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Electric Vehicles: The Next Step in Renewable Transportation?

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Electric Vehicles: The Next Step in Renewable Transportation?

**A Major Qualifying Project
Submitted to the Faculty of the
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Arts**

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Abstract

This report is a look into electric vehicles and whether or not electric vehicles are a viable option to replace internal combustion engine vehicles for consumer transportation. Perspectives from both the federal and state levels will be addressed as well what previous Presidential administrations passed with regards to renewable energy since many of those policies were the stepping stones to policies used today. Lifecycle analysis and a basic outline of electric vehicles will be provided. The objective of this report is to educate the reader about electric vehicles since EVs are mentioned in the news from time to time and may be the next wave of transportation for those who commute to work via their own personal car.

Note from the Author

As a student who has studied a range of subjects from engineering to mathematics and history I made the decision to focus my efforts on the environmental field with the objective of helping to solve some of the bigger problems that this generation encounters regarding energy and global warming. My overall goal with this project is to incorporate the skills I obtained while studying at WPI from different disciplines and apply that knowledge to a problem – US oil consumption, particularly in the automotive industry – and a potential solution – electric vehicles. I hope that those who read this report walk away with at least some knowledge of electric vehicles and the policies that are behind them, and a basis for forming their own ideas and opinions about the subject as this technology progresses.

I first became interested in electric vehicles because I felt that this new technology would allow people to begin to transition from traditional cars to emission-free driving. While I understood that it is a daunting task, I also knew that unless people were willing to sift through the problems that are associated with a new method or technology, that technology will never become popular. Inventions such as the telephone, the computer and the internet were first thought to be technological advances that required a lot of time and effort to utilize for the common person, but these inventions are in common use today. It is my goal to see electric vehicles become more of a factor as people try to be more environmentally cognizant while also maintaining their economic budget.

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The readers for their interest and time

List of Acronyms

Listed in Alphabetical Order:

ARRA	American Recovery and Reinvestment Act
CBO	Congressional Budget Office
CCC	Clean Cities Coalition
CMAQ	Congestion Mitigation and Air Quality
CNG	Compressed Natural Gas
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOER	Department of Energy Resources
DSIRE	Database of State Incentives for Renewables & Efficiency
EIA	Energy Information Administration
EOEEA	Executive Office of Energy and Environmental Affairs
EPA	Environmental Protection Agency
EVs	Electric Vehicles
EVSE	Electric Vehicle Supply Equipment
FY	Fiscal Year
HOV	High Occupancy Vehicle
IEA	International Energy Agency
MBTA	Massachusetts Bay Transportation Authority
MEPA	Massachusetts Environmental Protection Act
NEC	National Electric Code
NECPA	National Energy Conservation Policy Act
NGPA	Natural Gas Policy Act
NWPA	Nuclear Waste Policy Act
PIA	Plug In America
PV	Photovoltaic

Introduction

There have been growing concerns in the general population regarding how the world's current energy policies are harming the environment. As people's anxiety has increased about global climate change, air quality and major changes within specific ecosystems, people have begun to look for other alternatives to traditional energy consumption. Now, more than ever, people are being conscientious about "going green", and are trying to do their part to save the environment for future generations. The United States, due to the high demand for oil, remains highly dependent on oil imports from overseas since the current supply within the United States cannot sustain the amount that citizens consume on a daily basis (EIA 2010). While the initial cost of some alternative energy options may be pricey at first, they can become economically suitable options for the average consumer if there is sufficient investment and development of technology. It is important for people to focus on alternative energy products and reduced energy consumption, since it will not only help the environment by reducing the amount of pollution that is released into the atmosphere, but also will cut down on costs such as transportation (Union 2005). Finally, there is the harsh truth that while it is convenient to use fossil fuels, there is a limited supply and that supply dwindles with each passing day (Oil Problem 2006).

While the federal government has created national policies and propositions for reduced energy consumption and cleaner alternative energy, it is the role of the state and local governments to help implement these new policies across the country. For the Commonwealth of Massachusetts there are multiple organizations within the state government that focus on utilizing funds given by the federal government to state projects. One of those organizations is the Executive Office of Energy and Environmental Affairs, or EOEEA, which focuses on

projects involving water policy/regulation, climate change, waste management, land and forest conservation and energy efficiency (EOEEA 2011). EOEEA and other organizations work to help utilize the funds given to them by state taxes and federal grants to work on existing policies ranging from environmental to educational concerns.

As people are trying to be more proactive when it comes to energy usage and saving the environment, one of the ideas that is gaining popularity is using electric vehicles to commute to and from work on a daily basis. It is because of this emerging technology that companies such as Coulomb Technologies have begun creating more of an environment in which electric vehicles can help transition people from using petroleum-based vehicles to those that consume less energy and produces fewer emissions. This report will not only help educate the reader about what electric vehicles are, but also showcase the problems and solutions that come with electric vehicles and some of the steps necessary to make electric vehicles as mainstream as petroleum-based vehicles are today.

Background

The concept of renewable energy dates back to Socrates with the idea of utilizing the sun's energy to heat homes in the winter and keep them cool in the summer. In the United States, focus on renewable energy and reduced consumption began in earnest with the energy crisis of 1973 (ProCon 2011). President Carter addressed the United States regarding the country's oil usage, and urged the country to begin to make the transition to alternative energy methods (Carter). "The most important thing about [alternative energy] proposals is that the alternative may be a national catastrophe." President Carter set out goals for the country that he hoped would be accomplished by 1985 (Carter):

- ❖ Reduce gasoline consumption by 10% below its current level.
- ❖ Cut in half the portion of US oil which is imported [6 – 16 million barrels a day]
- ❖ Use solar energy in more than 2.5 million houses.

Looking back, even though President Carter saw the potential problems with excessive energy and oil consumption, it was difficult for the country to make the adjustment from oil-based energy to alternative energy sources, due to economic and technological barriers.

