Final Report on ABEN456/656 Group Project

Electric Vehicles

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Contents

Introduction

Electric vehicles are essential to our environment and future economy. With a growing need for a new transportation fuel type, electric vehicles provide a great option with technology which has already been discovered.

Historical background of Electrical Vehicles.

Electric vehicles date way back to the 1800s where the first ever electric motor was built in 1828. Following the first ever motor, starting in 1832, electric carriages and cars were designed and built by a few different people. Between 1842 and 1881, better batteries with a higher storage capacity were invented to make electric vehicles more practical. However, these batteries did not offer a rechargeable system. In 1899, the world record for fastest land speed was set by an electric racing car called the "La Jamais Contente." In America, the first electric vehicle was established in 1897 featuring a fleet of New York City Taxis. By the 1920s, America had a better system of roads to connect cities as well as the Texas crude oil discovery making gasoline affordable. With the price of gas powered motors produced by Henry Ford being between $500 and $1,000 and the electric vehicle being around $1,750, electric vehicles became very rare and about disappeared by 1935 (*The History of Electric Vehicles Began in 1830*, n.d.).

Motivation for increasing electrical vehicle production and use.

Starting back up in the 1960s, electric vehicles production attempts occurred in efforts to reduce the problems of exhaust emissions from engines and to reduce the dependency on imported crude oil. With the US transportation using up a high percentage of the US petroleum, and petroleum extraction expected to become very expensive in the future, the need to produce efficient electric vehicles has become very important. Electric vehicles are said to be zero emission as there is no tailpipe emission while gas powered vehicles contribute to air pollution by releasing greenhouse gasses from the tailpipe (*Alternative Fuels Data Center: Emissions from Hybrid and Plug-In Electric Vehicles*, n.d.). Another reason for the push of electric vehicles is no need for liquid energy. Liquid energy which is used in gas powered vehicles today in the form of gasoline is made from the crude oil petroleum. With renewable energy being such an important factor in the world, making a liquid renewable energy is very difficult. Renewable energy such as from water or air turbines can be used to produce electricity which can be used to charge electric vehicles without major environmental impact. With a greater production of electric vehicles, a greater trend in electric vehicle usage is projected to occur.

Past, Present and Future outlook of technology change in Electrical Vehicles.

One of the biggest technologies in electric vehicles that has been improved and is still in the working of being improved more, is the battery. EV batteries went from non-rechargeable to rechargeable to having a significant range increase. EVs have made great improvements by providing greater power and more miles on a charge. Battery costs have also dropped significantly over the years providing electric cars with greater batteries for a cheaper price (*Global EV Outlook 2019 – Analysis - IEA*, n.d.). However, batteries are still being researched in order to provide more miles per charge and a better material used in the batteries. Tesla, an electric vehicle manufacturer, has made significant improvements to their vehicles making them run for longer than ever before and also providing a very modern and fancy style with a very sophisticated interior technology. More and more improvements to EVs are on the way with little talk of how much better an EV battery can get.

Categories of Electric Vehicles and their architecture

There are mainly three types of electric vehicles based on the source of their energy and their connection to the power grids. They are All-electric vehicles (*Alternative Fuels Data Center: All-Electric Vehicles*, n.d.), Hybrid Electric Vehicles (Ehsani et al., 2007) and Plug-in Hybrid Electric Vehicles (*Battery Electric Vehicles, BEV, EVs,* *HEVs, BHEV's | EVgo*, n.d.). In this section different types of electric Vehicles with their description and operation are explained.

All-electric Vehicles or Battery Electric Vehicles (BEV)

All-electric vehicles are also called Battery Electric Vehicles (BEV) which uses a battery as the power source. Battery is solely responsible to run the motor and provide power to run the vehicles. This is also called the first generation of the electric vehicles. These vehicles have no tailpipe emission therefore, they are also called pollution free vehicles. However, the first generation of Electric vehicles have limitations of battery power storage capacity which hinders the long-distance travel. Besides this they are uneconomical because batteries are expensive and lack the possibility of charging them by other sources. Description of BEV and their operation is explained in section below.

Description of All-electric Vehicles

BEV are fully electric vehicles having rechargeable batteries and no gasoline engine. Rechargeable Batteries, Motor and Controller and Potentiometer are the important components of the BEV which is shown in Figure 1.

