

# Determining the Viability of Electric Vehicles on Nantucket

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# Abstract

The goal of this project was to assist the Nantucket Energy Office by assessing the impacts associated with an increase of electric vehicles (EVs) on the island of Nantucket. This goal was achieved by surveying public opinion and gathering key stakeholder perspectives on EV charging and growth, and EV-based public transportation. Additionally, the project group assessed Nantucket's electric vehicle charging infrastructure, usage patterns, and grid impacts. Based on the survey results and other findings, the project group developed policy and infrastructure recommendations for the Nantucket Energy Office. Among the recommendations were locations for public EV charging stations, awareness and outreach initiatives, and the further exploration of public EV transportation on Nantucket.

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## **Executive Summary**

The transportation sector generated 1.8 billion metric tons of carbon emissions in 2014, which was 26% of total emissions (Hill, 2016, U.S. Environmental Protection Agency, 2014). In order to reduce carbon emissions, alternative renewable energy sources such as solar and wind based energy generation have been explored to provide energy for the transportation sector and the energy grid that supports it. Within the transportation sector, the use of electric vehicles (EVs) has grown as a sustainable alternative to internal combustion powered vehicles due to lower lifetime carbon emissions. As a result of the long term benefits of the use of EVs, many state and local governments launched initiatives to promote the ownership and responsible use of electric vehicles (MassDEP, 2016).

Nantucket, Massachusetts presents a unique environment for the possible encouragement of electric vehicles due to its fluctuating population and energy needs, and its limited electrical energy supply. In particular, Nantucket's strong tourism industry draws approximately 400,000 visitors each summer, during which time electrical energy consumption increases accordingly, with peak electrical use in the summer reaching 48 megawatts (National Grid, 2016). The coupling of high summer electrical energy demand and limited energy resources creates a challenge for Nantucket, particularly as peak electrical use has grown at a rate 5 times that of mainland Massachusetts (Nantucket Energy Office, 2016).

Given the conflicting island circumstances of high gas prices and limited electrical supply, it is important to explore the effects of using and encouraging electric vehicles on Nantucket. A key stakeholder in this study is the Nantucket Energy Office (NEO). The primary efforts the NEO is focused on includes programs to reduce energy costs, recommend energy related policies, reduce energy waste, and serve as a resource and liaison to companies like National Grid (Nantucket Energy Office, 2016).

## **Project Statement**

The purpose of this project was to study the data available on EV adoption rates, as well as EV adoption and plans by island residents and visitors, and to analyze how EV use might increase on the island in both the short term and long term. This project was also focused on determining the current state of the EV-supporting charging infrastructure on Nantucket and offer recommendations on how that infrastructure should be expanded to support growth in EVs on the island. An additional focus was exploring potential systems for electric public transportation on Nantucket. Finally, the project team attempted to predict the impacts of greater EV use on the island's energy supply, and subsequently recommend procedures to promote responsible electric vehicle charging.

## Background

Due to their lower lifetime carbon emissions, electric vehicles (EVs) have gained popularity as a sustainable alternative to gasoline powered vehicles. Although EVs produce more emissions when they are manufactured than gasoline powered vehicles, they generate minimal or even zero-emissions when driven. As a result, the initial emissions manufacturing deficit can be offset after 6 to 16 months of average driving (Union of Concerned Scientists, 2015). The limited emissions associated with electric vehicle driving are due to the use of carbon-based fuels in power plants, which generate the electrical power needed to charge and EV. Power generation plants operate at 40% efficiency on average whereas gasoline vehicles achieve 14%–30% percent (U.S. Department of Energy). However, the use of carbon based fuels in power plants and the resulting emissions related to driving an EV are projected to decrease based on national data from 2013 to 2015 (Union of Concerned Scientists, 2015).

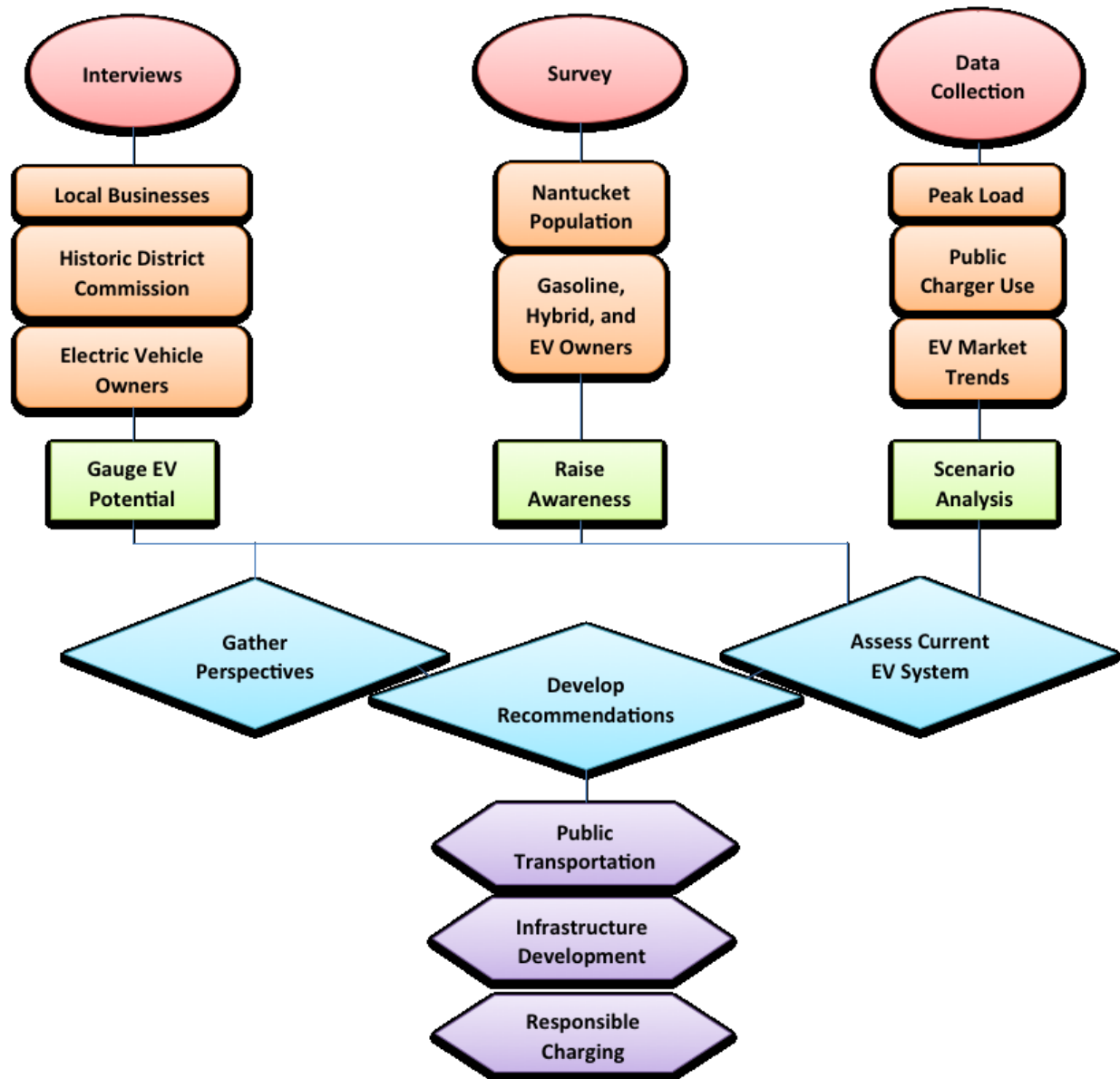
Although the benefits of electric vehicle use are clear from an environmental standpoint, a variety of other factors can influence the overall challenges and benefits of increased EV use. For example, when considering whether to purchase an EV, many individuals exhibit “range anxiety,” where the customer believes that the distance an EV can travel per charge may not be sufficient for their needs. However, studies suggest that 87% of day-to-day travel can be made in an electric vehicle, and that the few exceptions to this rule are longer trips that could be made with a shared or limited-use gasoline powered vehicle (Needell et al., 2015). Electric vehicles also typically have better fuel economy and fuel availability than their gasoline powered counterparts. Although electric vehicles take longer to recharge than simply refueling a gasoline tank and charging stations are less abundant than gas stations, today most EVs can achieve 100 miles per gallon equivalent, and the number of EV charging stations is rapidly growing due to the omnipresent electric grid (Alternative Fuels Data Center, 2016).

Due to the demonstrated benefits of the use of EVs, many initiatives to promote the ownership and responsible use of electric vehicles have been launched on a state and local level. These initiatives have included monetary incentives for purchasing an EV and incentives for charging during off-peak hours. For example, the town of Braintree, Massachusetts incentivized its residents to purchase electric vehicles by offering free test drives and pre-negotiated deals with local car dealerships, making the process of buying an EV easier and the consumers more informed (Braintree Drives Electric, 2016). In addition, the Braintree town government has offered \$250 to residents for installing an approved “smart” home charger to power the vehicle overnight (Libon, 2016). On a state level, the Massachusetts Electric Vehicle Incentive Program encourages municipalities to transition to electric vehicles by providing financial incentives to local agencies that shift their fleets to electric and hybrid vehicles (MassDEP, 2016). In addition to state and local government incentives for shifting municipal fleets to electric and hybrid vehicles, private companies such as Foothill Transit and Downtowner provide public transportation

options at little or no cost to the consumer in the form of electric buses and electric midsize vehicles, respectively (Foothill Transit, Downtowner, 2016). These programs demonstrate that electric vehicles can be a cost effective and environmentally friendly form of transportation.

## Methodology

In the flowchart below, we outline the methods we used, the key stakeholders we interacted with, and the ways in which we met our objectives.



**Figure I: Methodology Flowchart**

As illustrated above, the primary methods used to address our project goals were interviews, an informative survey, and data collection. Interviews conducted with electric vehicle owners were used to characterize EV charging trends and assess charging sites, which addressed

our first objective of assessing Nantucket's EV infrastructure and energy patterns. Perspectives from other key stakeholders such as hotels, rental companies, car dealerships, Downtowner, and the Historical District Committee were used to gain insight on the potential for growth in electric vehicle use and supporting infrastructure.

We used informative questions to make survey participants more aware of electric vehicles, peak load, and responsible charging. We also used the survey data to understand general opinion of EVs and certain trends of EV adoption specific to Nantucket.

The purpose of the scenario analysis tool was to help us better understand Nantucket's electrical infrastructure and the impact of EV charging on the Nantucket energy supply. The tool was used to illustrate growth in charger use since installation, monthly usage patterns, and grid effects, and was developed through recommendations from our advisors and research that detailed the effectiveness of this method in illustrating future effects of a perceived scenario. This tool provided insight to develop policy and infrastructure recommendations to the Nantucket Energy Office.

## **Findings**

Findings regarding electric vehicle charging were gained through a scenario analysis and interviews with electric vehicle owners, the Historical District Commission, and the Town Manager's Office. Perspectives on the growth potential of electric vehicles were gained through results from our informative survey and interviews with local businesses. Possibilities for electric public transportation systems were explored through the survey and a conversation with Downtowner, the Town Manager's Office, and our sponsor. Table I below outlines our key findings from each method:



**Table I: Methods and Related Findings**

Method	Findings
<b>EV Owner Interviews</b>	<ul style="list-style-type: none"> <li>• Current public electric vehicle charging stations have limited accessibility and convenience.</li> <li>• Range anxiety is not an issue on Nantucket.</li> <li>• People can purchase EVs for much lower costs than they think.</li> </ul>
<b>Other Stakeholder Interviews</b>	<ul style="list-style-type: none"> <li>• Challenges with installing public chargers include parking enforcement, selecting new or changed locations, and appropriate visual appearance.</li> <li>• Cape Air is an example of a successful commercial EV application.</li> <li>• The most significant challenge for renting EVs is charging time.</li> <li>• The most significant challenge to selling EVs is the cost of the equipment to the dealer needed to service them.</li> <li>• The Downtowner service is customizable based on a city or town's needs.</li> <li>• Advertisements might not be a viable option for financing a free electric transportation service, but this issue should be explored.</li> </ul>
<b>Survey</b>	<ul style="list-style-type: none"> <li>• Many Nantucket residents prefer a vehicle with off-road capabilities.</li> <li>• The most common EV concerns are charging, range, and price.</li> <li>• Nantucket residents responded positively when provided information about EV range, cost, and incentives.</li> <li>• A majority of survey respondents favored EV public transportation on Nantucket.</li> </ul>
<b>Scenario Analysis</b>	<ul style="list-style-type: none"> <li>• The effect of EV charging on peak load is negligible.</li> <li>• Chargers Downtown see more usage than other locations.</li> <li>• Over 80% of public charger uses last less than 3 hours.</li> <li>• Public charger use has increased yearly.</li> </ul>

## Recommendations

Below is a concise list of recommendations regarding three main topics: electric vehicle charging, electric vehicle growth potential, and electric vehicle public transportation.

### EV Charging

1. Begin the process of installing more public electric vehicle chargers at the locations specified below, while considering available grants, new locations that the town would approve, and new public charger technology. Our top three locations are:
  - a. Proposed parking garage
  - b. Mid-island Stop & Shop
  - c. Downtown Stop & Shop
2. Designate a charging station for Town use only.

3. Relocate one airport charger to another location downtown (possibly make it the third charger at the downtown parking lot) and relocate the high school charger to a more convenient location in the main high school parking lot.
4. Continue to provide free electric vehicle charging.
5. Inform and encourage all EV owners to charge during off peak times.
6. If and when the effect of EV charging on peak load becomes significant, collaborate with National Grid to implement an off-peak charging initiative.

### **EV Growth Potential**

1. Conduct a series of case studies highlighting successful electric vehicle use for both private owners and businesses.
2. Coordinate with potential sponsors to conduct an awareness and outreach campaign to spread information about electric vehicle incentives, charging, costs, and benefits.
3. Investigate the possibility tracking the number of electric vehicles brought to the island through Steamship Authority.

### **EV Public Transportation**

1. Further investigate electric public transportation options in order to select a model that is best suited for Nantucket.
2. Coordinate between the Nantucket Energy Office, the Town Manager's Office, and the Transportation Planner to assess the process, requirements, and challenges for a successful electric public transportation system.

### **Summary and Conclusion**

In this project, we have determined that electric vehicles are a viable option for Nantucket. Through our recommendations, the Nantucket Energy Office can best prepare for greater EV adoption by raising awareness of electric vehicles, improving electric vehicle supporting infrastructure, and eliminating the minimal effect of EV charging on the electrical grid. Our project may serve as an example for towns or cities that are experiencing early stages of EV adoption and wish to assess the impacts and benefits that EVs may have on their community.

Our project provides potential opportunities for future Interactive Qualifying Projects. Specifically, a project could be conducted to delve further into the issue of peak electrical load on Nantucket, which was only a small portion of our project, but itself is a large and complex issue for the island. An additional future project could also continue to aid the Town of Nantucket in exploring an electric public transportation option and relieve downtown congestion.

This project provided the team with valuable experience in conducting professional interviews, constructing and distributing a survey, and modeling a scenario using a data-driven tool. The project team gained additional skills in working cooperatively in a group and with a town government agency.

# Chapter 1: Introduction

The transportation sector generates 1.8 billion metric tons of carbon emissions annually, which is 26% of total emissions (Hill, 2016, U.S. Environmental Protection Agency, 2014). This is in part due to the fact that gasoline and diesel fuels provide 92% of the energy used in the transportation sector (The National Academy of Sciences, 2016). In order to reduce carbon emissions, alternative renewable energy sources such as solar and wind based energy generation have been explored to provide energy for the transportation sector and the energy grid that supports it.

Within the transportation sector, the use of electric vehicles (EVs) has grown as a sustainable alternative to internal combustion powered vehicles due to lower lifetime carbon emissions. Although EVs produce more emissions when they are manufactured than gasoline powered vehicles, they generate minimal or even zero-emissions when driven. As a result, the initial emissions manufacturing deficit can be offset after 6 to 16 months of average driving (Union of Concerned Scientists, 2015). The limited emissions associated with electric vehicle driving are due to the use of carbon-based fuels in power plants, which generate the electrical power needed to charge and EV. Power generation plants operate at 40% efficiency on average whereas gasoline vehicles achieve 14%–30% percent (U.S. Department of Energy). However, the use of carbon based fuels in power plants and the resulting emissions related to driving an EV are projected to decrease based on national data from 2013 to 2015 (Union of Concerned Scientists, 2015).

Although the benefits of electric vehicle use are clear from an environmental standpoint, a variety of other factors can influence the overall challenges and benefits of increased EV use. For example, when considering whether to purchase an EV, many individuals exhibit “range anxiety,” where the customer believes that the distance an EV can travel per charge may not be sufficient for their needs. However, studies suggest that 87% of day-to-day travel can be made in an electric vehicle, and that the few exceptions to this rule are longer trips that could be made with a shared or limited-use gasoline powered vehicle (Needell et al., 2015). Electric vehicles also typically have better fuel economy and fuel availability than their gasoline powered counterparts. Although electric vehicles take longer to recharge than simply refueling a gasoline tank and charging stations are less abundant than gas stations, today most EVs can achieve 100 miles per gallon equivalent, and the number of EV charging stations is rapidly growing due to the omnipresent electric grid (Alternative Fuels Data Center, 2016).

As a result of the long-term benefits of the use of EVs, many state and local governments launched initiatives to promote the ownership and responsible use of electric vehicles. These initiatives have included monetary incentives for purchasing an EV and incentives for charging during off-peak hours. For example, the town of Braintree, Massachusetts incentivized its residents to purchase electric vehicles by offering free test drives and pre-negotiated deals with local car dealerships, making the process of buying an EV easier and the consumers more informed (Braintree Drives

Electric, 2016). In addition, the Braintree town government has offered \$250 to residents for installing an approved “smart” home charger to power the vehicle overnight (Libon, 2016). On a state level, the Massachusetts Electric Vehicle Incentive Program encourages municipalities to transition to electric vehicles by providing financial incentives to local agencies that shift their fleets to electric and hybrid vehicles (MassDEP, 2016). In addition to state and local government incentives for shifting municipal fleets to electric and hybrid vehicles, private companies such as Foothill Transit and Downtowner have provided public transportation options at little or no cost to the consumer in the form of electric buses and electric midsize vehicles, respectively (Foothill Transit, Downtowner, 2016). These programs demonstrate that electric vehicles can be a cost effective and environmentally friendly form of transportation.

