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Internalizing the Externalities in Automobiles

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Introduction

This project will consist of an analysis of the automobile markets within Massachusetts. To start, the project will look at the history of electric vehicles. Specifically looking at how the market started, why research began to increase again in the 1970s, to their rise in popularity in the 21st century, and to how countries are now banning internal combustion engines and fully incorporating hybrid and electric vehicles. From there, the project will consist of an analysis of the Alternative Fuel Life-Cycle Environmental and Economic Transpiration (AFLEET) tool developed by the US Department of Energy (Energy.gov). The AFLEET tool is a calculator designed to provided comparable information about different vehicles. This information includes annual fuel and electricity costs, annual emissions, annual operating costs, and a cost of ownership. Based upon the research from The Greenhouse Gases, Regulated Emissions, and Energy use in Transportation Model (GREET) which is a calculator designed to calculate external costs based upon a polluter the AFLEET tool provides emissions in pounds of carbon dioxide, which can be converted to metric tons of carbon dioxide. From there, based upon ExternE's analysis of a price of carbon per metric ton, one can place an environmental cost based upon carbon emissions. This would then create a full economic cost based upon price of the vehicle, annual fuel and electricity cost, annual operating costs, and environmental costs. From there, this project will look into solutions of how to internalize these environmental costs into the price of the vehicle. This includes the externalities from mining the gasoline or the externalities from producing electricity. Possible solutions to internalize externalities include CAFE standards, Pigouvian taxes, Pigouvian subsidies, pollution permits, and cap and trade programs. Next, the project will look into mainstreaming electric vehicles in Massachusetts by comparing Massachusetts to the U.K. Finally, the project will conclude by summing up this research and offer policy recommendation for the state of Massachusetts.

History of Electric Vehicles

The history of the electric vehicle dates back to the early 1800s when British investor Robert Anderson developed the first crude electric carriage ("History of EVs"). However, it was not until 1890 when American born William Morrison made the first ever American electric car. This six-passenger vehicle was able to drive 14 miles per hour and helped spark an interest in the growing field. By the year 1900 electric vehicles grew to a third of all vehicles on the road, and by the early 1900s, electric vehicles were the cars of choice. They did not have a lot of the negative drawbacks of steam or gasoline cars. Electric vehicles were easy to drive, they did not emit a smelly pollutant, they were silent, and as more people gained access to electricity, they became easier to charge. However, that all changed starting with the invention of the Model T in 1908. By 1912, the Model T was sold for only $650 while an electric car was selling for $1,750. Also, in 1912 Charles Kettering invented the electric starter which got rid of the hand crank which made gasoline cars easier to start. By the 1920s, the United States discovered crude oil in Texas which caused gas prices to plummet and gas stations began to pop up across the country. With the start of the Great depression in 1929, electric vehicles completely disappeared from the market by 1935 because of the cheaper gas models.

However, the want and need for alternative vehicles came back to light in the late 1960s and early 1970s. As oil prices were skyrocketing which caused gasoline shortages, culminating with the 1973 OPEC Oil Embargo, many people in the United States wanted to lower the US dependence on foreign oil. One way to decrease this dependence would be by promoting electric vehicles. Congress noticed this and passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, which authorized the Energy Department to support the research and development of electric vehicles. In 1974, the Sebring Vanguard was created with a top speed of 44 miles per hour and a range of 50 to 60 miles. The Sebring Vanguard was the most produced American electric vehicle until the Tesla Roadster passed it in 2011 (Thompson). However, even with many of the successes for electric vehicles in this era electric vehicles were very limited in the sense that their top speed was 45 miles per hour and most electric vehicles had a range of 40 miles before needing to be recharged ("History of EVs").

After gas prices returned to normal, the want for alternative forms of vehicles lessened until the 1990s when federal policy renewed the interest in electric vehicles. The 1990 Clean Air Act Amendment and the 1992 Energy Policy Act spurred investment in electric vehicles. The California Air Resources Board also passed new regulations requiring automakers to make and sell at least one zero-emission vehicle in order for them to sell their cars in the state (Thompson). Because of these low gas prices and the booming economy of the 1990s, there was not much public attention for more fuel-efficient vehicles so therefore electric vehicles did not have a huge increase in sales even with the attention from the federal government.

