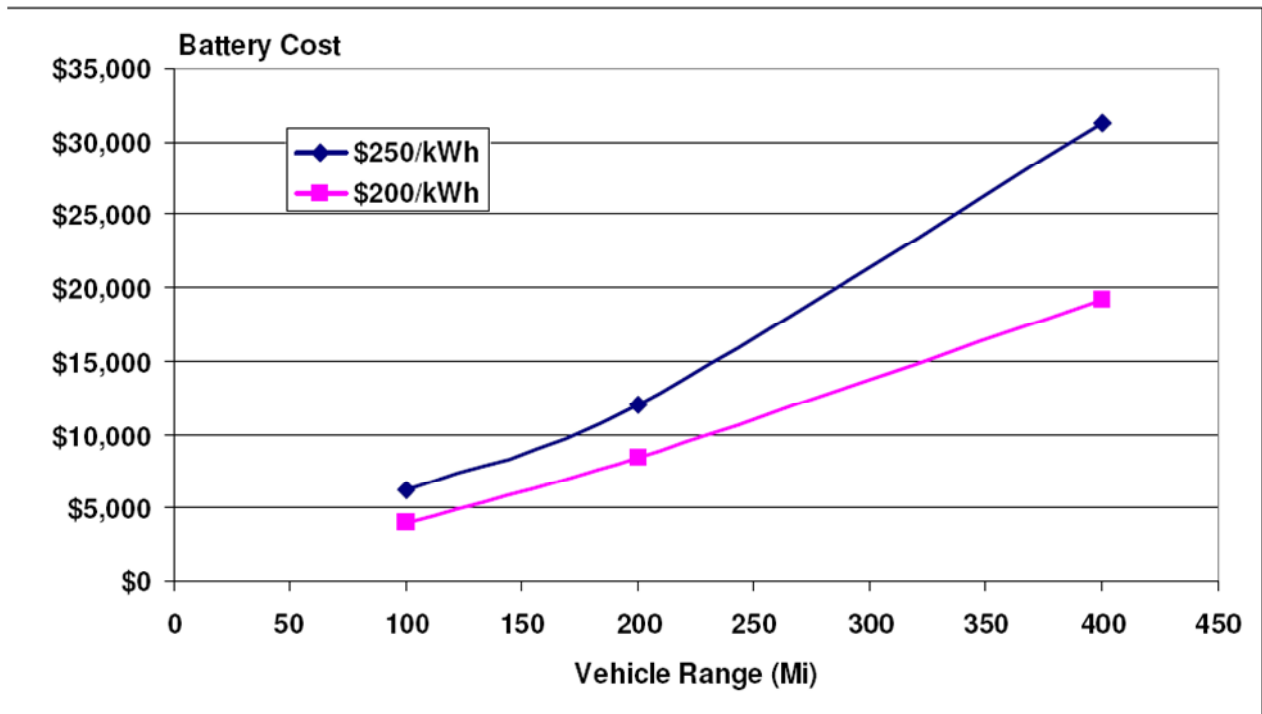


Figure 2 : Battery Cost

(Kromer & Heywood, 2007)

Charging

To encourage widespread adoption of EV's people will need to be able to quickly and conveniently charge their vehicles at home, work, and elsewhere. Charging an EV at home using a regular 120V outlet (known as 'level 1 charging' at up to 15 amps and 2.4kW) takes a relatively long time (approximately 8 hours) with current battery and charging systems (Markel, 2010; Control Module Industries, 2010). At home charging times could be reduced to approximately 4 hours using a 240V outlet up to 30 amps or 2 hours using a 240V outlet up to 70 amps (known as 'level 2 charging' at up to 19.2kW) (Control Module Industries, 2010; Markel, 2010). Most homes in the US have a 240V supply that is split on entry and provides a limited number of 240V outlets for appliances such as stoves and driers. Thus, most EV owners who live in houses (approximately 68.9% of the US population live in single-family residences) (U.S. Census Bureau, 2006) would need to install new 240V outlets that would be easily accessible for charging cars. Providing charging options for EV owners who live in apartments, hotels, etc. would present additional complications. Furthermore, the additional load imposed on the grid would need to be monitored carefully at the local level to avoid overloading transformers

(Markel, 2010). This could be done in many ways, but the most practical would be by use of a smart grid, which will be discussed in more detail later.

Charging an EV while out of the house presents problems such as having charging spots readily available for people to use on a regular basis. Various options have been proposed by various vendors and different planners about possible locations for charging stations. These include building charging stations at major parking lots, building charging stations at curbside parking, and building charging stations in heavily visited areas. Similar to the household sector, the public sector would need to have both level 1 and level 2 charging spots to allow customers the option of rapid or slow charging. They are both important because customers need the option of being able to charge their vehicle in a time frame of 8 hours to 2 hours. The level 2 chargers would cost more and would require heavy duty cables to support the higher current.

Developing an infrastructure of charging stations in a community faces a number of hurdles that must be overcome, including building codes, fire inspections, utilities and building inspections and different vendors (Markel, 2010). Details regarding building codes and other inspections vary from place to place because different countries, states, and towns have different restrictions. Furthermore, different vendors have created and developed different designs of charging stations with different requirements. For example, Holland is pilot testing charging stations that take credit cards (Figure 3). Hertz is renting out electric vehicles that will tell the driver if electric car charging spots are open and if so where they are (Motavalli, 2010). Other charging stations (Figure 4) require users to subscribe to a payment plan. For this payment plan users would have a key card that would be able to identify them as a user and pay for the electricity used at a later date. Another consideration would be the multi-party use of these charging stations. The multi-party use of these charging stations would be an issue because every charging chord would need to fit every charging station. There are a few standards set in place already such as the same adaptor for the plug for the car, and for the charging station itself. If there were not standards then charging at different stations would be impossible. Interoperability between these charging stations will be very important for the adoption of EV's. Some of the questions that remain to be resolved are:

- Would people be charged differently for using different companies' charge spots?
- Would every charge spot be owned by one company?

- How are people going to pay to charge their car outside of their house?
- How much would a charging station need to be used in order for it to be financially beneficial?

All of these questions are very important issues in the implementation of EV's. Unfortunately not all of these questions have answers. It is unknown whether it would be better to have one company own every charge spot or to have many different companies own charge spots. Another question deals with a "roaming" charge for using different charge spots. It is expected that if there existed multiple charging companies then there would be a "roaming" charge for using other companies charging spots or one company may charge less to use their charging station. This also brings up the question of payment for charging your EV.

If someone charges their EV at home then there is no question as to how they will pay for it, but charging outside the home does raise questions. Various options have been proposed such as payment plans and charging payable by credit card at the station itself. Through his company, Better Place, Shai Agassi is proposing the use of different payment plans, similar to those offered by phone companies. Electric vehicle users would enroll in a plan based on their expected electricity use. They would be billed at a charging station according to their plan. No matter which method is decided as the best, the key to each is interoperability, the ability for everyone to be able to use a charging station and to have it all be universal to some extent. Gas stations today are not all exactly the same but they all work in the same manner, for instance all gas stations have the same size nozzle, and that is what's important and that is what needs to be applied to these charging stations.



Figure 3 : Small Electric Car Charging in Holland

<http://gas2.org/2009/07/21/holland-installs-its-first-ever-electric-car-charging-stations/>



Figure 4 : Better Place Charging Stations in California

<http://www.treehugger.com/files/2008/11/better-place-coulomb-technologies-expand-california-electric-vehicle-infrastructure.php>

Battery Swapping Stations

Current electric cars have a limited range of about 100 miles per charge. In order to travel three hundred miles, therefore, an EV driver might have to stop and recharge the battery twice, and such recharging would take several hours. To overcome this problem, some proponents of electric cars are suggesting the development of battery ‘swapping’ stations. A battery swapping station deals with this issue and can extend the range of an EV. Shai Agassi of Better Place has come up with the idea of taking the battery out of the price of the car, which lowers the initial cost of the car, and allowing the battery to become interchangeable. With this system the owner of the car doesn’t own the battery and in a sense, leases it from another company. The company Better Place is a leader in the battery swapping industry. If the vehicle owner doesn’t own the battery then it will change the way people look at EV’s. What this allows is the unlimited range of an EV, which was limited to a few hundred miles before. Agassi has partnered with Renault-Nissan to create these electric cars which would have interchangeable batteries to increase sustainability. Current electric vehicles are not designed to have the battery changed frequently and this could be problematic for the battery swapping stations.

The proposed ideas are that there would be battery changing stations conveniently placed, for example where current gas stations are now, and when a vehicle would need to have a battery change, the vehicle would pull up and attach to a conveyor belt, similar to a car wash. From there the vehicle would move down the track, the mechanism would take the old battery out and put a new battery in. The whole process would take two to three minutes and then the driver would be on the road again in roughly the same amount of time it takes to fill up a gas tank. The fact of being able to change out a battery for a new one significantly changes things because one of the most important issues with EV’s in the past was their limitations on range, and now with these battery swapping stations it would no longer be an issue (Agassi, 2010). The only issue with this plan is that every EV would need to have a battery that is designed to be taken in and out and most EV’s today are not designed for that. The benefit to this is that every battery swapping station would be the same and everything would be universal and have the maximum amount of interoperability. In Israel, Australia, Japan, Denmark, China, Hawaii, and very recently California are some of the places where Better Place is promoting EV’s, and this type of infrastructure. For example, in Japan, Better Place has conducted a pilot study where they have replaced a large number of taxis with electric vehicles and they have incorporated into the taxi

system the concept of the battery swapping stations. The electric taxis in Japan worked out so well that they decided to extend the study by three months. In these countries, the federal governments and local governments are aiding in the promotion of EV's by creating higher taxes on internal combustion vehicles and other

Smart Grid Technology

A smart grid is simply designed to maximize the efficiency of electrical consumption in any given area (Schuler, 2010). One of the benefits to having a smart grid is that it can tailor the electrical usage to towns, building, and even a specific person's house (Edwards, 2010). A smart grid would allow electrical devices like dishwashers to be run automatically at night when the electricity usage is off-peak. This is crucial to leveling electrical usage which reduces electricity rates.

Taking this concept one step further a smart grid can then be used to manage electric vehicle charging. Using this technology, the amount of energy demanded from charging vehicles during the day can be minimized. The peak hours of public power usage are from 7am to 9pm (Energetix Energy Services Company, 2010). Therefore electric cars, if the option is available, should be charged during off peak energy usage hours. Using a personalized smart grid the owner of a house can dictate when they would like their vehicle to be charged. This is in opposition to the owner simply plugging their vehicle in and having it charge whenever the vehicle is plugged into the wall. Smart grids are designed to help smooth out peaks and valleys in electrical usage and help lower costs. Off peak charging will save the consumer money because they will not be using energy when it's at its most expensive rate.

Electric cars can also serve as energy storage when not in use. The Nissan Leaf which has a twenty four kilowatt hour battery can store enough energy to power an average US home for a day (Department of Energy, 2010; Nissan, 2010). The reverse side of this argument is that if the Nissan Leaf is charged during the day, during peak hours, it can double a home's electricity use. With an increasing amount of intermittent alternative power sources being utilized such as solar, wind, and tidal there is demand for devices that can store the energy when the demand is not great enough. Once the battery is fully charged the vehicle can then return energy back into the grid when the demand is high, this process is called vehicle-to-grid (Fontaine, 2008). Many

smart grid models have been incorporating electric cars as an important part of reducing peak energy demand (Edwards, 2010).

Battery swap stations have some unique advantages over public charging stations in a smart grid. Discharged batteries that are removed can be charged at night during off peak hours and reinstalled during the day. Smart grid technology will be able to regulate when the best time is to charge the batteries and reduce the impact of battery charging on the power grid. Therefore battery swap stations could be a coordinated part of a smart grid system and further help to reduce energy costs.

Some of the problems that need to be addressed with the use of a smart grid are that some people will need to charge their vehicle during peak hours. If cities and towns are going to encourage specialized parking for electric vehicles they will have to expect that people will want to charge their vehicles in the designated spots during peak usage. Most of the other promoters of electric vehicle charging stations like General Electric's Watt Station will revitalize the owner's vehicle while the owner is doing their daily errands, working or any other activity that has a charging station in the parking lot (GE Watt Station, 2010). Charging stations will add convenience but in order to fully grasp the energy consumption problem another strategy will have to be added.

A combination of charging stations and battery swap areas will make it more convenient for residents to own electric vehicles. Ideally people who have jobs where they can charge their vehicles at work may be less likely to use a battery swap station but people whose jobs involve driving to many places will often use the swap station. Smart grid technology would work at its maximum efficiency if drivers charged their vehicles at night or used the battery swap stations that only charged their batteries at night. If a wind turbine were to be placed at a battery swap station, then the energy produced could be used to charge the batteries at the station (Edwards, 2010). By eliminating the fossil fuels that would be needed to charge the battery then the vehicle could be charged with energy that is truly environmentally conscious.

Conclusion

Technology is advancing rapidly and many communities are trying to encourage greater use of electric vehicles for a variety of reasons, but especially to reduce the consumption of

petroleum and the emissions of CO₂. Nantucket is a special case. It wants to promote 'green technologies' but it does not want to increase electricity consumption on the island. Indeed, Nantucket is looking to the possibility of having electric cars to help manage and even reduce electricity costs through integration in a smart grid system. Many questions remain about the feasibility of these ideas, as well as the acceptability of electric vehicles among government officials, business leaders, and members of the public on the island. How our group went about answering these questions will be described in the next section.

Methods

Introduction

The goal of this project was to assist the Town of Nantucket to determine if it is desirable and feasible to expand the use of electric vehicles on the island. The goals for our research were to identify the range of policies and programs that have been proposed or implemented in order to encourage greater use of electric vehicles, to conduct scenario analyses to gauge the costs and benefits of encouraging greater use of electric vehicles on Nantucket, to characterize the knowledge, attitudes, and perspectives of key stakeholders on the island with regard to electric vehicles, to outline the advantages and disadvantages covering all aspects of electric vehicles and to present these to the Town and allow them to decide if they should move to promote greater use of electric vehicles. The tasks necessary to achieve the objectives are described below.