### **Energy Use and EVs on Nantucket**

Nantucket, Massachusetts presents a unique environment for the possible encouragement of electric vehicles due to its fluctuating population and energy needs, and its limited electrical energy supply. In particular, Nantucket’s strong tourism industry draws approximately 400,000 yearly visitors, the vast majority of whom visit during the peak summer tourist season months of late June to early September. During this time, electrical energy consumption increases accordingly, with peak electrical use in the summer reaching 48 megawatts (National Grid, 2016). However, Nantucket’s geography poses unique energy concerns. For example, gasoline must be imported to the island via ferry, driving the cost of fuel substantially higher than mainland costs to as high as \$4.50 per gallon (Nantucket Energy Office, 2016). Electricity, on the other hand, is supplied to the island by two undersea power transmission cables with a combined electrical capacity of 74 megawatts, and the cost of electricity on the island is only ~0.5-1.0 cents/kWh higher than on the mainland as a result of the cable surcharge (National Grid, 2016). The coupling of high summer electrical energy demand and limited energy resources creates a challenge for Nantucket, particularly as peak electrical use has grown at a rate 5 times that of mainland Massachusetts (Nantucket Energy Office, 2016).

Given the conflicting island circumstances of high gas prices and limited electrical supply, it is important to study the effects of using and encouraging electric vehicles on Nantucket. A key stakeholder in this study is the Nantucket Energy Office (NEO), founded in 2011 to “assist the Town in identifying and implementing energy efficiency, conservation, and renewable energy programs that are economically viable, environmentally responsible, and socially respectful” (Nantucket Energy Office, 2016). The primary efforts the NEO are focused on includes programs to reduce energy costs, recommend energy related policies, reduce energy waste, and serve as a resource and liaison to companies like National Grid (Nantucket Energy Office, 2016).

**Project Focus**

The purpose of this project was to study the data available on EV adoption rates, as well as EV adoption and plans by island residents and visitors, and to predict how EV use will increase on the island in both the short term and long term. This project was also focused on determining the current state of the EV-supporting charging infrastructure on Nantucket and offer recommendations on how that infrastructure should be expanded to support the predicted EV adoption rate on the island. An additional focus was exploring potential systems for electric public transportation on Nantucket. Finally, the project team attempted to predict the impacts of greater EV use on the island's energy supply, and subsequently recommend procedures to promote responsible electric vehicle charging.

## **Chapter 2: Background**

The advancement of technology in the modern world has created both problems and solutions to the global issue of climate change. In the automotive industry, electric vehicles (EVs) have arisen as a viable alternative to petroleum fueled vehicles. However, a number of challenges have yet to be overcome before widespread EV use is feasible on a national level. Among these challenges are the ability of EVs to meet the needs of the population, the development of national infrastructure to support large-scale EV use, and financial payoff for companies, government organizations, and individual owners. In order to understand and overcome these challenges in any place where EVs may be promoted, it is necessary to examine the costs and benefits that electric vehicles will have in a given location.

The island of Nantucket presents a unique environment for increased use of EVs, and the Nantucket Energy Office is exploring the potential impacts of more EVs on the town's electrical energy capabilities. In order to assist with this study, we will describe in the background chapter the environmental, technological, political, and socioeconomic factors influencing the growth of electric vehicle use in the United States. In turn, we hope to apply these concepts to Nantucket by considering characteristics that are specific to the island.

### **2.1 - Electric Vehicles**

Historically, in the late 1800's the primary mode of transport preceding automobiles was the horse drawn carriage. At the time, the electric vehicles' only competitors were steam and gasoline powered vehicles, but the state of operation for steam and gasoline vehicles was crude and cumbersome. Electricity, on the other hand, was a resource that was only available to city residents. Considering this, the electric vehicle still represented over one third of the nascent automobile industry.

By 1911, continued improvements to the gasoline-powered car made it more practical and affordable than steam and electric vehicles for general transportation. The invention of the starter motor and oil discoveries in Texas also made the gasoline vehicles easier to operate and more practical for long distance driving. The lack of infrastructure for electric vehicles also led to the extinction of a technology that was inherently easier to use and less complex mechanically than gasoline or steam vehicles. The electric vehicles' critical downfalls were the limited access to electricity for charging the vehicle's battery and the lack of driving range due to the primitive battery technology (U.S. Department of Energy, 2014).

In comparison to the early 1900's, the electric vehicles of today can compete with gasoline vehicles in every category of private automobile performance, excluding towing and off-road capabilities, and have even been developed for commercial applications. As a result, the number of electric vehicles, including all-electric and plug in hybrids, increased by 70 percent from 2014 to 2015 (International Energy Agency, 2016).

With a better understanding of the infrastructure and operational needs for electric vehicles to be successful, the technology and investments necessary to accommodate them can be developed. If the infrastructure and technology is improved then the concerns and reservations associated with electric vehicle adoption will be alleviated and lead to an industry of sustainable and environmentally responsible transportation.

### 2.1.1 - History of Electric Vehicles

The exact birthplace of the electric vehicle cannot be precisely distinguished. However, the electric vehicle's creation can be attributed to breakthroughs in the 1800s - in particular the invention of the electric battery and electric motor (U.S. Department of Energy, 2014). Many inventors tinkered with the concept of the electric car, but it wasn't until the mid-19th century that the first practical electric vehicles were invented.

In the U.S. the first successful electric vehicle emerged around 1890, invented by William Morrison, a chemist who lived in Des Moines, Iowa. He created a six-passenger vehicle that could reach a top speed of 14 miles per hour. It "was little more than an electrified wagon, but it helped spark interest in electric vehicles" (U.S. Department of Energy, 2014). Around this time electric vehicles reached their peak, and would remain this way for the next decade. The vehicle in Figure 1 illustrates the style of electric carriage available at the time.

The success of the electric vehicle in the early 1900s can be attributed to the lack of available alternatives. At the time, the only proven alternative was steam power, but it did not serve to be practical for personal vehicles due to long startup times and the need for frequent refilling of water. Gasoline vehicles, on the other hand, were in their infancy and came with many disadvantages, including cumbersome operation, high noise levels

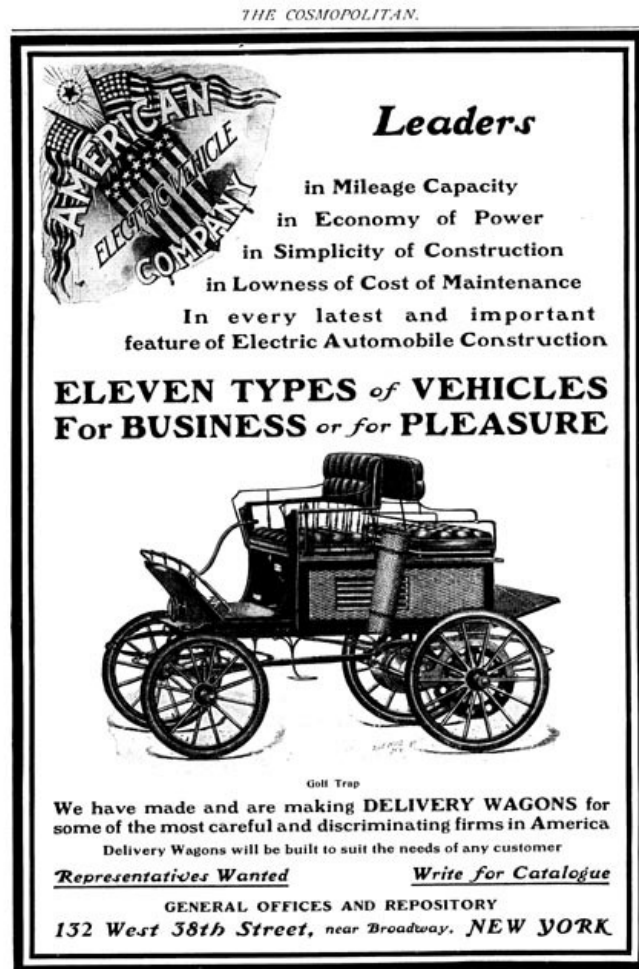


Figure 1: 1900's Electric Vehicle Advertisement  
(<http://my.ece.msstate.edu/faculty/jwbruce/EVads/>)

and unpleasant exhaust fumes. This left buyers with one remaining option: the electric car.

Electric vehicles did not have many of the inconveniences of their steam or gasoline counterparts. Electric vehicles were easy to drive and quiet in operation. These traits made them a popular choice for urban commuters. Inventors around the world took note of the electric cars' popularity and began developing and making improvements to different aspects of the vehicle such as the battery and electric motor. Specifically, "Thomas Edison, one of the world's most prolific inventors, thought electric vehicles were the superior technology and worked to build a better electric vehicle battery" (U.S. Department of Energy, 2014). He collaborated with Henry Ford to build a more practical and affordable electric vehicle.

Although the electric vehicle had many benefits, an electric vehicle was expensive to purchase. In 1908 when the Model T made its debut, being the first mass-produced and affordable gasoline car, the electric vehicle market declined due to the cost differences and improvements in gasoline-powered vehicles. At this time the gasoline car cost \$650 on average, where the electric car cost \$1750 (U.S. Department of Energy, 2014).

Along with the decrease in gasoline vehicle prices, many of the inconveniences of driving gasoline vehicles were addressed. In 1912, the electric starter motor was introduced, making it easier for anyone to operate a gasoline powered vehicle. The U.S. development of better roadways also made gasoline vehicles more desirable, due to their longer driving range capabilities. Crude oil found in Texas at the turn of the century led to a decrease in gasoline prices and gas stations began to emerge all across the country, making it convenient for anyone to fill up their tank or service their vehicle. In contrast, only city residents had access to electricity at the time. The inaccessibility of electricity, along with the invention of the starter motor, led to the extinction of electric vehicle by the 1920's.

Gasoline vehicles prospered for the next 50 years until the supply of oil became an issue. The Arab Oil Embargo of 1973 further drove the search for oil in the U.S. and interest in furthering the development of electric vehicles. The price of fuel rose, "Congress took note and passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, authorizing the Energy Department to support research and development in electric and hybrid vehicles" (U.S. Department of Energy, 2014). This led to the slow but promising rebirth of electric vehicles and many improvements were made to allow for their continuing evolution.

### **2.1.2 - Modern Electric Vehicle Technology**

There are three main types of electric vehicles: all-electric vehicles (EVs, also known as Battery EVs, or simply BEVs), electric vehicles (HEVs), and plug-in hybrids (PHEVs). These vehicles produce fewer emissions than their petroleum counterparts by taking advantage of the efficiency of electric motors and high efficiency batteries for energy storage.



Electric vehicles use stored energy from onboard batteries to power an electric motor in order to propel the vehicle. When the battery is drained it can be recharged using a standard wall outlet or a dedicated charging station. Electric vehicles are also extremely efficient due to design advantages, including regenerative braking and high efficiency when not moving - the equivalent of a conventional vehicle shutting off the engine when idling. Regenerative braking is the process by which the electric motor harnesses the kinetic energy of the moving vehicle in order to charge the battery and in turn brings the car to a stop. In this process, when the user releases the drive pedal, the vehicle uses the motor to slow the car and recharge the battery rather than using conventional brake pads. Furthermore, electric vehicles do not consume much power when stopped; the electric motor simply stops and does not need to idle like most conventional vehicles.

Modern EVs generally have range capabilities adequate for most commutes. According to the Union of Concerned Scientists, “Fully-charged, most battery electric cars have a driving range of between 70 to 100 miles, well within the day-to-day range requirements of most Americans, though some BEVs can go up to 265 miles on a single charge.” These ranges are often higher on average for HEVs and PHEVs, so for individuals with a higher range requirement, these vehicles are a suitable option.

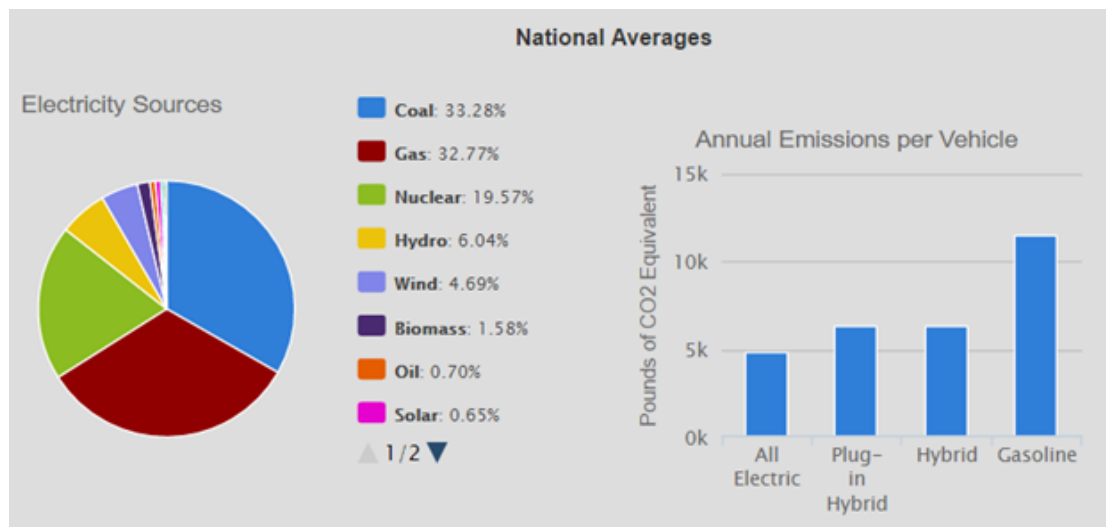
Hybrid electric vehicles are similar to EVs, however they typically have a small gasoline engine on board. This engine is used in tandem with the electric motor to either provide power directly to the wheels or charge the battery of the vehicle in order to extend the range. The vehicle actively switches between using the electric motor, the gasoline engine, or the two simultaneously, depending on the driving situation. Conventionally, when an HEV is in city driving conditions or in heavy traffic situations, it almost entirely relies on the electric motor. However, when the vehicle is in more demanding terrain, such as an uphill climb, it will utilize the gasoline engine or both the electric motor and gasoline engine. The goal of a HEV is to use the electric motor as frequently as possible to cut down on fuel usage and reduce its overall emissions output.

Plug-in hybrid electric vehicles generally have larger batteries compared to HEVs, but smaller than EVs, and can be plugged in to charge the battery. PHEVs contain a gasoline engine that typically does not directly power the wheels; its main purpose is to extend the vehicle's range by charging the battery. This is achieved by using the gasoline engine to power a generator to charge the battery when it drops below a percentage established by the manufacturer. The main differentiating factor between a traditional hybrid and a plug-in hybrid is the ability to plug in the PHEV in order to charge the battery. PHEVs, like HEVs, also utilize the inherent efficiencies of an electric motor to propel the vehicle, and in turn create an overall more efficient mode of transport and reduce emissions.

### 2.1.3 - Environmental Effects of Electric Vehicles

In recent decades, the continued use of petroleum-based energy is becoming widely seen as unsustainable in the long-term; as a result, more efficient energy consumption and effective energy alternatives are being investigated and developed. Among these alternatives is the shift away from gasoline-powered vehicles towards more environmentally friendly, zero-emission electrically powered vehicles.

Plug-in hybrid electric vehicles generally have larger batteries compared to HEVs, but smaller than EVs, and can be plugged in to charge the battery. PHEVs contain a gasoline engine that typically does not directly power the wheels; its main purpose is to extend the vehicle's range by charging the battery. This is achieved by using the gasoline engine to power a generator to charge the battery when it drops below a percentage established by the manufacturer. The main differentiating factor between a traditional hybrid and a plug-in hybrid is the ability to plug in the PHEV in order to charge the battery. PHEVs, like HEVs, also utilize the inherent efficiencies of an electric motor to propel the vehicle, and in turn create an overall more efficient mode of transport and reduce emissions.



**Figure 2: National Averages of Electrical Power Sources and Respective Vehicle Emissions**  
([http://www.afdc.energy.gov/vehicles/electric\\_emissions.php](http://www.afdc.energy.gov/vehicles/electric_emissions.php))

The data provided by National Grid, as shown in Figure 2, clearly illustrates a substantial decrease in emissions of EVs as compared to standard vehicles. With that said, these numbers are driven by the emissions of the generated electricity and improvements can be made by means of cleaner energy production. For example, in comparison to the national average, California's emissions of all electric vehicles drops to 2,706 pounds of CO<sub>2</sub>, nearly 44 percent less than the national average. This change is attributed to the fact that in the state of California, solar, hydro, geothermal, and wind power generation contribute to over 27 percent of the total state electrical generation infrastructure. Furthermore, the state's use of coal is down over 99 percent compared to the national average, equating to a large decrease in CO<sub>2</sub> emissions.

Although electric vehicles have demonstrated environmental benefits relative to gasoline vehicles, a more in-depth analysis is necessary to accurately assess the environmental impact EVs have not only when they are driven, but throughout the lifecycle of the vehicle. In 2015, the Union of Concerned Scientists (UCS) released a report on the lifelong emissions of battery electric vehicles (BEVs) in comparison to similar gasoline powered vehicles. In the Executive Summary, the Union presents a scope of the environmental impacts and benefits of using BEVs “from cradle to grave,” meaning from manufacture through use and disposal. It was explained in this report that despite a generally higher emissions cost to manufacture BEVs, the lack of gasoline consumption allows overall emissions to “break even” relatively early in the life of the BEV. More specifically, the emissions associated with manufacturing a mid-size BEV average 15% more than its gasoline-powered counterpart, while this figure increases to 68% for a full-size BEV. Despite this initially poor environmental impact, manufacturing related emissions are offset by 4,900 miles of driving in a mid-size BEV, and 19,000 miles in a full-size BEV, which equates to about 6 and 16 months of average driving, respectively. This implies that the remainder of the vehicle's lifetime is spent reducing driving related emissions relative to a gasoline vehicle, and that the environmental benefit increases with greater vehicle use.

Additionally, the UCS report outlines future goals for decreasing the emissions profile of EVs and suggests actions in public policy, government regulations and incentives to achieve these goals. The most important factor in increasing the environmental benefits of EVs is the amount of energy generated from renewable sources. Coal and natural gas together are the sources of most electricity generation today, each producing 33% of electrical power in the U.S. (Alternative Fuels Data Center, 2016). This means that in addition to all other electricity that is consumed, power used to charge EVs is derived from nonrenewable fuels. While the overall use of these fuels is considerably less than in a gasoline-powered vehicle, it still contributes to adverse effects on climate and ecosystems. In order to mitigate climate effects, public policy and economic incentive must drive power sources toward increased use of renewable energy, particularly solar and wind (Union of Concerned Scientists, 2015).