The biggest turning point for electric vehicles was the creation of the Toyota Prius in 1997 (“History of EVs”). The Toyota Prius was the first mass produced hybrid electric vehicle. This is due in part because of the Great Recession which saw rising gas prices and because of global concern about carbon emissions due to climate change. The next turning point for electric vehicles was when Tesla Motors announced that it would start producing a luxury electric sports car. To do this, Tesla got a $465 million loan from the Department of Energy, and it was actually able to repay the loan nine years early. Since then, Tesla Motors has become the largest automobile industry employer in California. In late 2010, the Chevy Volt and the Nissan LEAF were released in the United States. The Chevy Volt was the first commercially available plug-in-hybrid and the Nissan LEAF was the first battery electric vehicle. Through President Obama’s Recovery Act, $115 million was invested in charging infrastructure which installed 18,000 charging stations. By 2014, there is now 8,000 new charging locations and over 20,000 charging outlets. The new lithium-ion battery cuts the costs fifty percent which allows electric vehicles to be more competitive. In 2012, President Obama launched the EV Everywhere Challenge, which is an Energy Department initiative to make plug in electric vehicles more affordable than combustion engines by 2022. Globally, electric vehicles will make up a third of the global market by 2040 and by 2025 half of the global electric vehicle market will be from China (Cunningham). If both electric vehicles and combustion engines are unsubsidized, electric vehicles are projected to hit cost parity by 2024.

How to Determine the Full Economic Cost of an Automobile

The full economic cost of an automobile can be found based upon the price of the car, annual fuel or electricity cost, annual operating cost, and the environmental cost. This information is based upon the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool developed by the US Department of Energy (Energy.gov). AFLEET is a calculator designed to internalize much of the costs when buying a car. The price of the car that AFLEET uses is determined from Edmunds List. The Annual Fuel or Electricity Costs is based upon the fuel mileage of the car, yearly driving distance, and the price of the fuel. The fuel mileage data that AFLEET uses is taken from fueleconomy.gov. AFLEET uses an average yearly driving distance of 11,926 miles with 5,301 miles in the city and 6,6,25 miles on the highway. The cost of gasoline is based upon the Massachusetts state average price of regular gasoline with is $2.75 ("MA Gas Prices"). The Electricity Cost per kilowatt-hour (kWh) is based upon the US Energy Information Administration average retail price of 20 cents per kWh. ("State Electricity Profiles"). The annual fuel cost is achieved by diving the number of miles driven by the miles per gallon of the selected car and multiplying that by the price of the fuel of the vehicle. The annual operating cost is a sum of costs such as tires, maintenance, registration fees, license fees, and insurance. These costs are taken from a study done by the American Automobile Association (AAA) and represent the average costs based upon the model of the car (Stepp). The environmental costs are determined by calculating the emissions emitted in pounds per carbon dioxide, converting that number into metric tons of carbon dioxide, to multiplying the metric tons of carbon dioxide by the determined external price of carbon. The annual emissions are determined from the full fuel cycle based upon The Greenhouse Gases, Regulated Emissions, and Energy use in Transportation Model (GREET). The GREET model analysis the energy use and emissions output of various vehicle and fuel combinations ("Energy Systems"). To calculate emissions from electricity, GREET uses the EPA Power Profiler to determine the energy mix of a specific state. AFLEET then uses the GREET model to demine the yearly emissions based upon the input variables such as fuel mileage which they put in pounds of carbon dioxide equivalent. Carbon dioxide equivalent is a way to compare emission across different pollutants. The external cost of carbon is based off of the research of ExternE. ExternE is a global organization that was launched to determine a price of carbon ("Externalities of Energy"). Based upon their estimates, they determined a lower and upper emissions cost estimate. The lower estimate is around $12 per metric ton of carbon and the upper estimate is $350 per metric ton of carbon. Figures 1-3 uses both estimates in pricing carbon. The cost of ownership or full economic cost is determined by adding the price of the vehicle, annual fuel or electricity cost, annual operating cost, and the annual environmental cost. There is an average assumption of a 10.6 years lifetime ownership of the vehicle.