The Carter Administration (1977 – 1980)

The energy crisis in 1973 brought anxiety to the United States and showed how vulnerable the country was if a gas shortage would occur. In order to help avoid another crisis, President Carter on April 18th, 1977 spoke to the United States citizens regarding his concerns and his plan to help bring about a more stable source of energy for the future. "The energy crisis has not yet overwhelmed us, but it will if we do not act quickly. It is a problem we will not solve in the next few years, and it is likely to get progressively worse through the rest of this century

(Jimmy Carter).” It was President Carter that addressed the growing consumption of oil in the United States and noted that changes needed to be made to the efficiency in energy use in order to maintain steady growth. Some of the statements made by President Carter resonate with some of the issues that the United States face today: “Along with that money [for imported oil] we will continue losing American jobs.” “75% of energy comes from oil and natural gas.” (Jimmy Carter)

It was from these statements that President Carter set out to make new policies to help encourage the use of alternative energy by approaching Congress with his ten principles. These principles were the framework of what the goals would be for future energy and environmental policies and mandates which include reducing the potential vulnerability to embargos from other countries, having the government take responsibility for the policy, and being fair to regions, classes and interest groups across the country (Jimmy Carter). President Carter approached Congress with a set of goals in mind (Jimmy Carter):

- Reduce the annual growth rate in energy demand by less than 2%
- Reduce gasoline consumption by ten percent below the 1977 level
- Cut down half of imported oil into the United States
- Create a petroleum reserve to act as a six-month reservoir
- Increase coal production by two-thirds to a billion tons a year
- Insulate ninety percent of American homes and new buildings
- Use solar energy in over two and a half million homes

On August 4th, 1977, Congress passed the Department of Energy Organization Act which President Carter signed that combined the Federal Energy Administration, the Energy Research and Development Administration and the Federal Energy Regulatory Commission (History Division). The goal of the Department of Energy is to manage, create and implement energy conservation strategies to deal with the short-, mid- and long-term energy problems of the United States (Energy Problems). The act continues to lay out the powers that the new department has

in working with Secretaries of State, Treasury and Defense in order to coordinate effective national policies regarding energy (Energy Problems). Overall, the Department of Energy Organization Act was the stepping stone to later acts by President Carter regarding energy policy.

In response to the 1973 energy crisis, Congress enacted the National Energy Act which included statutes like the Energy Tax Act, National Energy Conservation Policy Act, Natural Gas Policy Act and Power Plant and Industrial Fuel Use Act (Energy Timeline). The Energy Tax Act, enacted on November 9th, 1978, helped encourage consumers to utilize alternative energy methods by offering tax incentives and credits to those that installed solar, wind or geothermal sources of energy for their homes. The credit given to consumers equaled 30% of the cost of the equipment up to \$2000 while any costs above \$2000 were given 20% credit up to \$10000 (IEA Databases). The National Energy Conservation Policy Act is currently the backbone of energy requirements from the late 1970's to the present day (NECPA). It includes guidelines and standards for Federal buildings to meet regarding energy consumption and incentives for meeting with said guidelines. The Natural Gas Policy Act enabled the Federal Energy Regulatory Commission to establish price ceilings for certain types of natural gas which ended up helping consumers that were farther away from the producing field (NGPA 1978). The Power Plant and Industrial Fuel Use Act "restricted the construction of power plants using oil or natural gas as a primary fuel and encouraged the use of coal, nuclear energy and other alternative fuels" (Repeal). Other acts soon followed that followed along the same lines as those that were enacted by the National Energy Act.

With all of these acts in place, energy conservation and efficient use seemed to be within reach but a few key facts prevented these acts from succeeding in the long run. The biggest

reason why some of these acts failed, namely the Natural Gas Policy Act, is that there was not a large enough demand for natural gas which caused the market for natural gas to crash once the price ceiling was removed on almost all types of natural gas. The Fuel Use Act also suffered from the lack of demand in the natural gas market since it restricted the use of natural gas in power plants. When the act was repealed in 1987, there was a dramatic increase in the use of natural gas from 2.6 trillion cubic feet to 5.7 trillion cubic feet in 2002. Had President Carter utilized natural gas more effectively, more companies and factories could have utilized natural gas instead of fossil fuels since it has now been determined that natural gas is less harmful for the environment. Another major issue that came with President Carter's attempts was the lack of interest and extra capital for interested consumers. Although the tax credit was handy for the average consumer, many interested citizens did not have enough money to front the expensive installation and would need to wait until they were partially reimbursed by the government. This discouraged consumers since it was a cheaper alternative in the short-run to continue using oil for their energy needs. Overall, it was the lack of interest from the general population that led to the downfall of some of these acts, but it became a stepping stone for the United States government for future energy policies.

The Reagan Administration (1981 - 1988)

The general public was not happy with the way President Carter was using the government and taxpayer money to try and prepare for the future rather than handle the economic problems of the present. Although President Carter had well-thought intentions with his environmental and energy policies, the technology during his administration was not able to complete his challenges for a more sustainable energy supply for the United States. During the

campaign trails for the 1980 election, Reagan had four main economic principles to challenge President Carter's stance on the economy:

- 1) Reduce the growth of government spending
- 2) Reduce marginal tax rates on income from both labor and capital
- 3) Reduce regulation
- 4) Reduce inflation by controlling the growth of the money supply (Reaganomics)

These were also known as 'Reaganomics' where his main focus was not on energy, the environment or on the far future, but rather focus on the problems at hand which was the increasing inflation rate, the issue of benefits for the people who were not in the main workforce such as college students and retirees, and on preventing another war from starting with his efforts to increase defense spending. President Reagan was more focused on the economic side of the United States and began to mold the economy into what is seen today with regards to tax cuts and inflation regulation.

President Reagan was not known for investing much time into the environment but he felt that the general public would not blame him because environmental issues were not looked at as closely as it is in present-day. At one point President Reagan requested that the Department of Energy be disbanded and that the duties of the Department would be spread out among the other departments to help cut down on government spending, but this was met with massive friction in Congress. To further his point about his views on alternative energy, he took down the solar panels that were atop the White House because he felt it was wasting too much of the taxpayer's money. Although he did not focus on alternative energy as much as President Carter, one of his main focuses was on nuclear energy and the proper way to store nuclear waste. Yucca Mountain still remains as an issue from the Nuclear Waste Policy Act of 1982 and today's science has yet to find an acceptable method to destroy or deteriorate the amount of nuclear waste (NWPA). President Reagan did not approve of the alternative energy methods that President Carter was

trying to implement such as natural gas because of the restrictions of oil and the fact that the market was not yet ready for the demand for natural gas as the main source of fuel. In response to this project, President Reagan used the Crude Oil Windfall Profit Tax to reduce the control limits that were in place during the Carter administration to help reduce the dependency of foreign oil which was a growing issue since the limits caused the purchasing of more foreign oil rather than domestic oil.