The Union of Concerned Scientists found that an energy grid powered by renewable sources is key to increasing the effectiveness of BEVs. According to their projections, a grid that was powered by 80% renewable sources versus the current 5% would decrease the manufacturing emissions of BEVs by 25% (Union of Concerned Scientists, 2016). However, a shift in industry this large is unlikely to occur without supporting government policies and incentives for private companies. Such a shift would be most effectively aided by strong state policies and comprehensive plans to meet emissions reduction targets. Carbon pricing mechanisms and setting new standards in clean electricity are other possibilities in green policy, as they would lend support to a more renewable energy grid. For electric vehicles specifically, the greatest benefit would

come from both government and private efforts to develop batteries that require less resources to manufacture (Union of Concerned Scientists, 2015).

#### **2.1.4 - Effects of EVs Charging on the Grid**

The growth of plug-in electric vehicles may result in increased demand on electric grids. “The electric power industry expects a 400% growth in annual sales of plug-in electric vehicles by 2023, which may substantially increase electricity usage and peak demand in high adoption areas” (U.S. Department of Energy, 2014). Utility companies hope to better understand the trends of electric vehicle growth in order to make the necessary investments to improve electrical infrastructure. Investments will need to be made strategically in order to see promising returns while maintaining adequate power capabilities. The U.S. Department of Energy’s Smart Grid Investment Grant (SGIG) looks to analyze this issue with six utility companies.

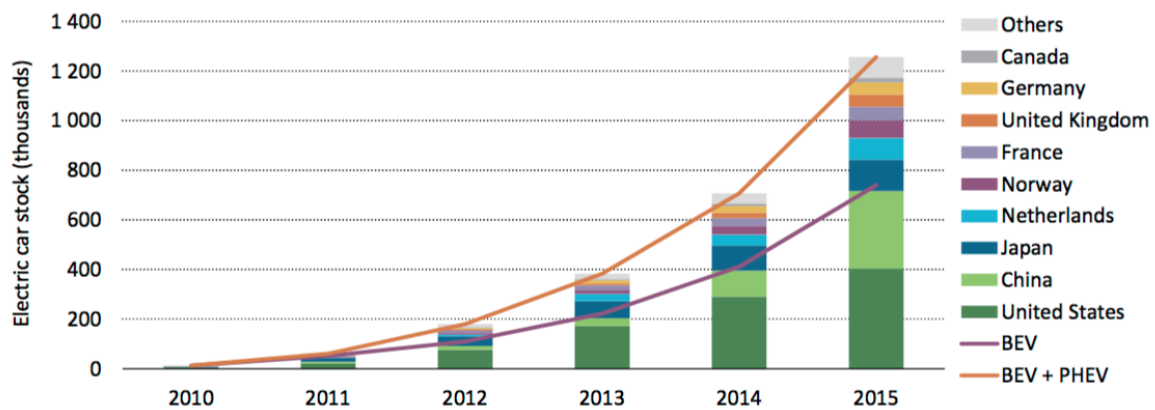
- Burbank Water and Power (BWP)
  - Duke Energy (Duke)
  - Indianapolis Power & Light Company (IPL)
  - Madison Gas and Electric (MGE)
  - Progress Energy (now part of Duke Energy as a result of a merger in 2012)
  - Sacramento Municipal Utility District (SMUD)
- (U.S. Department of Energy, 2014)

Relative to the utility companies’ scale of operation, the low number of electric vehicles on the road today do not serve as a realistic example of potential grid effects in the long run. In order to better understand potential challenges, the project set out to analyze the trends of a small group of public chargers and users. The utility companies approached the project in various ways, but their primary goal was as follows: “the technical performance of the charging systems, the potential grid impacts of charging during peak periods, and the potential need for distribution system upgrades and capacity additions to meet expected electricity demand growth from rising adoption of plug-in electric vehicles” (U.S. Department of Energy, 2014). The project results showed inconsequential effects on the grid; however, it did serve as useful data to predict usage trends in order to make the necessary accommodations for increased adoption.

#### **2.1.5 - Electric Vehicle Market and Projections**

As a result of the environmental benefits of electric vehicles, they have become increasingly popular. At the end of 2015, there were 1.26 million EVs globally, almost double of what existed the year before. Ten years before that, the total number was still measured in hundreds. Figure 3 shows the evolution of global EV stock since 2010, broken down by year and country. The United States, as well as China, Japan, the

Netherlands, and Norway account for 80% of the EVs on the road in 2015, with the US and China being the largest contributors (International Energy Agency, 2016).



**Figure 3: Evolution of the Global Electric Car Stock, 2010-15**

([https://www.iea.org/publications/freepublications/publication/Global\\_EV\\_Outlook\\_2016.pdf](https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf))

This growth is expected to continue, especially if further policy to encourage electric vehicle purchases by individuals, and adoption by communities, government entities, and businesses is passed. This includes financial incentives and additional constriction on fuel usage and emissions regulations, which have already contributed to the sudden growth of EVs in the past decade. Increasingly higher power batteries, and publicly accessible charging stations have also contributed to this growth, and it is expected that they will continue to do so as technology advances (International Energy Agency, 2016).

### 2.1.6 - Electric Vehicles in the United States

Electric vehicles were reviewed by the United States government following the enactment of the Federal Clean Air Act Amendments of 1990, which required states to limit regional air pollution. This policy led to electric vehicles being seen as an effective method of reducing gaseous emissions. Of the many states that enacted their own laws to meet the standards of these Amendments, California was seen as the state taking the greatest measures to transition to zero-emission vehicles. The state mandated that by 1998, two percent of all vehicles must be zero emission, with an ultimate goal of ten percent by 2003. In addition to this, there was a \$262 million partnership between the U.S. Department of Energy and the automobile industry, with a goal of developing advanced batteries to power electric vehicles.

Despite legislative measures, the initial effectiveness of the federal government's efforts on the transition to EVs was limited. In a 1994 report titled "Electric Vehicles: Likely Consequences of U.S. and other Nation's Programs and Policies," many barriers are presented to the introduction of electric vehicles, including technological limitations, high prices, and gaps in current infrastructure. The report additionally highlighted the

fragmentation of U.S. funding and policies across multiple departments and levels of the government, placed in contrast to the more coordinated and commercialized efforts of other nations. Federal efforts did not yet have a cohesive way to fund and implement the shift to EVs, while state mandates brought about concern of creating an artificial market for EVs. The overall tone of the report can be characterized by this excerpt from the Results in Brief:

“The range and diversity of electric vehicles’ economic, energy, and environmental effects suggest that they could not solve all transportation and environmental problems even if they were available immediately. Yet, without comprehensive support, they are not likely to achieve enough success to contribute at all to increasing energy security and decreasing air pollution.”  
(Chan, 1994)

In contrast, today’s advances in technology, more organized government efforts, and a growing body of knowledge about electric vehicles in the past twenty years have led to increased possibilities for EV adoption. In a recent MIT study, it was found that “the energy requirements of 87% of vehicle-days could be met by an existing, affordable electric vehicle” (Needell et al., 2016). This evaluation shows that current EV range is able to meet the transportation needs of the population, with a few exceptions. Instances such as road trips or moving can contribute to “range anxiety,” or the public’s aversion to electric vehicles due to the fear of not having enough range to make the trips they need. However, the study suggests that the use of gasoline-powered vehicles could be limited to only using them when necessary, such as sharing a truck that would only be used for moving material over long distances. Meanwhile, individually owned electric vehicles would be able to meet average daily transportation needs.

## **2.2 - Public Transportation Programs**

Electric and hybrid public transportation is beginning to emerge across the country. Transport companies, such as Foothill Transit, a California based company, are replacing their old gas powered vehicles with all-electric vehicles. All electric fleets can save a substantial amount of money annually. For example, the Foothill Transit battery electric buses (BEBs) cost \$0.02 per mile in maintenance cost, compared to compressed natural gas (CNG) buses, which are \$0.08 per mile (Eudy et al., 2016). Furthermore, electric vehicles have inspired new types of transportation, like Downtowner, which provides a new twist on the taxi system.

Foothill Transit has been working on replacing their fleet with BEBs and hopes to complete this transition by 2030 (Foothill, 2016). In 2010, Foothill Transit performed a demonstration where they replaced three of their buses with BEBs. The goal of the demonstration was to assess the durability and range of the BEBs and to make sure the buses could handle Foothill Transit’s bus routes. The demonstration was determined to be

so successful that the company purchased 12 additional BEBs, which were fully operational by 2014. Since then, Foothill Transit has been collecting data (Table 1) to see how the BEBs are comparing to other bus options. Foothill Transit chose CNG buses in order to obtain a qualitative comparison. The CNG buses were chosen because of their specifications, such as sizes, weights, and years, closely match those of the BEBs. (Eudy et al., 2016)

**Table 1: Data Comparing BEBs and CNGs**  
(Eudy, L., Prohaska, R., Kelly, K., & Post, M. (2016, January 27). Foothill Transit Battery Electric Bus Demonstration Results. National Renewable Energy Laboratory, Vi-Xi. doi:10.2172/1237304)

Data Item	BEB	CNG
Number of buses	12	8
Data period	4/14–7/15	10/14–7/15
Number of months	16	10
Total mileage in period	401,244	364,373
Average total miles per bus	33,437	45,547
Average monthly mileage per bus	2,333	4,555
Total operating hours	47,462	—
Availability (85% is target)	90	94
Fuel economy (kWh/mile or miles/GGE <sup>a</sup> )	2.15	4.04
Fuel economy (miles/DGE <sup>b</sup> )	17.48	4.51
Average speed (mph)	10.6	17.6
Miles between roadcalls (MBRC) – bus	9,331	45,547
MBRC – propulsion system only	25,078	91,093
MBRC – ESS <sup>c</sup> only	133,748	—
Total maintenance (\$/mile) <sup>d</sup>	\$0.16	\$0.18
Maintenance – propulsion system only (\$/mile)	\$0.02	\$0.08

<sup>a</sup> Gasoline gallon equivalent.

<sup>b</sup> Diesel gallon equivalent.

<sup>c</sup> Energy storage system.

<sup>d</sup> Work order maintenance cost.

As shown in Table 1, there are only three areas where the BEBs seem to be different in comparison to CNG buses. The first two are average speed and average total miles per bus during that trial period. These significant differences can be explained by the actual length of the routes; CNG buses ran on longer routes while the BEBs ran on shorter routes due to the BEBs' lower range capabilities and more efficient operations, especially during stop and go operations. The last point where the BEBs were significantly different than the CNG buses was the miles between road calls (MBRC), shown in Table 1. According to the report Foothill Transit Battery Electric Bus Demonstration Results, "a road call ... is defined as a failure of an in-service bus that causes the bus to be replaced on route or causes a significant delay in schedule" (Eudy et al., 2016). Although the MBRC for BEBs is significantly lower than CNG buses, Foothill Transit considered the BEBs a success. This MBRC statistic along with the impressively high MBRC for electric storage systems (ESS) specifically are "...exceptional for an advanced technology bus in the early stage of commercialization." There were only three road calls regarding the ESS the whole trial period (Eudy et al., 2016).

The BEBs fuel economy and maintenance costs were significantly better than the CNG buses: the BEBs get about four times more miles per diesel gallon equivalent than

the CNG buses and save about 75% on propulsion system maintenance cost per mile. Overall this data suggests that the BEBs are definitely a viable busing alternative for the Foothill Transit's routes (Eudy et al., 2016).



**Figure 4: Bus Docked at Fast Charging Station**

(Eudy, L., Prohaska, R., Kelly, K., & Post, M. (2016, January 27). Foothill Transit Battery Electric Bus Demonstration Results. National Renewable Energy Laboratory, Vi-Xi. doi:10.2172/1237304)



**Figure 5: Overhead Fast Charging Unit**

(Eudy, L., Prohaska, R., Kelly, K., & Post, M. (2016, January 27). Foothill Transit Battery Electric Bus Demonstration Results. National Renewable Energy Laboratory, Vi-Xi. doi:10.2172/1237304)

The most critical challenge Foothill had with the BEBs was that all of the buses had to be charged relatively frequently. To address this challenge, Foothill Transit installed a fast overhead charging station with two chargers (Figure 4 and 5) at the midway point of each route and planned for layover time so the bus could be charged. If completely discharged, the bus should fully charge in about 10 minutes. However, layover times lasted only about 5 minutes, so charging did not delay the buses as much as Foothill Transit had expected (Eudy et al., 2016). These chargers cost about \$350,000 each and \$300,000 to install. However, the cost of these chargers continues to drop as technology improves (Eudy et al., 2016).



There are other unique public transportation options that have surfaced since the idea of electric public transportation. An example of this is Downtowner, which is a company that is currently in five cities and shuttles people around a small area or the last mile of the commute. The radius of this area depends on what the municipality deems fit for the service. The passengers use an app to request a vehicle and the closest available one picks them up (Downtowner, n.d.). The vehicles the company uses (Figure 6) are street legal golf carts, with an operational cost of about \$0.03 per mile. Depending on the configuration and battery size, these vehicles can go anywhere from 25 to 65 miles on one charge (Polaris, n.d.). In these five cities, Downtowner has greatly reduced traffic in congested areas. Although it only operates within a smaller area, it has made an impact and could be applied to other communities (Downtowner, n.d.).



**Figure 6: Downtowner Electric Vehicles**  
(<http://www.ridedowntowner.com/>)

## 2.3 - Incentive Programs

Incentives are the most common way to increase the adoption of electric vehicles and have, in general, had a positive impact on electric vehicle adoption (Langbroek et al., 2016). However some incentives are more effective than others. The most effective incentives were found to be grants and rebates that decreased the initial cost of the vehicle (Langbroek et al., 2016).

Electric vehicles are generally more expensive than conventional vehicles. Incentives in the form of rebates make it much easier for people to make the initial investment. The incentives that proved to be least effective were the traffic and parking incentives because they tended to increase traffic in already congested areas, making the incentives counterproductive. The traffic incentives are also very location specific so they are only benefitting people within a certain area (Langbroek et al., 2016).

### **2.3.1 - Federal Incentive Programs**

The Federal government is trying to encourage the use of electric vehicles on a national level by providing tax breaks for people who have purchased electric vehicles. Any all-electric or plug in vehicles purchased on or after 2010 can be eligible for up to \$7500 in tax credit, which can vary based on the capacity of the vehicle battery (DMV, n.d.).

Tax incentives are not considered very effective in promoting electric vehicle purchases. The largest problem people have with purchasing electric vehicles is the upfront cost and tax credits do not directly address that disadvantage of electric vehicles directly (Langbroek et al., 2016).

The US government has recently been taking steps towards a cleaner environment by addressing climate change, reducing oil dependence and increasing access to greener technologies. This year, the US Department of Energy (DOE) sponsored the first Sustainable Transportation Summit (STS), a meeting where transportation and mobility leaders get together to discuss how the transportation system, on national level, can eventually be converted to all-electric (U.S Department of Energy, 2016). In the first meeting, the group decided on a new set of principles they called the “Guiding Principles to Promote Electric Vehicles and Charging Infrastructure” (Office of the Press Secretary, 2016). These principles have been signed by nearly fifty organizations and have a primary goal of ensuring that all electric vehicle owners will have the ability to charge at home, work, and for public charging stations to be more commonly found. The group plans on achieving their goal by:

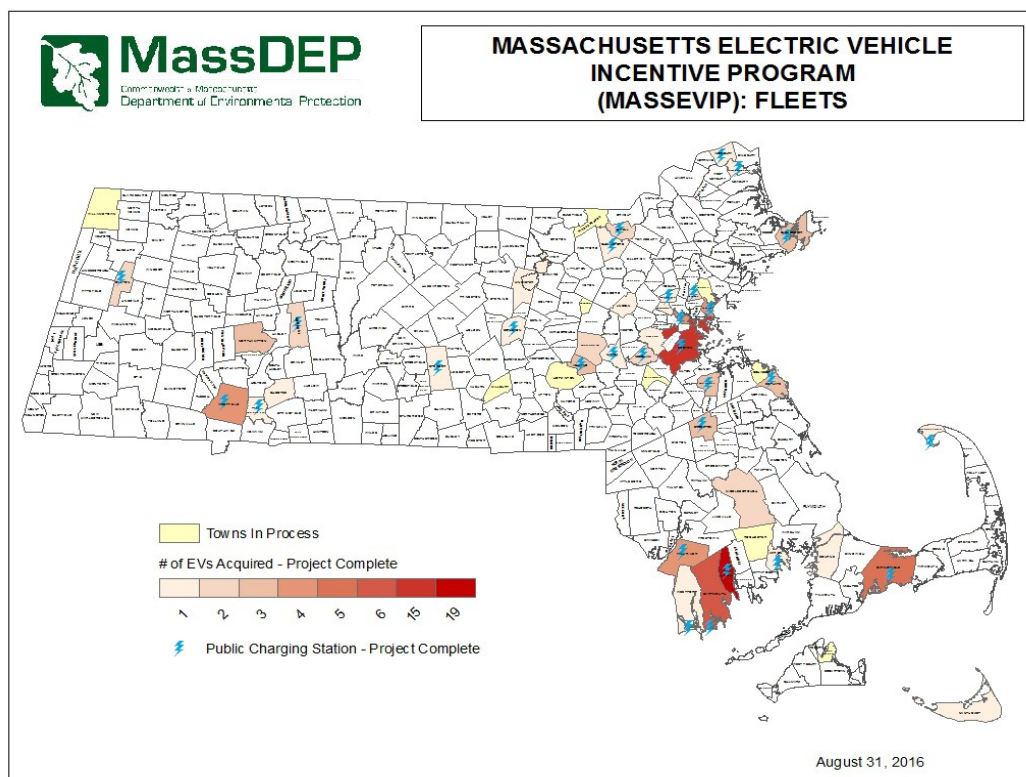
- Giving loans and grants to support innovative electric vehicle charging facilities,
- Installing more fast charging stations and infrastructure
- Encourage states, counties, and municipalities to work with the Federal government to get electric vehicle fleets at discounted prices
- Host electric vehicle awareness events
- Publish guides containing all of the information and policies of this program, and obtain more signatures on the “Guiding Principles to Promote Electric Vehicles and Charging Infrastructure” (Office of the Press Secretary, 2016)

The electric vehicle infrastructure in the US has improved greatly in the last eight years. In that time, the number of plug-in electric vehicle models increased from one to more than 20, battery costs have decreased 70 percent, and the number of electric vehicle charging stations has increased from less than 500 in 2008 to more than 16,000 today. However, the Department of Energy feels there is still room for improvement (Office of the Press Secretary, 2016).