Surveys and Interviews

Public Survey

Our group conducted a public survey with the residents of Nantucket with the hope to gain the opinions of the residents about electric cars in many different areas. The survey questions consisted of demographics such as a person's age, their current vehicle, driving habits such as how far and for what purposes a person drives their vehicle, their interest in electric vehicles, and their knowledge of electric vehicles. We developed the bulk of the survey questions based on the two surveys referenced to above. We revised our survey instrument following discussion with our sponsors and advisor, and after conducting a pilot survey. Through the pilot survey we identified what questions were worded poorly and how long the survey took to administer and changed the survey accordingly. Ten pilot surveys were conducted at Hatch's gas station on Nantucket on Saturday the 6th of November. While conducting the pilot surveys, one person refused to take the survey. The survey was conducted verbally, the responses were recorded by the person administering the survey, and the survey was anonymous as indicated by the preamble.

The final surveys were conducted at Stop and Shop grocery store, Grand Union grocery store, Hatch's Gas Station, and On Island Gas starting from November 11 until November 21. In total 102 surveys were conducted. Fifteen surveys were conducted at Grand Union, fifty-five

surveys were conducted at Hatch’s gas station, twenty-eight surveys were conducted at On Island Gas, and four surveys were conducted at Stop and Shop. We chose to do most of our surveys at gas stations because we wanted to target those who already owned cars and it was extremely convenient to ask the drivers questions while they filled up with gas. We chose to survey at Stop and Shop and Grand Union as a convenient location to balance our sample demographics. Out of all the surveys conducted, excluding the pilot surveys, there were thirty-six refusals, five of the people asked to participate in the survey were not residents and were not surveyed, and five of the surveys that were administered were not able to be completed. Below is a table describing the refusals, non-residents, and partial surveys and where these occurred.

Location of Survey	Full Surveys	Refusals	Non Residents	Partial Surveys
Hatch’s Gas Station	55	3	2	0
Stop & Shop	4	7	0	0
On Island Gas Station	23	12	3	5
Grand Union	15	14	0	0
Total	97	36	5	5

Table 4 : Public Survey Response

All of the partially finished surveys were at On Island gas station. The reason that these surveys were not completed was because the survey took up too much time and one of the conditions we agreed to when we were allowed to survey at the gas stations was that we would not hold up their customers; because of this agreement the survey had to be ended if was taking

too long. The time it took to administer the survey proved to be an issue because sometimes the survey took longer to administer than it took for a person to refuel their vehicle. This was true because either the person was not getting that much gas, they wanted to talk with us more about the subject, their car had a small gas tank and therefore did not take long to fill up, or any combination of these.

Surveys were utilized because it was the best way to canvass a wide range of the public in a limited time frame. Public opinion was crucial in understanding what aspects of electric car adoption would be favored and what aspects would make the public hesitant to buy an electric vehicle. The survey that was used is shown in Appendix A.

Interviews

We also conducted many interviews with key stakeholders including taxi companies, rental car companies, car mechanics, and various Town departments with a significant number of vehicles in their fleet. The point of these interviews was to canvass the knowledge of various entities heads, taxi companies, etc., to better understand the use of the vehicles in their fleet, and to determine if any vehicles in their fleet could be switched over to electric vehicles. The reason we chose certain departments to interview was because their vehicle fleet had the most potential to be converted to electric vehicles and each interview was tailored to fit the different groups. Each interview detailed below was conducted either in person or over the phone.

Key Department Interviews

Certain department heads were vital in determining whether or not the town owned vehicles would be able to be switched over to electric vehicles. The departments that held special interest to our project were the planning department, the department of public works, the building department, the police department, the NRTA, the HDC, the airport, the board of health, the Nantucket Energy Committee, and the Wannacomet Water Company. These departments were of particular interest mostly because of their fleet size. The reason the different department heads were important to interview was because we wanted information about their vehicle fleet such as what they use their vehicles for, whether or not the vehicles could be converted to electric vehicles, and if so how many could be converted. We interviewed the departments that had the most potential vehicles that could be converted. The potential vehicles were determined to be small SUV's, small trucks, and sedans after looking at the makeup of vehicles in each

department which we received from the selectman's office. This information proved to be very important because when we were looking at changing over part of the town owned fleet to electric vehicles it was important to know the makes and models of their vehicles.

The questions we asked the department heads were tailored to each interview. We adjusted each set of questions according to the applications of the particular department head, and also kept the main questions the same such as:

- How many vehicles are in your fleet;
- What are the main uses of your vehicles; and,
- How many vehicles in your fleet could be switched over to electric vehicles?

What differed in the interviews were their reasons why or why not they would switch some of their vehicle fleet over to EV's. The first group we interviewed was the key town administrators. The Assistant Town Manager assisted us in coordinating meetings with different department heads and this allowed us to gain a better sense of who else to interview. The Transportation Planner of Nantucket helped us create a better understanding of the plausibility of the infrastructure changes that would be necessary as well as the terrain the vehicles on the island encounter on a daily basis. Our interviews with the selectmen focused on the political aspects of encouraging greater use of electric vehicles, including public attitudes and opinions. Key figures in the Energy Study Committee were able to provide detailed problems that they were dealing with in regards to energy consumption and how the electricity consumption may go up with the added electric vehicles.

The head of the DPW held a large interest with us because it has the largest vehicle fleet in the town and it may be the most promising for converting over partially to electric vehicles. The topics we discussed with him consisted of:

- His opinion of electric vehicles in general;
- If it would be possible to convert a few of the vehicles in the fleet to EV's;
- How would EV's work in his fleet; and,
- Are there any preferable places on DPW property where public charging stations would be feasible?

We focused mainly on the small trucks that were a part of the vehicles in the DPW fleet such as the Ford Rangers. Due to the fact that his vehicle fleet was the largest, it was important to speak with the head of the department of public works on the amount of vehicles that could be adopted by his department, and the results of this interview will be outlined in the findings section later on.

Speaking with a member of the Historic District Committee (HDC) was of great importance to us because this was group on Nantucket that could give us usable feedback on whether or not to place charging stations on the town's main streets. The topics of discussion with Mark Voigt, member of the HDC, were:

- HDC's stance of having charging stations in the downtown area;
- What would have to be done in order for there to be charging stations in the downtown area; and,
- If they cannot be installed downtown, there where would be viable alternatives to place public charging stations?

The main focus of this interview was to gauge the amount of resistance that this committee would have if we were to recommend charging stations on Main Street. The results from this interview will be discussed in the findings section.

Interviewing the head of the Wannacomet Water Company, Bob Gardner, was very important because there are proposed solar panels going up on his property. The water department also had a fair amount of small trucks that could possibly be switched over to electric vehicles which made this interview even more important. The topics of discussion were:

- Wannacomet Water Company's opinion of electric vehicles;
- How he felt they would play a role on Nantucket;
- How many vehicles in his fleet would be able to be switched over to electric vehicles; and,
- Is there a place on his property that could support public charging stations?

The main focus of this interview was to gauge Bob's opinion of where the charging stations should be placed and how many of his vehicles have the potential of being switched over

to electric vehicles. Also given the upcoming solar arrays, the water department made for an excellent place to have municipal EV's because the energy used to charge them could come directly from the solar panels and would promote a truly zero emission transportation method.

Many other interviews with stakeholders were conducted and were tailored in the same way that these are illustrated above. The complete list of interviewed stakeholders is found in Appendix C. These are just a few examples of the way in which these interviews were conducted and the how the information from these interviews was extracted.

Through this series of interviews we attained a clear view of what the key figures hoped to gain from increasing the amount of electric cars on the island as well as what may be the major obstacles preventing electric vehicle adoption. We were able to identify these obstacles, and they will be discussed further in the findings section. The specific questions for the interviews were designed based on the public surveys with the people living on the island. By knowing what the public wanted we could then identify what needed to happen in order for EV's to be adopted on Nantucket as well as apply this knowledge to our interviews.

There were a few other private entities that expressed interest in our project such as Cape Air, reMain Nantucket, Optimized Energy Networks (OEN), Nantucket Island Resorts (NIR), Don Allen Ford, and DattCo Commercial Buses. These groups were important because they were interested in the possibility of using electric vehicles in their business. We met with these groups and discussed the possibility of there being EV's on the island of Nantucket and what that could potentially mean for their businesses. The information received from these meetings will be discussed further in the findings section.

The information from the interviews with the people listed above was critical in understanding the ability of the Town of Nantucket to adopt EV's. This was critical because our group saw the Town of Nantucket as being the first group on the island to be able to adopt EV's. The information and opinions gathered from all of these interviews are used in our scenario and cost analyses. All of our information gathered from our surveys, analysis and interviews can be found in the findings section.

Mechanic Interviews

The other group that we targeted was mechanics. Nantucket is an island which makes repairing cars more complicated. Cars that need to be repaired have to be repaired either on the island or ferried off the island to be repaired elsewhere. If there are no mechanics who are qualified to service electric vehicles on the island, then the adoption of electric vehicles will be slowed significantly because it will make repairing them problematic, unless the mechanics are willing to be trained how to service them.

Based on their local knowledge, the staff in the planning department identified three major repair shops on the island. We wanted to understand how these repair shops might respond to an increase in electric cars on the island and whether or not they had any experience repairing electric cars or even hybrids. The three shops we looked at were the Don Allen Ford dealership and repair, Barrett's Garage, and Nantucket Emissions. The Don Allen Ford dealership was of special interest because they were the only car dealership on the island. We asked questions about their certifications and the certifications necessary to service electric vehicles. The information we received from these questions will be outlined in the findings section.

Electric vehicles are very similar to hybrid vehicles, and hybrid vehicles have been around for longer and more is known about their repair, therefore we geared most of our questions towards hybrid vehicles. We drafted these questions before hand, but as the interviews evolved, we asked more questions geared towards their own personal knowledge. For example Barrett's Garage had much more knowledge about electric vehicles than we anticipated. We also asked them questions about what they thought about electric vehicles and their views on how they would play into Nantucket.

Taxi Interviews

Due to the nature of our project, certain groups of individuals held special interest regarding electric car adoption. Taxi drivers and taxi companies held greater interest because taxis spend roughly twenty hours a day on the road. The ownership cost of an electric car will break even with a standard gasoline car faster the more the cars are driven. This is due to the fact that the fuel used to power the electric car is much cheaper.

The information we received from the assistant town and county clerk told us that there are fifty-three taxis on the island. Most taxi companies owned only one vehicle and there were nine companies that owned two or more vehicles. The reason that most taxi companies only owned one vehicle was because the town has put restrictions on how many taxis there can be on the island and there are a few exceptions to this rule and the companies mentioned above have been grandfathered in and are allowed to have more than one taxi. We conducted an in-person interview with the owner from A-1 taxi, and a phone interview with the owner from Rodger's taxi company to discuss things such as:

- Their opinions of EV's;
- How many taxis is their company in charge of;
- What are the types of vehicles in their taxi fleet;
- How many miles do their taxis drive in a day;
- Their ability to incorporate EV's into their taxi fleet; and,
- What the major problems would be regarding EV's in their fleet.

The main focus of these interviews was to gauge the companies' use of their vehicles as well as the ability to switch some of their vehicles over to electric vehicles. The questions that were the most important were the questions about how many miles are driven per day and per year by their taxis. This allowed us to gauge the ability of taxi companies, both the ones we interviewed as well as the ones we did not interview, to adopt electric vehicles into their fleet.

Rental Car Companies

Rental car companies also held a special interest in our research and data gathering for our project. Our group explored the possibility of switching over some of the rental car fleet to electric vehicles.

We held an interview with one of the rental car companies on the island, unfortunately only two of them are open year round and we could only interview one in the allotted amount of time. One of the two rental car companies was Young's Bicycle Shop, which rents out bikes as well as cars and jeeps. Nantucket Windmill Auto Rental was not able to meet with us during our stay. The topics that we did speak to Young's about were:

- Their willingness to rent out electric cars to their customers;

- Their willingness to offer charging stations for their customers to use during their rental period; and,
- Their general opinion of electric vehicles for Nantucket.

We gathered information about Young's rental fleet including how often they replace their cars and the time between reserving rentals, both in the summer and in the off season. All of this data we received from Young's was factored into our scenario analysis, our cost analysis and is present in our findings.

Scenario Analysis

Our goal for the scenario analysis was to assess the possible ranges of costs and benefits of switching over different portions of the public, taxi, rental car, and town-owned vehicle fleets to electric vehicles. During the course of our project, we also assessed different infrastructure options for Nantucket such as public charging stations, battery swap stations, and commercial charging stations. To complete this objective we used data collected during the public surveys and interviews described above, on items such as average miles driven and the make-up of the different vehicle fleets. The scenario analysis was based on initial cost analyses comparing electric vehicles with gasoline vehicles.

Cost Analysis

The purpose of the cost analysis was to find an estimate of the difference between the total costs of owning and running electric vehicles compared to those of similar gas powered cars. To better explain how we completed the cost analyses, we will use an example comparing the Nissan Leaf and the Nissan Altima, two similar vehicles. We will now outline how we completed the cost analysis in a few steps.

- (1) We started the cost analysis by finding the Manufacturer's Suggested Retail Price (MSRP) of both the Nissan Leaf and the Nissan Altima from Nissan's website.
- (2) We also added in our estimate for the cost to install a level 1 charging station and deducted the \$7,500 federal tax credit from the Nissan Leaf to get the initial cost of both the Nissan Leaf and the Nissan Altima.
- (3) We got the fuel efficiency for the Nissan Altima by using the EPA's city MPG estimate which we found at www.fueleconomy.gov because the EPA's city MPG estimate best

reflected the nature of driving on Nantucket. We got the fuel efficiency for the Nissan Leaf by taking the Leaf's battery capacity and range and calculating an estimate of the fuel efficiency of the Leaf from those values.

- (4) We assumed that maintenance cost for electric and conventional ICEV were the same, although this overestimates the likely maintenance cost for EV's. Our interviews with mechanics revealed that electric vehicles don't need oil changes and that electric cars can go further between brake replacements because regenerative braking used in electric vehicles reduces the wear on the brakes. (Almeida, 2010; Barret, 2010)
- (5) To project the gasoline and energy costs on Nantucket into the next 10 years, we used electricity and gasoline cost projections we found on GE's website from 2010 to 2020 in one year increments. Because the website showed no change in electricity rates between 2010 and 2020 and only a 9% increase (\$.9 per kWh to \$.10 per kWh) between 2020 and 2030, we chose to project Nantucket's electricity rate as stable at \$.19 per kWh between 2010 and 2020. The biggest flaw with this estimate is how it does not account for how the proposed renewable energy projects on the island may affect the electricity rates on Nantucket.