During the Reagan administration there were multiple wars involving the supply of oil all of which enabled Reagan's Windfall Profit Tax to succeed even more since the supply of oil was bountiful and translated into lower gas prices for the American consumer which helped the economy even further. These military events included the Gulf of Sidra incident of 1981 and the Iran-Iraq War from 1987 to 1988 in which afterwards the United States gained access to a greater supply of petroleum. Because one of President Reagan's main agendas was to increase military spending, his reelection was practically secure because in times of war, since the Cold War was still ongoing, the general public favored Reagan for bolstering the military force of the United States. This was at the cost of other government agencies such as the Department of Energy and the Environmental Protection Agency whose budget was cut almost 30%. Although one of Reagan's 'four pillars' of his campaign was to cut government spending, his spending during his first term in office almost matched that of President Carter. Reagan turned some of the extra money gained from the tax cuts into a restructured system for Medicare and OASDI Trust funds: Old-Age, Survivors, and Disability Insurance Trust Funds.

The Bush Administration (1989 - 1992)

As the Vice President during Ronald Reagan's administration, George H. W. Bush had a different outlook on the United States than his predecessor did with regards to the economy.

Although former President Reagan stimulated the economy and provided benefits to many, the national debt had increased drastically and President Bush wanted to help reduce that debt. The main issue with reducing the national debt was that it either meant cutting government spending like former President Reagan did or to add or increase taxes which would go against President Bush's promise during his campaign trail to not create more taxes. In the end President Bush decided to increase taxes due to a primarily democratic congress, but this ended up being his major downfall for the 1992 election against Bill Clinton. During his presidency, President Bush had military operations in Panama and the Persian Gulf as well as was in office when the Berlin Wall fell so the Cold War was ending as well. Regarding his environmental and energy policies, President Bush appointed William K. Reilly to head the Environmental Protection Agency along with other strong environmentalists as President Bush wanted to take a more active role when it came to the environment.

Most of his environmental policies were updates of previous policies. One of these policies was the Clean Air Act which started in 1970 during the Nixon Administration. President Bush's amendment in 1990 focused on different aspects such as:

- Urban Pollution
 - Focused on Ozone, Carbon Monoxide and Particulate Matter
 - 96 cities, including Los Angeles, that are ranked from 'marginal' to 'extreme' based on pollution levels
- Permits
 - Operating permits for states to reduce emissions due to enforcement standards.
- Motor Vehicles
 - Vehicle Emissions – starting with the 1994 model year vehicles will have higher standards for reduced emissions with hydrocarbons, carbon monoxide and nitrogen oxides.
 - Fuels – starting with 1995, various cities will start having particular blends of gasoline to reduce emissions in the most extreme cases for cities.
 - Clean Cars – starting in 1996, pilot programs for cleaner cars will be introduced in the state of California while other states can opt-into the program.

- Air Toxics
- Acid Rain
- Ozone Depletion (Clean Air)

His other movements regarding the environment were similar to that of former President Carter in that President Bush created policies to encourage the use of alternative and renewable energy sources. Rather than offer incentives to consumers for pursuing and using the new technology, President Bush's approach was to reduce the manufacturing costs for renewable energy. This process began with the Renewable Energy and Energy Efficiency Technology Competitiveness Act which set goals in the United States to have a certain percentage of energy used by the United States is from renewable sources by 1995. Another program that President Bush initiated was the Partnership for a New Generation of Vehicles (PNGV) which aimed to bring vehicle fuel efficiency up to eighty miles per gallon in which various government departments formed a partnership to pass incentives and tax cuts for consumers who wanted to take advantage of this new wave of technology. Sadly, this partnership ended in 2001 at the request of automakers. During his final year in office, President Bush signed the Energy Policy Act of 1992 which addressed different renewable energy fields to complement the Renewable Energy Act in areas such as alternative fuels in which "gave the U.S. Department of Energy power to regulate the required minimum number of alternatively fueled vehicles for a federal fleet (EPA 92)." Conjoining with alternative fuels, the Energy Policy Act of 1992 also created energy codes for buildings, utilities and even began research into electric vehicles (EPA 92).

The Public Climate of Energy

Dr. Barbara C. Farhar, a senior policy analyst at the National Renewable Energy Laboratory has researched into the public opinion during the Carter administration and points

beyond and found that generally, during the Carter Administration, the population did not recognize the energy crisis as a ‘crisis’ but more of a concern regarding the rise in electricity costs (Trends 603). “Inflation, unemployment, and crime were more important concerns than energy at that time” and it appeared that energy only became a paramount concern for the general public in 1979 which was before the Presidential election between President Carter and Ronald Reagan (Trends 604). In a Roper sample taken in 1980, 51 percent of people felt that the government had enough oil in reserves and that the energy crisis was formulated “for economic and political reasons” and based on Dr. Farhar’s research this trend continued into the 1990’s and based on news reports throughout the past decade there is some who feel that the situation has not changed with regards to the amount of oil that is held in reserve for the United States.

With regards to favorability in the public eye, the Department of Energy’s status fluctuated based on numerous reasons but the major reason being the price of oil. It was in 1986 when the Department of Energy received its highest favorable rating which was during the Reagan administration when the price of oil was significantly cheaper due to the fewer restrictions placed on oil companies. Conversely, the lowest rating during this data collection between 1979 and 1992 was in 1990 when it was “tied with the Department of Commerce and Labor for sixth place” which occurred when President Bush took over in office (Trends 609). Interestingly enough, the data gathered with regards to where people preferred their energy be coming from changed after the Reagan administration since people showed a decrease in preference to fossil fuels and nuclear energy and preferred the energy be produced from renewable resources but only after cost was dismissed from the questioning. The overall consensus was that people wanted there to be less of a demand for energy and more of a supply

which correlates with the growing market of higher efficiency in energy appliances and in vehicles as well (Trends 610).

The data analysis goes on to discuss the topic of energy supply preferences which begins in 1977 when this question was asked: “which energy sources do you think are realistically possible to use for replacing (oil) for the next five years?” (Trends 610) The most popular answer was to use coal followed by the use of solar energy. As time progressed solar energy became more of a popular answer as research was being conducted on the properties of coal and the bi-products of burning coal for electricity. Similar trends can be applied when asked about the type of vehicle that consumers would drive since more people preferred to not use a full-sized vehicle from 1979 to 1989 which correlates with the growing trend of people living closer to cities and thus would prefer a more fuel-efficient vehicle rather than a full-sized vehicle and also correlated with the trend regarding the percentage of workers that would drive alone to work since more than 73 percent of workers did so in 1990 compared to 64 percent in 1980 (Trends 612-614). These trends help define what the public was hoping for from their government and where the economic trends would be with regards to the automobile industry.