### 2.3.2 - Massachusetts Incentive Programs

Massachusetts has recently been working with its communities to become more environmentally friendly, especially to promote electric vehicles. To encourage their communities to participate, the Massachusetts government developed the Massachusetts Electric Vehicle Incentive Program (MassEVIP). The Massachusetts Department of Environmental Protection (MassDEP) created this program to encourage electric vehicle use. Since its creation in 2013, the program has been operating in phases, on a first come first serve basis, as funding has become available. Figure 7 portrays all of the communities that have taken advantage of this program as of August 2016.

One of the most pertinent phases has been [MassEVIP: Fleets Phase III](#). This phase specifically provides incentives to eligible municipalities to implement electric vehicles, hybrids, zero-emission electric motorcycles and charging stations. This program will only give grants for specific models of electric vehicles so the community in question must choose from that list. Once communities apply and receive approval, they are required to sign an End-User Agreement (EUA) and have 180 days to acquire the vehicles and install the charging station. The program will apply the incentives directly to the vehicle and/or to the charging station company, depending on their needs (MassDEP, 2016). This program has benefitted many communities so far, as portrayed in Figure 7 (MassDEP, 2016), and is actually considered the fifth best electric vehicle incentive program in the country (Cobb 2016).



**Figure 7: Communities That Have Implemented the MassEVIP Program**  
(<http://www.mass.gov/eea/agencies/massdep/air/grants/massevip-municipal.html>)

Another program that Massachusetts provides is the [Massachusetts Offers Rebates for Electric Vehicles \(MOR-EV\)](#) program. Since 2014, this program has offered rebates to individuals and/or businesses that wish to switch over to electric vehicles. Rebates can be anywhere from \$750 to \$2500. The state has issued about \$3.8 million for 1,606 vehicles and has cut Massachusetts gas emissions by about 4500 tons annually. Due to all of the incentive programs they have in place, Massachusetts is well on its way to a cleaner environment.

Some communities in Massachusetts have taken advantage of these incentive programs (Figure 7) but some have also implemented electric vehicle programs of their own. The Braintree Electric and Light Department (BELD) created the Braintree Drives Electric (BED) initiative. The goal of this initiative is to promote electric vehicles and to provide awareness of economic incentives to the public. People who participate in the program can earn up to 175 free miles a month if they charge overnight at off peak hours and use an at home smart charger (Libon, 2016).

## **2.4 - Nantucket Energy**

Energy is a term that encompasses power delivered by chemical or physical means. For example, the burning of gasoline or coal is used to convert stored energy within the material to usable energy. These methods in which energy was first harnessed was manageable and adequate; however, it was not environmentally responsible. The innovative ways in which we can now harness energy is sustainable and environmentally conscious but the implementation is costly and the technology is still in its infancy. Solar, wind and geothermal energy, although eco-friendly, have a low power output in comparison with coal or oil. These environmentally sound solutions generally utilize more space and are more expensive per unit of power to implement compared their fossil fuel counterparts. These characteristics may make renewable technologies seem less feasible, yet with large scale implementation the cost decreases and the technology continues to improve over time.

The island of Nantucket poses an additional challenge due to its geography. The issues associated with energy are compounded when you have a limited electrical supply. Additional barriers arise due to the island's historical significance. The issue at hand is that in order for renewable forms of energy to be implemented, they must seamlessly integrate with Nantucket's historic architecture.

### **2.4.1 - Nantucket's Energy History**

Energy on Nantucket began in the Whaling Era when settlers realized the potential of whale oil, and Nantucket quickly became a global energy supplier. The oil was used to power lamps and other machines. Nantucket whalers succeeded in this industry until the year 1840 when the Island's isolated geography resulted in higher costs

that no longer made the Nantucket Whaling industry competitive compared to direct rail transport at the mainland and the added cost of shipping whale oil to the mainland. However, the island's isolation, although causing the demise of that industry, presented a certain mystique that lured residents and annual vacationers (Nantucket Energy Office, n.d.).

Electrical power on Nantucket in the late 1800s through 1996 was generated on island with steam engines followed by diesel generators. Due to the islands 13,000 year round residents and approximately 400,000 annual visitors, these power generation methods proved to be insufficient.

#### **2.4.2 - Nantucket's Current Energy Infrastructure**

Undersea power transmission cables running from Cape Cod currently provide electrical power on Nantucket. The first cable was installed by National Grid in 1996, it was capable of 36MW and cost 30 million dollars. The demand for electrical power quickly surpassed this cable's capabilities and a second cable was installed in 2006. This cable was capable of providing 38 MW and cost 41 million dollars.

The problem lies in the fact that "in recent years, Nantucket's demand for electricity has increased significantly. On July 23 2013, Nantucket's energy usage hit an all-time high: 45 MW, a 12.5% increase from the previous record high of 40 MW in 2012" (Nantucket Energy Office, n.d.). This demand exceeds the capabilities of any one cable. Therefore, if one cable were to fail during the summer season there would be outages across the island. This hasn't proven to be an issue thus far, but the island is taking initiatives to reduce energy consumption and delay the need for a third cable.

National Grid is calling their energy conservation initiative the "non-wires alternative," the goal is to conserve energy by educating and engaging customers to change energy habits. This will be achieved by "time-varying rate structures, [and] a voluntary program in which customers would allow National Grid to control their thermostat and air conditioning units" (Graziadei, 2014). National Grid's primary solution, however, is the implementation of renewable resources such as wind and solar. Nantucket's environment is suitable for these kinds of energy generation technologies but the island's historical significance poses a challenge when it comes to approving these initiatives.



#### 2.4.4- Electric Vehicle Infrastructure on Nantucket

In October of 2010, the Massachusetts Division of Energy Resources announced that they would provide grants to communities interested in installing electric vehicle chargers. In December of the same year, the Nantucket Planning and Economic Development Commission worked with private companies, such as Cape Air and ReMain Nantucket, to submit a proposal to receive one of these grants (Pykosz, 2011). The Town of Nantucket subsequently received a grant for five dual charging stations and \$5,000 to install them.

Four different sites were selected and proposed to the Historic District Commission. These sites were the Greenhound Station, behind the Town Hall Annex, the back of the high school, and Hangar 2 at the airport. The Nantucket Planning Department, a project consultant, a local electrician, and an engineer from the National Grid reviewed them for their practicality and feasibility. The commission approved all but the Greenhound Station, as they thought it was not a popular enough location. The others were installed in May of 2012 at the locations tagged in Figure 8 (Electric Vehicles, N.d.).



**Figure 8: Locations of Dual Charging Stations on Nantucket**

(<http://www.ackenergy.org/electric-vehicles.html>)

#### 2.4.5- Initiatives to Increase Electric Vehicle Awareness



**Figure 9: Panamera SE Hybrid Prepared for Test Drive**

(<http://www.ackenergy.org/electric-vehicles.html>)

Since the EV chargers were installed on Nantucket, the town has tried to promote the use of electric vehicles and the chargers. For example, on August 19th, 2013, the Nantucket Energy Office hosted a public viewing and charging demo of two TESLA vehicles. A year later, on August 14th, 2014 the Nantucket Energy Office also teamed up with Porsche to hold a charging demo and provide test-drives of their Panamera SE Hybrid, seen in Figure 9 (Electric Vehicles, N.d.).

Along with the EV chargers and initiatives to promote them, the Town of Nantucket has also begun developing a municipal fleet of EVs, through the MassEVIP Program. In February of 2016, the 2016 Ford Fusion plug-in hybrid was acquired and put to use by the Health Department (Nantucket Energy Office, 2016).

## **2.5 - Background Summary**

On a national level, a variety of factors influence the rate of electric vehicle adoption. Factors to consider include environmental impact, range, current battery technology, government incentive programs, cost, and supporting infrastructure. Nantucket, on the other hand, has additional unique considerations with regards to electric vehicles. Among these are increasing peak electric load, the effect of vehicle charging on the electric grid, public sentiment about electric vehicle capabilities, historical preservation, and public charging stations. Together, these two sets of factors were considered to develop a holistic view of the potential growth in electric vehicle use and supporting infrastructure on Nantucket. The following chapter details the methods developed by applying our research.

## Chapter 3: Methodology

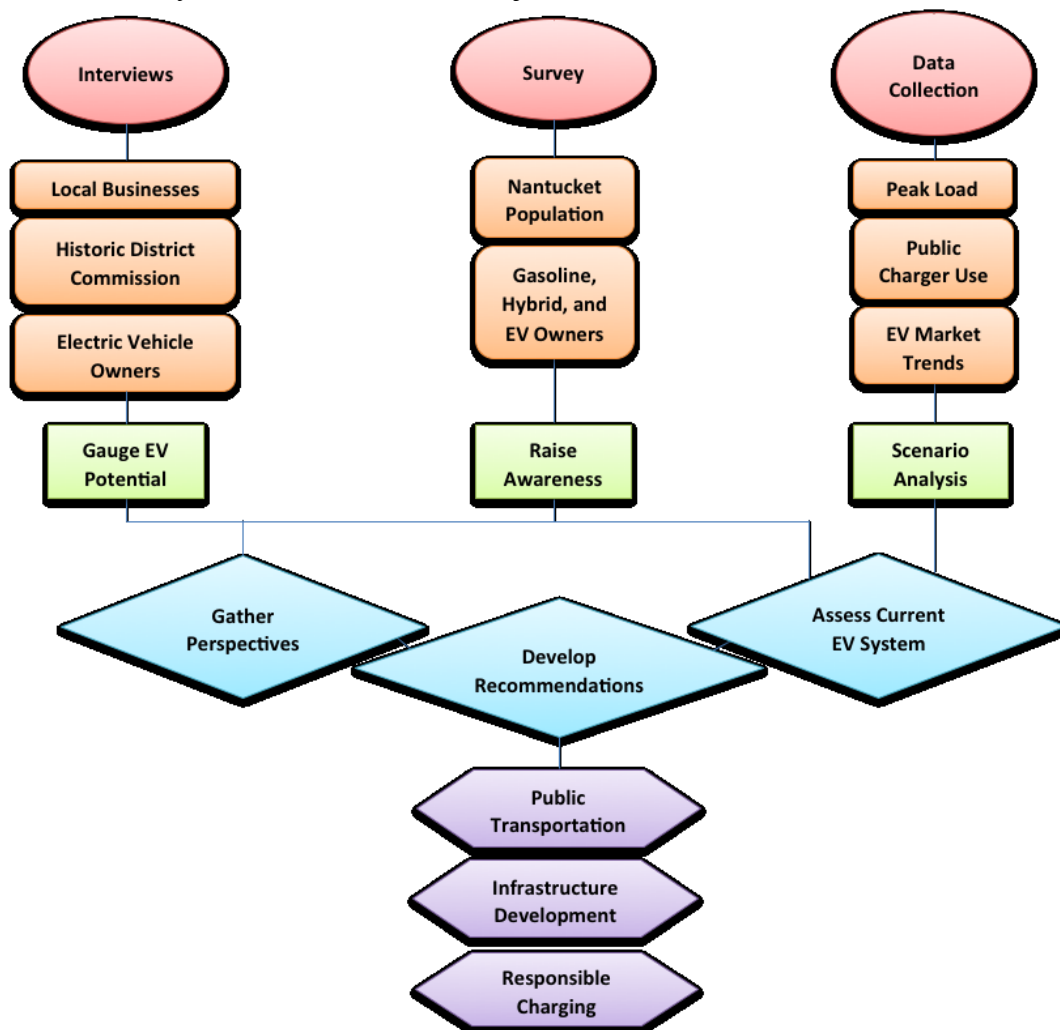
### Mission Statement

The goal of this project was to assess the impacts associated with an increase in electric vehicles on the island of Nantucket.

### Objectives

1. Gauge public opinion and gather stakeholder perspectives while raising awareness of electric vehicles and responsible charging.
2. Assess Nantucket's electric vehicle charging infrastructure, usage patterns, and subsequent grid effects.
3. Develop policy and infrastructure recommendations for the Nantucket Energy Office.

In Figure 10 below, we outline the methods we used, the key stakeholders we interacted with, and the ways in which we met our objectives.



**Figure 10: Flowchart That Details the Process By Which Our Methods Were Used to Achieve Our Objectives**



As illustrated in Figure 10, the primary methods used to address our project goals were interviews, an informative survey, and data collection. Interviews conducted with electric vehicle owners were used to characterize EV charging trends and assess charging sites, which addressed our first objective of assessing Nantucket's EV infrastructure and energy patterns. Perspectives from other key stakeholders such as hotels, rental companies, car dealerships, Downtowner, and the Historical District Commission were used to gain insight on the potential for growth in electric vehicle use and supporting infrastructure.

We conducted a survey of Nantucket residents and seasonal visitors, which served a dual purpose of increasing the public's awareness of EVs while characterizing their knowledge and opinions towards EVs. This, in combination with interviews, served our second objective of gathering key stakeholder perspectives.

Information was collected via online database research regarding Nantucket peak electrical load, general EV market trends, viable public transportation services, and incentives for off-peak charging. Additional data was provided by our sponsor and other stakeholders regarding Nantucket's public charger use, the number of electric and hybrid vehicles registered on the island, and the number of vehicles brought to the island via ferry. Using this information, we created a scenario analysis tool that allowed us to further address our first objective by assessing and predicting the effects of electric vehicles on the Nantucket grid.

The insight gained from the assessment in our first objective was used in conjunction with key stakeholder input to form a set of recommendations for the Nantucket Energy Office. These recommendations included options for encouraging responsible charging, implementing EV public transportation, and increasing EV-supporting infrastructure.

## **3.1 - Interviews**

While on Nantucket, we gathered information from the different stakeholders involved or influenced by an increase in EVs on the island, including but not limited to utility companies, taxpayers, EV users, and other drivers. In order to address our three objectives, we compiled their knowledge and opinions on EVs and how they affect the island, and used their insight to develop recommendations for moving forward.

Before any data was recorded from the interviewees, we received their permission to use pictures and recordings through our IRB Consent Form (Appendix 2). This form informed them of the purpose of our project, and allowed them to consent to the portions of the interview they would be comfortable with.

### **3.1.1 - EV Owner Interviews**

We started by planning to meet with 11 EV owners on the island, from whom we hoped to gain more insight about owning an EV on Nantucket, the daily benefits and

challenges associated with owning an EV, and general driving and charging habits on the island. We also hoped to inform them of peak energy load, and to encourage them to modify their charging habits based on this knowledge. With these goals in mind, we formed key research questions and developed an interview plan that would help us gather the information needed (Appendix 1).

After the planning stage was complete, we interviewed the 11 EV owners. We conducted the interviews in pairs, with one teammate asking questions and the other taking record of the interview. In order to make recording and analyzing the information gained from interviews easier and more comprehensive, we developed a uniform document for gathering and organizing responses (Appendix 3).

### **3.1.2 - Determining EV Popularity**

In order to address our second objective, we also interviewed individuals with key perspectives on the popularity of EVs on the island. This included a car dealership, a rental company, clubs on the island that have installed private chargers for their members, and one of Nantucket's ferry systems.

From the rental company, [Young's Bicycle Shop](#) and the dealership, [Don Allen Auto Service](#), we gathered information on the demand for EVs that they have experienced, and whether or not people specifically request them on the island. We also spoke to the manager of White Elephant Hotel, who installed a charging station for their guests, and the manager of Great Harbor Yacht Club, who already installed Tesla chargers for their members to use (Will take pictures). From these stakeholders we gained insight on how many people come to the island with EVs, and whether or not they have access to chargers while visiting.

Data was also gathered from the Steamship Authority about the vehicles they transport on the ferry since all vehicles transported to the island are registered through their system by make and model.

### **3.1.3 - Public Charger Stakeholders**

We also met with representatives from institutes and committees to discuss public EV chargers and the possible implementation of more on the island, including the Chairman of the Historic District Committee. During these interviews, we also gathered more information on the requirements for EV chargers and their aesthetics, as well as the possibilities for installing more around town. Using this information, we addressed our third objective by forming recommendations for new charging stations and charger relocations.

### **3.1.4 - Public Transportation Stakeholders**

We contacted the CEO of Downtowner to obtain information on potential public electric vehicle transportation services for Nantucket. Using this information, we began a

discussion with relevant stakeholders on the island. For details about the traffic effects that this service may have, we contacted the town Transportation Planner. Another stakeholder that was involved in this discussion was a frequent visitor of Nantucket who was interested in implementing a similar service to Downtowner.

## **3.2 - Public Survey**

The primary goal of the survey was to raise awareness of electric vehicles and promote responsible charging. We used informative questions to make survey participants more aware of electric vehicles, peak load, and responsible charging. We also used the survey data to understand general opinions of EVs and certain trends of EV adoption specific to Nantucket. The key research questions we developed to address our goals and objectives were:

- How many EVs come to island in the summer?
- What is the current interest in EVs?
- What are Nantucket residents' likelihood to purchase an EV?
- What is the potential growth of EVs on the island?
- What are the most common vehicles on the island?
- What is the interest in electric public transportation?
- What EV features and incentives are residents already aware of?

We chose an educational survey as the best way to address these research questions while informing the public of issues relevant to EV adoption.

We began constructing the survey with background research on effective survey practices. This included how to write efficient, unbiased questions to get the best results possible. We then drafted our key research questions that we wanted to answer with the survey. From these concepts we were then able to produce a list of specific survey questions. Following sponsor and advisor input, we refined the survey to better address our objectives. In addition to gathering public perspective, we used the survey platform to spread awareness of electric vehicle charging and Nantucket's peak electrical load. We created the survey using SurveyGizmo, which enabled us to distribute the survey via email to permanent and summer residents of Nantucket. We also contacted the Social Media Supervisor of Nantucket to distribute the survey through Twitter.

## **3.3 - Scenario Analysis Tool**

The purpose of the scenario analysis tool was to help us better understand Nantucket's electric vehicle charging infrastructure and the impact of EV charging on the Nantucket energy supply. Specifically, the tool was used to illustrate growth in charger use since installation, monthly usage patterns, and grid impacts, and was developed through recommendations from our advisors and research that detailed the effectiveness of using a scenario analysis tool to illustrate future effects of a perceived scenario.

Steps to developing the tool included the following:

- Background Research
- Obtain Stakeholder Perspectives
- Developed Scenario Analysis Research Questions
- Determined Assumptions
- Determine Tool Outputs
- Acquire Data
- Build the Tool
- Test All Calculations
- Use Scenario Analysis Tool to Answer Research Questions

Our scenario analysis background research was composed of learning from professional scenario analysis examples as well as online sources that illustrate the steps and considerations when conducting a scenario analysis. We also spoke with our advisors who have experience in this subject, more specifically one of our advisors, Dr. Looft who incorporates modeling in his graduate Systems Engineering courses and conducts models in his professional research and publications. We also learned from a modeling scenario analysis conducted in 2010 by a previous WPI team researching electric vehicles. Through this we were able to observe strategies that yielded accurate projection data by comparing to recent data. We also took note of the visual aspects that made output data clear and easy to interpret.