However, the same website showed gasoline prices steadily increasing from 2010 to 2020 so we chose to use a linear model to project gasoline prices on Nantucket from 2010 to 2020. To get the most accurate model we could with limited data, we surveyed all of the gas stations on Nantucket to get an average estimate of the gasoline prices on Nantucket. To represent how the delivery of gasoline to Nantucket from the mainland is the primary reason for why gasoline prices are significantly higher than on the mainland of Massachusetts, we calculated the difference between the average cost of gasoline on Nantucket and the predicted cost of gasoline in 2010 from GE's website, and assumed that the difference was from the cost of transporting gasoline from the mainland to Nantucket. We then added the assumed cost of gasoline delivery to the 2020 gasoline price estimate from GE's website and took that to be the projected cost of gasoline on Nantucket in 2020. With the 2010 and 2020 estimates of the cost of gasoline, we were able to make a linear model expressing the cost of gasoline as a function of time.

With the model of the cost of gasoline over time, we were able to calculate the

cost of gasoline over arbitrary periods of time by integrating the model and multiplying by the number of gallons of gasoline used per year.

- (6) By using the estimates for the fuel costs, maintenance costs, and initial costs of the two vehicles, we were able to project the costs of the two vehicles into the next ten years.

With these two projections, we were able to graph the relative costs and calculate when the two vehicles broke even with each other.

- (7) To assess the validity of our estimates, we compared our savings estimates with ones we calculated using Project Get Ready's online Total Cost of Ownership (TCO) calculator. (Rocky Mountain Institute). Because the Project Get Ready's TCO calculator predicted a similar estimate of how long it would take for the Altima and Leaf to break even, we felt confident that our cost analysis presented a reasonable estimate of the cost differences between the Altima and Leaf.

For our cost analyses, we assumed that the following pairs of EV's and ICEV's were comparable:

- The Nissan Leaf and the Nissan Altima
- The Ford Transit Connect EV and the Ford Transit Connect
- The Pheonix SUV and the Ford Explorer
- The Pheonix SUT and the Ford F150

General Public Fleet

We used the results from the public survey to create estimates for the cost, MPG rating, and yearly mileage of the average gas vehicle on Nantucket. The yearly mileage may have been skewed higher using this method because the survey favored the cars that had to refuel more often, and therefore had higher annual mileage. We also sorted the results from the survey into a few categories representing different available electric vehicles on the market and created a hypothetical average EV by averaging the cost, range, battery capacity, and efficiency of the selected electric vehicles weighed by the size of the corresponding categories from the survey results. We chose this method because it represented how different EV's would be adopted by different consumers with different needs and expectations from their vehicles. What this method did not take into account included relative availability of different EV models and the economic feasibility of adopting the corresponding EV. We assessed the size of the public vehicle fleet

using estimates for the size of total vehicle fleet on the island, which we based on data from the Nantucket Registry of Motor Vehicles and subtracting the number of taxi, rental and municipal vehicles based on data from the Assistant Town and County Clerk, Tax Assessor, and Board of Selectmen respectively. From this we created several scenarios assuming different rates of electric vehicle adoption by 2020. We used adoption rates of 12% and 45% based on the ‘reasonable’ and ‘optimistic ranges given in the Boston Consulting Group’s report. (The Boston Consulting Group, 2009). We also ran a scenario assuming 100% EV adoption as a bounding exercise.

For each of the adoption rates, we calculated:

- Total number of EV's adopted
- Total battery capacity of EV's(MWh)
- Yearly gasoline saved (gal)
- Yearly electricity used (MWh)
- Daily electricity used (MWh)
- Percentage increase in annual electricity usage
- Yearly fuel cost savings (\$)
- Maximum charging impact (MW)
- Average charging impact (MW)

To calculate all of these estimates, we used the averages gained from the public survey, the data on the fleet size as indicated, and an estimate on the electricity usage from September 2009 to August 2010. We assumed for the maximum charging impact that all of the adopted EV's would be using level 2 charging at the same time and calculated the total electricity usage by the charging stations. For the average charging impact however, we assumed that all of the EV's on Nantucket would be recharging in a manner such that the energy use from the charging was spread evenly over an eight hour period. We also assumed that the EV's were recharging the battery capacity used in driving for a day.

Municipal Fleet

For the scenario analysis of the municipal fleet, we interviewed representatives from town departments to determine to the number and types of existing ICEV's that could be

replaced by electric vehicles. From these interviews, we composed a list of municipal vehicles that could be converted to electric vehicles and the corresponding electric vehicle they could be replaced with. We also created a range of five estimates of yearly mileage to see to what degree annual mileage affected the time it took for the selected vehicles to break even and we calculated the cost impact of replacing the selected vehicles with EV's by conducting cost analyses for the individual vehicles and summing the gains/losses together to get a net gain/loss. We also calculated using the results from the individual cost analyses the total battery capacity and net increase of electricity consumption and decrease in gas use.

Taxi

To conduct the scenario analysis of the taxi fleet, we planned to use the taxi registration data we collected from the assistant town clerk, but it did not list the make or model of any of the taxis for 2010. To rectify this, we used the make and model information from the latest year for which we had data, 2008, and calculated the average cost and MPG rating of a taxi on Nantucket. We combined this with the size of the fleet in 2010 to create a scenario analysis. Due to time constraints, we could not get an accurate average yearly mileage of taxis so we conducted the scenario analysis for 3 different average yearly mileages and 4 different adoption levels. They were 100% adoption 5%, 10%, and 15% adoption. We used these low estimates because our interviews with taxi owners showed that it is doubtful that taxi companies will be able to adopt many electric vehicles given that the vehicles are typically in operation constantly and would not be idle long enough to allow charging. A battery swapping station would alleviate this problem, but it is unlikely that there are enough vehicles in total on Nantucket to warrant the cost of building and operating such a station. For each of these scenarios, we used the same method as in the general public scenario analysis to calculate:

- Total EV's adopted
- Total battery capacity (MWh)
- Yearly gasoline saved (gal)
- Yearly electricity used (MWh)
- Daily electricity used (MWh)
- Percentage increase in annual electricity usage
- Yearly fuel cost savings (\$)

- Maximum charging impact (MW)

Rental

The rental fleet scenario analysis was particularly difficult to complete because we could only find the size of the rental fleet and not its composition. Because of this, we could not confidently estimate yearly gasoline savings but we were still able to calculate electricity use increases. For this scenario analysis, we assumed that all of the electric vehicles adopted would be the Nissan Leaf because it was the most economically viable EV available at the time. We used five different adoption level estimates, 12% adoption, 45% adoption, 100% adoption, and 110% adoption assuming that the town increased the available medallions for rental cars by 10% for electric vehicles and that those extra rental cars were added to the previous estimate of adoption. For this scenario analysis, we used the yearly mileage estimate obtained from Young's Rental.

Findings

In this section we will discuss what information was revealed to us through our data collection process. The public surveys that were conducted revealed information about public attitudes and opinion, the interviews revealed some of the complexity of trying to encourage greater adoption of electric vehicles, and the scenario analyses indicated that the costs of EV's are high in the short term, but can save the owner money over a long period of time, even at the high cost of electricity on the island. EV's also have other benefits, such as reduced noise and air pollution.

Public Survey

Public opinion is vital when assessing if electric vehicles and the necessary infrastructure should be encouraged. If the residents of Nantucket are not willing to adopt the new technology then no advances will be made towards electrically powered vehicles on the island.

The four largest vehicle companies that people had models of were Ford, Chevrolet, Dodge and Toyota (Figure 5). The most common model driven by those surveyed was a Ford Explorer a sport utility vehicle (Figure 6). Many residents and guests like to drive sport utility vehicles onto the many trails and beaches on the island. Twenty-four residents surveyed only use

their vehicles for work. Our surveys were limited to the daylight hours and we primarily conducted the surveys near midday which increased our chances of getting older residents as well as those using their work vehicle. On average the year of any given vehicles was 2002, got eighteen miles per gallon and drove 8,441 miles per year (Figures 7 and 8).