The Clinton Administration (1993 – 2000)

Although President Clinton did not focus on energy issues like some of his predecessors did, but he did try to utilize the concept of saving energy and conserving fuel to help cut back costs and stimulate the economy. For the first two years of his administration President Clinton did not act on energy policy, but soon after he started focusing on projects similar to those used by former President George Bush and President Carter to try and incentivize the use of alternative energy. One of the more controversial acts that President Clinton tried to pass during his administration is the ‘BTU tax’ where BTU, or British thermal unit, is a form of measuring

the amount of energy consumed by a residence or place of business. The tax would help incentivize alternative energy solutions and help raise revenue for government energy endeavors, but the BTU tax was so strongly opposed that it never even got a chance to be voted on. President Clinton would try to pass along various notions to help promote alternative and renewable energy but Congress did not fully endorse the notions because the technology was not proven enough and the economy was still struggling.

One success story with President Clinton's attempts with energy policy was the 'Clean Car Initiative' which collaborated Ford, Chrysler and General Motors to keep car prices stable for consumers but provide better fuel options whether it be improving the consumption of fossil fuels or finding alternative measures such as electricity, diesel or ethanol. This would lead to automotive manufacturers to focus on creating more fuel-efficient vehicles which eventually led to other car manufacturers in creating vehicles such as the Toyota Prius which is now considered a staple when discussing fuel-efficient cars. Another policy that was enacted with President Clinton was the Climate Change Action Plan in which the government would begin to take measures to help reduce emissions for the sake of preventing drastic changes in the environment such as global warming. Rather than try and find a quick solution to the problem, the Climate Change Action Plan focused on working with the problem comprehensively with varying groups rather than just focus on one or two individual groups such as industry or residential. The concept was to rapidly implement policies such that progress would be made almost immediately rather than wait at least five years to see the results of the project. By taking into effect of efficiency of the electric grid and other factors relating to energy costs, the plan was designed to minimize the amount of initial capital needed to make these changes and, in some cases, actually profit from these actions. Overall President Clinton laid down the foundation for potential

projects that would need quick action in order to meet the demand of keeping the environment safe.

The George W. Bush Administration (2001 – 2008)

Much like his predecessors, President George W. Bush wanted to cut back on the amount of foreign oil being used by the American public in an effort to alleviate gas prices and higher energy costs. One act that he did not pass was the efforts of the Kyoto Protocol that was first signed by former Vice President Al Gore but then rejected via a 95-0 vote in the Senate.

President Bush's stance on the Protocol was displayed in a letter to Senators Hagel, Helms, Craig and Roberts saying "I oppose the Kyoto Protocol because it exempts 80 percent of the world, including major population centers such as China and India, from compliance, and would cause serious harm to the U.S. economy (Letter)." Although the United States chose not to follow the Protocol's specifications, President Bush wanted to help reduce the amount of emissions produced in the industry and focused those efforts for the Energy Policy Act of 2005. The Energy Policy Act of 2005 was the main act that would help the President's goal in reducing the amount of oil imported from overseas by investing and creating subsidies for various fuel technology from biofuels, coal production and wind technology.

In his 2006 State of the Union Address, President Bush said "America is addicted to oil" implying that there is too much oil being imported from other countries and has an adverse effect on the United States economy. To combat against this 'addiction', President Bush planned on using technology to help alleviate the need for oil in general and thus becoming more independent from the market of rising oil prices. He announced the Advanced Energy Initiative which increased the amount of clean-energy research done by the Department of Energy to help improve how "we power our homes... and change how we power our automobiles. We will

increase our research in better batteries for hybrid and electric cars and in pollution-free cars that run on hydrogen (SOTU 06).” Similarly, in his 2007 State of the Union address, President Bush reiterated the notion that the United States was too dependent on foreign oil and that alternative fuel technology would need to improve. “We must continue changing the way America generates electric power by even greater use of clean-coal technology; solar and wind energy; and clean, safe nuclear power. We need to press on with battery research for plug-in and hybrid vehicles and expand the use of clean-diesel vehicles and biodiesel fuel (SOTU 07).”

The Obama Administration (2009 – 2012)

President Obama took the issue of energy usage as seriously as former President Carter did after the energy crisis of 1973 due to the reports of a shortage of oil and the increasing gasoline prices. The goals of the Obama administration with regards to energy, which stated on the President’s website, include (E&E):

- New clean energy jobs and technologies
- Make America more energy independent
- Reduce carbon emissions

The biggest act with regards to energy passed by President Obama was the American Recovery and Reinvestment Act of 2009 which was specifically designed to help promote clean energy through new technology and enabling new jobs in the process. Many smaller programs were initiated through the \$80 billion including building a smarter grid for electricity in more rural areas, making federal buildings more energy efficient and support state and local energy efforts (E&E). President Obama also wanted to make the energy that Americans consumed much more efficient, particularly in the transportation department which is why he raised fuel efficiency standards and promoted more alternatively fueled cars to be used by not only the consumer but also by federal fleets.

In President Obama's *Blueprint for a Secure Energy Future*, the document starts with a quote from the President with regards to the future:

“We cannot keep going from shock to trance on the issue of energy security, rushing to propose action when gas prices rise, then hitting the snooze button when they fall again. The United States of America cannot afford to bet our long-term prosperity and security on a resource that will eventually run out. Not anymore. Not when the cost to our economy, our country, and our planet is so high. Not when your generation needs us to get this right. It is time to do what we can to secure our energy future (Blueprint).”

The Blueprint goes into detail about the various steps that the Obama administration will plan to undergo throughout the remainder of the President's term in office. There are a few sections that regard electric vehicles including 'Promoting the Transition to Electric Vehicles' which discuss the importance of the United States becoming a pioneer when it comes to the production and implementation of electric vehicles. In his State of the Union Address in 2011, President Obama made a statement to the nation regarding the production of electric vehicles saying, “With more research and incentive, we can break our dependence on oil with biofuels, and become the first country to have a million electric vehicles on the road by 2015.” Utilizing the funds established in the American Recovery and Reinvestment Act, President Obama plans to make electric vehicles more efficient and more economically viable for average consumers to obtain an electric vehicle since transportation is sometimes the largest annual expense for a family rather than housing.

What kinds of federal/state policies currently exist?

While there is an environmental incentive to focus on alternative energy options, since alternative energy sources typically emit substantial reduced emissions, it is important to appeal to more people by also making these options economically beneficial. In order to help with the

initial cost of some of these options, the government provides these incentives as well as policies to help make it easier and more affordable for people to take advantage of these alternative energy options (DOE 2008). Some of the ways that the government helps implement alternative energy options for the general public is to provide incentives for residential, commercial and municipal groups as well as create a better market for alternative energy to help stimulate the growth of newer technologies.