Obtaining stakeholder perspectives was a necessary step in understanding what important functions our tool must have. We first spoke with our sponsor to understand what outputs would be most useful to the Nantucket Energy Office. We also learned about the island's electrical infrastructure and peak load patterns via a phone call with a National Grid representative. When determining the outputs of our tool we spoke with Dr. Looft on how to best quantify data and illustrate projections. We discussed how to model scenarios where a specified percentage of growth in EV adoption can be modeled to understand the effects of that growth.

To acquire data, we contacted National Grid and the Registry of Motor Vehicles (RMV) with the help of our project sponsor. National Grid was able to provide peak load data within their confidentiality requirements. The RMV provided data on the registered electric and hybrid vehicles on the island. Some assumptions were required due to the limitations of the data we were able to acquire. The assumptions that we chose to make were stated clearly to make the tool transparent and for users to understand what calculations are being made. We also made sure those assumptions were conservative in order to ensure that our projections were realistic and accounted for a worst-case scenario. We also designed the tool such that any parameter can be changed when new perspectives or data is obtained.

The building process involved looking at templates for ideas on various layout options. We chose to use Microsoft Excel to create our tool, starting with placeholders

that represented data and our list of assumptions. We also created the desired graphs prior to inputting the data in order to determine a visually appealing layout. The calculations were then input in various columns, with the input data on one tab and the outputs on a separate tab. We then input the data and verified the mathematical calculations manually.

# Chapter 4: Results & Recommendations

Our key findings and recommendations fall under three main categories:

1. Electric vehicle charging
2. Electric vehicle growth potential
3. Public electric vehicle transportation

Our recommendations regarding electric vehicle charging were influenced by a scenario analysis and interviews with electric vehicle owners, the Historical District Commission, and the Town Manager's Office. Perspectives on the growth potential of electric vehicles were gained through results from our informative survey and interviews with local businesses. Possibilities for electric public transportation systems were explored through the survey and a conversation with Downtowner, the Town Manager's Office, and our sponsor.

## 4.1 - Electric Vehicle Charging

Our key findings regarding electric vehicle charging are as follows:

1. The effect of electric vehicle charging on peak load is negligible.
2. Chargers closer to Downtown see substantially more usage than any other location.
3. Over 80% of public charger users charge for less than 3 hours.
4. Public charger use has increased by over 50% from 2013 to 2015.
5. Some of the current public electric vehicle charging stations have limited accessibility and convenience.
6. Electric vehicle owners, the Historic District Commission, and the Town Manager's Office are supportive of expanding electric vehicle infrastructure.
7. Challenges to installing more public electric vehicle chargers include parking enforcement, selecting the number of new or changed locations needed, and appropriate visual appearance.

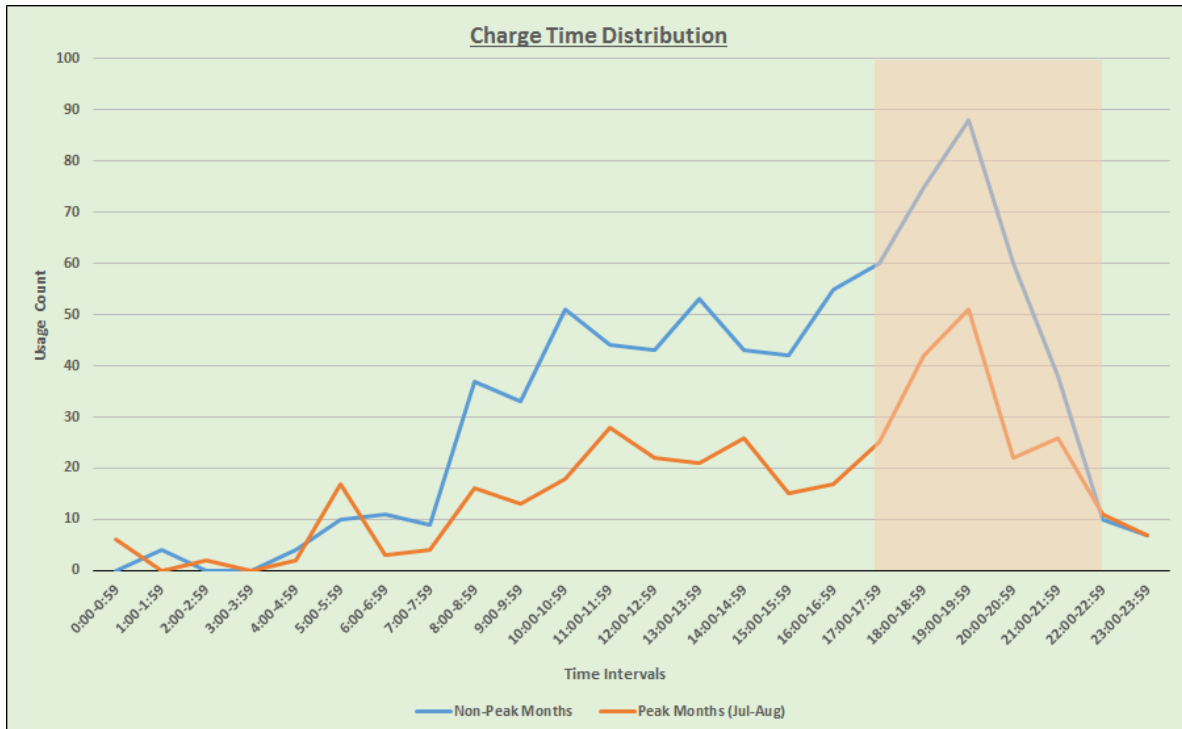
### 4.1.1 - Scenario Analysis

The first function of our scenario analysis tool was to analyze the usage of the six electric vehicle public chargers on Nantucket. We made our calculations using data that our sponsor obtained from [Aerovironment](#), the company that supplied the electric vehicle chargers. We compiled the charging station usage data in order to illustrate charging trends such as time of day, monthly usage, and charge duration. We also calculated effects on peak load by creating a worst-case scenario and illustrating the effects that charging electric vehicles would have on the grid. Lastly, we used the charger usage data

to illustrate the growth in usage per year. Each of these scenarios will be described in more detail below.

### Public Charger Usage Trends

The data sample we received spanned from March 2012 to September 2015. The usage was first sorted into two categories, peak months (July and August) and non-peak months (remaining months). We then graphed the data and found that usage by time of day during peak months follows the same pattern as the remaining months as shown in Figure 11 below.



**Figure 11: Charge Time Distribution**

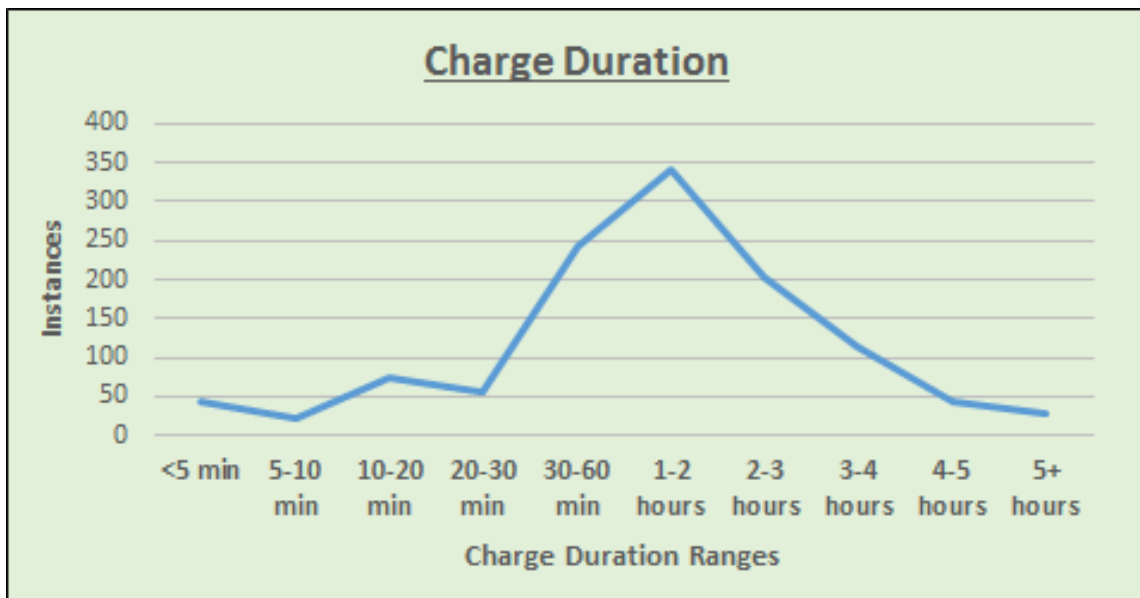
Although usage times are similar during non-peak and peak months it is important to note the frequency of usage. Our calculations showed that during non-peak months the average was 19 uses per month, whereas during the peak months the average was 49 uses per month.

We also sorted the data in order to observe what charging locations were most popular in order to make recommendations for future electric vehicle charger installations. The charger usage per charging station is as follows:

Airport Left	662
Airport Middle	101
Airport Right	44
High School	45
37 Washington Left	190
37 Washington Right	129

The high school charger along with the rightmost charger at the airport saw the least usage in the data period so relocating them would be in the public's best interest. Furthermore, the majority of the usage from the downtown chargers occurred during July and August. This increased usage suggests that chargers in the downtown area are more desirable to summer visitors as well as full time residents of the island.

Another aspect of the data that we evaluated was the length of time that the vehicles were charged. This data, as illustrated in Figure 12 below, shows that the most common charging duration was 1-2 hours, also we calculated that over 80 percent of users charge for less than 3 hours at a time.



**Figure 12: Charge Duration Distribution**

These results were critical in understanding whether or not enforced parking times would impede on a user's ability to charge their vehicle and what charging time limit would capture the greatest percentage of users.

### **Calculated and Projected Effects on Grid**

Another use of our tool is to calculate the effects that charging electric vehicles would have on the grid in order to quantify the effect on peak load. We designed a worst-case scenario in which all 6 public chargers along with the 15 confirmed full time residents would be charging simultaneously. We also applied local trends to the increased population in the summer months in order to estimate that 75 seasonal vehicles would be on the island at one given time. We assumed that all of the 15 on-island EV owners used a 240V charger in order to calculate a true worst-case scenario. When it came to the seasonal EV owners we made the assumption that they would charge using a standard 110V charger because that is the only portable charging option.

Our results show that if all 6 public chargers, 15 resident EV owners and 75 seasonal EV owners were to charge at the same time, the total energy draw would be



0.264MW. This is approximately 0.33% of the island's total electrical capacity of 80MW, excluding the 12MW of emergency roll-on power generation. We also doubled these numbers to account for growth in adoption for the next few years and that totaled 0.527MW of total power usage or 0.66% of the island's total power capacity however this is not an accurate projection. The electric infrastructure on Nantucket is changing in the coming years and there were too many unknown variables, for this reason we were not able to make an accurate projection of grid effects.

Based on these findings we conclude that the total effect on the grid is negligible given the current level of EV adoption. Furthermore, although the total power draw would not change, the effects on peak load can be easily eliminated with a proper off-peak charging initiative. An initiative of this kind would incentivize individuals to set timers on their charging equipment to activate charging at off-peak hours, thereby eliminating effects of charging on peak load. We also found that all but one of the EV owners we interviewed said they would participate in an off-peak charging initiative, and some said they would charge off-peak regardless of incentives.

### Public Charger Usage Growth and Costs

Lastly our scenario analysis tool was used to calculate whether or not there was a growth in usage of the chargers since their initial installation. We compiled the data based on total usage per month in a given year. The results are illustrated below in Figure 13 below.

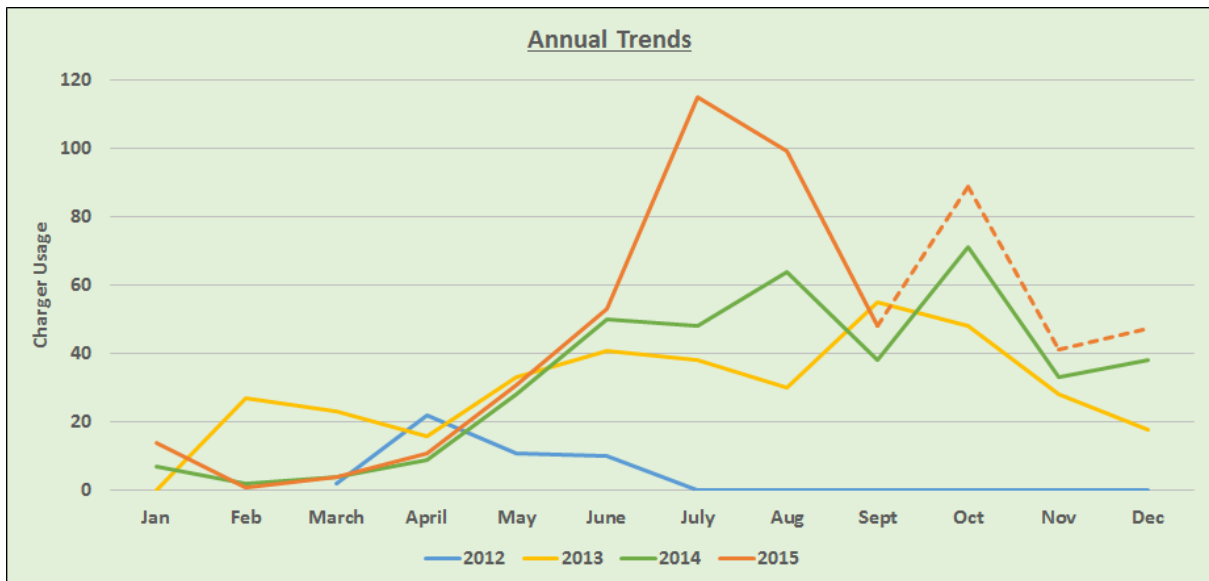


Figure 13: Annual Trends of Charger Use

This data sample spans from March 2012 to September 2015, for this reason we interpolated the remaining data from September 2015 to December 2015, as shown by the dashed orange line. The data was interpolated using the average growth from April to September between 2014 and 2015. This growth was applied to the remaining months to get a full data sample for 2015.

Overall we found that there was significant growth between 2012 and 2013 and moderate growth between the remaining years averaging 248% growth per year. However, we assumed that the relatively small number of uses in 2012 was due to users being unaware of chargers upon their installation. Therefore, we calculated that the average growth from 2013 to 2015 was 26% growth annually.

#### 4.1.2 - Public Charger Perspectives

The section below details our findings from interviews with electric vehicle owners and key stakeholders in the Town of Nantucket government.

##### Electric Vehicle Owners

Through interviews with EV owners on the island, we gained opinions about the public chargers from the users' perspectives. Overall, only four of eleven EV owners interviewed use the public chargers on a regular basis, but almost all have used one or were aware of them. The following table shows the comments we received about each public charger location (Table 2).

**Table 2: Public Charger Opinions by Location**

Public Charger Opinions		
Location	Advantages	Disadvantages
<b>Downtown Parking Lot</b>	<ul style="list-style-type: none"> <li>• Reserved parking during summer</li> <li>• Convenient if Downtown</li> </ul>	<ul style="list-style-type: none"> <li>• Far from town center</li> <li>• Often taken by Town's car</li> </ul>
<b>Nantucket High School</b>	<ul style="list-style-type: none"> <li>• Good if you have a reason to be at the high school</li> </ul>	<ul style="list-style-type: none"> <li>• Set far back and often blocked</li> <li>• Inconvenient for most people</li> </ul>
<b>Airport Hangar Two</b>	<ul style="list-style-type: none"> <li>• Good for Cape Air to charge their vehicle</li> </ul>	<ul style="list-style-type: none"> <li>• Too remote</li> <li>• Not much to do while charging</li> <li>• Best to have someone pick you up for errands while charging</li> </ul>

Interviewees often stated that the chargers were not very convenient for their personal needs, but the Downtown Parking Lot chargers were good for visitors who would not have access to an at-home charger while on the island. However, the downtown chargers are not well advertised and frequent outages can discourage use. Other locations were largely seen as inconvenient for the general public.

The general consensus about the public chargers is that they are a great way to incentivize further EV adoption, and more should be installed in more convenient locations. Suggested locations include Stop & Shop, the proposed Downtown garage, and public beaches. A complete list can be found in Appendix 4.

We also gained sentiment from EV owners about the Town installing a pay-to-use system for use of the public chargers. The comments we received can be seen below in Table 3, organized by those that were for and against adding fees for charging.

**Table 3: Opinions on Pay-to-Use Public Chargers**

Pay-to-Use Public EV Chargers	
For	Against
<ul style="list-style-type: none"> <li>○ Would still cheaper than gas</li> <li>○ Make people more responsible about charging time limits</li> <li>○ People would be more careful with equipment</li> <li>○ Okay if it means more were to be installed</li> </ul>	<ul style="list-style-type: none"> <li>○ Paying for pay-to-use equipment may not be offset by the revenue made</li> <li>○ People might use it just for parking</li> <li>○ May be too soon to start charging if it's to be used as an incentive</li> <li>○ People with at home chargers will use them less</li> </ul>

### **Town of Nantucket Interview Results**

Through contact with the Assistant Town Manager, we found that Jetties Beach and Surfside Beach would be suitable locations for public electric vehicle chargers due to the fact that summer visitors frequently visit these beaches, and public chargers would provide a convenient opportunity for EV owners to charge their vehicles while visiting. We were also told that the Town has considered the installation of public charging stations at 2 Fairgrounds Road if a new municipal building was constructed there; however, past plans for a municipal building at this location were cancelled.

Our evaluation of the charging station at Nantucket High School was supplemented by an interview with the Director of Facilities for Nantucket Public Schools. In this interview we learned that the public charger at Nantucket High School sees little use and is in a relatively inaccessible location. Users would benefit if it were relocated to a more accessible location on the high school campus. The Assistant Town Manager also expressed this viewpoint.