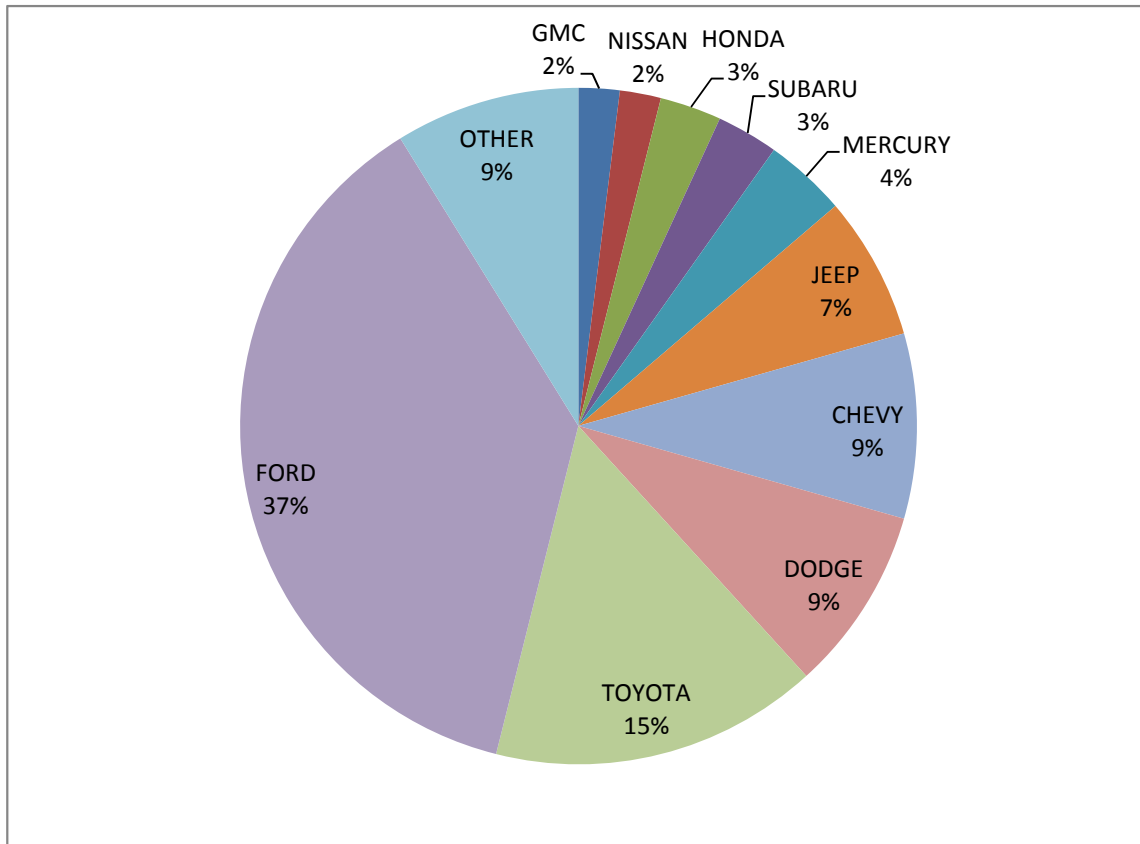


Figure 5 : Survey Results - Car Make

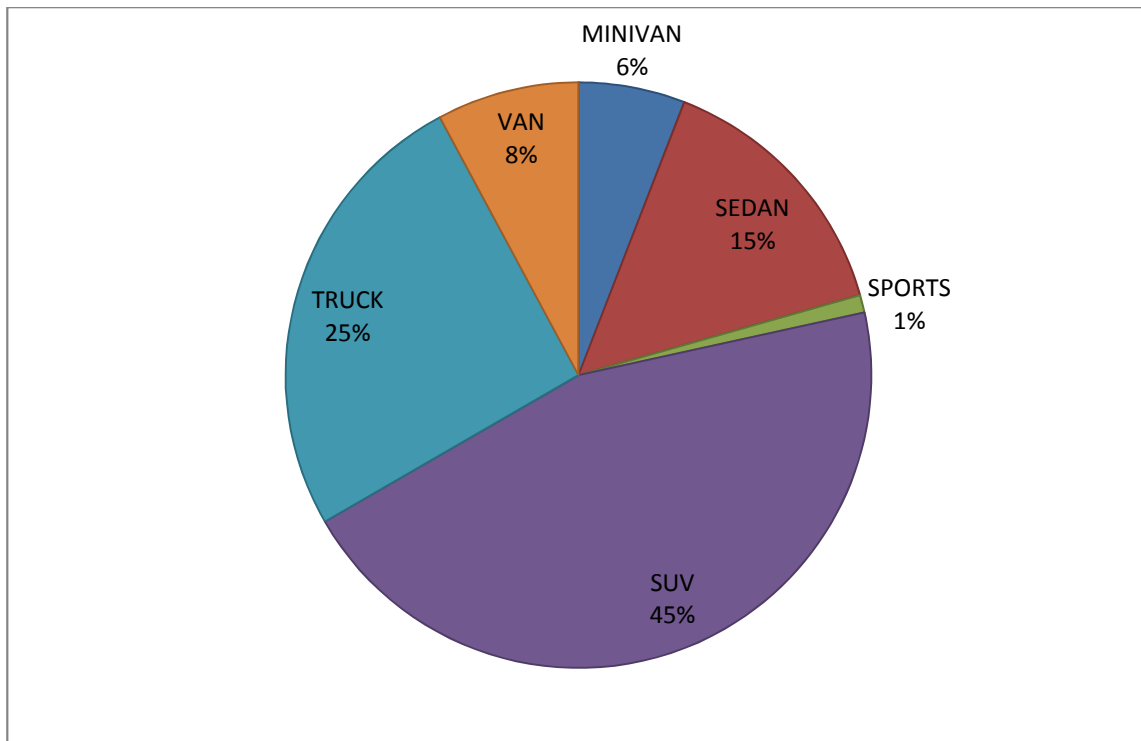


Figure 6 : Survey Results - Type of Vehicle

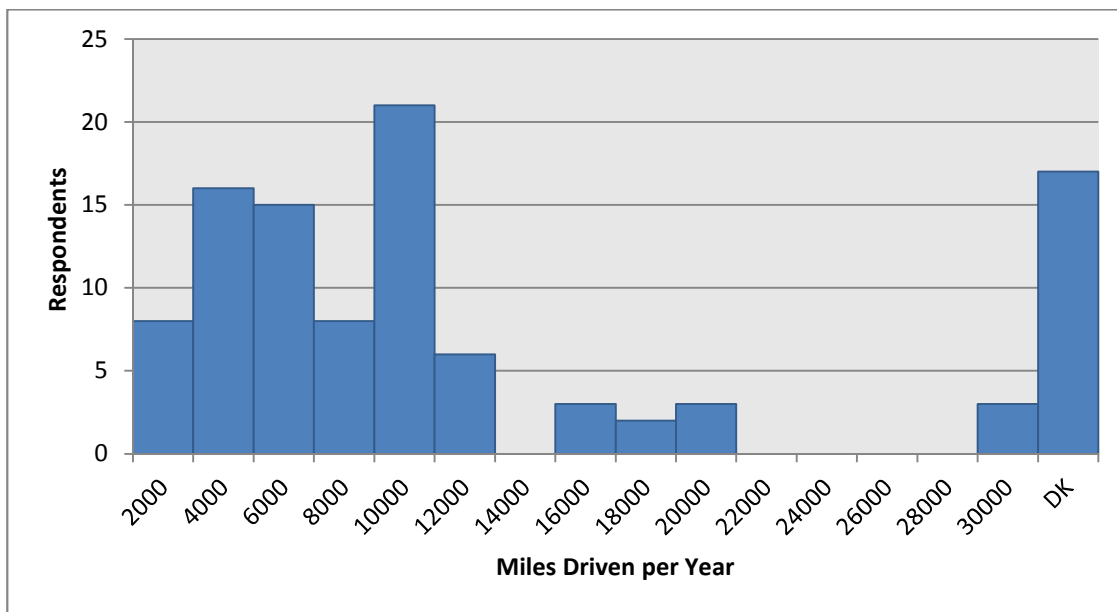


Figure 7 : Survey Results - Annual Mileage Histogram

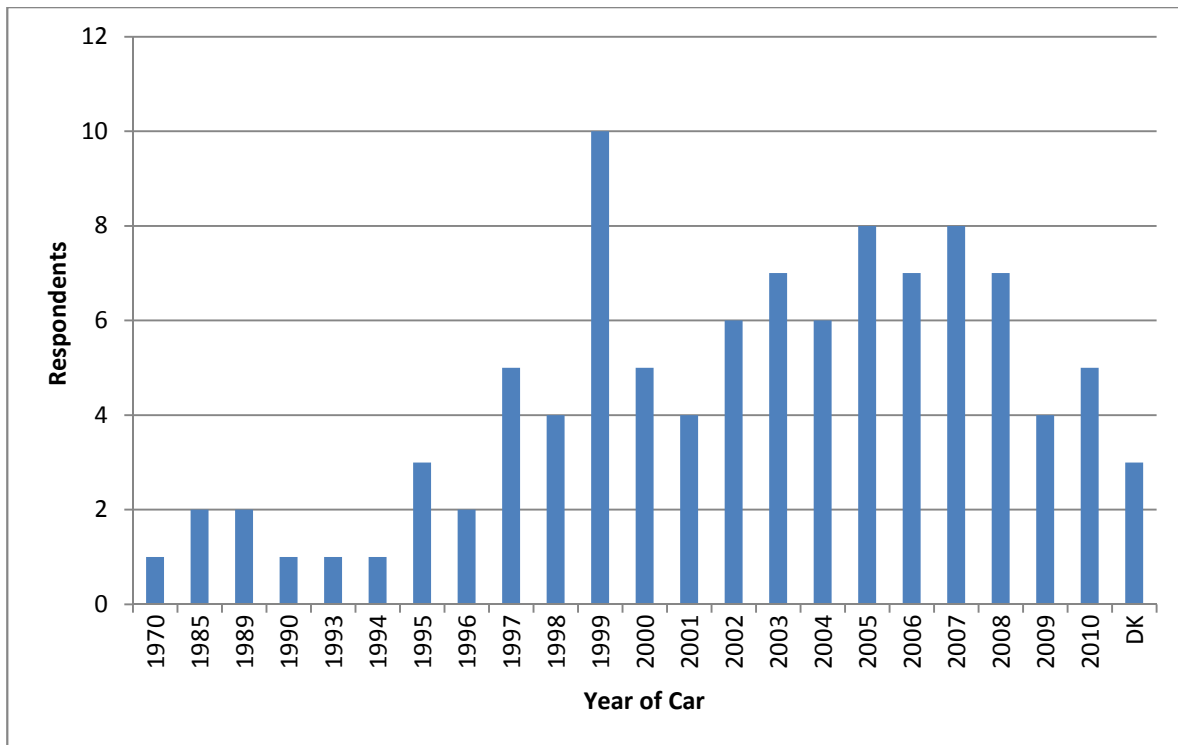


Figure 8 : Survey Results - Car Year

From all of the residents that we surveyed 86% owned their own car. When asked if they considered a hybrid or electric vehicle 75% of those surveyed said they did not consider buying one. About half of the people surveyed planned to buy a new car in the next five years, which is consistent with the average age of a vehicle among those surveyed. For the residents that planned to purchase other vehicles in the next five years they were divided about whether they were going to buy a new (47%) or used (40%) vehicle. Although most people (75%) said they did not consider buying a hybrid or an electric vehicle when they last purchased a vehicle (Figure 9) almost two thirds (65%) of those surveyed said they would consider buying an electric vehicle in the future (Figure 10). When we asked why people didn't want an electric vehicle the most common answers were that they didn't know enough about EV's, could not afford them, EV's were not suited for Nantucket's needs, they don't come with four wheel drive, or they were satisfied with the car they currently had (Figure 11). Among those who said they would consider buying an electric vehicle the most common reasons given were that they want to support a new technology, think that electric vehicles are good for Nantucket, would save money on fuel, and help protect the environment.

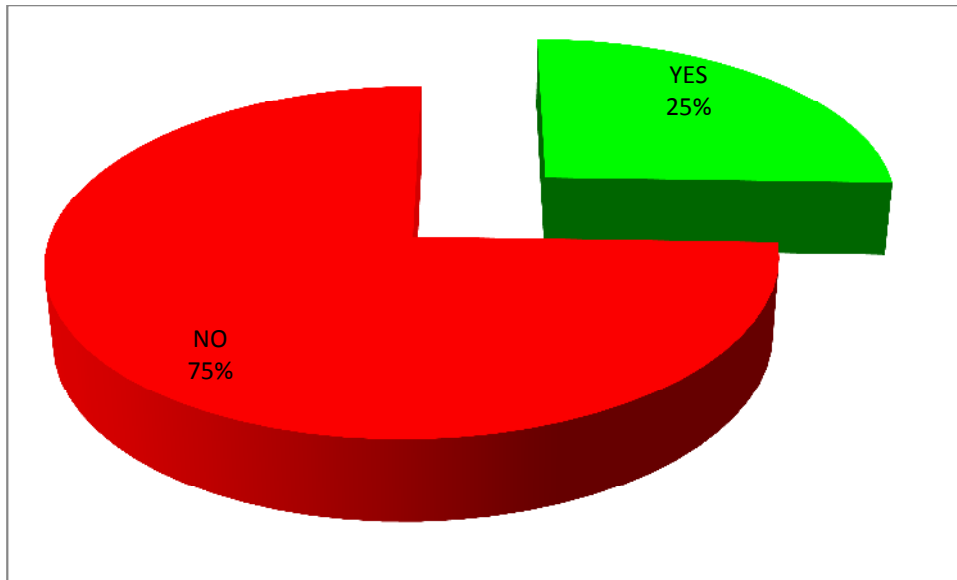


Figure 9 : Survey Results - Considered a Hybrid or EV at Time of Last Vehicle Purchase

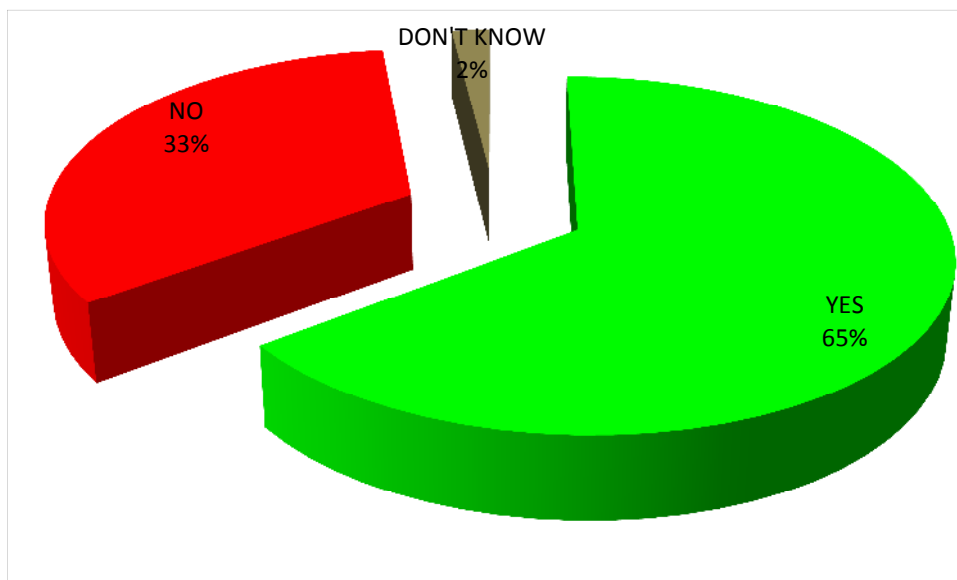


Figure 10 : Survey Results - Would Consider Purchasing an Electric Vehicle

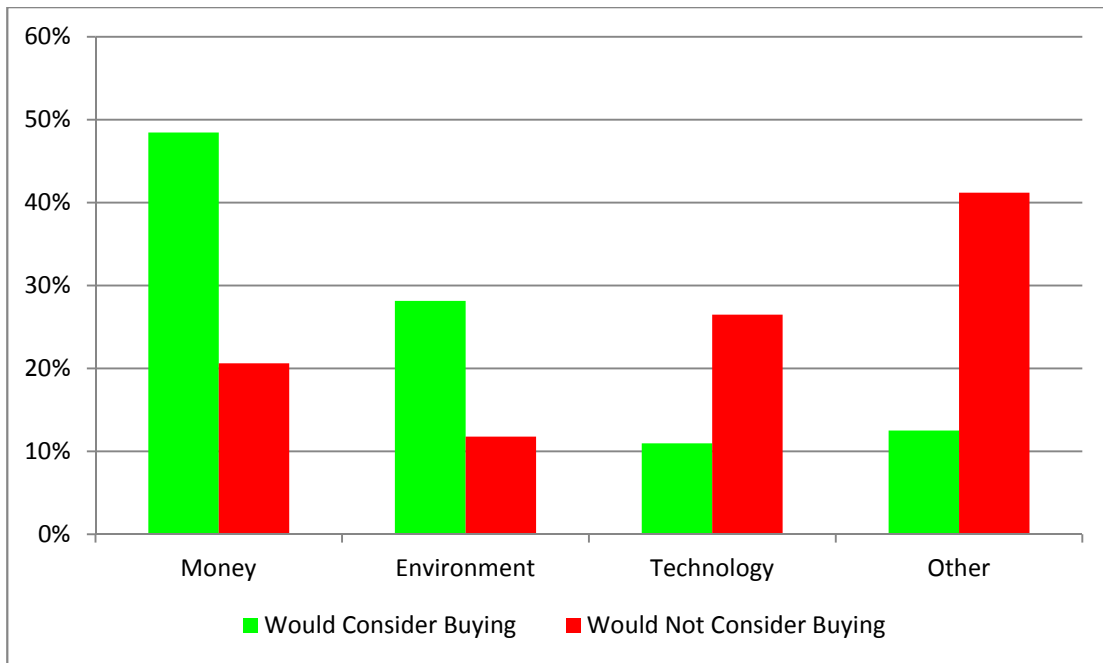


Figure 11 : Survey Results - Reasons For and Against Purchasing an EV

The survey revealed that the public actually has a reasonable knowledge of some of the major aspects of the current technology. On average, the people surveyed thought that electric cars take seven hours to charge and can travel 150 miles on a single charge although most people were unaware of government incentives. The majority of the residents surveyed thought that electric cars cost more to purchase and maintain but less to fuel than equivalent gasoline powered cars (Figure 12). Most people were unaware that the government offered incentives to purchase electric cars (Figure 13).