Tax Incentives

One of the ways that the government makes it more affordable for people to utilize alternative energy solutions is to offer tax rebates. Currently there are tax credit options for people who use alternative energy systems such as solar-electric panels, fuel cells and wind-energy systems (DSIRE 2011). Some people use solar panels to fuel their household appliances while still being connected to the electric grid in the event that the weather is cloudy or in case the panels malfunction (WBIR 2011). The Department of Energy has made a list of tax incentives for utilizing alternative energy to fuel homes, and also for using alternative energy vehicles (DOE 2008). In some states, such as Oregon, Colorado and California, there are additional tax incentives to further encourage people to invest in alternative energy vehicles (PIA 2010).

Policies

During his State of the Union Address, President Obama spoke about innovation, and particularly about transitioning away from oil to renewable and alternative energy. He also stated that renewable energy will “strengthen our security, protect our planet and create countless new jobs” (State of the Union 2011). In furtherance of this objective, the government has utilized money from the American Recovery and Reinvestment Act, or ARRA, to create policies

such as tax incentives, rebates and proposals to help encourage the development of renewable energy technology. With the development of alternative energy solutions, jobs will be created since there will be the need for technicians, sellers of new products, and those who can provide adequate training for consumers. Such policies can help lead the way towards reducing the amount of oil that is brought into this country and place more money back into the United States economy.

States' Role in Implementing Federal Policy

As mentioned earlier in this report, when the federal government creates a bill or establishes goals, it is often up to the state and local governments to implement and execute these goals. Some programs are delegated to states, and funding is provided to the state agency to carry out the program. Other program goals are reached through a competitive process, in which each interested state agency requests a certain amount of funds from the federal government with a proposal for each project the state hopes to execute. These proposals are reviewed, edited and occasionally accepted by different federal departments such as the Department of the Interior, Department of Defense, and others. After the funds have been allocated, it is the role of the head of each state to monitor the use of these funds and to report all findings back to the federal government to verify that the goals of the proposals have been attempted, met or improved upon.

The Commonwealth of Massachusetts's role regarding electric vehicles is to create a basic infrastructure throughout the state to accommodate the upcoming supply of electric vehicles by various automakers. Utilizing federal grant money from the Department of Energy as well as some money from penalties and taxes, Massachusetts aims to install over 150 EVSE's in various counties, towns and cities to help initiate a pilot program to facilitate and enable

consumers' use of electric vehicles. The Commonwealth will be able to analyze the data from people utilizing the stations to help determine where the next wave of charging stations should be placed. It also is the Commonwealth's goal to begin retrofitting municipal and commercial vehicles from gasoline-based to hybrid gas/electric, compressed natural gas and pure electric. Later in this report will be details regarding the primary project called 'ChargePoint America' that provided funding to many metropolitan areas to create an electric vehicle infrastructure including Boston in which the state expanded the project to include communities across the state of Massachusetts including providing stations to WPI.

Electric vehicles 101

What are Electric Vehicles?

Electric vehicles, or EVs, are vehicles that are “propelled by an electric motor (or motors) powered by rechargeable battery packs” (Fuel Eco 2011). The initial concept of the electric vehicle was created in 1828, when a Hungarian citizen invented an electric motor and utilized it to power a tiny model car (About 2011). Since then the concept of an electric motor was tested and implemented in carriages until about the early 1900’s, when gasoline engines became more popular. The primary reason for the popularity of gas-powered automobiles was that such technology overcame various obstacles associated with owning electric vehicles at the time (About 2011). Those obstacles included long charge times, short driving ranges, and long start-up times during cold mornings. With people finding gasoline engines much easier to manage, the electric car appeared to be something only collectors would want.

In the late 20th and early 21st century, companies have begun trying to overcome some of the obstacles that the electric vehicle faced back in the early 1900’s, thanks to technological advances in batteries and efficient power management.

The Start of the EV in the late 20th Century

In 1990, the state of California passed the ‘Zero Emission Vehicle mandate’ which essentially challenged auto manufacturers to create alternatively fueled vehicles that would be available for consumers in the state of California or not be able to continue sales in the state (Zero Emission Mandate). Several auto manufacturers did not like the idea, but several EVs were created including General Motors’ EV-1. As depicted in the documentary *Who Killed the Electric Car*, the EV-1 was a vehicle that consumers found to be ‘amazing’ since the drive was

smooth and the distance that was needed to travel to and from their place of business was within the basic range of the EV-1. There was also a network for charging stations and the EV-1 began to gather momentum as consumers began to learn the benefits of an EV compared to a vehicle with an internal combustion engine. In 2003, the California Air Resources Board who had initially passed the 'Zero Emission Vehicle mandate' decided to rescind the mandate due to pressure from the automotive industry as well as the evidence presented to the board regarding the lack of interest in the consumer population. While the electric car was considered to be unpopular, the idea behind using an alternative fuel for transportation was not lost since varying attempts in hydrogen fuel cells, solar paneled cars and compressed natural gas were all used in an attempt to help resolve the United States' need to import oil for the sake of transportation.

The reemergence of the EV came from a combination of energy policies that encouraged alternative energy fueled transportation along with higher miles-per-gallon requirements of gasoline vehicles. Toyota decided to use an electric motor with their vehicle to help conserve energy and is the technology commonly used in the Toyota Prius which was the benchmark of sustainable driving. With the emergence of hybrid vehicles and only a few car manufacturers appearing to be putting consumers' minds at ease with regards to the debate of global warming, other car manufacturers wanted to challenge the hybrids with their own vehicles. As part of this challenge to the hybrids on the market, General Motors came out with the Chevy Volt while Nissan came out with the Nissan Leaf in hopes that the general population would be looking past the hybrid and become more independent from the prices of oil by having their cars fueled by electricity.

As more EVs began to emerge on the market, government organizations as well as certain business began creating an EV infrastructure to help resolve the issue of 'range anxiety'.

‘Range anxiety’ is the fear that the battery on an EV will become depleted of power while still on the road, sometimes miles from the nearest charging station. A relatively important question regarding EVs became apparent: “What’s to come first, the vehicles or the infrastructure?” Similar to the common argument of ‘The Chicken and The Egg’ the issue with regards to building an EV infrastructure comes down to predicting the market environment for these vehicles. Makers of the charging stations do not want to install the charging stations, also known as Electric Vehicle Supply Equipment or EVSEs, unless they know that consumers will purchase EVs and be using the stations such that there would be a potential market in charging customers later on to recharge their vehicle; conversely, consumers do not want to purchase an EV unless they know that, apart from their home, they can charge their vehicle as they do their day-to-day activities such as going to work. This dilemma was at least partially solved with the help of the federal government as several energy policies gave grants to makers of EVSEs to help create an infrastructure for EVs and help ease the anxiety of consumers.

What are the problems with Electric Vehicles?