The Assistant Town Manager and the Historic District Commission (HDC) Chairman provided details on the process and potential challenges associated with installing charging stations. Specifically, we found from the Assistant Town Manager that grant funding improves the chances of a charging station gaining approval by the Finance Committee and town Selectmen. We also found that although designated parking spaces for electric vehicle charging have encouraged EV owners to use the chargers, it is challenging to reserve and enforce time limits for these spaces due to limited patrol staff and large parking demand. Similarly, it would be challenging for the Town to enforce a town-only EV charging space if it were put in place, although our previous results from interviews with electric vehicle owners suggest that a town-only space for charging

would alleviate demand on the downtown chargers. The Director of Facilities for Nantucket Public Schools also expressed that if the Town was to install additional public chargers, a charger should be designated for exclusive Town use.

The Chairman of the Historic District Commission indicated that the Commission is currently open to the possibility of chargers that have a modern appearance and are freestanding, in contrast to the current custom gray, wall-mounted chargers. At the time the current public charging stations were installed, the Historic District Commission approved six of the ten proposed stations. The Chairman indicated that today, the HDC may be more open to approving electric vehicle charging stations as long as they coexist with the atmosphere and history of Nantucket.

### **Recommendations**

We recommend that additional public chargers be installed. This recommendation is supported by our scenario analysis results as well as our interviews with EV owners that stated the downtown chargers were occupied for a majority of the summer months. To alleviate this situation we recommend that the town designate a charger for town use only to increase availability of public chargers in high usage periods.

When it comes to the existing chargers on the island we recommend that one of the chargers at the airport be relocated to a location closer to downtown, such as the downtown parking lot. Furthermore, based on input from the Assistant Town Manager and the Director of Facilities for Nantucket Public Schools, we recommend that if a public charger is to remain at Nantucket High School, it should be relocated to a parking spot or location at the school building with greater visibility and accessibility.

We also recommend that the town continue to provide free electric vehicle charging because the benefits associated with aligning with the state of Massachusetts goal to increase electric vehicle adoption greatly outweighs the relatively low cost of providing free electricity. Furthermore, there are incentives available through the state that the town could take advantage of to install future electric vehicle chargers.

In terms of the effects of charging on the grid, the current worst case power usage illustration indicates that EV charging has an inconsequential effect on the grid and for this reason we feel that an incentivized off-peak charging initiative is not justifiable at this time. However, we recommend that the town inform all electric vehicle owners about peak load and ask that they charge during off-peak hours. This recommendation is supported by our interviews, which outlined that a majority of electric vehicle owners would charge off-peak regardless of incentives.

Below are our summarized recommendations regarding electric vehicle charging:

1. Begin the process of installing more public electric vehicle chargers at the locations specified below, while considering available grants, new locations that the town would approve, and new public charger technology. Our top three locations are outlined below:

- a. Proposed parking garage
  - b. Mid-island Stop & Shop
  - c. Downtown Stop & Shop
2. Designate a charging station for Town use only.
3. Relocate one airport charger to another location downtown (possibly make it the third charger at the downtown parking lot) and relocate the high school charger to a more convenient location in the main high school parking lot.
4. Continue to provide free electric vehicle charging.
5. Inform and encourage all EV owners to charge during off peak times.
6. If and when the effect of EV charging on peak load becomes substantial, collaborate with National Grid to implement an off-peak charging initiative.

## 4.2 - Electric Vehicle Growth Potential

Our key findings regarding electric vehicle growth potential are as follows:

1. Many Nantucket residents prefer a vehicle with off-road capabilities.
2. The most common electric vehicle concerns are charging, range, and vehicle price.
3. Nantucket residents responded positively when provided information about electric vehicle range, cost, and incentives.
4. Cape Air is an example of a successful commercial application of an EV.
5. The most significant challenge for adopting electric vehicles for renting purposes is charging time.
6. The most significant challenge to selling electric vehicles on the island is the cost of the equipment and training needed to service them by the local dealer.
7. Range anxiety is not an issue on Nantucket.
8. People can purchase electric vehicles for much lower costs than they think.

### 4.2.1 - Informational Survey

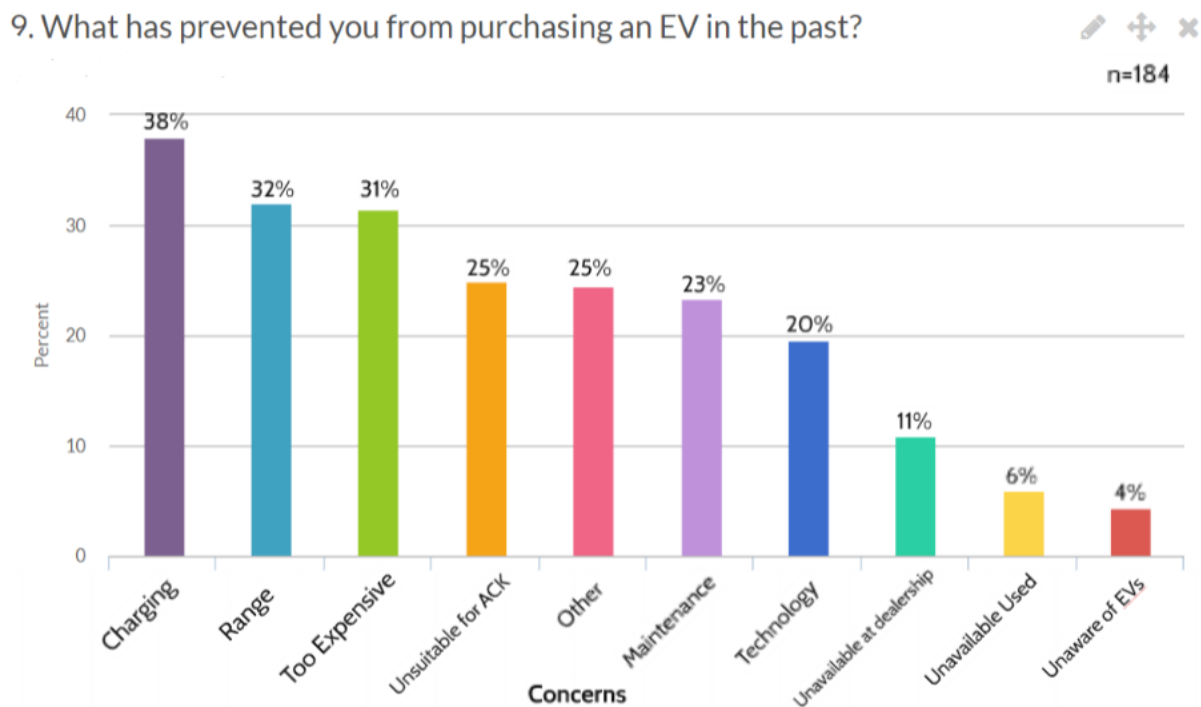
The survey provided insight into where the public stands on electric vehicle adoption while providing them with useful information about EVs. We obtained 214 total responses but not all of the participants answered every question. The survey was also adaptive, so depending on how a participant answered a certain question, they were taken to a specific set of questions. (Additional survey data is presented in Appendix 6.)

The survey participants are represented by the data below:

- Total responses: 214
- Most common age group: 45-54 (29%)
- Residential status
  - Year round: 66 %

- Seasonal/Visitor/Commuter: 31 %
- Type of vehicle
  - Gasoline: 84 %
  - Do not bring a vehicle over: 8 %
  - Have EV: 2 %
- Most popular vehicle: Jeep Grand Cherokee
- Consider an EV for last purchase?
  - No: 83 %
  - Yes: 17 %

Generally, people were accepting of EVs but they are not yet willing to make the transition for various reasons. The most popular reasons are represented in Figure 14 below:



**Figure 14: EV Purchasing Prevention Results**

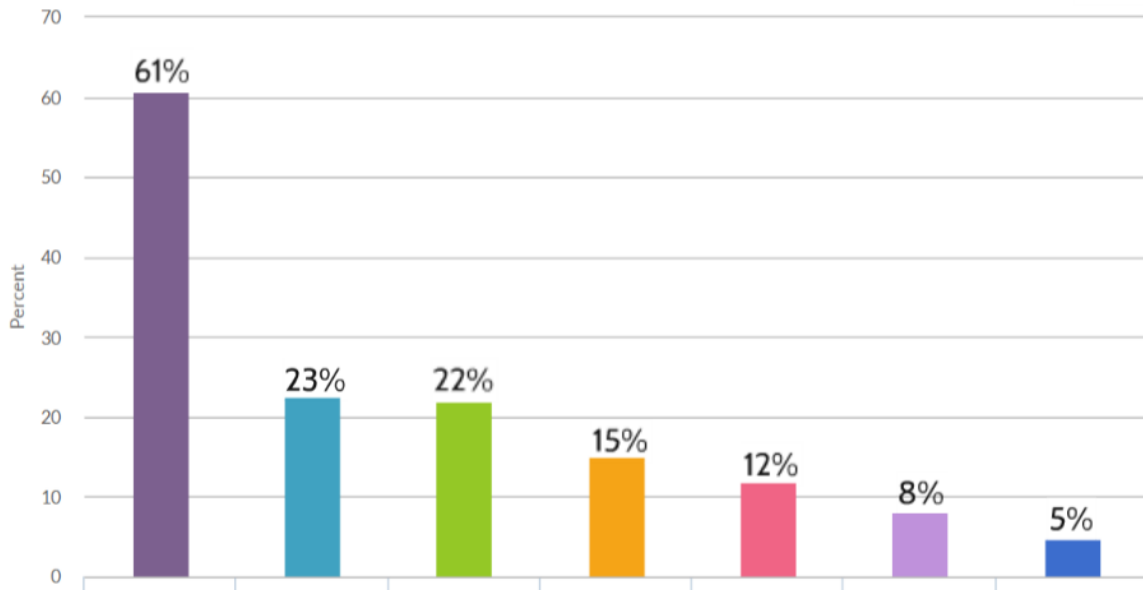
Concerns about the frequency of charging and charging locations were the most popular concerns, followed by total driving range capabilities and the price of the car itself. These results support our background research about the most common concerns about EVs on the mainland. Therefore, although Nantucket has a unique geography, the most critical concerns about EV adoption on Nantucket align with national trends.

Limited model selection is another barrier to adoption. In Figure 15 below are the results of the most popular type of vehicle:

17. Which vehicle types are you most interested in? (select all that apply)



n=186

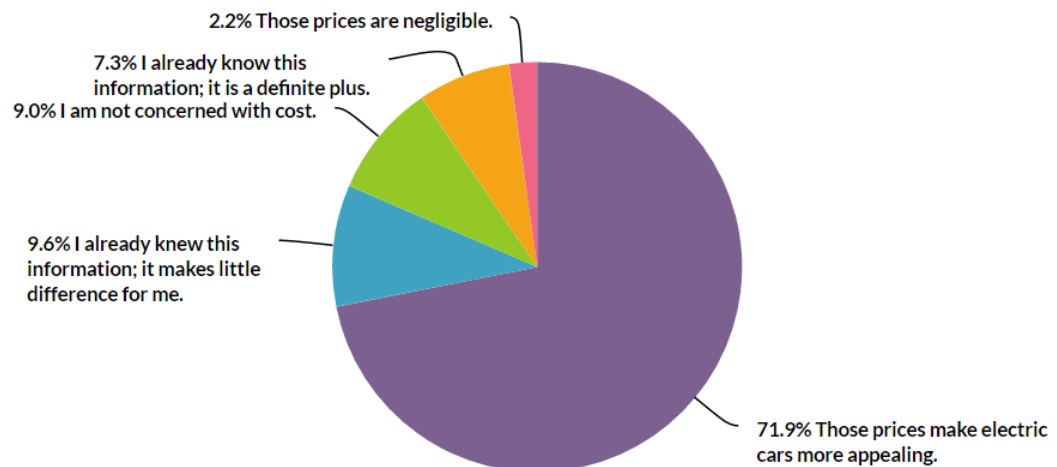


**Figure 15: Most Popular Vehicle Types**

SUVs were the most popular vehicle type, followed by trucks and crossovers. This was consistent throughout the survey results because people expressed that they found four-wheel drive to be a necessary feature for a vehicle on Nantucket to accommodate for the island's off-roading conditions and they were aware that most EVs do not have that feature. Also, the most desirable vehicle price range was \$20,000 to \$30,000 and an all-electric SUV cannot be purchased within that price range at this time. These results imply that it may not currently be feasible for island residents to purchase an EV, however interested residents should revisit the option when technology improves, such that more EV models are available with four-wheel drive, and configurations and body styles are similar to Jeeps and other SUV type vehicles. Finally, the 27% that selected compact and sedan are ideal candidates for EV adoption. Vehicles in that category fit within the most popular price range.

This survey provided the participants with information on available incentives, the cost of operation compared to gasoline vehicles, the general cost of EVs, and perspectives of EV owners on Nantucket. The results of the question about incentives are shown in Figure 16 below:

20. You can receive up to \$10,000 in monetary incentives in MA. and residents of Nantucket have obtained EVs for as low as \$14,000. How does this change your opinion about electric vehicles?



**Figure 16: Informative Question Results**

Of those who responded, 72% said they did not know about those incentives and that incentives made electric vehicles more appealing. This was the trend throughout the informational questions, the majority expressed that after learning the information, electric vehicles seemed more appealing. This data strongly supports the finding that people respond positively to receiving information on electric vehicles that clarify misconceptions or perceived limitations.

#### **4.2.2 - EV Owner Interviews**

Through our interviews with EV owner, we found that they previously had some of the same concerns that the public has about EVs that were portrayed in our results, including range, charging, maintenance, and price. Table 4 displays these concerns and how they have been resolved, after having their vehicles for anywhere from three months to three years.



**Table 4: EV Reservations & Outcomes**

EV Reservations & Outcomes	
Reservation	Outcome
Range Concerns	<ul style="list-style-type: none"><li>• New vehicles have higher range</li><li>• Not an issue on Nantucket</li></ul>
Charging Concerns	<ul style="list-style-type: none"><li>• Becomes second nature</li><li>• Don't need to be charged often on Nantucket</li></ul>
Servicing on Nantucket	<ul style="list-style-type: none"><li>• EVs require less maintenance</li><li>• Very similar to servicing non-EVs in most cases</li></ul>
Cost Effectiveness	<ul style="list-style-type: none"><li>• Available incentives</li><li>• Dealerships offer deals</li></ul>

The table shows that these concerns were quickly addressed, and all EV owners said that they are very happy with their vehicle. Almost all of them expressed that they think EVs are perfect for Nantucket and that more people should have them. We also asked what the EV owners think prevents others from purchasing EVs. The most common response was that generally the public has a lack understanding about current EV technology. Further information and opinions from EV owners can also be found in the Interviews Summary, which contains opinions of all EV owners on a variety of topics (Appendix 4).

### **4.2.3 - Local Business Interviews**

Our interview with Young's Bicycle Shop gave us perspectives on the unique challenges associated with renting electric vehicles. Young's Bicycle Shop offers two automobile models for rental: the Honda Civic and the Jeep Wrangler. When renting vehicles, the shop has chosen to simplify their vehicle selection to best suit customer demands and to provide quick turnaround. Particularly during the peak summer months, the shop endeavors to clean and prepare returned vehicles for another rental within 30 to 60 minutes. This quick turnaround would present a challenge for electric vehicles due to charging time, which limits the potential of electric vehicles as a rental option.

Our interview with Don Allen Auto Service (the island's Ford car dealer) provided additional insight regarding the primary barriers to selling electric vehicles on Nantucket. The foremost challenge would be the cost to the dealership in order to buy the tools and train a mechanic to service EVs. This, in combination with the franchise premium for the dealership to carry electric vehicles, would amount to an approximate investment of \$30,000 for Don Allen Auto Service. Considering the minimal demand for the non-plug-in hybrid vehicles currently offered by the dealership, it would be challenging for the dealership to achieve a return on this investment if it were to adopt plug-in electric or hybrid vehicles. We also found that the highest selling model was the

Ford Escape, which supports survey findings that suggest all wheel drive capabilities are a priority for Nantucket vehicle owners.

In contrast to the challenges and barriers to EV adoption presented in the previous two interviews, we found that Cape Air has successfully implemented an electric vehicle as a part of their business model, and from an interview with company representatives we were provided details on the implementation process and benefits of adopting an electric vehicle. Prior to leasing a Nissan LEAF beginning four years ago, Cape Air transported luggage from Nantucket Memorial Airport to customers' places of residence using taxi services, which was an expensive operation. After an analysis of the cost, range, and technology available for electric vehicles at the time, Cape Air chose to lease a Nissan LEAF for three years, and has recently begun a second lease of the vehicle. Cape Air has found that using the vehicle to transport luggage has greatly reduced costs and emissions associated with luggage delivery, with no range anxiety despite traveling 40-100 miles per day.

The Westmoor Club and Great Harbor Yacht Club are two additional businesses that provided us information on summer visitors and demand for electric vehicle charging. Both clubs have two Tesla 220V charging stations installed by the company for promotional purposes. Following the installation of the charging stations, Tesla Motors has held events at each club showcasing their vehicles, and continues to hold an annual summer event at the Westmoor Club. However, managers of both clubs have expressed that the chargers see minimal use and may be more frequently used by members if replaced with universal charging stations.

## **Recommendations**

Our conversation with Cape Air indicated that the company would be interested in and willing to participate in a case study highlighting their success using an electric vehicle. We recommend that the Nantucket Energy Office communicate with Cape Air to initiate such a study.

We found from our survey results that respondents reacted positively when provided information addressing the perceived limitations of EVs. Additionally, the majority of electric vehicle owners interviewed expressed that a lack of information is the foremost barrier to individual EV adoption. For these reasons we recommend an educational campaign about EV technology and available incentives to benefit the community and further promote a reduction in emissions on the island. This campaign and related EV showcase events could be jointly sponsored by the Town of Nantucket and companies that sell a variety of electric vehicles.

We also believe that additional data on the number of electric vehicles coming to the island during the summer season would be useful in gauging the potential for EV growth. For this reason, we recommend further communication between the Town of Nantucket and Steamship Authority to encourage tracking EVs brought over on the ferry.

Below are our summarized recommendations regarding electric vehicle growth potential:

1. Conduct a series of case studies highlighting successful electric vehicle use for both private owners and businesses.
2. Coordinate with potential sponsors to conduct an awareness and outreach campaign to spread information about electric vehicle incentives, charging, costs, and benefits.
3. Investigate the possibility tracking the number of electric vehicles brought to the island through Steamship Authority.

## **4.3 - EV Public Transportation**

Our key findings regarding electric vehicle transportation are as follows:

1. An overwhelming majority of survey respondents thought that EV based public transportation was appropriate for Nantucket.
2. The Downtowner service is customizable based on a city or town's needs.
3. Advertisements would not be a viable sponsor for a free electric transportation service on Nantucket, but this issue should still be explored in depth.