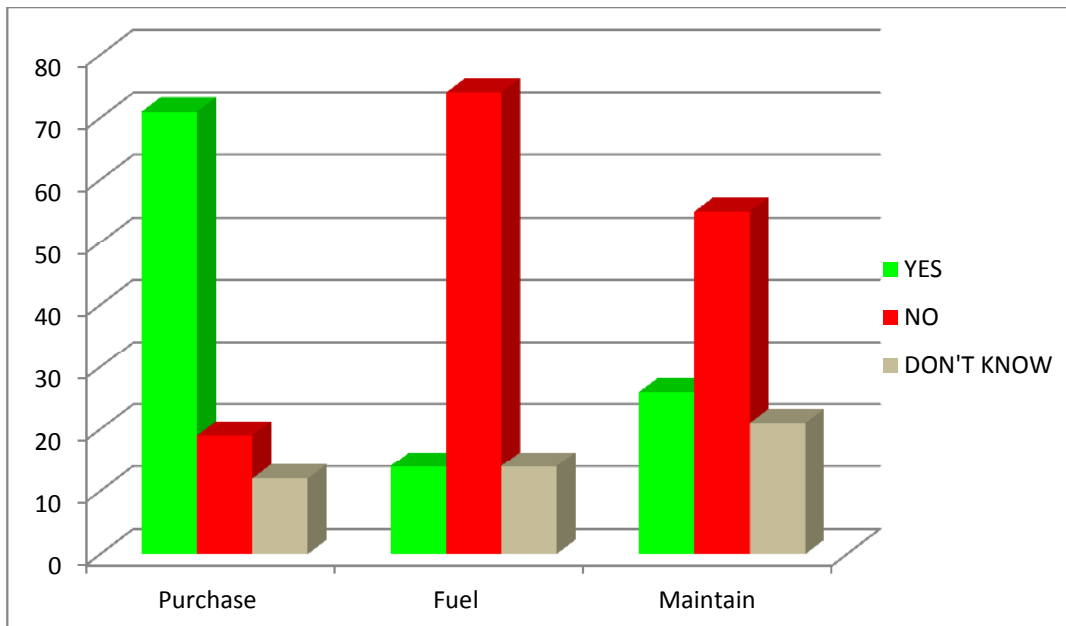


Figure 12 : Survey Results - Do EV's Cost More to Purchase / Fuel / Maintain

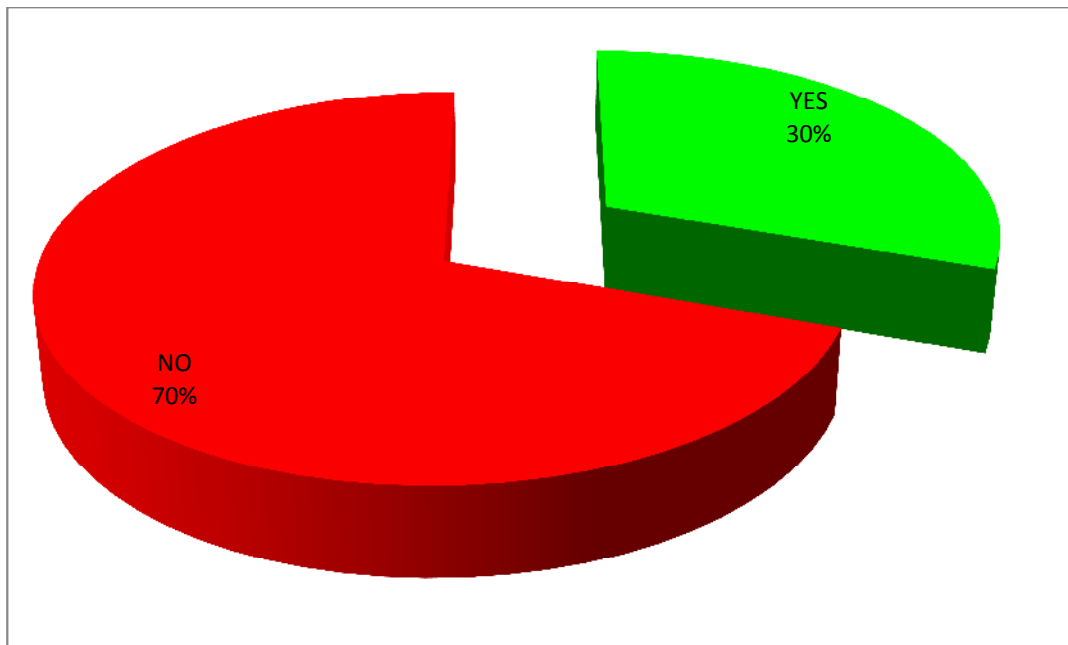


Figure 13 : Survey Results - Percent of Residents Aware of Government Incentives

In order to promote electric cars the town first must have an understanding of public opinion. Between 68% and 72% of people were in favor of the town encouraging greater use, replacing part of its fleet and encouraging taxi companies to have electric vehicles (Figure 14). Between 60% and 72% of those surveyed were in favor of charging stations being placed downtown, at the airport and in large parking lots such as at the supermarkets (Figure 15).

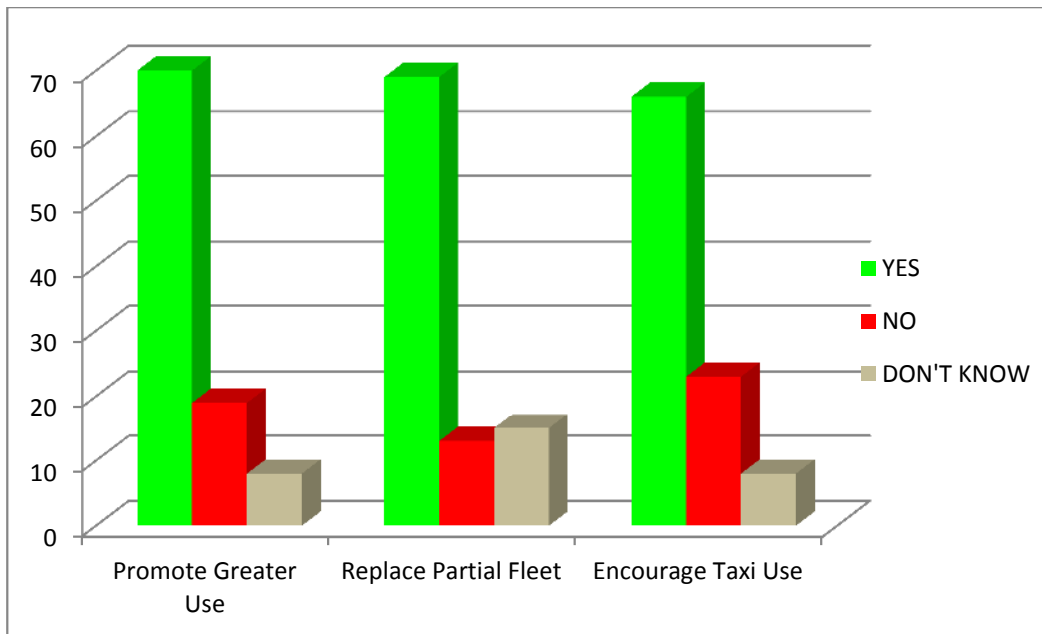


Figure 14 : Survey Results - What the Town Should Do

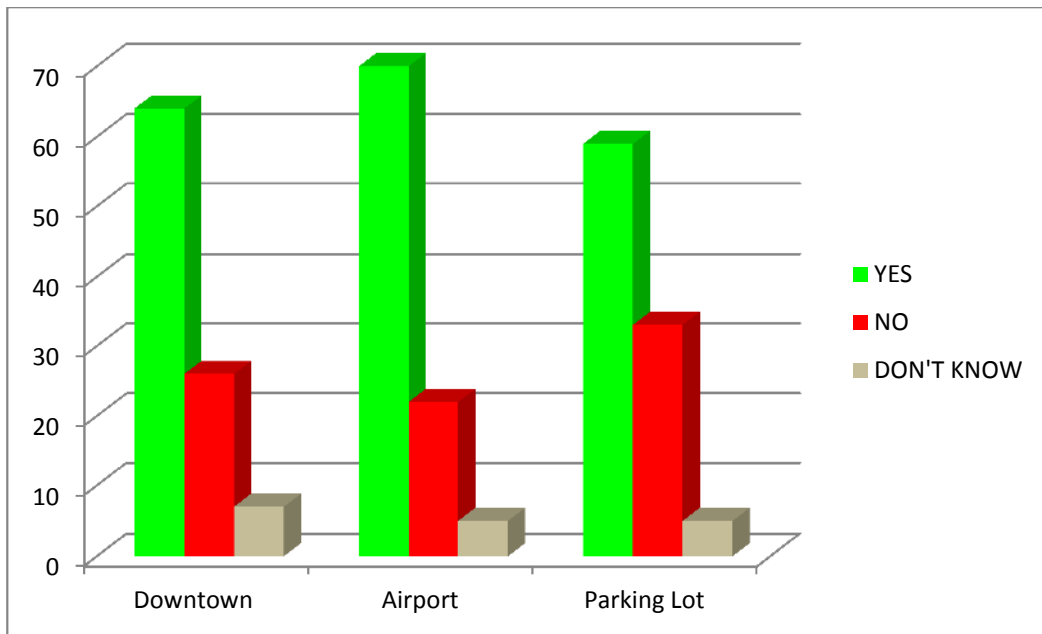


Figure 15 : Survey Results - Where to Install Public Charging Stations

At the end of the survey we asked everyone who was being surveyed if they had any more concerns. Residents were concerned that they did not know enough to make informed decisions

- “Where would charging stations go?”

- “It’s not the town’s responsibility to encourage electric car adoption. “
- “Electricity is already expensive and having electric cars will only make it more expensive.”
- Some people also wanted to know more about what happens to the battery after it can no longer be used.

Looking at demographics like age can help show what groups will be more or less willing to adopt the technology. Half of adults over sixty-five that were surveyed would not consider buying an electric car compared to people who were of the age twenty-six to thirty-five where only three out of thirteen residents said they would not consider buying an electric car. Two thirds of residents would consider buying an electric car that are of the age range forty-six to fifty-five. Also, looking at what vehicle the owner drives can be used to predict trends. Four out of ten sedan owners will not consider buying an electric car. This could be due to the fact that they don’t think that an electric car would be cost effective for them over their current car. Educating people who are older about the new technology and encouraging those who are educated to consider electric vehicles will help to advance the adoption of electric vehicles. We got similar results to the two prior studies mentioned in the Literature Review, the EPRI and the CEA studies.

Interviews

Interviews for our project consisted of speaking with key decision makers about how they see electric vehicles fitting into their fleet and the public sector on Nantucket. Aside from some basic information on fleet composition and so forth, the interviews were designed to identify some of the more complex issues associated with the adoption of electric vehicles on the island according to some of the key stakeholders and decision makers, such as municipal workers, taxi drivers, rental agencies, and car dealer and repair shops.

Town Departments

An organization that was interested in electric vehicles was the Wannacomet Water Company. The head of the company, Robert Gardener, would be in support of installing charging stations at his facility. When asked about his fleet he said that he could replace three or four vehicles in his fleet with electric vehicles if they saved him money and were equivalent to

current vehicles. His interest in alternative fuel technology and cost savings is also evident in his plans to install solar panels at his facilities. Using such solar energy to charge the cars would reduce his overall electricity use while promoting green technology. It may be possible to put a park and ride in the gravel parking lot by the office with a few charging stations for the public to park their car and take a bus. A bus stop already exists nearby for residents and tourists to use so no additional bus routes would need to be scheduled.

The Department of Public Works has the largest fleet of municipal vehicles, but most of these are larger trucks and/or four wheel drive vehicles are for plowing, transporting heavy material, and driving on sand. Presently, it would be possible to replace only one vehicle in the fleet with an electric vehicle, such as the Phoenix Truck. Such a vehicle could be used in the summer by an employee who has to drive into town to do small jobs, such as picking up litter and replacing trash can covers. The DPW would be willing to consider purchasing one four-wheel drive electric vehicle for their fleet when a reliable model becomes available.

Nantucket's Police Department has a number of Ford Crown Victoria's that are used for patrolling and other police work. The police chief stated that the vehicles he chooses for his fleet need to be designed as police vehicles in order to provide the most amount of protection for his officers. Equipment like radios and computers need to be easily transferred from one vehicle to another. The police cruisers travel more than 200 miles in a day and can be on the road for up to three shifts straight. Outside of that the Police Department does have one recently purchased Ford Taurus that is used for the court system and could easily be replaced with an electric car.

The head of the Board of Health (Richard Ray) drives a hybrid Ford Escape giving him firsthand experience driving a vehicle with an electrically assisted motor. One of the major benefits to having a hybrid was that it got roughly twenty-four miles per gallon. Although the hybrid saved money on gasoline, Richard Ray had issues with it riding too low to the ground and not having enough power to the point that he got it stuck in the sand. Also the electric battery shuts off when the air conditioner or heater is turned on which limits the benefits of owning a hybrid Escape to the spring and fall months. The Board of Health needs vehicles with four-wheel drive because they have to travel onto the sand to perform water testing at some of the beaches. The building department also needs four-wheel drive vehicles such as the Ford Ranger because they need to have a high enough clearance and use the four-wheel drive for getting onto

construction sites. These and many other departments rely on having vehicles that have four-wheel drive and a high ground clearance.

If public charging stations are going to be installed it will be based on the planning department's recommendations. The senior planner expressed that the beach, the Wannacomet Water Company parking lot and somewhere downtown possibly the proposed Wilkes Square parking lot would be best for electric car charging stations. A shuttle to the Wannacomet Water Company would encourage people to charge their cars while also relieving traffic, such as a park and ride system.

The Historic District Committee preserves the historic nature of downtown, which is an area residents have showed interest in seeing electric car charging stations. The head of the committee believes that charging stations downtown would compromise the historic look and feel of the area. Charging stations by nature are technologically advanced and would be awkwardly juxtaposed against the cobble stoned streets and brick buildings. In a similar situation parking meters were discussed for installation in downtown. Nantucket is determined to preserve its historic feel and the selectmen felt that parking meter would take away from that. Not only would the stations be distracting but the necessary signage and parking spot markings would be an important obstacle to overcome to have charging stations on Main Street. As an alternative, installing charging stations near the renewable energy sources such as the high school windmill were suggested and would be beneficial because it would lead to the thought process that the car is completely green and runs off of all natural energy.

Electricity Usage

Nantucket has an Energy Committee that discusses and assists in implementing programs to advance renewable energy. Currently the committee is looking into all renewable sources of electricity on a municipal scale in order to save money and produce power on a local level. The Energy Study Committee feels that electric vehicles are strongly worth looking into because of the potential for energy storage in electric cars to reduce peak load and store excess energy from windmills or solar arrays when needed. The recently elected chair of the committee personally believes that charging stations should be located at mid-island locations, specifically at existing gas stations and near the airport. She believes it is important to alleviate the fear of being stranded without a charge to increase electric car adoption.

Optimized Energy Networks is working in conjunction with the Nantucket Energy Committee to evaluate the use of smart grids to reduce the amount of energy used during peak energy usage. Electric cars are proposed to be storage devices for intermittent renewable energy sources that produce more energy than can be used. This process is called “vehicle to grid” and although Nantucket is constantly increasing their renewable energy sources, the technology to return energy back into the grid from a vehicle is not incorporated into the electric vehicles currently released (Fontaine, 2008). When the technology is available the price of electricity has to fluctuate costing less to charge a vehicle in the off peak hours and yet be paid more to sell the power during the peak usage. In that respect, the term net metering only refers to energy made using renewable energy sources which means that selling back power that was stored in an electric car would not be considered net metering.

Transportation

Nantucket Regional Transit Authority (NRTA) in 2010 purchased two hybrid diesel busses. When considering what kind of busses to purchase the transportation planner had to take into consideration that the state would only pay for a strictly diesel bus. A public interest group called reMain Nantucket covered the additional price of the vehicles. Additionally, in order for the NRTA to purchase a transport vehicle like a bus, the vehicle is required to meet federal regulations pertaining to durability, length, efficiency, and many other factors. Additionally the NRTA has switched to ultra-low sulfur diesel which burns cleaner. Nantucket had tried an electric bus in the past and it reportedly had trouble handling the streets and the amount of time it took to charge the battery was far too long.