Electric vehicles have the ecological advantage of not consuming gasoline and thus dramatically reducing harmful environmental emissions from manufacturing the necessary energy. However, the technology has various challenges that hamper its acceptance by consumers. These include:

- ❖ Battery life – As more gasoline-powered vehicles approach miles-per-gallon ratings of forty and higher, consumers will not explore the option of electric vehicles until they can find similar efficiency.
- ❖ Total emissions – While electric vehicles do not emit any greenhouse gases while in use, in looking at where the electricity comes from as well as the amount of energy that goes into creating the vehicle, users will not achieve 100% reduction in greenhouse gases. (EPA 2011)

- ❖ High initial cost/Maintenance – Due to the types of materials used in making an electric vehicle, EVs can cost as much as \$100,000. Combined with the cost of replacing an electric vehicle’s battery, certain EVs are cost-prohibitive for many consumers. Other electric vehicles, like the Chevy Volt and the Nissan Leaf, cost \$41,000 and \$32,780 respectively. (Tesla MSRP 2011, Christian Science 2010)
- ❖ Infrastructure/Charging station availability – This presents a “chicken and the egg” scenario. Consumers will be reluctant to purchase EVs without knowing that they can conveniently charge their vehicles, while companies will not install charging stations until they know they can turn a profit from users utilizing the stations.
- ❖ Driving range – (Also coupled with driving anxiety) Consumers worry about how short the range is on electric vehicles, and thus that they cannot travel very long distances with EVs unless they make constant stops at charging stations along the way. The driving anxiety comes from the fear of the battery going dead in an uncomfortable scenario.
- ❖ Extreme weather – Just like in the early 1900’s, people are concerned with how electric vehicles will react to colder climates since batteries are affected by the surrounding temperature. High amounts of heat also will cause the battery’s energy supply to decrease.
- ❖ Selection – There are only a handful of different brands/models of electric vehicles currently available on the market.
- ❖ Strain on electrical grid – With all of the electric vehicles being introduced to the electric grid, consumers are worried that the sudden increase in electric vehicles charging may cause strain on the grid.
- ❖ Safety – How will people be able to handle the safety procedures that come from approaching an electric vehicle or a hybrid? This includes first responders and maintenance workers to repair and rebuild electric vehicles. There is also the fear of electrocution from the electrical system that comes within the electric vehicle.

These are some of the primary obstacles that electric vehicles need to face today in order to become more economically sound for consumers.

In September of 2012, the Congressional Budget Office created a report which looked at the effects of policies related to the tax incentives for electric vehicles. “The tax credits apply to

the first 200,000 vehicles sold by each manufacturer for use in the United States, after which the credits gradually phase out (CBO III).” The primary issue is that due to the rising standards set by President Obama for the fuel efficiency of vehicles, the incentive for electric vehicles may be too much since other auto manufacturers will be focusing on selling their traditional hybrids instead of electric vehicles (CBO IV). This specific issue is purely economic and will depend on how the market for EVs develops in the coming years.

Where do EVs stand on these problems?

While EVs do have their problems, it will take time and investment to solve most of them. With the help of federal funding and scientific research, it is the hope of many that electric vehicles are now poised to become more popular in the market.

- ❖ **Battery life** – Batteries can last as long as 8-10 years, which is almost equivalent to the amount of time consumers keep their cars before purchasing new ones. (BCG 2011)
- ❖ **Total emissions** – The majority of the emissions from an electric vehicle occur when creating the battery. Even though the battery can last anywhere between 8-10 years, due to the amount of emissions that go into creating the necessary electricity for the vehicle, it may take the entire lifetime of the battery before the consumer begins saving on emissions. (BCG 2011) Lifecycle analysis is explained for EVs later in this report.
- ❖ **High initial cost/Maintenance** – As noted above, federal and state governments have created incentives for consumers to explore this new technology by providing tax rebates and credits for purchasing a high-efficiency vehicle.
- ❖ **Infrastructure/Charging station availability** – Programs in various states, such as Oregon and California, have begun creating pilot programs to install charging stations (EV Infrastructure 2010). Companies such as Coulomb Technologies have also partnered with the Department of Energy to create the ChargePoint America program to implement EV stations in metropolitan areas (Coulomb 2011).
- ❖ **Driving range** – Apart from the Tesla Roadster, models such as the Nissan Leaf are capable of traveling 60-100 miles on a single charge. While that may not solve the

‘range anxiety’ problem which stems from longer road trips, for the average commuter it can help save the consumer from going to gas stations.

- ❖ Cold weather – Current companies that have an electric vehicle on the market, such as Nissan with the Leaf, have a ‘cold-weather package’ that is designed to help the electric vehicle maintain its performance in colder climates. (Nissan 2010)
- ❖ Selection – More companies are creating their own version of the electric vehicle to try and compete for what is anticipated to be a growing electric vehicle market. These companies include BMW, Mitsubishi, Honda and Toyota. (See further reading)
- ❖ Strain on the electric grid – OnStar has partnered with several electric companies to begin pilot programs to monitor how much electricity is consumed by electric vehicles during off-peak hours. This will help navigate through various pitfalls that may come in the near future with electric vehicles. (Comverge 2011)
- ❖ First Responders – There are programs out there that help educate first responders so that they can assess what kind of vehicle is in the particular accident and know what to watch out for, as well as know the best way to assist those involved. (Worker’s Comp 2011) There also are public outreach programs designed to help educate consumers about the safety hazards of an electric vehicle.

Electric vehicles are still in the infant stage with regards to technological development. The capabilities and cost-effectiveness of EVs and the associated charging infrastructure will continue to improve with time, investment and dedication. Many of the issues with range and emission factors can be addressed by improving battery technology, which will not only improve the efficiency of the vehicle, but also cut down on charge times and become more convenient for the average consumer.

ChargePoint America

As mentioned earlier, President Obama created the American Recovery and Reinvestment Act to help create ‘green jobs’ by investing in programs to help promote cleaner energy made in the United States to help cut back on foreign oil imports. One of the programs

funded by the ARRA was the ChargePoint America program which was a partnership between Coulomb Technologies and the Department of Energy to help create an electric vehicle infrastructure in metropolitan areas across the United States. The cost of the initial program was \$37 million, half of which was provided by the Department of Energy and the program was to install 4600 level two charging stations across the United States. This program was also sponsored by several auto manufacturers since it would help ease the implementation of electric vehicles on the roads with companies that include BMW, GM and Nissan. The funding of the program helped pay for the charging stations provided by Coulomb Technologies so that the state would not have to pay for installation costs or for the stations themselves to ease the stress the charging stations would otherwise put on the state's budget respectfully. The initial metropolitan areas selected for this program was the following (Expand ChargePoint):

- Orlando, FL
- Washington DC
- New York City, NY
- Southern Michigan
- Austin, TX
- San Francisco, CA
- Los Angeles, CA
- Sacramento, CA
- Bellevue/Redmond, CA

The goal of the initial locations was to showcase the benefits of electric vehicles and to help solve the problem commonly called 'The Chicken and the Egg' scenario where auto manufacturers would not create electric vehicles unless there was an infrastructure for them and individuals wouldn't have a charging station installed unless there was going to be demand for electric vehicles. The ChargePoint America program was designed to gather data for the first two years of the program to gauge the amount of use that each station had and to determine

which location(s) would be suitable for the next wave of charging stations and determine the most appropriate method of payment and control for the consumer in the coming years.