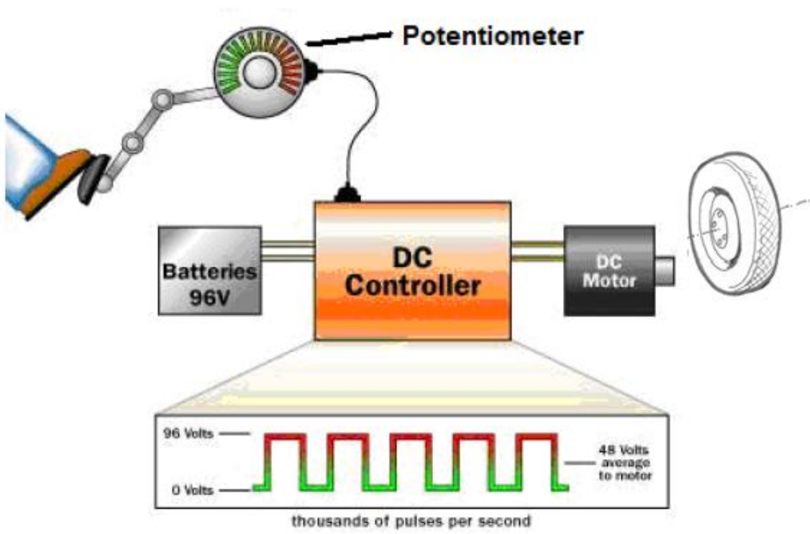

Figure 1. All Electric Vehicles Components to drive vehicles

Potentiometer is the kind of variable resistor to signal the DC controller. The DC controller gives power to the motor according to the signal from the Potentiometer. They are attached near to the pedal as shown in Figure 1. Battery acts as a source of power storage to run the dc controller. There are three types of batteries used by Electric Vehicles. They are lead-acid batteries, nickel metal hydride (NiMH) batteries, and lithium-ion (Li-ion) batteries (Naumanen et al., 2019). Controller uses power from the battery and signal from the potentiometer to propel the motor. Controllers can give a full power when the accelerometer is high and can give zero power when vehicles are stopped. Finally, the motor is the part which is responsible for turning the wheels of vehicles. They are controlled by a controller as shown in figure 1.

Operation of All-electric Vehicles

Four components described in the Description section are responsible for running the electric vehicles. When the driver puts his foot on the pedal, the Potentiometer creates a signal according to the force from the foot. This signal controls the voltage generated by the controller. When the accelerometer is high then the controller generates full voltage and when the accelerometer is zero the controller creates zero voltage. Besides, signals from the potentiometer controller get power from the battery source as shown in figure 1. And then controllers control the motor to generate a torque or force to turn a wheel of the vehicles. This causes vehicles to move forward and backward.

Hybrid Electric Vehicles (HEVs)

Hybrid Electric vehicles (Ehsani et al., 2007) name itself suggests they are hybrid technology in automobile industries. These vehicles are hybrid in a sense that they have both Gasoline engine (internal combustion engine) and motor to run the vehicles. They also have batteries to save energy from gasoline engines and break. Electric energy is generated by the vehicle's own braking system to recharge the battery. Toyota Prius Hybrid, Honda Civic Hybrid are the examples of HEV. Besides the benefits of having both gasoline engines and motor to propel the vehicles they have some drawbacks. Tailpipe emission and inability to charge a battery over the network are major drawbacks of HEVs.

Description of HEVs

Hybrid electric Vehicles (*Alternative Fuels Data Center: How Do Hybrid Electric Cars Work?*, n.d.) are powered by both Internal combustion engine and Motor. Motor uses power from the battery to drive the vehicle's wheel. They also have other different components which is shown in figure 2. Those components are auxiliary battery, DC converter, Electric generator, Exhaust System, Fuel filler, Fuel Tank (gasoline), Power electronics controller, Thermal system(cooling), Traction Battery pack and transmission. Auxiliary batteries help to start the car before the traction battery is used and they also provide the power to the vehicle accessories in vehicles. DC converter converts High power DC from traction battery to low power Dc to charge auxiliary battery and to power vehicle accessories. Electric generators are used to generate electricity from rotating wheels when brake is applied which help to recharge the traction battery. Some vehicles use motor generators that perform both driving of vehicles and regenerations. Exhaust system help is tailpipe emission, Fuel filler help to fill the gasoline tank and Fuel tank store gasoline. These parts are associated with gasoline and gasoline engines. Power electronic controller manages the flow of electrical energy and controls the speed of the motor. Thermal System maintains the proper temperature of the vehicle components, Traction battery is source of electrical energy and transmission transfers mechanical energy from gasoline engine or motor to drive a wheel of the vehicles