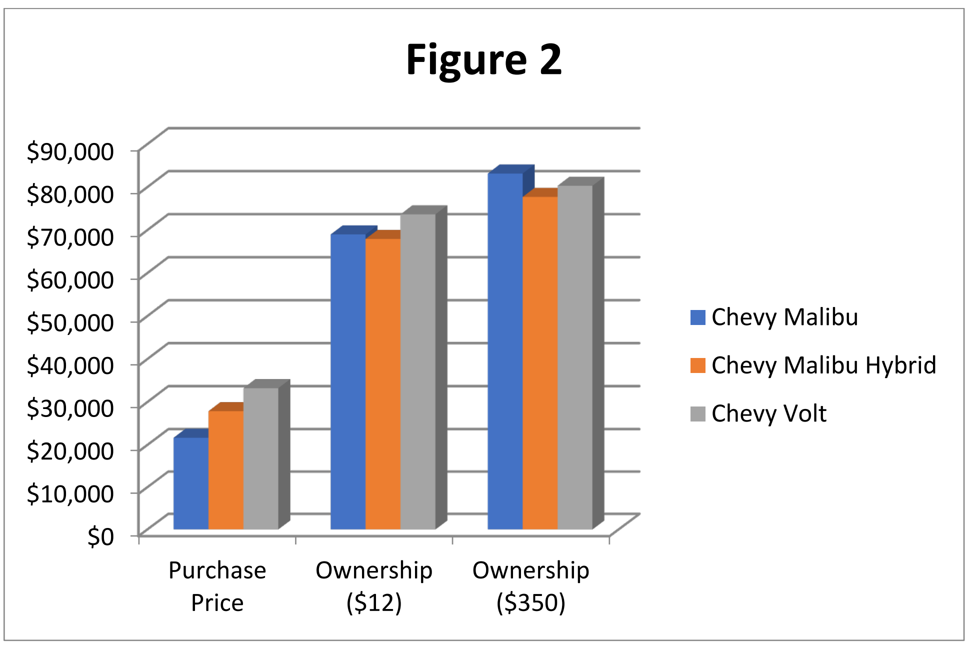

Figure 2 shows the relationship between price and cost of ownership between the Chevy Malibu, the Chevy Malibu hybrid, and the Chevy Volt. As seen in the graph, the Chevy Volt is the most expensive while the Chevy Malibu is the cheapest. However, when looking at the lifetime cost of ownership, the Chevy Malibu is the most expensive with the Chevy Malibu Hybrid being the cheapest. The Chevy Malibu was originally about $6,000 cheaper than the hybrid version but when looking at the environmental costs the Chevy Malibu is about $1,000-$6,000 more expensive.

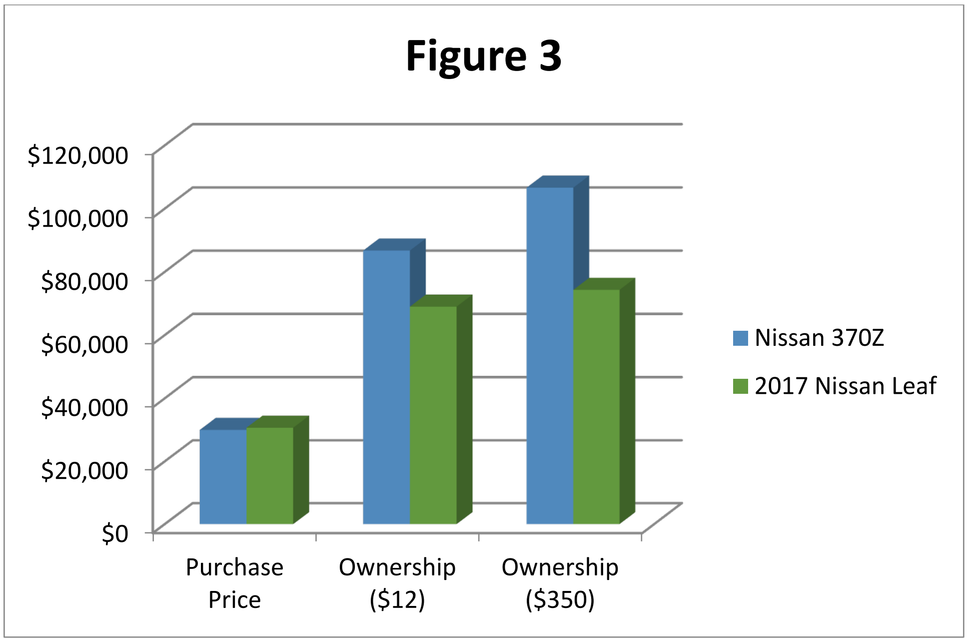

Figure 3 shows a similar idea. When looking at the Nissan LEAF compared to the Nissan 370Z, the same relationship is true. When looking at current pricing the LEAF is about $1,000 more expensive, however when doing a full cost analysis, the LEAF becomes about $18,000-$32,000 cheaper, which could be enough savings to buy another Nissan 370Z. This shows the potential savings and viability of electric vehicles and hybrids if environmental impacts were incorporated into pricing.