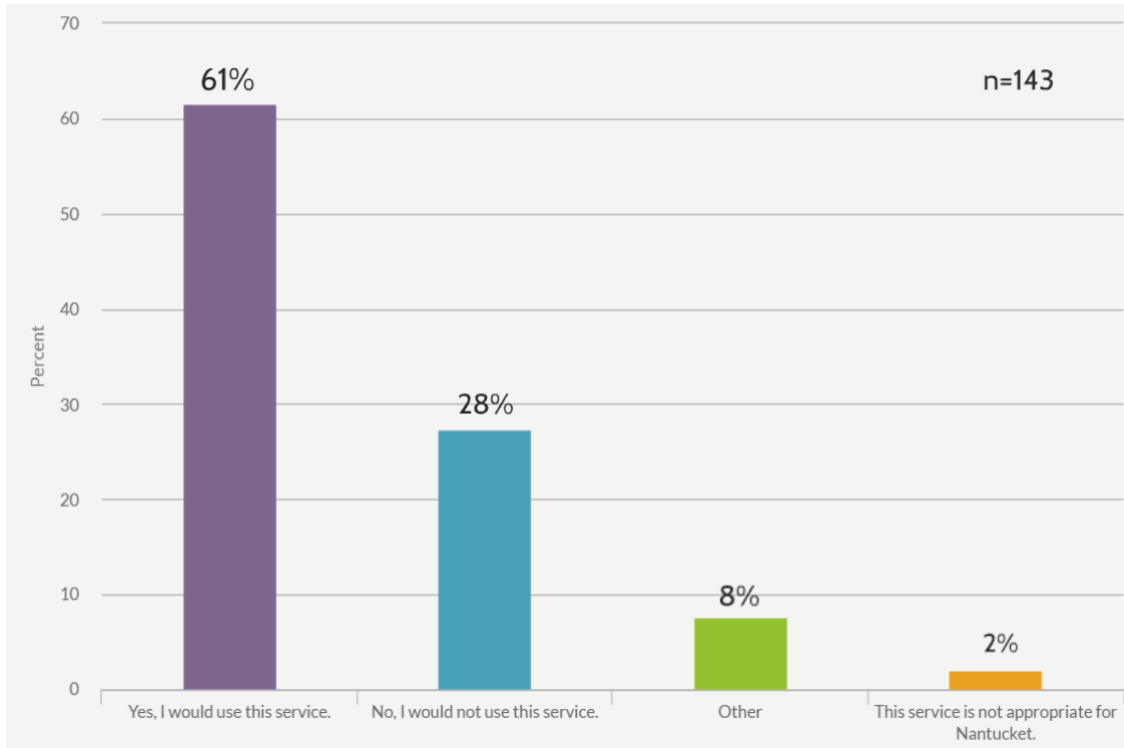
### **4.2.1 - Public Transportation**

We explored various electric public transportation options to help relieve the traffic congestion downtown during the summer months, while promoting clean energy use. According to the Assistant Town Manager, in order to begin the implementation process of such a service, the NEO needs to reach out to the Nantucket Regional Transportation Authority (NRTA) since the NRTA can obtain state grants for approved transportation services.

One of the options we considered was the Downtowner model explained in the background chapter. We began a conversation with the CEO of Downtowner to understand the process of implementing this service. Some of the main findings from this interview were as follows:

- Downtowner is customizable to a Town's needs
- The company has worked with Towns that have advertising restrictions
- The only two things the company would rather not compromise on are that they do not have fixed routes and that the service is always free to the user.
- The Town can be as involved as they would like to be, the only thing the Downtowner organization requires is an assigned town employee liaison.
- Downtowner can set up an exchange program so another organization can use the vehicles in the off season so Nantucket does not need to store them.

In addition to our phone interview, in the survey we asked a question about the public's interest in a free shuttle service from mid-island to downtown, like Downtowner, that could either be funded by the Town or by advertisements. The results of this question can be seen in Figure 17 below:



**Figure 17: Public Likelihood of Using EV Shuttle Service**

A majority (61%) of survey participants said they would use this service but some of the respondents expressed that although they would not use it themselves, it is a great idea for visitors. Finally, only 2% said the service was not appropriate for Nantucket. This means that there is interest in such a service to address the traffic situation downtown during the summer while addressing clean energy use.

### **Recommendations**

We found from our conversation with the CEO of Downtowner that their program is adaptable and that the company is willing to continue dialogue with the Town of Nantucket on how to best fit its needs. This, in combination with survey results suggesting the public would be interested in using such a system, leads us to recommend that the Town explore public EV transportation options.

We also understand from our discussions with the Assistant Town Manager, the Town Transportation Planner, and our sponsor that significant communication among Town entities is needed to address the many regulations and aspects involved in the implementation of an EV transportation program.

Our recommendations regarding electric vehicle transportation are as follows:

1. Further investigate electric public transportation options in order to select a model that is best suited for Nantucket.
2. Coordinate between the Nantucket Energy Office, the Town Manager's Office, and the Transportation Planner to assess the process, requirements, and challenges for a successful electric public transportation system.

## Chapter 5: Conclusion

In this project, we have determined that electric vehicles are a viable option for Nantucket. Through our recommendations, the Nantucket Energy Office can best prepare for greater EV adoption by raising awareness of electric vehicles, improving electric vehicle supporting infrastructure, and eliminating the minimal effect of EV charging on the electrical grid. Our project may serve as an example for towns or cities that are experiencing early stages of EV adoption and wish to assess the impacts and benefits that EVs may have on their community.

Our project provides potential opportunities for future Interactive Qualifying Projects. Specifically, a project could be conducted to delve further into the issue of peak electrical load on Nantucket, which was only a small portion of our project, but itself is a large and complex issue for the island. An additional future project could also continue to aid the Town of Nantucket in exploring an electric public transportation option and relieve downtown congestion.

This project provided the team with valuable experience in conducting professional interviews, constructing and distributing a survey, and modeling a scenario using a data-driven tool. The project team gained additional skills in working cooperatively in a group and with a town government agency.

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# Appendix 1: EV Owner Interview Plan

This document contains the questions we created and topics addressed in our interviews with electric vehicle owners.

## EV Owner Interview Plan

### Interview Methodology: Key Informant Interview

- Assessing current electric vehicle infrastructure.

### Interview Details

- Key Informant: EV Owners
- Interviewers: Joseph Switzer, Caeli Tegan, Anna Kjelgaard, Joseph Abinader
- Note: Contact Interviewee to see what location and what date/time is best
- Record Interview? Ask beforehand
- Summary immediately following
- Thank you note next day including summary

### Team Responsibilities

- 2 team members per interview:
  - Verbal Interviewer:
  - Recorder:

### Information Sought

- General information about their EV
- Charging station accessibility
- Whether they have a home charger or not
  - How much on average it costs to fully charge an EV on Nantucket (if they know)
- How much they would be willing to pay to charge at public charging stations
- The challenges and benefits of electric vehicles in general
- Opinions of EVs before and after owning an EV, and if their opinion has changed

### Interview Schedule

1. Introductions
  - a. Introduce group members
  - b. Introduce project
  - c. Informed consent form
  - d. Thanks for taking the time to interview
2. Basic Questions
  - a. Why did you get an EV?
    - i. What first made you look into EVs?
    - ii. What were some reservations you had about buying an EV?
      1. Were these addressed or are you unhappy with your EV?
    - iii. What were your criteria for selecting an EV? Why?
    - iv. Does anyone else in your household drive your EV, and why?  
Does anyone choose not to drive it, and why?
  - b. Make & model

- i. What led you to choose that specific model over other EV models?
  - c. How long have you had an EV?
    - i. Have you ever had to get it repaired? If so where did you go?
    - ii. How much did it cost compared to gasoline vehicles?
  - d. How often do you charge your vehicle?
  - e. Do you charge at home or use the public chargers?
    - i. (If at home) Do you have an at-home charger or do you use a standard wall outlet?
    - ii. When do you usually charge your EV?
    - iii. (If they don't charge during off-peak hours) Will you be willing to charge during off-peak hours?
    - iv. (If no) Would you be more willing if there were incentives to do so?
      - 1. Would you be more interested in monetary incentives or free equipment that automatically regulates your charging (so you don't have to worry about it)?
- 3. Usage
  - a. Is your EV your primary vehicle?
    - i. If not, what is your other vehicle?
      - 1. What does this vehicle provide that your EV cannot?
    - ii. What do you use your EV for?
      - 1. What is the typical distance you travel per day?
- 4. Public Chargers
  - a. Are the public chargers in convenient locations?
    - i. Is there anywhere else that you think an EV charger would be beneficial?
  - b. Do you ever run into a situation where the charger you want to use is unavailable?
  - c. If the public charging stations became a pay-to-use system would you still be willing to use them?
    - i. If so, how much would you be willing to pay?
- 5. Broad Questions/Summary Questions
  - a. What was your overall opinion of EVs before you purchased one?
  - b. What is your overall experience with and opinion of having an EV?
    - i. Does being on Nantucket change any of this, compared to living on the mainland?
    - ii. What are some unforeseen challenges of owning EVs
    - iii. What are the benefits?
  - c. What are your 3 favorite things about driving electric?
  - d. What's the number one misconception/complaint about EVs you hear from non-EV drivers?
  - e. Is there anything you wish you'd have known before you purchased your EV?
- 6. Summary
- 7. Thank you

## Appendix 2: Informed Consent Form

This is the document we presented to our interviewees to explain the mission of our project and outline their agreements regarding confidentiality. This document also satisfied the WPI IRB requirement to obtain informed consent from interviewees.

### Informed Consent Form: Worcester Polytechnic Institute Interactive Qualifying Project

Project Title	Determining the Viability of Electric Vehicles on Nantucket
Project Sponsor	Lauren Sinatra, Energy Project and Outreach Coordinator, Nantucket Energy Office
Interviewee Name, Title & Affiliation (if applicable)	
Location	
Date	
Interviewers	
Student Email Contact	ack16neo@wpi.edu
Program Information & Final Project Report	<a href="http://wp.wpi.edu/nantucket/">http://wp.wpi.edu/nantucket/</a> Report will be available ~ February 2017

1. Purpose of project: To assess the costs and benefits associated with a greater presence of electric vehicles on the island of Nantucket.
2. Purpose of interview: To obtain electric vehicle owners' perspectives on owning and using an electric vehicle on the island of Nantucket, including current EV-supporting infrastructure and the future of EVs on the island.
3. Participation: An interview 30-40 minutes long regarding the reasons the owner chose an EV and their experiences charging, driving, and maintaining their vehicle.
4. Our request regarding confidentiality: With your permission, we would like to use the information from this interview to prepare a final project report that will be publicly available online. No information from this interview will be used to identify you except for relevant photographs of your vehicle and other non-personal photographs. Your consent to the use of any of the above items is completely voluntary.
5. Do you have any questions about our project or our request for your participation?
6. Would you like to participate? Please note that your participation is completely voluntary and you may stop at any time and skip any questions or discussion that you wish.

Your permissions regarding confidentiality are noted below:

Yes	No	I give permission for...
		This interview to be recorded (audio/video)

		The information I provide to be made public
		My name to be used publicly in reports, presentations, websites, etc.
		Photos or videos of me to be used publicly in reports, presentations, websites, etc.
		Are any other confidentiality considerations appended to this form?
		Please email a link to the final report to me at (email):

**If you have questions, concerns or second thoughts regarding this project or your participation**, you may contact the Student Team at email above; Prof. Scott Jiusto, IGSD, Worcester Polytechnic Institute (WPI), 100 Institute Road, Worcester, MA ([sjiusto@wpi.edu](mailto:sjiusto@wpi.edu)); the Chair of the WPI Institutional Review Board (Prof. Kent Rissmiller, 508-831-5019, [kjr@wpi.edu](mailto:kjr@wpi.edu)); or WPI's University Compliance Officer (Jon Bartelson, 508-831-5725, [jonb@wpi.edu](mailto:jonb@wpi.edu)).

\_\_\_\_\_ Participant's Signature (only if necessary)

## Appendix 3: EV Interview Summary Template

This document is a blank template which we used to organize the responses from our EV owner interviews.

Interview Summary				
Interviewee:		Make & Model:		
Time:		Date:		
Interviewers:				

Vehicle Usage Questions
1. Why did you get an EV?
2. What first made you look into EVs?
3. What were some reservations you had about buying an EV?
4. Have those reservations changed since you purchased the vehicle?
5. What were your criteria for selecting an EV & why?
6. Does anyone else in your household drive your EV & why?
7. What led you to choose that specific model over other EV models?
8. How long have you had an EV?
9. Have you ever had to get it repaired? If so where did you go?
10. Do you feel that the overall costs of your EV is comparable to a gasoline vehicles in the same class?
11. How often do you charge your vehicle?

12. Do you primarily charge at home or use the public chargers? If at home what type of charger do you use?
13. When do you usually charge your EV?
14. If the time specified in Q13 falls between 5:00-10:00PM, knowing that time is considered "peak time," would you consider charging outside those hours?
15. Would you be more willing to charge outside those hours if there were incentives to do so? Such as?
16. Is your EV your primary vehicle & Why?
17. If not, what is your other vehicle and what does this vehicle provide that your EV cannot?
18. If your EV is not your primary vehicle, what is its primary use?
19. What is the typical distance you travel per day?
<b>Public Chargers</b>
20. What do you think about the public chargers overall?
21. Are the public chargers in convenient locations?
22. Is there locations that you think an EV charger would be beneficial?
23. Do you ever run into a situation where the charger you want to use is unavailable?
24. If the public charging stations became a pay-to-use system would you still be willing to use them?
<b>Summary Questions</b>
25. What was your overall opinion of EVs before you purchased one?
26. How has your opinion changed after becoming an EV owner?



27. Do you ever take your vehicle to the mainland?
28. Would you have the same opinions about EV's regardless of living on Nantucket?
29. What are some unforeseen challenges of owning an EV?
30. What are the benefits of owning your EV?
31. What are your favorite things about driving electric?
32. What's the number one misconception/complaint about EVs you hear from non-EV drivers?
33. What is the biggest reasons you feel that prevent more people from buying EV's?
<b>Action Items</b>
<b>Other Notes</b>

## Appendix 4: EV Owner Combined Interview Summary

Below are the combined results of our interviews with electric vehicle owners. This includes a comparison of different EV owners' responses to the interview questions and common answers that formed the basis of our findings from EV owner interviews.

Interview Summaries Summary	
<b>EV Types:</b> <ul style="list-style-type: none"><li>• Tesla Model S</li><li>• 2 Nissan Leaf</li><li>• 2 Tesla Model X<ul style="list-style-type: none"><li>• Smart Car</li><li>• 2 BMW i3</li></ul></li><li>• Ford Fusion Plug-in Hybrid</li><li>• Ford Transit Connect</li></ul>	
Vehicle Usage Questions - Key Answers	
1. Why did you get an EV/what made you look into them?	
<ul style="list-style-type: none"><li>• More ecologically friendly</li><li>• More environmentally conscious</li><li>• Wanted to be more energy conscious/efficient</li><li>• Great for Nantucket because of range</li><li>• Good deals with incentives</li><li>• Reducing emissions</li></ul>	
2. What were some reservations you had about buying an EV and how do you feel about them now?	
<ul style="list-style-type: none"><li>• Range<ul style="list-style-type: none"><li>○ Got a vehicle with higher range</li><li>○ Got used to capabilities</li><li>○ Not an issue on Nantucket</li></ul></li><li>• Servicing on Nantucket<ul style="list-style-type: none"><li>○ Going off-island</li><li>○ Very similar to servicing non-EVs in most cases</li></ul></li><li>• Charging<ul style="list-style-type: none"><li>○ Charging becomes second nature</li></ul></li></ul>	
5. What were your criteria for selecting an EV & why?	
<ul style="list-style-type: none"><li>• High range</li><li>• Economical, feasibility</li></ul>	

<ul style="list-style-type: none"> <li>• Size</li> <li>• Good ground clearance</li> </ul>
6. Does anyone else in your household drive your EV & why?
<ul style="list-style-type: none"> <li>• Various family or other employees</li> </ul>
7. What led you to choose that specific model over other EV models?
<ul style="list-style-type: none"> <li>• Range being viable for Nantucket</li> <li>• Being cool</li> <li>• Affordability</li> <li>• Aesthetics</li> <li>• Ease of repair</li> </ul>
8. How long have you had an EV?
<ul style="list-style-type: none"> <li>• 3 months - 3 years</li> </ul>
9. Have you ever had to get it repaired? If so where did you go?
<ul style="list-style-type: none"> <li>• Off island if necessary</li> <li>• Nothing related to EV capability</li> <li>• Goes off island once a year to get it checked</li> </ul>
10. Do you feel that the overall costs of your EV is comparable to a gasoline vehicles in the same class?
<ul style="list-style-type: none"> <li>• Pittman: \$6-8 to charge every few days, while Tacoma costs \$60 to fill every other week</li> <li>• Gary: used to spend \$25/month on gas, now spends zero on charging and MA incentives (\$10k) made the vehicle cheaper than a gas Smart Car.</li> </ul>
11. How often do you charge your vehicle?
<ul style="list-style-type: none"> <li>• Ranges from everyday to every couple of weeks <ul style="list-style-type: none"> <li>◦ Median every 3 or 4 days</li> </ul> </li> </ul>
12. Do you primarily charge at home or use the public chargers? If at home what type of charger do you use?
<ul style="list-style-type: none"> <li>• 240V at home - 4</li> <li>• 110V at home - 3</li> <li>• Primarily public chargers - 3</li> </ul>
13. When do you usually charge your EV and Why?
<ul style="list-style-type: none"> <li>• Varies but typically in the evening when people get home</li> </ul>