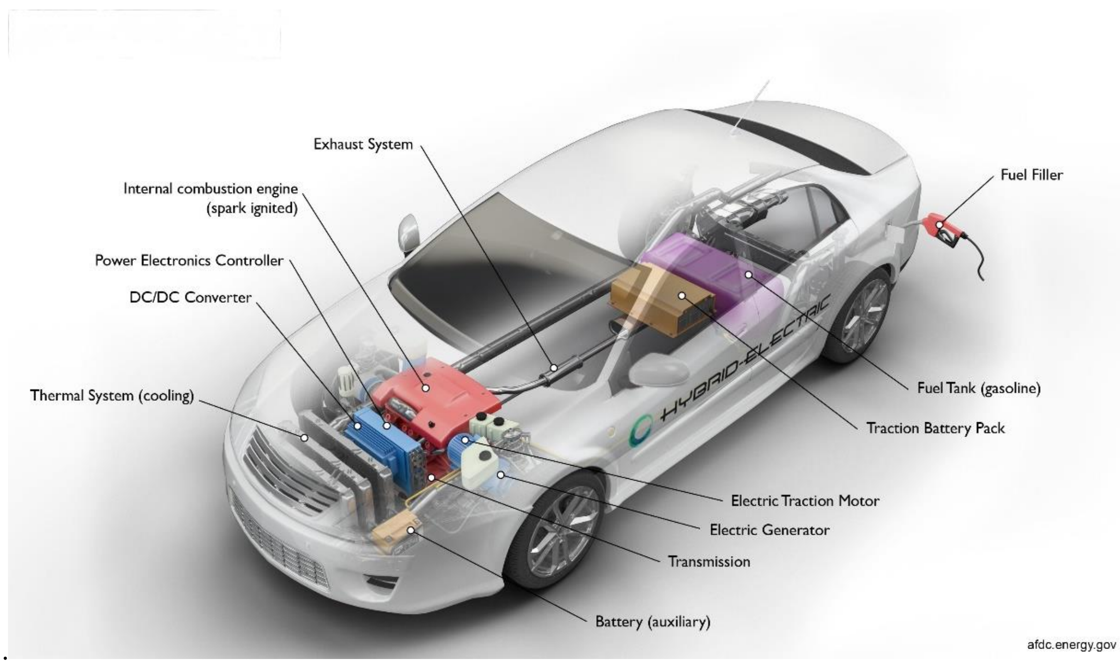

Figure 2. HEVs Components to drive vehicles

Operation of HEVs

In Hybrid Electric Vehicles Internal Combustion engines and traction motors are responsible for their operation. When the driver puts his foot on the pedal, the electric generator converts energy from the internal combustion engine into the electrical energy which is stored in the battery. Then the battery provides power to run a motor. Internal combustion engines and motors run simultaneously to produce a power. Both powers are used to turn the transmission which turns the wheel ultimately driving the vehicles forward or backward. When breaking energy is used to convert into electrical energy. During braking instead of turning a wheel by motor, wheels turn the motor to generate electricity which is stored in the battery. This also slows down vehicles. Eventually both gasoline engine and motor turn off and charge is used to turn on accessories in vehicles like light and dashboard.

Plug-in Hybrid Electric Vehicles (PHEVs)

Plug-in Hybrid Electric vehicles' names suggest their features. They have functionality of both Battery electric vehicles and Hybrid Electric Vehicles. They can be plugged into the electric grid for charging which is the limitation of the previous two vehicles we talked about. They required batteries with more capacity than that of HEV. Battery should be charged and discharged more rapidly than that of HEV. They can travel a longer distance than that of HEV using electric mode. The important feature of PHEV's is that they can be connected to the power grid and can perform bi-directional flow of power from Grid to Vehicle and Vehicle to grid. The transfer of power from Grid to vehicles is called V2G whereas transfer of power from vehicles to grid called G2V.