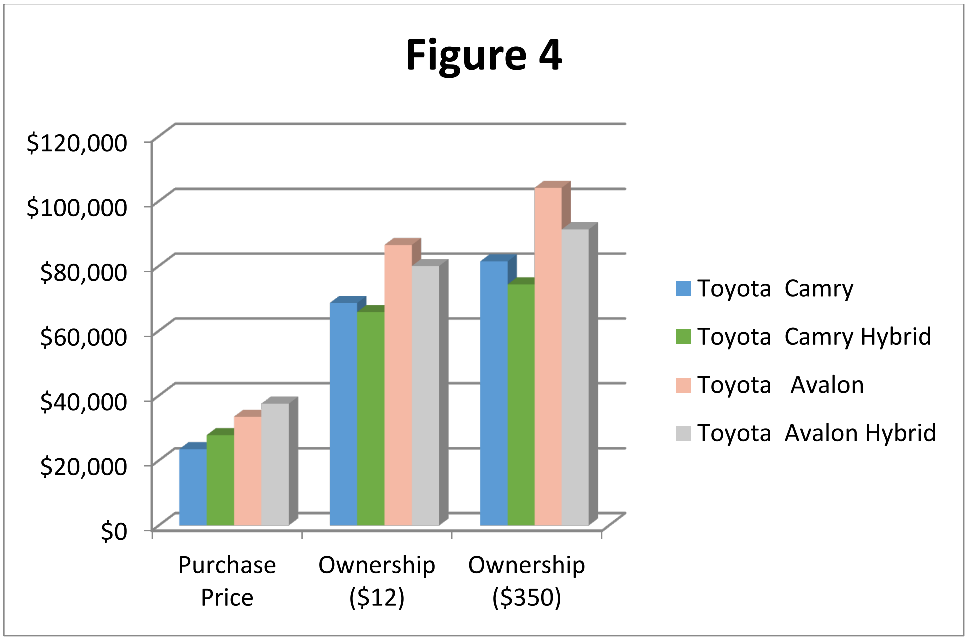

Figure 4 reiterates the previous figures while comparing the different Toyota models. While the Toyota Avalon and Camry Hybrid cost more than the regular Toyota Avalon and Toyota Camry when incorporating environmental costs into the cost of ownership, the Avalon Hybrid and Camry Hybrid are much more cost effective and can save you about $13,000.

Figure 1:

Make	Model	Price	Fuel Type	Annual Fuel Use/ Electricity Use	Annual Fuel Cost/ Electricity Cost	Annual Emissions (metric ton of CO2)	Emissions Cost ($12)	Emissions Cost ($350)	Annual Operating Cost	Cost of Ownership ($12)	Cost of Ownership $350)
Buick	LaCrosse	$32,065	Gasoline	473 gal	$1,301	5.15	$139.05	$1,802.50	$3,559.00	$85,054.93	$102,687.50
Chevy	Cruze Premier	$23,475	Gasoline	353 gal	$970	3.84	$103.68	$1,344.00	$3,227.00	$69,062.21	$82,209.60
Chevy	Impala	$27,895	Gasoline	462 gal	$1,270	5.03	$135.81	$1,760.50	$3,528.00	$80,193.39	$97,415.10
Chevy	Malibu	$21,680	Gasoline	380 gal	$1,046	4.14	$111.78	$1,449.00	$3,304.00	$68,974.87	$83,149.40
Chevy	Malibu Hybrid	$27,875	Hybrid	262 gal	$721	2.86	$77.22	$1,001.00	$2,979.00	$67,913.53	$77,705.60
Chevy	Volt	$33,220	Plug in Hybrid	68 gal/ 2812 kWh	$752	1.94	$52.38	$679.00	$3,010.00	$73,652.43	$80,294.60
Chrysler	300	$28,995	Gasoline	500 gal	$1,375	5.44	$146.88	$1,904.00	$3,632.00	$83,626.13	$102,251.60
Dodge	Challenger	$26,995	Gasoline	500 gal	$1,375	5.44	$146.88	$1,904.00	$3,632.00	$81,626.13	$100,251.60
Dodge	Charger	$28,495	Gasoline	500 gal	$1,375	5.44	$146.88	$1,904.00	$3,632.00	$83,126.13	$101,751.60
Ford	Fusion	$27,045	Gasoline	493 gal	$1,357	5.37	$144.99	$1,879.50	$3,615.00	$81,285.09	$99,670.90
Ford	Fusion Energi	$33,120	Plug in Hybrid	146 gal/ 2028 kWh	$808	2.45	$66.15	$857.50	$3,066.00	$74,885.59	$83,273.90
Ford	Fusion Hybrid	$25,295	Hybrid	285 gal	$783	3.1	$83.70	$1,085.00	$3,041.00	$66,716.62	$77,330.40
Honda	Civic	$19,700	Gasoline	357 gal	$982	3.89	$105.03	$1,361.50	$3,240.00	$65,566.52	$78,885.10
Honda	Fit	$16,190	Gasoline	326 gal	$897	3.55	$95.85	$1,242.50	$3,155.00	$60,157.21	$72,311.70
2017 Honda	Accord	$30,895	Gasoline	453 gal	$1,246	4.93	$133.11	$1,725.50	$3,504.00	$82,655.97	$99,535.30
2017 Honda	Accord Hybrid	$29,605	Hybrid	249 gal	$685	2.71	$73.17	$948.50	$2,943.00	$68,837.40	$78,115.90
Hyundai	Elantra	$16,950	Gasoline	368 gal	$1,013	4.01	$108.27	$1,403.50	$3,271.00	$63,508.06	$77,237.50
Hyundai	Sonata	$22,650	Gasoline	401 gal	$1,104	3.37	$90.99	$1,179.50	$3,361.00	$70,943.49	$82,481.70
Kia	Forte	$16,600	Gasoline	362 gal	$995	3.94	$106.38	$1,379.00	$3,253.00	$62,756.43	$76,246.20
Kia	Optima	$22,500	Gasoline	455 gal	$1,250	4.95	$133.65	$1,732.50	$3,508.00	$74,351.49	$91,299.30
Kia	Rio	$14,165	Gasoline	368 gal	$1,013	4.01	$108.27	$1,403.50	$3,271.00	$60,723.06	$74,452.50
Mazda	3	$18,095	Gasoline	364 gal	$1,000	3.96	$106.92	$1,386.00	$3,258.00	$64,363.15	$77,921.40
2017 Nissan	LEAF	$30,680	Electric	3652 kWh	$733	1.55	$41.85	$542.50	$2,838.00	$68,976.21	$74,283.10
Nissan	370Z	$29,990	Gasoline	534 gal	$1,468	5.81	$156.87	$2,033.50	$3,726.00	$86,709.22	$106,601.50
Subaru	Impreza	$18,495	Gasoline	428 gal	$1,177	4.66	$125.82	$1,631.00	$3,434.00	$68,705.29	$84,660.20
Subaru	Legacy	$22,195	Gasoline	407 gal	$1,119	4.43	$119.61	$1,550.50	$3,377.00	$71,120.47	$86,287.90
Toyota	Avalon Hybrid	$37,500	Hybrid	302 gal	$832	3.29	$88.83	$1,151.50	$3,089.00	$80,004.20	$91,268.50
Toyota	Camry	$23,495	Gasoline	344 gal	$947	3.75	$101.25	$1,312.50	$3,205.00	$68,579.45	$81,418.70
Toyota	Camry Hybrid	$27,800	Hybrid	229 gal	$630	2.49	$67.23	$871.50	$2,887.00	$65,792.84	$74,318.10
Toyota	Corolla	$18,550	Gasoline	373 gal	$1,027	4.06	$109.62	$1,421.00	$3,284.00	$65,408.57	$79,309.20
Toyota	Avalon	$33,500	Gasoline	473 gal	$1,301	5.15	$139.05	$1,802.50	$3,559.00	$86,489.93	$104,122.50

Based upon the data from Figure 1, hybrids and electric vehicles have a much lower lifetime cost of ownership if environmental costs are taken into consideration, whether using the upper or lower estimate. The question then becomes, how can environmental costs be internalized.