DattCo sold the two diesel busses mentioned above to the NRTA. On top of selling hybrid diesel busses they are also marketing an all-electric delivery vehicle called the eStar. This delivery truck can travel 100 miles on one battery, takes six to eight hours to recharge and the maximum speed is fifty miles per hour which will not be an issue on the island. Currently companies such as FedEx are adapting this new technology to reduce fuel consumption and promote their environmentally friendly image. The DattCo salesman I spoke with highly recommended electric vehicles for the island because of Nantucket’s size and the projected fuel savings.

ReMain Nantucket is a philanthropic organization aimed at promoting the islands wellbeing. Their interest in greener technologies could extend past hybrids busses to supporting projects that would help the adoption of electric cars on Nantucket. Their ability to finance projects that could encourage large scale electric vehicle adoption could promote more than just the municipal fleet having electric vehicles. During an interview with two of their lead members we discussed what issues they encountered while trying to get hybrid busses on the island. Wheel base size was an important consideration because some of Nantucket's roads are too tight for most normal busses. ReMain is very interested in the possibility of having electric vehicles on the island both for their environmental implications and also as a way to help mitigate the energy peaks on the island.

Nantucket Island Resorts owns four of the major hotels on the island and many of the shops downtown. The management team perceives electric vehicles as being a positive and environmentally concerned direction that their customers would recognize and appreciate. Since they are a resort business that is constantly running shuttles to pick up their guests an electric wagon such as the electric Ford Transit Connect would be beneficial. From our interview he expressed interest in already purchasing a gas version but sees the benefits to owning an electric version. Tim Milstead, the head of the NIR, said that typically his shuttle vans drive about 4,000 miles a year. When asked how he would feel about his customers using charging stations at his facility he said that if electric vehicles became more prevalent then he would provide his customers with the necessary charging stations. Where or not the guest would have charge an electric rental car at a hotel or inn would depend on how long the visitor is staying there. Through this interview as well as the interview with the rental car company we found that if a renter was staying for a period of under three days then they would most likely not need to recharge their electric car but if they were staying for a period of over three days then they would need to charge their car at some point in their stay. Tim told us in the interview that the average rental time was one to two days in the winter, and three to four days in the summer. Another company that is interested in promoting their green image with electric vehicles and deals with tourism is Cape Air one of the major airlines out of Nantucket with locations in other similar resort communities. They already have many projects to help increase their environmentally friendly mindset and they feel that electric cars would complement what they have worked on.

Nantucket Memorial Airport is also interested in electric vehicles and having electric car charging stations installed. Solar arrays are going in at the airport which could directly charge electric vehicles at a lower rate than the current electricity cost since the energy was produced without burning fossil fuels. Although it may be less expensive than home charging it is important to consider billing fees on top of the electricity cost. Plans are being made to build a long term parking lot which would be ideal to put slow chargers. In an effort to promote green technology and save on cost the airport has switched to high efficiency diesel emergency vehicles and plans to purchase sixteen-passenger hybrid shuttles. Currently the airport has a Ford Ranger used by the janitorial staff that could be replaced by an electric vehicle assuming an adequate vehicle is available. To reduce fuel consumption on planes the airport is planning to plug planes into the airport to run electronics and air-conditioning while the plane is docked.

Rental and Taxi

Taxi

Taxi companies consistently use their vehicles every day for long periods of time which could expedite the cost saving with a similar electric vehicle replacement. Due to the rapid use of the minivans a taxi company changes over its vehicles after three years of use. A specific taxi company that we interviewed was Roger's Taxi that has five vehicles that they use in the summer and they take two to three off the road in the winter. On a busy day in the summer their taxis can travel 100 to 200 miles. Depending on the season, taxis can be sitting waiting for a customer from anywhere from two hours on average in the winter to twenty minutes in the summer. When they have to replace a vehicle they regard size for luggage and passenger room as their number one concern.

Another larger taxi company, A1 Taxi, also has five taxis and is starting a delivery service. They have three delivery trucks and nine transport vehicles. She predicts that her delivery service will expand very quickly but currently the delivery vehicles travel fifty to seventy miles a day. Also A1 has taxis that receive a substantial number of miles in a very short period of time and they are replaced every two years. In the busiest times in the summer the taxis average 200 miles a day. Annually their vehicles travel about 100,000 miles. In the summer there is no down time between customers and in the winter there can be no wait to a wait of forty minutes. Most customers take the taxi from the airport or ferries to hotels or guest houses which

provides a wide range of distances covered. A1 Tax's owner was also concerned about the down time of their vehicle while charging and feared that it would take too long to be practical. Typically the taxis have a break in the constant demand for rides between three am to five am. When deciding which vehicles to add their fleet passenger and luggage room is also a primary concern.

Rental

While on the island there was only one rental business that was open and had managerial staff available for us to speak with and that was Young's Bicycle Shop. They only keep their rentals for fifteen months then they sell them, making resale price extremely important. Young's is willing to rent out electric cars but the initial price has to be low enough. In order to increase electric car use more state allotted rental vehicles could be offered to rental car companies that would add electric vehicles to their fleet. It was suggested that the electric cars be used for one day rentals in order to prevent customers from being stranded without a charge. Anything longer would involve finding a place to charge a car. Their rentals travel roughly sixty miles per day at the maximum. Young's has 30 vehicles and is the fifth largest car rental agency on the island and their fleet consists of fourteen passenger vehicles and sixteen jeeps. The only other rental car agency open in the off season is Windmill Rental which has 187 vehicles. Hertz is the largest car rental agency but their vehicles can only be rented in the summer, they have 310 vehicles. Currently in New York Hertz is a renting electric vehicles which shows their interest and support of the new technology (Motavalli, 2010).

Repair and Sales

Repair Shops

To have a new type of car on the island there has to be repairmen certified to fix them. Barrett's Auto Repair Shop has one of the few repairmen on the island that is certified to work on electric vehicles. He believes that electric vehicles are easier to work on since there have fewer moving parts. Although he thinks electric cars would be good for the island he feels that sand could be an issue if it gets into the engine based on his experience building solar powered cars for a long distance race called the Tour De Sol. He predicts that repair shops on the island will service electric cars regardless of whether not they are certified. From his previous experience he expects that maintenance costs will be less based on his knowledge from the work

he's done on hybrids which shows that regenerative breaks reduces the strain on brakes and rotors and thus lessening maintenance costs.

Nantucket Emissions is another hybrid certified repair shop on the island. The general manager does work on hybrids and knows that the brakes need to be replaced less often. He also predicts that it will be more difficult for other repair shops to be certified to service electric vehicles. Contrary to Barrett's mechanic Nantucket Emissions believes that the salt air of Nantucket will be corrosive and affect the wiring in vehicle but does not feel that sand will be an issue. He also feels that taxis go through too much wear and tear to be a good target area for electric car adoption.

Sales

Don Allen Ford is the only dealership on the island and is a vital member in promoting electric cars on Nantucket. The owner plans on purchasing five to ten electric cars to when Ford comes out with their new model of the Focus next year. He is in support of putting in charging stations at his dealership. From the interview, we gathered that Ford had an electric truck, the Ranger, which was tested for power companies to do meter readings in 2000 but was not successful. He had purchased small electric cars the size of golf carts from Ford called Th!nk City cars but had to give them away because they did not travel over forty-five miles per hour which is the fastest speed limit on the island. In order to service the electric cars his mechanics had to be certified, which was made possible with help from Ford. Getting other smaller mechanic shops certified will be a problem because most repair shops cannot have a larger company like Ford pay for them to get certified. The transition from gasoline to electric cars will be made easier because they have Ford to support them on the transition also.

Scenario Analysis

Cost Analysis

From our cost analysis only the Nissan Leaf fared well against equivalent gasoline powered vehicles economically. When compared to its normal internal combustion engine (ICE) model, the Ford Transit Connect EV did not break even under all but the highest mileage scenarios. It needed a yearly mileage of at least 20,731 miles to break even in 10 years. This was largely because the electric version of the Transit Connect cost more than twice as much as

the regular Transit Connect. Using the estimate of 8,500 miles per year we got from the public survey, the Pheonix SUT is not a very cost effective replacement for standard pickup trucks such as the Ford Ranger. The Phoenix SUT needs a yearly mileage of at least 14,787 miles to break even with the Ranger after 10 years of use. This is because the Ford Ranger costs less than half the Phoenix SUT and achieves a very high gas mileage for a truck of 22 miles to the gallon. Even against the F-150, it took the Phoenix over 9 years to break even with the moderate yearly mileage estimate of 8,000 miles per year. However, when the Nissan Leaf is compared with the Nissan Altima, it is clear that the Leaf is a viable alternative economically. It takes 4.3 years for the buyer to start saving with the Nissan Leaf assuming an average 8,500 miles per year. A graph showing the effects of annual mileage on the time it takes to break even for several EV models is shown below in Figure 16.

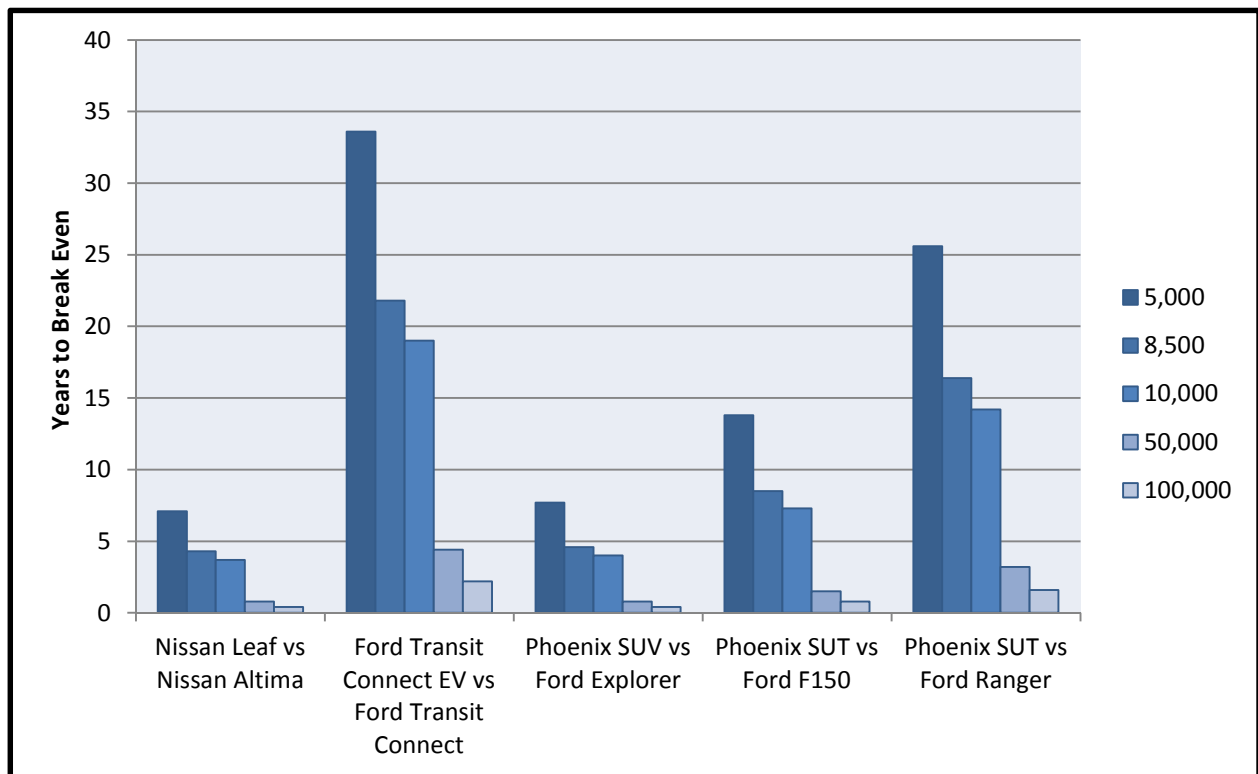


Figure 16 : Time for Different Electric Vehicles to Break Even for Different Scenarios

Municipal Fleet

With the listing of municipal vehicles we got from the Nantucket Town Clerk and the input from interviews with town department members, we compiled a list of ten municipal vehicles that could be replaced with electric vehicles, as shown below in Table 5. Our scenario

analysis revealed that it would be economically feasible for the town to switch over the 10 selected vehicles to EV's if they are driven 8,000 miles a year or more but not if they are driven less than 5,000 miles a year as shown in Figure 17 below. If the town replaced the ten vehicles with electric vehicles, the town would start saving money in less than nine years if the vehicles have a yearly mileage of 8,000 miles, however, if those vehicles have a yearly mileage of 5,000 miles or less, the town would only break even after at least nine years which would be economically impractical.