14. Have you any thoughts about how the time of day you charge might impact the local electric grid? If the time specified in Q13 falls between 5:00-10:00PM (peak time) would you consider charging outside those hours?
<ul style="list-style-type: none"> <li>• Most will start trying to do so</li> <li>• A few already do</li> <li>• Most have timers they can set when they get home</li> <li>• One said it would be inconvenient</li> </ul>
15. Would you be more willing to charge outside those hours if there were incentives to do so? Such as?
<ul style="list-style-type: none"> <li>• Equipment - 2 <ul style="list-style-type: none"> <li>○ Good for people who don't already have chargers or chargers with timers</li> </ul> </li> <li>• Monetary - 4 <ul style="list-style-type: none"> <li>○ Reduced rates was a suggestion</li> </ul> </li> </ul>
16. Is your EV your primary vehicle & Why?
<ul style="list-style-type: none"> <li>• Yes - 7</li> <li>• No - 3 <ul style="list-style-type: none"> <li>○ Dept vehicle</li> <li>○ On-island vehicle</li> <li>○ Wife's vehicle <ul style="list-style-type: none"> <li>■ Still enjoys driving it</li> </ul> </li> </ul> </li> </ul>
17. If not, what is your other vehicle and what does this vehicle provide that your EV cannot?
<ul style="list-style-type: none"> <li>• Police car</li> <li>• Jeep for the beach</li> <li>• Car for off-island with longer range</li> <li>• Truck for off-roading</li> </ul>
18. If your EV is not your primary vehicle, what is its primary use?
<ul style="list-style-type: none"> <li>• Island use</li> </ul>
19. What is the typical distance you travel per day?
<ul style="list-style-type: none"> <li>• Ranges from 1 miles/day to 25 miles/day</li> </ul>
<b>Public Chargers</b>
20. What do you think about the public chargers overall?
<ul style="list-style-type: none"> <li>• Downtown charger was broken: <ul style="list-style-type: none"> <li>○ Discourages use</li> </ul> </li> </ul>

- Needs better system for reporting outages
- Good for prime parking
- There should be more
- Frequently taken by town car
- Incentives should be focused on at-home charging

#### 21. Are the public chargers in convenient locations?

- Downtown
  - Far from center, especially during colder months
  - Good place
  - Good for people going downtown
- High School
  - Good if you have a reason to be there
  - Unsure of reasoning/convenience
- Airport
  - Remote
  - Not much to do around them
- General
  - More should be added
  - Not well advertised

#### 22. Are there locations that you think an EV charger would be beneficial?

- Stop & Shop
  - Mentioned by 8 EV owners
- Airport parking lot
  - 2 EV owners
- Beaches
- By the ferry
- New garage being built downtown
- Police station
- Curbside downtown
- Hospital

#### 23. Do you ever run into a situation where the charger you want to use is unavailable?

- Never need to charge that badly
- Can switch to gas
- Town car
  - 3 EV owners expressed it should have its own charger
- Cape Air should have to pay to use chargers or get their own

24. If the public charging stations became a pay-to-use system would you still be willing to use them?

- For:
  - Still cheaper than gas
  - Need to be easy to use
  - Make people more responsible about charging time limits
  - People would be more careful with equipment
  - If in turn, more were installed
- Against:
  - Could be more expensive than just giving it away
  - People might use it just for parking
  - Great incentive for promoting EVs
    - May be too soon to start charging
  - People with at home chargers will use them less

### Summary Questions

25. What was your overall opinion of EVs before you purchased one?

- Interested in the technology and environmental advantages
- Thought they were cool
- Always had a high opinion
  - Hard to find dealerships pushing them or with vehicles to test drive
- Been looking to get one for a while
  - Always been environmentally conscious and energy aware
- Thought they were great for the environment and Nantucket
- Expensive and concerned about safety with small size

26. How has your opinion changed after becoming an EV owner?

- Didn't realize how fun it would be to drive
- Thinks Tesla is currently the only viable option
- Still some things that need to be worked out but the technology is valuable
- Perfect for Nantucket
  - More people on island should have them
- Very impressed
  - Especially with acceleration
- More affordable than people think
- Very enthusiastic about EVs now
- Believes market and technology will advance and grow in the coming years
- Loves it; no regrets

27. Do you ever take your vehicle to the mainland?

- Yes
  - Visits friends in ME or NY or road trips
    - Used to be harder with lack of chargers but there's a lot more infrastructure now
- No
  - Wouldn't because of short range
  - Has a different vehicle on the mainland
  - Only for inspections or maintenance
  - Too expensive to take on ferry
    - Cheaper to rent for the day
  - No need to
- Not yet, but plans to

#### 28. Would you have the same opinions about EV's regardless of living on Nantucket?

- No, Tesla's high range makes it good for the mainland too
- Yes, would need more range
  - 5 EV owners
- Not in an urban area
- As long as there were chargers nearby
  - 3 EV owners

#### 29. What are some unforeseen challenges of owning an EV?

- Difference in range based on season
  - Battery charge doesn't last as long in the winter
- Possibly higher insurance costs
- Learning curve for new technology and features
- Sometimes chargers don't work
- Kind of small
- Servicing off island
- Low to ground
  - Problems with cobblestone
- Getting used to remembering to charge

#### 30. What are the benefits of owning your EV/favorite things?

- Fun to drive
- Responsive and easier to control
  - Regenerative breaking
  - Good acceleration
- Fits lifestyle
  - Range

<ul style="list-style-type: none"> <li>○ Philosophically</li> <li>● Looks cool</li> <li>● Less guilty about short commutes</li> <li>● Dedicated parking spots</li> <li>● Easier &amp; cleaner than gas</li> <li>● Good ground clearance</li> <li>● Fuel costs</li> <li>● Environmental benefits</li> <li>● Low maintenance</li> <li>● Cost pay offs</li> <li>● Quiet &amp; convenient</li> <li>● “Cool factor”</li> <li>● Low weight</li> </ul>
32. Are people interested in your vehicle? How so? what interests them most?
<ul style="list-style-type: none"> <li>● People generally get very positive feedback <ul style="list-style-type: none"> <li>○ Interest</li> <li>○ Questions</li> <li>○ Impressed</li> <li>○ Want to look into getting their own</li> </ul> </li> <li>● Some concerns from summer residents about driving on the mainland</li> </ul>
33. What is the biggest reason you feel that prevent more people from buying EV's?
<ul style="list-style-type: none"> <li>● Expensive</li> <li>● Lack of infrastructure</li> <li>● Want more range</li> <li>● Stubborn and don't like change</li> <li>● Need more options</li> <li>● They're uninformed about technology</li> <li>● Size</li> <li>● Lack of 4-wheel drive</li> </ul>
<b>Other Notes</b>
<ul style="list-style-type: none"> <li>● Premium parking would further incentivize EVs</li> <li>● Town should be promoting EVs more</li> </ul>



## Appendix 5: Survey Questions

Below is a list of the questions included in our survey. This is an export of all survey questions and is not representative of the appearance of the distributed survey. Survey respondents did not see all the questions because the survey was adaptive based on given responses, as outlined by the skip logic.

### Electric Vehicles on Nantucket

---

#### 1) Informed Consent:\*

☐ I understand that participation in this survey is voluntary and my responses will be completely anonymous. The survey may be terminated at any time.

---

#### Demographics

##### 2) Age Group:

- ☐ Under 18
- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ 65 or over
- ☐ Prefer not to answer

##### 3) Gender:

- ☐ Female
- ☐ Male
- ☐ Other

##### 4) Residential Status:

- ☐ Year round
- ☐ Seasonal (Less than 6 months)
- ☐ Visitor/Commuter
- ☐ Other

**Page exit logic:** Skip / Disqualify Logic**IF:** Question "What type of vehicle do you primarily use on the island?" #5 is one of the following answers ("I do not bring a vehicle to the island.", "I do not own a vehicle.") **THEN:** Jump to [page 5 - Estimated Purchasing Timeframe](#)

**Page exit logic:** Skip / Disqualify Logic**IF:** Question "What type of vehicle do you primarily use on the island?" #5 is one of the following answers ("Gasoline", "Diesel") **THEN:** Jump to [page 3 - Vehicle Model & EV Considerations](#)

**Page exit logic:** Skip / Disqualify Logic**IF:** Question "What type of vehicle do you primarily use on the island?" #5 is one of the following answers ("All-Electric Vehicle", "Plug-In Hybrid") **THEN:** Jump to [page 8 - Electric Vehicle Drivers](#)

**Page exit logic:** Skip / Disqualify Logic**IF:** Question "What type of vehicle do you primarily use on the island?" #5 is one of the following answers ("Hybrid") **THEN:** Jump to [page 4 - Hybrid Vehicles](#)

**5) What type of vehicle do you primarily use on the island?\***

- ☐ Gasoline
- ☐ Diesel
- ☐ Hybrid
- ☐ All-Electric Vehicle
- ☐ Plug-In Hybrid
- ☐ I do not bring a vehicle to the island.
- ☐ I do not own a vehicle.

---

## Vehicle Model & EV Considerations

**Page exit logic:** Skip / Disqualify Logic**IF:** **THEN:** Jump to [page 5 - Estimated Purchasing Timeframe](#)

**6) What is the make/model of this vehicle?**

---

**7) Is this vehicle owned or leased?**

- ☐ Own (purchased new)
- ☐ Own (purchased used)
- ☐ Lease

**8) Did you consider an EV last time you purchased a vehicle?**

- ☐ Yes
- ☐ No

**9) What has prevented you from purchasing an EV in the past? (select all that apply)**

- ☐ Charging concerns
  - ☐ Range concerns
  - ☐ Too expensive
  - ☐ Unsuitable for Nantucket's terrain/local driving needs
  - ☐ Other: \_\_\_\_\_
  - ☐ Maintenance concerns
  - ☐ Didn't know much about the technology
  - ☐ Unavailable at the local dealership
  - ☐ Unavailable used
  - ☐ Unaware of electric vehicles
-

## Hybrid Vehicles

**10) What is the make/model of this vehicle?**

---

**11) Is this vehicle owned or leased?**

- ☐ Own (purchased new)
- ☐ Own (purchased used)
- ☐ Lease

**12) Did you consider an all-electric vehicle the last time you purchased a vehicle?**

- ☐ Yes
- ☐ No

**13) What has prevented you from purchasing an all-electric vehicle or plug-in hybrid in the past? (select all that apply)**

- ☐ Unaware of all-electric vehicles
  - ☐ Didn't know much about the technology
  - ☐ Range concerns
  - ☐ Charging concerns
  - ☐ Maintenance concerns
  - ☐ Unavailable at the local dealership
  - ☐ Unavailable used
  - ☐ Too expensive
  - ☐ Unsuitable for Nantucket's terrain/local driving needs
  - ☐ Other: \_\_\_\_\_
- 

## Estimated Purchasing Timeframe

**Page exit logic:** Skip / Disqualify Logic**IF:** Question "

**When do you expect to need to purchase your next vehicle?**

" #14 is one of the following answers ("I don't intend to purchase a motor vehicle.")

**THEN:** Jump to [page 9 - Electric Public Transportation](#)

**14) When do you expect to need to purchase your next vehicle?\***

- ☐ 1-2 years
  - ☐ 3-5 years
  - ☐ 5+ years
  - ☐ Other: \_\_\_\_\_
  - ☐ I don't intend to purchase a motor vehicle.
- 

## Future Vehicle Considerations

**15) What is your estimated price range for your next vehicle purchase or lease? (select all that apply)**

- ☐ Less than 5,000

- ☐ 5,000 to 10,000
- ☐ 10,000 to 20,000
- ☐ 20,000 to 30,000
- ☐ 30,000 to 50,000
- ☐ 50,000 to 100,000
- ☐ 100,000 +

**16) Do you feel that an EV can fit within the price range you specified?**

- ☐ Yes
- ☐ No
- ☐ Not sure

**17) Which vehicle types are you most interested in? (select all that apply)**

- ☐ Sedan
- ☐ SUV
- ☐ Crossover
- ☐ Compact
- ☐ Truck
- ☐ Utility Vehicle
- ☐ Other: \_\_\_\_\_

**18) What are the most important features when purchasing a vehicle for Nantucket? (select 3)**

- ☐ Cargo Storage
- ☐ Fuel Efficiency
- ☐ Four Wheel Drive
- ☐ Aesthetics
- ☐ Comfort
- ☐ Electronics (such as GPS, Bluetooth, etc.)
- ☐ Environmental Performance
- ☐ Large Size
- ☐ Small Size
- ☐ Other: \_\_\_\_\_

**19) Which of these are important limitations you associate with EVs? (select all that apply)**

- ☐ Cargo Storage
- ☐ Fuel Efficiency
- ☐ Four Wheel Drive
- ☐ Aesthetics
- ☐ Comfort
- ☐ Electronics (such as GPS, Bluetooth, etc.)
- ☐ Environmental Performance
- ☐ Large Size
- ☐ Small Size
- ☐ Other: \_\_\_\_\_

---

**Did You Know...?**

**20) You can receive up to \$10,000 in monetary incentives in MA. and residents of Nantucket have obtained EVs for as low as \$14,000.**

**How does this change your opinion about electric vehicles?**

- ☐ Those prices make electric cars more appealing.
- ☐ Those prices are negligible.
- ☐ I am not concerned with cost.
- ☐ I already know this information; it is a definite plus.
- ☐ I already knew this information; it makes little difference for me.

**21) Electric vehicles can be purchased new for as low as \$21,750 and used for as low as \$9,100 with most cars being 2012-2015 models boasting many modern features.**

With this said, which of the following best reflects your thinking?

- ☐ I was unaware of these prices; I now feel they can be cost effective.
- ☐ I was unaware of these prices; I still feel they are not cost effective.
- ☐ I was aware of these prices; I feel they can be cost effective.
- ☐ I was aware of these prices; I feel they are not cost effective.
- ☐ I was aware of these prices; it makes little difference to me.
- ☐ Other: \_\_\_\_\_

**22) Based upon the current cost of fuel and electricity on Nantucket (\$3.57 per gallon, \$0.18/KWh as of 11/14/16), driving an electric vehicle would be about half the cost of driving an average sedan and one-third the cost of driving a full-size SUV.**

How does this change your opinion about electric vehicles?

- ☐ Those savings make electric cars more appealing.
- ☐ Those savings are negligible.
- ☐ I am not concerned with fuel cost.
- ☐ I already know this information; it is a definite plus.
- ☐ I already knew this information; it makes little difference for me.

**23) All of the EV owners interviewed on Nantucket expressed that they are overwhelmingly happy with their vehicles and they would definitely recommend an EV for anyone on Nantucket. They explained that the range is more than sufficient for their daily commutes and the vehicles drive incredibly well, even on the cobblestones.**

Knowing this, how likely is it that you will purchase an EV as your next vehicle?

- ☐ Definitely
- ☐ Somewhat likely
- ☐ Neither like nor unlikely
- ☐ Not likely
- ☐ Definitely not
- ☐ Other: \_\_\_\_\_

---

## Electric Vehicle Drivers

**24) What specific make/model vehicle do you have?**

---

**25) What first made you look into EVs?**

---

**26) What features did you most strongly consider when purchasing your EV? (select all that apply)**

☐ Affordability

☐ Range

☐ Cargo Storage

☐ Four wheel drive

☐ Aesthetics

☐ Comfort

☐ Smart features

☐ Other: \_\_\_\_\_

**27) Are you satisfied with your EV?**

☐ Yes

☐ No

☐ Other: \_\_\_\_\_

**28) Why or why not?**

---

**29) About how many miles per week do you drive on Nantucket during the summer?**

☐ 0-9 miles

☐ 10-19 miles

☐ 20-29 miles

☐ 30-39 miles

☐ Over 40 miles

**30) Where do you primarily charge?**

☐ At home

☐ At the Town's public chargers

☐ Other: \_\_\_\_\_

**31) What kind of charger do you use at home most frequently?**

☐ Level 1 (110V)

☐ Level 2 (240V)

☐ Other: \_\_\_\_\_

**32) Have you used the Nantucket public charging stations? If so how often?**

☐ Never

☐ Once or twice

- ☐ Occasionally
- ☐ Often

**33) If these public charging stations became a pay-to-use system would you still be willing to use them?**

- ☐ Yes
- ☐ No
- ☐ Other: \_\_\_\_\_

**34) Are there locations on Nantucket that you think an additional public EV charger would be beneficial?**

- ☐ Stop & Stop (Downtown)
- ☐ Stop & Shop (Mid-Island)
- ☐ Jetties Beach
- ☐ Nantucket Cottage Hospital
- ☐ Other: \_\_\_\_\_

**35) Nantucket's summer electric usage is growing five times the statewide average, peaking between 5-10 pm. If this trend continues, a third undersea cable may be necessary, historically paid for by Nantucket customers.**

**Given this information, how likely are you to participate in an off-peak charging initiative?**

- ☐ Definitely
- ☐ Somewhat likely
- ☐ Neither likely nor unlikely
- ☐ Not likely
- ☐ Definitely not
- ☐ Only if there were incentives
- ☐ Only if it had no effect on getting a full charge

---

## **Electric Public Transportation**

**36) The Town is interested in exploring the concept of a free electric shuttle service between mid-island and downtown, which would be sponsored by local businesses and/or the Town of Nantucket.**



<http://www.ridedowntown.com/cities/aspen/>

**Would you be interested in this service?**

- ☐ Yes, I would use this service.
- ☐ No, I would not use this service.
- ☐ This service is not appropriate for Nantucket.
- ☐ Other: \_\_\_\_\_

---

## Final Thoughts

**37) Do you have any thoughts or concerns regarding EVs, energy use, or this survey that you would like to share with us?**

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## Thank You!

Thank you for taking the time to take our survey. Your response has been recorded.

If you have any questions or concerns feel free to contact us at [ack16neo@wpi.edu](mailto:ack16neo@wpi.edu) or the Nantucket energy coordinator Lauren Sinatra at [lsinatra@nantucket-ma.gov](mailto:lsinatra@nantucket-ma.gov)

If you would like more information about EVs or about how they can fit into your lifestyle visit [FuelEconomy.gov](http://FuelEconomy.gov).

If you would like to know more about our project:

Electric vehicles (EVs) are on the rise, particularly plug-in vehicles. [Clean Technica](#) stated, “While EV sales still make up a small slice of the overall market, they are actually selling at a faster pace than the first generation of hybrid cars.” Electric vehicles are becoming more affordable and practical as the technology improves. Furthermore, according to [Bloomberg](#), EV purchases will become 35% of all global new car sales by 2040.

EV owners on Nantucket are very enthusiastic about their vehicles and have expressed that EVs are an excellent option for Nantucket. Although we aim to spread awareness of EVs, we are also considering peak electrical load during the summer. Electricity on Nantucket is supplied through two undersea cables that have specific capacities (36MW and 38 MW) and “National Grid, the island’s sole electric utility, has determined that Nantucket’s demand for electricity is growing more than five times the Massachusetts state average.” ([Nantucket Energy Office](#), 2016). If this increase continues, a third undersea cable may be required, which may impact the electric rates of Nantucket customers. Our goal is to encourage EV use while promoting responsible off-peak charging.

### More Information:

Rebates: [MOR-EV.org](http://MOR-EV.org)

Tax Credit: [IRS.gov](http://IRS.gov)

Best Used EVs: [Autotrader.com](http://Autotrader.com)

Tips on how to save energy: [MassSave.com](http://MassSave.com)



## **Appendix 6: Survey Responses**

The responses to our survey are located in a separate file also available at this [location](#).