Solutions to Internalizing Externalities

An externality is when an activity of one entity directly affects the welfare of another outside of market activities (Rosen). These types of activities can either be positive, such as vaccinations, or negative, such as carbon emissions. The cause of an externality can be seen as an inability to establish property rights or as a failure in the market. These market failures include inadequate research and demand, demonstration, and deployment of new technology, imperfections in risk or capital markets, inadequate public networks, inadequate reliable information, and inadequate appreciation of co-benefits (Gough 69). There are many different ways to incorporate an externality into a market. This includes Pigouvian taxes or subsidies, pollution permits, cap and trade programs, CAFE standards, and through direct government regulation.

A Pigouvian tax or subsidy is a tax or subsidy levied on a market activity that generates an externality. With the assumption is that all firms try to maximize profits, they operate where their marginal benefit equals their marginal private costs. However, there is a socially efficient output that occurs where marginal social cost equals marginal benefit. This marginal social cost is equal to marginal private cost plus marginal damage (Rosen 93). If the socially efficient output is different from the actually output that the firm produces, then there is an externality in the market. Therefore, this externality can be seen as marginal damage, which is the amount needed of the tax or subsidy to balance the market. Some benefits of Pigouvian taxes are that it directly internalizes the externality, and it can discourage the use of gasoline powered cars (Eidelwein). However, some problems with Pigouvian taxes is that it can be difficult to estimate marginal damage, which can make it difficult to find the correct tax rate, it can be hard to impose the burden the tax on produces and not consumer, and it can be hard to gain public approval of such taxes (Rosen).

Another solution to internalizing externalities is pollution permits. This pollution permits would be sold by the government which brings in revenue. One type of a pollution permit system would be a cap and trade program. This occurs when the government sets a pollution ceiling which prohibits the production of a pollution over a certain threshold. In order to pollute over this imposed threshold, a firm most purchase the ability to pollute from another firm. Some benefits of these systems include reducing the uncertainty of the level of production, it encourages cost-minimizing technology to obtain the standards, and it allows a firm the freedom to set a price per ton of the pollutant. However, some drawbacks are that the pollutant will still be produced, and firms will lobby heavily for less restrictions and the ability to pollute more.

CAFE standards are another form of internalizing externalities. CAFE standards require each auto manufacturer to produce a variety of cars and trucks that average a set number of miles per gallon. Some benefits of CAFE standards include better fuel-efficient vehicles which reduces the environmental costs of driving and it can lead to greater innovations, and it can lead to less money spent on fuel. However, high CAFE standards can have some cons, such as an increased price of a vehicle and increased congestion due to the lowering of the cost per mile of driving. This can actually promote congestion and can diminish your goal of eliminating the externality.

Another method of internalizing the externalities can come through direct government regulation. This is currently what is being done in China as they try to become the world's leader in environmental sustainability (Pennington). China has recently suspended the production of over 500 vehicle models that do not meet their fuel standards (Tabuchi). This ban is said to affect over 1% of the entire Chinese market. They are also the world's biggest supporter of electric vehicles with tremendous incentives for both producer and consumers for electric vehicles. The Chinese government is also issuing quotas for the number of automobiles that automakers must sell. These quotas include by 2025, one in five cars produced must be of alternative fuels, which would result in the sale of 300,000 electric vehicles per year (Bradsher). China is already the world's largest maker and seller of electric vehicles and this number is only going to rise if the Chinese stick to their plans. However, while China is trying to cut emissions by switching to electric vehicles, by relying largely on coal power this diminishes the amount of emissions that will be cut.

How to Mainstream Electric Vehicles: A Comparison to the U.K.

Now that the world is coming to grasp with the future effect of climate change many countries have announced plans to ban internal combustion engines and start an electric vehicle-based economy. These countries include China, India, France, Britain, Norway, Germany, Japan, South Korea, and Spain (Petroff). In order to do this, these countries will have to significantly invest in electric vehicle charging technology as well as technology to expand their grid. While the state of Massachusetts has some plans to increase the use of electric vehicles, such as the MoreEV program, the state is lacking in several areas in which it can learn from other countries, one country being the United Kingdom.