Year	From	To	Department
2007	Ford Explorer	Phoenix SUV	Airport
1998	Ford Ranger	Nissan Leaf	Water
1998	Ford F150	Phoenix SUT	Water
2004	Ford Ranger	Nissan Leaf	Water
2008	Ford F150	Phoenix SUT	Park and Rec
1990	Ford F150	Phoenix SUT	Finance
2000	Ford F150	Phoenix SUT	Land Bank
2010	Mercury Milan	Nissan Leaf	School
2008	Ford Taurus	Nissan Leaf	Police
1998	Ford 500	Nissan Leaf	Water

Table 5 : Municipal EV Replacement Candidates

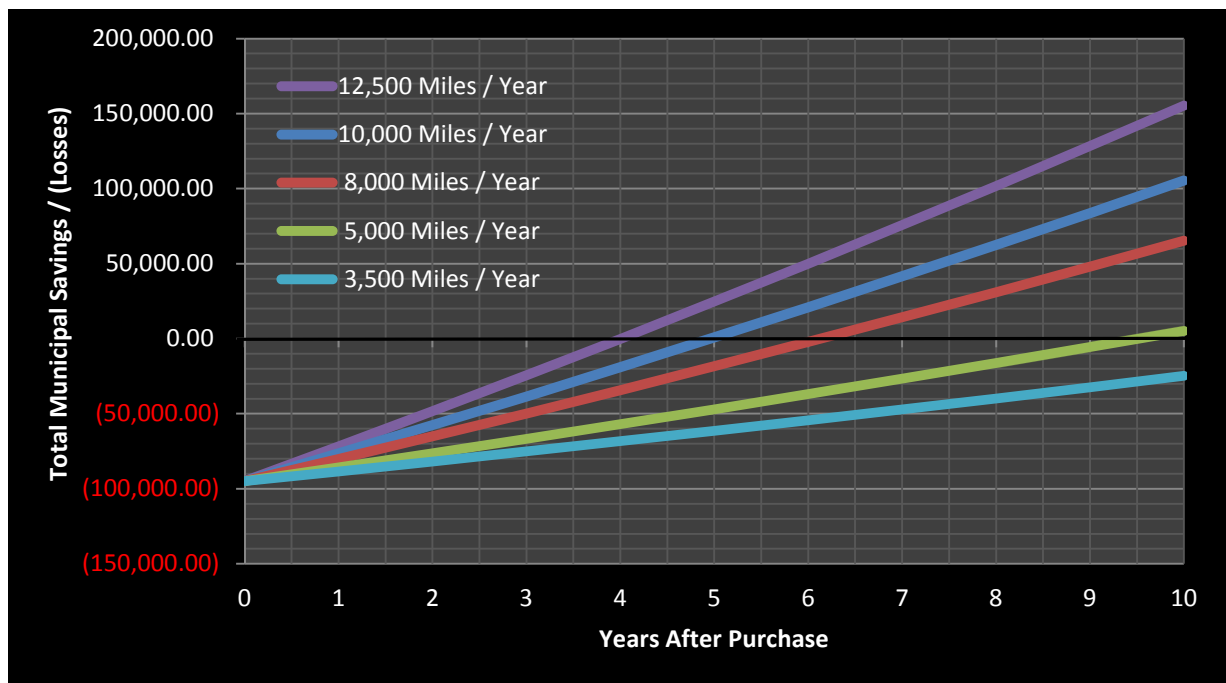


Figure 17 : Time for Selected Municipal Fleet EV Adoption to Break Even

Figure 17 shows the ten municipal vehicles listed in Table 5 and how the net savings or losses are affected by the annual mileage of the vehicles.

General Public

Under most scenarios, the Town of Nantucket would be able to support a moderate adoption of electric vehicles on the island if charging was controlled to an extent. If there was a low (12% adoption of electric vehicles by the general public, the annual gasoline usage would be reduced by 860,000 gallons of gasoline and the annual electricity usage would be increased by 3.3%. The annual savings in fuel would amount to \$28 million (without adjusting for inflation). Moreover, for the low and high adoption estimates of 12% and 45%, the annual electricity usage would be increased modestly by 3.3% and 12.4% respectively which correspond to 4.1MWh and 15MWh increases in electricity annually. If the town used a smart grid to encourage or regulate home charging to be done at night during off peak hours, the effect on the electricity usage would be further minimized. If all of the taxis, rental cars, and municipal vehicles were converted to electric vehicles, the annual electricity usage would increase 29.41%. Under the average case scenario for EV charging where charging is spread evenly across 8 hours, the electricity usage of the island is increased by 1.4 MW for the low adoption scenario and by 5.3 MW for the high adoption scenario. However, as shown below in Table 6, under the low public adoption scenario, the worst case scenario where every electric vehicle is being charged at once using 19.2kW chargers would bring up the islands electricity usage by 34.4MW, roughly half of the capacity of the power cables supplying the island. To prevent Nantucket's power grid from being disrupted by this, the town would need to discourage or disallow charging in the day during peak hours.

	Adoption Rate	Total EV's Adopted	Maximum Electricity Use Rate (MW)	Average Electricity use Rate (MW)	Yearly Gasoline Saved (Gal)	Yearly Electricity Used (MWh)
Low Adoption	12%	1,795	34.5	1.4	861,667	4,156.9
High Adoption	45%	6,730	129.2	5.3	3,230,653	15,585.3
Full Adoption	100%	14,955	287.1	11.9	7,178,963	34,632.8

Table 6 : Selected General Public Scenario Analysis Results

Rental Fleet

Due to the poor response rate from our requests for interviews with rental car company owners, we were not able to conduct a detailed scenario analysis. In spite of this, we calculated what the effects of replacing portions of the rental fleet with the Nissan Leaf would be, as shown in Table 7. As it is displayed, the worst case power demand increase is moderate for lower adoption rates but it becomes much more significant at higher adoption rates.

Adoption Rate	Very Low	Low	Moderate	High	Full	110%
Rate of EV Adoption%	5%	12%	27%	42%	100%	110%
# of Adopted EV's	35	84	189	294	700	770
Total Battery Capacity (kWh)	840.0	2,016.0	4,536.0	7,056.0	16,800.0	18,480.0
Yearly Electricity Used (MWh)	67.2	161.3	362.9	564.5	1,344.0	1,478.4
Percentage Increase	0.05%	0.13%	0.29%	0.45%	1.07%	1.18%
Worst Case MW Increase (MW)	0.7	1.6	3.6	5.6	13.4	14.8

Table 7 : Selected Rental Fleet Scenario Analysis Results

Taxi Fleet

Compared to the public fleet, the absolute number of cars converted in all scenarios for the taxi fleet is low. Because of this, adoption of electric vehicles by the taxi fleet has a small if not negligible effect on the grid despite their significantly higher annual mileage, as shown in Table 8. In the worst case scenario for EV charging in the full adoption scenario only increases the power usage of the island by 1.02 MW. However, because of the much higher annual mileage of the taxis, the gasoline savings are more than those seen in the general public scenario analysis. Therefore, the taxi fleet scenario results with the highest fuel savings with minimal impact on the grid.

	Low	Moderate	High	Full
Yearly Mileage	50000			
EV Adoption (%)	5%	10%	15%	100%
EV Adoption (Cars)	3	6	8	53
Total Battery Capacity (kWh)	84	168	224	1484
Yearly Gasoline Saved (Gal)	9,141	18,282	24,376	161,489
Yearly Electricity Used (MWh)	52.5	105.0	140.0	927.5
Daily Electricity Used (MWh)	0.14	0.29	0.38	2.54
Annual Town Energy Use Increase (%)	0.04%	0.08%	0.11%	0.74%
Normal Case Power Increase (MW)	0.02	0.04	0.05	0.32
EV Adoption (%)	0.06	0.12	0.15	1.02
Yearly Mileage	75000			
EV Adoption (%)	5%	10%	15%	100%
EV Adoption (Cars)	3	6	8	53
Total Battery Capacity (kWh)	84	168	224	1484
Yearly Gasoline Saved (Gal)	13,711	27,423	36,563	242,233
Yearly Electricity Used (MWh)	78.8	157.5	210.0	1,391.3
Daily Electricity Used (MWh)	0.22	0.43	0.58	3.81
Annual Town Energy Use Increase (%)	0.06%	0.13%	0.17%	1.11%
Normal Case Power Increase (MW)	0.03	0.05	0.07	0.48
EV Adoption (%)	0.06	0.12	0.15	1.02
Yearly Mileage	100000			
EV Adoption (%)	5%	10%	15%	100%
EV Adoption (Cars)	3	6	8	53
Total Battery Capacity (kWh)	84	168	224	1484
Yearly Gasoline Saved (Gal)	18,282	36,563	48,751	322,977
Yearly Electricity Used (MWh)	105.0	210.0	280.0	1,855.0
Daily Electricity Used (MWh)	0.29	0.58	0.77	5.08
Annual Town Energy Use Increase (%)	0.08%	0.17%	0.22%	1.48%
Normal Case Power Increase (MW)	0.04	0.07	0.10	0.64
EV Adoption (%)	0.06	0.12	0.15	1.02

Table 8 : Selected Taxi Fleet Scenario Analysis Results

Conclusions and Recommendations

Conclusions

The goal of our project was to assist the Town of Nantucket to determine if it is desirable and feasible to expand the use of electric vehicles on the island. To do this, we conducted interviews with business owners and town department heads, surveyed the public on their knowledge and opinions on electric vehicles, and conducted a scenario analysis. In this section we will present our conclusions from our research and make recommendations based on those conclusions.

The results from our survey of the public revealed that the residents of Nantucket have a reasonable understanding of the capabilities of electric vehicles. A third of the people who estimated how far an electric car could travel guessed it was 100 miles which is the projected distance of the Nissan Leaf (Nissan, 2010). Half of the people who estimated a charging time for an electric car thought that it took eight hours to charge. For an unknown technology having a portion of the public that can reasonably estimate the range and charge time of an electric car is a positive sign that can lead to greater knowledge of the capabilities of electric vehicles. At the same time around 27% of those who were surveyed did not feel comfortable giving an estimate, this shows that there still is public uncertainty with the technology. As more people buy electric cars, we anticipate that public knowledge about the advantages and disadvantages will increase.

The results from the public survey also show a potential demand for electric vehicles. When asked if they considered buying a hybrid or electric vehicle the last time they purchased a vehicle, 75% of those surveyed said they did not, while 65% said they *would* consider buying an electric vehicle in the future. The responses here may be misleading, however, since the average age of vehicles among those surveyed was 8 years, and in 2002 hybrid and electric vehicles were not widely available. Many residents supported the idea that the town promote electric vehicle use, including replacing part of the municipal fleet. Many of the respondents cited the cost of gas as a major reason for considering an electric vehicle with the caveat that it has to be close to or cheaper than a gas powered car to own and run. When we consider that the Nissan Leaf fares

very well against the Nissan Altima and other similar sedans we conclude that there is a demand for electric vehicles in Nantucket.

Contrary to our expectations, more residents responded positively to the possibility of the town installing charging stations at the airport or downtown than to having charging stations installed in major parking lots such as grocery stores. Inherently the airport would have cars parked for longer, followed by two hour parking in the downtown and then cars parked for the duration of a grocery shopping trip. From this we can conclude that residents want charging stations where they predict their car will sit for a longer period of time.

According to our findings, having taxi companies adopt EV's into their fleet is not yet a viable option for Nantucket for several reasons. Taxi companies prefer to use minivans and no electric minivans are yet available. The electric Ford Transit Connect may have some of the same functionality, but it does not have the same passenger room and would be substantially more expensive to buy and operate. Since taxis run all day and night, charging is not an option and battery swapping stations require a large market of electric vehicles, something that Nantucket does not have. To accommodate electric taxis there first has to be an electric model of the minivan and the necessary infrastructure such as a battery swap stations to handle constant demand for a charged battery.

In our interview with a rental shop owner we learned that there are companies willing to introduce electric rental vehicles into their fleet, but they are concerned about the lack of allotted rental cars on the island. Also we have decided that the price of an electric car will still have to come down further before it can be adopted by rental car companies because they only keep their cars for a very short period of time.

Of all of the battery electric vehicles we analyzed, the Nissan Leaf was significantly more economically viable for Nantucket. The Ford Transit Connect EV was expensive and didn't break even with the gas powered version within ten years of ownership. The Phoenix SUT has a less expensive purchase price making it more comparable to the Ford Ranger and Ford F150. The Nissan Leaf however, fared much better against its competitors and its limited range is of little concern because of Nantucket's small size.

According to our research, the island can support moderate adoption of electric vehicles if it took measures to encourage charging during off peak hours and discourage charging during peak hours. Using our high estimate of electric vehicle adoption, the power cables would not be able to support all of the vehicles charging at once. However, if charging was spread throughout the off peak hours, the island would be able to support the increased demand in electricity.

Our results showed that the economic feasibility of adopting electric vehicles in the municipal fleet is largely limited by the yearly mileage of the vehicles being replaced and four wheel drive capability. Many departments require vehicles that can travel over sand, snow, construction sites, or vehicles specifically designed for work such as police vehicles or plow trucks. For low estimates of yearly mileage, there were no significant savings. The savings only became significant at higher mileages of 8,000 miles a year or higher. With an increased yearly mileage savings also increases. Nantucket is considered to be ideal for electric vehicles because the range of the vehicles will rarely be exceeded while driving on the island. These two facts are counterproductive and limit the number of situations where it becomes viable for trucks to be replaced on the island. Electric sedans like the Nissan Leaf on the other hand have a much earlier payback period and are more ideal for Nantucket's climate and size.

Recommendations

There were many different contributing factors that led us to these recommendations for the adoption of electric vehicles for Nantucket. One of the things addressed in the conclusions is that the general public will not adopt electric vehicles unless public charging stations are available. Surveys by EPRI and others suggest that most people will charge their cars at home, but public charging stations are necessary to allay public fears of being stranded with a depleted battery. Some of the areas we are proposing to place charging stations are the airport, in the proposed Wilkes Square parking garage, and at the Wannacommet Water Company. The town should encourage electric car charging stations at the airport in conjunction with solar arrays that are going to be installed. Another reason to place charging stations there is because people tend to park their cars at the airport for extended periods of time which is ideal for charging the battery of an electric vehicle. The town should continue to explore placing charging stations at the proposed Wilkes Square parking garage because it is the only place close enough to the

downtown area where charging stations will be able to be placed. The town should also consider and keep exploring placing charging stations near the water company where the proposed park and ride parking lot will be. This would help to reduce congestion down town in the summer but it would require the implementation of a shuttle service.

The town could install charging stations at various locations, it could give preferential parking privileges to electric vehicles, it could restrict or extend the number of taxi and/or rental car 'medallions' (depending on state laws) and give out more medallions for electric car taxis and/or rental cars. These are possibilities that the town could consider doing if they chose to encourage electric vehicles. The town might want to do this because they want to promote a greener/cleaner technologies, have the potential in the future to use electric vehicles as battery storage in conjunction with a smart grid, respond to public demand (e.g. if more visitors or residents are going to bring electric vehicles to the island, the town may be obliged to accommodate them), and to lower congestion in the down town area with the addition of the park and ride station and the shuttle to main street.

We cannot recommend that the town consider the possibility of using vehicle to grid technology at this time. The town cannot yet use an electric vehicle to feed power back into the grid because the technology is very new and not implemented in the current 2010 models. On the public level the current electrical usage and payment system with National Grid does not allow for consumers to be charged less for off peak charging which would mean the consumer would lose money if they were to put power back into the grid. At this time Nantucket is charged the same rate during peak and off peak hours therefore selling electricity back into the grid would not be a feasible option because there is no monetary incentive to sell the electricity back because the town would not make money by doing so.

We cannot recommend that the town adopt any electric trucks at this time. The technology for electric trucks needs to be more developed and by doing so the price will come down. Electric trucks are too expensive right now for them to be applicable for municipality use. Municipal vehicles do not drive enough miles and are not kept long enough for an electric truck to become cost effective over a conventional gasoline truck.