Description of PHEVs

PHEV's (Enang & Bannister, 2017) get power through both electric motors and gasoline engines like that of HEV. They can be charged by electric grid and ICE. They run using battery until they are charged and are automatically changed to Internal Combustion Engine.

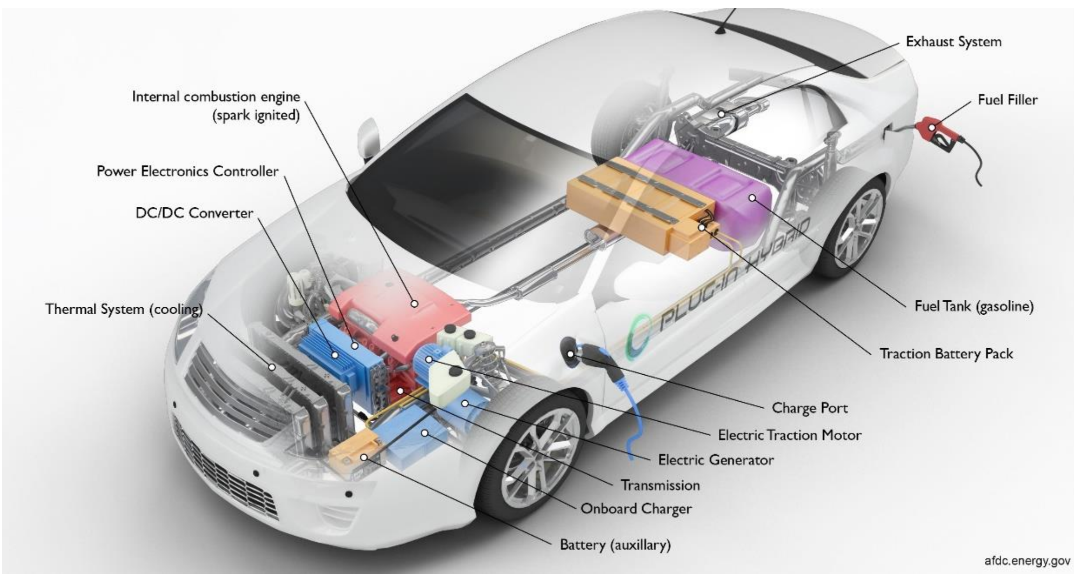

Figure 3. PHEVs Components to drive vehicles

Figure 3 shows the different parts of PHEV. They have Internal Combustion Engine, Electric Motor, auxiliary battery, DC converter, Electric generator, Exhaust System, Fuel filler, Fuel Tank (gasoline), Power electronics controller, Thermal system(cooling), Traction Battery pack and transmission as shown in figure 3. They have the same functionality as that of HEV's we talked about in HEV's Description section. Besides these they have on board charger, charger port as shown in Figure 3. Charger ports are connected to charging stations having electric grids. Onboard charger takes an AC signal from the Charge Port and converts it into the DC signal to charge the battery. It also monitors the status of battery during charge.

Operation of PHEVs

PHEV is mainly operated by electric power and ICE like that of HEV's. They have larger battery than that of HEV's which makes them travel longer distance than that of HEV's using electric power only. When driver put foot on pedal, electric generator converting energy from ICE into the electrical energy to store charge on battery. Battery supplies power to the electric motor which drives transmission to turn the wheel of the vehicle. PHEV can run using the electric mode until charge is depleted from the battery and change automatically to the gasoline engine mode.

Battery can be charged using Charge port from power grid which is converted to DC by Onboard charger as shown in figure 3.

Charging Level and Charging Control Structure of EVs

There are usually two levels of charging. Level 1 is Home Charging and Level 2 is Home and Public Charging. Level 1 charging cords are standard equipment on new electric vehicles. These only require a grounded 120V outlet and can add about 40 miles of range in an eight-hour overnight charge (Binetti et al., 2015). Overnight charging is suitable mostly for low and medium range plug in hybrids. And for all electric vehicles with low daily driving usage.