After the ChargePoint America program came underway there were several areas that wanted to participate in the program due to a variety of reasons including long pre-order lists for electric vehicles for their state. To meet the demand set by these areas, Coulomb Technology expanded the program to accommodate six additional locations (ChargePoint America):

- Baltimore, MD
- Boston, MA
- Tampa, FL
- Santa Barbara, CA
- Ventura, CA
- Monterrey, CA

The expansion of the program was to help spread out the infrastructure as well as create more of a ‘social network effect’ for electric vehicles to ease the acceptance of the concept to the general public.

Lifecycle Analysis for Electric Vehicles

One of the major concerns that consumers have regarding electric vehicles is the amount of emissions that are not only produced by the production of an EV but also the amount of emissions generated from the electricity that fuels EVs. This section looks at the lifetime emissions of EVs compared to traditional gasoline-powered vehicles.

A British-based group called ‘LowCVP’ made a report on the lifecycle study of electric vehicles versus other types and found the following:

Vehicle Type	Est. Total Emissions (tonnes of CO₂)	Proportion of emissions in production	Estimated emissions in production (tonnes CO₂)
Standard gasoline	24	23%	5.6
Hybrid	21	31%	6.5
Plug-In Hybrid	19	35%	6.7
Battery Electric	19	46%	8.8

Source: http://lowcvp.org.uk/assets/pressreleases/LowCVP_Lifecycle_Study_June2011.pdf

From this table it is apparent that battery powered EVs create the most emissions from production and in large part because of the batteries themselves. The conversion of tonnes to pounds is one to 2204.62 which means that a battery powered EV creates 19400.656 pounds of CO₂ from production whereas a standard gasoline model creates 12345.872 pounds of CO₂ which creates a difference of 7054.784 pounds of CO₂. The ‘advantage’ that has been claimed by many for electric vehicles has been when fueling/charging the vehicles and comparing the emissions.

According to the U.S. Energy Information Administration, a gallon gasoline produces 19.64 pounds of CO₂ but bear in mind that gasoline found at gas stations have 10% ethanol in them so the number goes down to 17.68 pounds of CO₂ (Ethanol). To compute how much CO₂ is produced per mile, simply divide 17.68 by the miles per gallon that your vehicle has registered.¹ To determine the amount of emissions for a battery EV, one has to look at where the electricity comes from. The Environmental Protection Agency has developed a system where by inputting your zip code and then indicating your electricity provider, it displays the distribution of where the electricity comes from (Electricity Calculator). As an example, the city of

¹ At this point found CO₂ per mile in user’s car

Worcester generates 728 pounds of CO₂ per megawatt-hour which is below the national average of 1216. To fuel a Nissan LEAF, a battery powered EV, it takes 7 hours from empty to full using a 240-volt charging dock (Nissan LEAF). This translates to 5.2 kW per full charge which in turn translates to 26.5 pounds of CO₂ per full charge (NEC Code). According to the EPA, the LEAF has a full range of 73 miles so the ratio of pounds of CO₂ to mile is 0.363.

Looking back to the CO₂ generated from a gasoline vehicle, assume that your vehicle has 22 mpg which is about the average which means the ratio would be 0.804 pounds per mile, a difference of 0.441 pounds per mile. To make up for the difference in production emissions, the Nissan LEAF would need to travel about 16000 miles before saving on emissions compared to a gasoline powered vehicle. Below are the calculations for both the LEAF and the Chevy Volt. The Chevy Volt uses 11.9 Kwh to fully charge on a 240-volt charging station and a 35 mile range so the ratio is 0.248²:

Distances (miles)	Nissan LEAF (N)	Chevy Volt (C)
MPG - 10	5021.20	4641.31
MPG - 15	8645.57	7580.36
MPG - 20	13540.85	11092.43
MPG - 25	20508.09	15363.21
MPG - 30	31215.86	20668.31

² Please note that the distances for the Chevy Volt is the distance traveled purely on the electric motor and not from any use from the gasoline engine.

$$7054.784 \text{ pounds } CO_2 / \left[\left(\frac{17.68 \text{ pounds } CO_2 \text{ per gallon}}{MPG} \right) - \left(E * \frac{\text{pounds } CO_2}{MwH} * \frac{.0364 MwH}{73 \text{ miles}} \right) \right] = N \text{ miles}$$

$$7054.784 \text{ pounds } CO_2 / \left[\left(\frac{17.68 \text{ pounds } CO_2 \text{ per gallon}}{MPG} \right) - \left(E * \frac{\text{pounds } CO_2}{MwH} * \frac{.0119 MwH}{35 \text{ miles}} \right) \right] = C \text{ miles}$$

Where ‘E’ is the number obtained through the EPA’s website regarding the cleanliness of your electricity and ‘MPG’ is the miles per gallon of your vehicle as stated by the EPA.

Benefits of the Electric Vehicle

Economic

While the up-front cost of an electric vehicle may seem daunting to the average consumer, there are economic benefits that come with owning an electric vehicle. For starters, there is no need to go to a gas station and fill up the car since all the car will need is electricity that is gathered by charging stations at home or in multiple places around metropolitan areas. The price of electricity for the average consumer is generally cheaper than having to go to a gas station and fill up a new car even with the improving standards set by the EPA for fuel economy on vehicles (EIA 2010). As mentioned in previous sections, federal and state governments have created programs to not only help lessen the initial cost by providing tax credits and rebates, but also help create programs to make charging stations more widely accessible. As more consumers invest in this technology, there will be less of a demand for oil, which reduces the cost of importing foreign oil. With the amount of money that is saved from this process, the government can better manage its funds and can focus on other projects such as the national debt or to help with other crises.