We recommend that taxi companies wait for electric car battery technology to improve until either electric cars cost the same or less than equivalent gasoline powered cars. The biggest obstacles we found in our research were that electric cars can't travel far enough between charges, take too long to charge, and that the batteries don't last long enough.

We recommend that rental car companies consider adopting a few electric vehicles as a test to see the demand for electric rental cars. These rental cars should only be rented out for shorter periods of time such as a one day rental. This method would ensure that the renter would not need to recharge the battery of the car while renting the car. If public charging stations became more available then rental electric cars would be much more feasible because renters would be able to charge a rental car and not risk running out of charge.

If the town of Nantucket wants to move towards an electric vehicle community, then we recommend that the town be one of the first to purchase an electric car. By doing this the town could provide a good advertisement and good PR for electric cars and it might entice more people into buying an electric car. Another key point is that the first few electric cars adopted by the town could only be charged at night during the off peak hours and the town should advertise that they are doing this. This will let people know that they are not adding to the peak cost of electricity and therefore not raising their electric bill. This pilot or trial program could be a good way to show people that electric cars are sustainable on Nantucket given the harsh driving conditions.

Works Cited

- Agassi, S. (2010). *Better Place*. Retrieved September 14, 2010, from <http://www.betterplace.com>
- Almeida, E. J. (2010, 12 2). Nantucket Emissions - General Manager / Mechanic. (D. Vinci, Interviewer)
- Barret, C. J. (2010, 12 2). Barretts Garage - General Manager. (D. Vinci, Interviewer)
- BetterPlace (Director). (2009). *Better Place Battery Swap Demonstration* [Motion Picture].
- Boston Consulting Group. (2009). *The Comeback of the Electric Car?* Boston: The Boston Consulting Group.
- Consumer Electronics Association. (2010, August 23). *Americans Want to Give Electric Vehicles a Test Drive, New CEA Study Reports*. Retrieved December 3, 2010, from Business Wire: <http://www.businesswire.com/news/home/20100823006181/en/Americans-Give-Electric-Vehicles-Test-Drive-CEA>
- Control Module Industries. (2010). Residential Charger with Power Share. Enfield, Connecticut , United States of America.
- Department of Energy. (2010, March 29). *Frequently Asked Questions*. Retrieved November 9, 2010, from Electricity: http://www.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home
- Diamond, D. (2008, Spring Semester). PUBLIC POLICIES FOR HYBRID-ELECTRIC VEHICLES: THE IMPACT OF GOVERNMENT INCENTIVES ON CONSUMER ADOPTION. Fairfax, VA.
- Eaves, S., & Eaves, J. (2003). *A Cost Comparison of Fuel-Cell and Battery Electric Vehicles*. Mesa: Arizona State University-East.
- eBus. (2008). *Home*. Retrieved December 13, 2010, from eBus: <http://www.ebus.com>
- Edwards, J. (2010, September 24). Impacts of Electric Cars on a Smart Grid. (Z. Lorch, Interviewer)

- Electric Power Research Institute. (2010). *Characterizing Consumers' Interest in and Infrastructure*. EPRI, Palo Alto, CA and Southern California Edison,.
- Energetix Energy Services Company. (2010). *Time of Use*. Retrieved September 26, 2010, from Energetix: <http://www.energetix.net/ResourceCenter/TimeOfUseInformation/>
- EPA. (2010, July 14). *Climate Change - Greenhouse Gas Emissions*. Retrieved October 6, 2010, from Human-Related Sources and Sinks of Carbon Dioxide: http://www.epa.gov/climatechange/emissions/co2_human.html
- Fabian, K., Wietschel, M., & Dallinger, D. (2010). Evaluation of European electric vehicle support schemes. *Fraunhofer*.
- Fontaine, P. J. (2008). Shortening the Path to Energy Independence: A Policy Agenda to Commercialize Battery-Electric Vehicles. *Electricity Journal*, 1-14.
- GE Watt Station. (2010). *Electric Vehicles*. Retrieved September 24, 2010, from The GE Show: http://www.ge.com/thegeshow/electricvehicles/?utm_source=goog_EV_Brand&utm_medium=PPC&utm_campaign=ge_show_ev_search#ch1
- Graham-Rowe, D. (2005, March 07). *Charge a Battery in Just Six Minutes*. Retrieved November 8, 2010, from New Scientist: <http://www.newscientist.com/article/dn7081>
- Hobbs, C. (2010, December 19). Sales Consultant. (Z. Lorch, Interviewer)
- Hybrid Center.org. (n.d.). *Hybrid Center :: Consumer Center :: Incentives*. Retrieved 9 25, 2010, from HybridCenter.org: <http://go.ucsusa.org/hybridcenter/incentives.cfm#MA>
- HybridCars.com. (2009, June 9). *Corporate Incentives for Hybrids and Alternative Cars*. Retrieved September 24, 2010, from hybrid CARS: <http://www.hybridcars.com/corporate-incentives.html>
- INL. (2010, June 14). *Comparing Energy Costs per Mile for Electric and Gasoline-Fueled Vehicles*. Retrieved October 5, 2010, from Idaho National Laboratory: Advanced Vehicle Testing Activity: <http://avt.inel.gov/pdf/fsev/costs.pdf>

- Johnston, J. (1997). *Driving America*. Washington, DC: American Enterprise Institute for Public Policy Research.
- Kromer, M. A., & Heywood, J. B. (2007). *Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet*. Cambridge: LFEE 2007-03 RP.
- Markel, T. (2010). *Plug-in Electric Vehicle Infrastructure: A Foundation for Electrified Transportation*.
- Mass.Gov. (2010, October 7). *Patrick-Murry Administration Announces Funding for Electric Vehicle Charging Stations*. Retrieved November 7, 2010, from Executive Office of Energy and Environmental Affairs:
http://www.mass.gov/?pageID=eoeepressrelease&L=1&L0=Home&sid=Eoeea&b=pressrelease&f=101007_pr_charging_stations&csid=Eoeea
- Morrow, K., Karner, D., & Francfort, J. (2008). *Plug-in Hybrid Electric Vehicle Charging Infrastructure Review*. The Idaho National Laboratory is a U.S. Department of Energy National Laboratory.
- Motavalli, J. (2010, December 7). Hertz Puts Electric Cars on the Fast Track, Starting in New York. *New York Times*.
- Nissan. (2010). *Charging*. Retrieved September 15, 2010, from Nissan Leaf:
<http://www.nissanusa.com/leaf-electric-car/index?dcp=ppn.39666654.&dcc=0.216878497#/leaf-electric-car/news/infrastructure>
- PBS. (2009, 10 30). *Timeline: History of the electric car*. Retrieved 9 26, 2010, from PBS:
<http://www.pbs.org/now/shows/223/electric-car-timeline.html>
- Phoenix Motorcars. (2001). *Phoenix Motorcars*. Retrieved November 7, 2010, from Phoenix Motorcars.
- Plug In America. (n.d.). *Plug In America Federal and State Incentives*. Retrieved 9 26, 2010, from Plug In America: <http://www.pluginamerica.org/incentives.shtm#federal>
- Popular Science. (2010). Archive Gallery: The Electric Car, 1916-Present . *Popular Science*, 1.

- Rocky Mountain Institute. (n.d.). *PGR Total Cost of Vehicle Ownership Calculator*. Retrieved 12 13, 2010, from Project Get Ready: <http://projectgetready.com/js/tco.html>
- Schuler, R. E. (2010). The Smart Grid. *The Bridge*, 42-50.
- Silvermen, B. (2010, December 13). Azur Dynamics . (S. Manager, Interviewer)
- Suzuki, D., & Taylor, D. (2009). *Big Picture : Reflections on Science, Humanity, and a Quickly Changing Planet*. Vancouver: Greystone Books.
- The Boston Consulting Group. (2009). *The Comeback of the Electric Car?* Boston: Boston Consulting Group.
- U.S. Census Bureau. (2006, March 01). *Housing Vacancies and Homeownership*. Retrieved October 02, 2010, from U.S. Census Bureau: <http://www.census.gov/hhes/www/housing/hvs/annual05/ann05t12.html>
- U.S. DOE. (n.d.). *Department of Energy - Tax Breaks*. Retrieved 9 22, 2010, from U.S. Department of Energy: <http://www.energy.gov/taxbreaks.htm>

Appendix A: Public Survey

WPI E-Cars Team Public Survey		PAGE 1		Survey #, Date, and Place			
<p>I'm a student from Worcester Polytechnic Institute. I'm part of a team conducting a research project on electric cars in Nantucket as part of my degree requirements. Would you be willing to answer a few questions? The survey is completely anonymous.</p>							
1	Are you a full time resident of Nantucket?			YES NO			
2	Ask the subject about these properties for the car that they are driving. Look at the car to save some time.						
	Make	Model	Year	MPG	Yearly Mileage	Ownership	Use
a							
3	Did you consider a hybrid or electric car when you last bought a car?				YES NO		
4	Do you plan on buying a car in the next 5 years? If yes, do you plan to buy new, used, or lease?			YES NO		NEW USED LEASE	
5	Would you consider buying/leasing an electric car?					YES NO	
	Why or why not?						
6	How long do you think it takes to charge an electric car?						
7	How far do you think an electric car can travel on a single charge?						
8	Do you think that electric cars cost more than gas powered cars to purchase?			YES NO		DON'T KNOW	
9	Do you think that electric cars cost more than gas powered cars to fuel?			YES NO		DON'T KNOW	
10	Do you think that electric cars cost more than gas powered cars to maintain?			YES NO		DON'T KNOW	
11	Do you know of any incentives that the government offers to encourage electric car purchases?			YES NO			

12	Tell the subject "I am going to read several statements. Please tell me if you agree or disagree with them."						
A	The town should encourage greater public use of electric vehicles	Agree	Don't Know	Disagree			
B	The town should replace part of its fleet with electric vehicles	Agree	Don't Know	Disagree			
C	The town should encourage taxi companies to use electric vehicles	Agree	Don't Know	Disagree			
D	The town should place charging stations downtown	Agree	Don't Know	Disagree			
E	The town should place charging stations at the airport	Agree	Don't Know	Disagree			
F	Charging stations should be installed in major parking lots such as Stop & Shop, Grand Union, etc.	Agree	Don't Know	Disagree			
13	Do you have any other concerns regarding electric vehicles on Nantucket?						
14	One last question. Please tell me how old you are?	<25	26-35	36-45	46-55	56-65	65+
Thank the subject for their cooperation and time.							

Appendix B: Infrastructure Cost Table

Level 1 Residential	Labor	Material	Permits	Total
EVSE (charge cord)	--	\$250	--	\$250
Residential circuit installation (20A branch circuit, 120 VAC/1-Phase)	\$300	\$131	\$85	\$516
Administration costs	\$60	\$43	\$9	\$112
Total Level 1 Cost	\$360	\$424	\$94	\$878

Level 2 Residential	Labor	Material	Permits	Total
EVSE (32 A wall box)	--	\$650	--	\$650
EVSE (charge cord)	--	\$200	--	\$200
Residential circuit installation (40A branch circuit, 240 VAC/1-Phase)	\$455	\$470	\$155	\$1,080
Administration costs	\$91	\$94	\$31	\$216
Total Level 2 Cost	\$546	\$1,414	\$186	\$2,146

Level 1 Apartment	Labor	Material	Permits	Signage	Total
EVSE (five charge cords)	--	\$1,250	--	--	\$1,250
Apartment complex circuit installation (five, 20A branch circuits, 120 VAC/1-Phase with separate meter and breaker panel)	\$1,200	\$516	\$155	\$350	\$2,221
Administration costs	\$240	\$353	\$31	\$70	\$694
Total Level 1 Cost	\$1,440	\$2,119	\$186	\$420	\$4,165
Total per Charger Cost	\$288	\$424	\$37	\$84	\$833

Level 2 Apartment	Labor	Material	Permits	Signage	Total
EVSE (five 32A wall boxes)	--	\$3,250	--	--	\$3,250
EVSE (five charge cords)	--	\$1,000	--	--	\$1,000
Apartment complex circuit installation (five, 40A branch circuits, 240 VAC/1-Phase with separate breaker panel)	\$1,400	\$696	\$165	\$350	\$2,611
Administration costs	\$280	\$353	\$33	\$70	\$736
Total Level 2 Cost	\$1,680	\$5,299	\$198	\$420	\$7,597
Total per Charger Cost	\$336	\$1,060	\$40	\$84	\$1,520

Level 2 Commercial	Labor	Material	Permits	Signage	Total
EVSE (ten 32A wall boxes)	--	\$6,500	--	--	\$6,500
EVSE (ten charge cords)	--	\$2,000	--	--	\$2,000
Apartment complex circuit installation (ten, 40A branch circuits, 240 VAC/1-Phase with separate meter and breaker panel)	\$3,400	\$3,899	\$700	\$350	\$8,349
Administration costs	\$680	\$780	\$140	\$70	\$1,670
Total Level 2 cost	\$4,080	\$13,179	\$840	\$420	\$18,519
Total per Charger Cost	\$408	\$1,318	\$84	\$42	\$1,852

Appendix C: List of Interview Participants

Throughout the course of our project, we interviewed many people on and off Nantucket. Here we wish to supply a comprehensive list of all of the people that we held interviews with.

- Alfred G. Peterson from the Nantucket Memorial Airport
- Andrew Vorce from the Nantucket Planning Department
- Anne Kuzspa from the Nantucket Energy Committee
- Chester Barrett Jr. from Barrett's Garage
- Comer Hobbs from Dattco Commercial Buses
- Dan Bennett from the New Hampshire Auto Dealers Association
- Ed Almeida from Nantucket Emissions
- Jeff Willett from the Department of Public Works
- Jim Wolf from Cape Air
- Lisa from A1 Taxi
- Mark Voigt from the Historic District Committee
- Melissa Philbrick from reMain Nantucket
- Noah Learner from Young's Bike Shop
- Paula Leary from Nantucket Regional Transit Authority
- Rachel Hobart from reMain Nantucket
- Richard Ray from the Nantucket Board of Health
- Robert W. Doane from Cape Air
- Robert Gardner from the Wannacomet Water Company
- Roger from Roger's Taxi
- Scott Ridley from Ridley and Associates, Inc.
- Steven Butler from the Building Dept.
- Tim Milstead from Nantucket Island Resorts
- William Tornovish from the Don Allen Ford car dealership