In the U.K. electric vehicle stocks have growth 100% per year since 2012 ("Charging Ahead"). The U.K. has also funded many incentives for purchasing electric vehicles and they have increased spending for charging stations. In the 2018 budget, the U.K. government has spent 400 million pounds towards a national charging network, 100 million pounds for grants to subsidize electric vehicles, and 40 million pounds for research into electric vehicles and charging stations. The Automated and Electric Vehicles Act 2018 set a numbered requirement of the amount of charging stations in an area to promote the purchasing of electric vehicles. Shell is also working with the U.K. to produce a new superfast highway charging network. The city of London is banning gas stations beginning in 2018. The U.K. government has decided to go with strict regulation as well as Pigouvian subsidies to spur interest in electric vehicles and to promote growth in the industry. However, the U.K. government has run into four main challenges. The first is the need for residential power grid reinforcement to make up for the increased electricity demand due to the use of electric vehicles. The second being the higher price of battery electric vehicles and the need to subsidize them so that it is cost-effective for consumers. The third is the need to support electric vehicle adoption rates by upscaling public charging infrastructure. And the fourth is the need to educate the public about the environmental benefits of electric vehicles. However, as long as the United Kingdom continues to invest and spend money on subsidizing electric vehicles, investing in charging station, and promoting research in the field, the U.K. should be well on there was to banning gasoline powered cars and becoming an electric vehicle-based economy. The state of Massachusetts could use a lot of the policies that the U.K. are implementing to mainstream electric vehicles. At this date, the main incentive to buy an electric vehicle in Massachusetts in the MOR-EV program. The MOR-EV program offers up to a $2,500 rebate on purchasing electric vehicles ("MOR-EV"). While the state has invested some money in charging technology, if they want to become truly committed to an electric vehicle-based economy, the state need to further incentives electric vehicles and commit to building the charging infrastructure needed to support it

Policy Recommendations

In order to mainstream the use of electric vehicles, the state of Massachusetts will have to make some policy changes. Currently, the MOR-EV has been able to promote the usage of electric vehicles, but it does not do enough. In order to successfully implement electric vehicles, then need to achieve three pillars for environmental policy (Gough 126). The first policy solution would be to raise the price of carbon to internalize the externality. As has been shown, electric vehicles are cost-effective and cheaper when environmental costs are applied. While the government may not want to put a price on carbon for political reasons, the government is capable of subsidizing electric vehicles so that electric vehicles are cost effective not only in the long term but in the short term as well. The second pillar has to do with government intervention and public outrage. Like many countries have already done, the state of Massachusetts needs to set clear goals for electric vehicles and should ultimately ban gasoline powered engines. Other countries that have set such goals are working with corporations who give them cheaper access to new electric vehicle technologies. At the same time, the government should be doing pubic outreach promoting the use of electric vehicles. The government should be educating the public about the dangers of climate change and the dangers of emitting carbon into the atmosphere. This promotion can create a public backing for change and may make an idea such as a carbon tax a viable political option. The third pillar has to do with development. This calls for a significant investment by the government and a partnership with private sector organization into the production of electric vehicles with strategic public planning and implementation. This idea similar to the second pillar by calling for a significant investing into new technologies and creating a path of development for the future.

Conclusion

In conclusion, electric vehicles were first introduced to the United States in the late 1800s and have seen their share of the market significantly rise and fall numerous times in their brief 100-year existence. However, with the dangers of climate change looming and more countries and people want to adopt clean technology and alternative forms of transportation, the market share of electric vehicles may only continue to rise. Based upon the research done by the AFLEET tool, hybrid and electric vehicles are cost effective when incorporating the negative externalities of emissions. The problem arises which is how to internalize these externalities. There are many potential solutions such as Pigouvian taxes or cap and trade programs, but they have one common program which is how much pollution is allowed or how large is the externality. Without knowing those numbers, it can be hard to successfully implement such policies. However, many countries are ignoring these types of policies and going with more of a hands-on approach by banning internal combustion engines and investing in electric vehicles. For Massachusetts, the best policy would be a mix of the two. An electric vehicle subsidy so it is cost effective in the present coupled with a strategic plan to implement electric vehicles with significant investment in infrastructure with set goals and priorities could mainstream electric vehicles in Massachusetts.

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