Many electric companies offer discounted rates on electricity consumption during off-peak hours to try and encourage consumers to charge their vehicles at night rather than during the day during peak hours (My Chevy 2010). Another advantage is that due to the minimal amount of moving parts in an electric vehicle, there is less need for regular maintenance, such as oil changes, since most of the work is done by the electric vehicle battery. While batteries are expensive, the average lifespan of a battery is 8-10 years and will only improve as the technology advances (BCG 2010).

Environmental

Along with the economic benefit of having to rely less on foreign oil, as consumers utilize more electric vehicles, there will be less need to use gasoline-powered vehicles which in turn will cause less greenhouse gas emissions. While burning coal at electric power plants is not that much better than burning oil, the electricity generated for electric vehicles also can come from power plants fueled by other energy sources that are much cleaner than oil and coal: hydro power, nuclear, geothermal, solar power and wind power (EPA 2011). While solar and wind power are not as efficient as other energy sources, these technologies, like electric car technology, are in their infant stages and will improve over time. Companies in the private sector have begun giving their employees incentives to take advantage of solar technology by subsidizing solar panels in the roofs of their employees' homes to make clean energy (WSJ 2011). As these technologies improve, the emissions associated with generating electricity for electric vehicles will be further reduced.

Social

As electric vehicle usage increases, so will the job opportunities associated with supporting EVs. Vehicle repair, maintenance of charging stations, and other new jobs will help reduce the unemployment rate in the United States. There also is the “social network effect”, where when one person decides to try out a new idea, method or technology and has their friends try out the new thing. This in turn spreads out to other people, who begin to accept the new idea as mainstream rather than an oddity that only certain individuals can or should take advantage of. One example is the Toyota Prius; when the Prius first came out in 1997, it was the source of many peoples’ jokes since it was a smaller car that introduced a conflicting new idea – conservation - into a society where the social normality was unbridled consumption. Nevertheless, as of 2011, more than two million Prius have been sold and now seems to be a common commodity among those who wish to be environmentally conscious as well as economically savvy (GCG 2010). The RMV, Registry of Motor Vehicles, tells the Executive Office that the Toyota Prius is the 7th most popular car registered in Massachusetts. With the emergence of electric vehicles such as the Chevy Volt and the Nissan Leaf, electric vehicles are slowly gaining some renown and may eventually become as popular as the Toyota Prius.

Future Steps needed for EVs

From my research to date and involvement with Massachusetts' EV program, it is apparent that a lot more steps need to be taken in order for electric vehicles to replace a meaningful portion of the gas-powered vehicles in use today. For starters, the effort cannot be conducted solely through the public sector. Private companies will need to start taking the initiative and support programs that help spread out the electric vehicle charging station infrastructure, and to help create a better social and economic environment for people to use this technology. Steps also will need to be taken with electrical grids, since the market for electric vehicles is still nascent and the electric companies will need to be prepared in the event that more consumers invest in these vehicles. Education regarding electric vehicles likewise is critical, since the average consumer then will be able to better formulate their own thoughts and opinions regarding electric vehicles with a greater understanding of the benefits and drawbacks of these vehicles.

Ideal Technological Advancements

In order for electric vehicles to become more socially accepted the standards for these vehicles will have to be comparable to vehicles that consumers use on a daily basis. For instance, the range on electric vehicles goes between 60-100 miles on a single charge whereas vehicles of the same class can go between 300-700 miles on a single tank. The range of selection will also need to increase so that the market can apply to consumers that may need something with more power than a small vehicle for their daily tasks. The cost of the vehicles will also have to be comparable to traditional vehicles today, but none of this is achievable without technological advancements in battery technology as well as efficiency through the charging stations so that the consumer will not have to wait up to eight hours to fully charge their

vehicle. There will also need to be roadside assistance available for consumers in the event that the electric vehicle runs out of energy at unexpected times to avoid unnecessary gridlocks on the road as well as accidents that can be caused by an electric vehicle suddenly stopping in the road.

Final Thoughts/Conclusion

“A journey of a thousand miles begins with a single step” – Lao-tzu, Chinese philosopher

While electric vehicles need vast improvements in order to be truly successful in the modern economy, the current status of electric vehicles is a step in the right direction. One of the ultimate issues in this era is the problem of ignorance. In most cases, people do not solve the problems that surround them because they are not aware of what is happening. There is also the issue of people being passive once they have the information needed to make an impact on a particular issue. There are countless people who complain about the fact that not enough is being done to solve the environmental crisis that occurs to this day even though these same people have the tools to go out and make a difference. Electric vehicles have a long road ahead in order to obtain the same familiarity that traditional vehicles have, but the potential that EVs bring is limited only by the actions of individuals. It is the hope of this author that, through working with electric vehicles, other projects will receive attention and prove to be useful in solving the environmental crisis. Solar panels, hydrogen technology, wind farms as well as greener textile materials are just example of technologies that are not popular in today’s society but can be explored more thoroughly with time, effort and investment.

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Further Readings and Articles

Below you will find articles that indicate the progression of electric vehicles as well as any particular book or film that relates to that of electric vehicles.

- *Who Killed the Electric Car?* – Released in 2006, directed by Chris Paine. A look into 1996 where GM came out with their version of the electric car, but due to poor marketing and pressure from the government and oil corporations, the idea of the electric car was pushed aside. <http://www.whokilledtheelectriccar.com/>
- *Revenge of the Electric Car* – Released in 2011, directed by Chris Paine. Ten years after the electric car was ‘killed’ a wave of interest from GM and Nissan move electric vehicles forward. <http://www.revengeoftheelectriccar.com/>
- List of purely electric vehicles for 2011-2012. <http://www.fueleconomy.gov/feg/evsbs.shtml>
- List of popular EVSE companies: <http://www.plugincars.com/need-electric-car-charging-station-here-are-companies-are-building-them-49735.html>
- IKEA and Walgreens installing EVSEs: <http://green.tmcnet.com/topics/green/articles/200646-walgreens-ikea-installing-ev-charging-stations.htm>
- The Electric Car: Development and Future of Battery, Hybrid and Fuel-Cell Cars. Author – Michael Westbrook. ISBN: 0852960131.
- More information for the Nissan Leaf: <http://www.nissanusa.com/leaf-electric-car/index?dcp=ppn.63023882.&dcc=0.240189300#/leaf-electric-car/index>
- More information on the Chevy Volt: <http://www.chevrolet.com/volt-electric-car>
- More information on the Tesla Model S: <http://www.teslamotors.com/models>
- More information on the Tesla Model X: <http://www.teslamotors.com/modelx>
- More information on the Tesla Roadster: <http://www.teslamotors.com/roadster>
- More information on the Mitsubishi MiEV: <http://www.mitsubishi-motors.com/special/ev/>