Level 2 charging typically requires a 240V charging unit. Like the outlet for clothes dryers and other appliances. Charging rates depend on the vehicles respective acceptance rate and the maximum current available. With a typical 30-amp circuit, about 180 miles can be added during an eight-hour charge. Level 2 chargers are the most common public chargers, and you can find them at places like offices, grocery stores, and parking garages. All public Level 2 chargers have a standard electric vehicle connection plug that fits all current vehicles, except for Teslas, which require an adapter (Binetti et al., 2015).

The public charging is currently the fastest available recharging method. It can typically add 50 to 90 miles in 30 minutes, depending on the stations power capacity and the make of the electric vehicle. Tesla on the other hand has super chargers are even faster. Adding up to 170 miles of range in a half hour. The length of time that is takes to recharge really depends on two factors. How much energy has been used and what is the power output of the charger? Level 1 charger can replace 4-5 of driving each hour of charging. Level two chargers are much faster. Adding 15-25 miles of range per hour (Galus et al., 2013). These chargers can recharge most long-range battery electric vehicles during an eight-hour charge. It is important to note that most drivers will go less than 50 miles a day. So even relatively slow Level 1 chargers will go less than 50 miles a day.

Many cities have public places where electric vehicles can come and charge. As stated above most of these are Level 2 charging stations. City planners have to make the decision on how many of these to put in. Where would it work best to implement the charging stations? Electric vehicle drivers tend to plug in their cars right when they get home. If a large number of drivers in a neighborhood return home and start charging their cars at the same time. Demand may exceed the capacity of the distribution transformer or other local infrastructure (Gan et al., 2013). Rather than increasing the hosting capacity of the distribution grid, shifting load to times of day when the grid is underutilized is and effective way of providing additional electricity without investing in grid upgrades. Although one benefit of electric vehicles is the increased sale in electricity. But co-ops will want to strategically procure cheaper off-peak power over expensive peak power. And shift demand to times of the day when electricity rates are lower. In addition to this, as variable renewable energy sources increase their shares of the power supply, co-ops may need to match flexible loads like electrical vehicles to the available supply. More than 70% of electric vehicle charging occurs at home. Since electric vehicles are at home overnight and for long periods of time, allowing flexibility in when the vehicle is charged. Level 1 charging of the electric vehicles can draw anywhere from 8 to 20 amps of the AC current, providing 3 to 16 miles of charger per hour. The member controls and schedules charging through the vehicle or through the vehicles app. But the co-op has no insight into the charge behavior. Level 2 charging tends to me more expensive but is more controllable. Which will deliver up to 80 amps. And provides 10 to 60 miles of charge per hour and can communicate with both the member and the co-op. It is important to note that without Level 2 charging the co-op cannot directly control the charging and must rely on members to charge during beneficial times.

Residential charging control strategies fall into two main approaches. Indirect or direct control. Indirect control provides behavior changes through incentives like financial changes, rewards programs and green power mix options. Direct control is managed by the co-op or a third party, often through the Level 2 charging. This includes auto demand response and flexible charging services.

The electric vehicle and power supply markets are rapidly and simultaneously transforming, and the well-prepared co-op will be able to respond to and capitalize on this change. Many co-ops already control electric vehicle charging public and private. In the longer term, direct and especially real-time control of electric vehicle charging may be necessary to better match electric vehicle load with a more variable supply and increase distribution grid load factor. Although some direct control strategies can be carried out using a load control switch, Level 2 offers a broader range of control strategies, including managed control that allows the co-op to respond to real-time pricing, supply fluctuations, and grid conditions, Because it will take time to deploy Level 2 into the field in significant numbers, co-ops should begin planning for direct control strategies in the near-term, deciding which Level 2 best suits their needs.

Socio-economic and environmental impact of EV

Transportation sectors consume the large portion of the petroleum oil in the World and US out of total energy consumption (*The Annual Energy Outlook explores long-term energy trends in the United States*, n.d.). Figure 4 (*The Annual Energy Outlook explores long-term energy trends in the United States*, n.d.) shows the US transportation sectors energy consumption in the past and projection in the future. And 70% of oil is consumed in the transportation sector. Electric vehicles are related to the transportation sectors which means EV's have a huge socio-economic and environmental impact on our society and country.

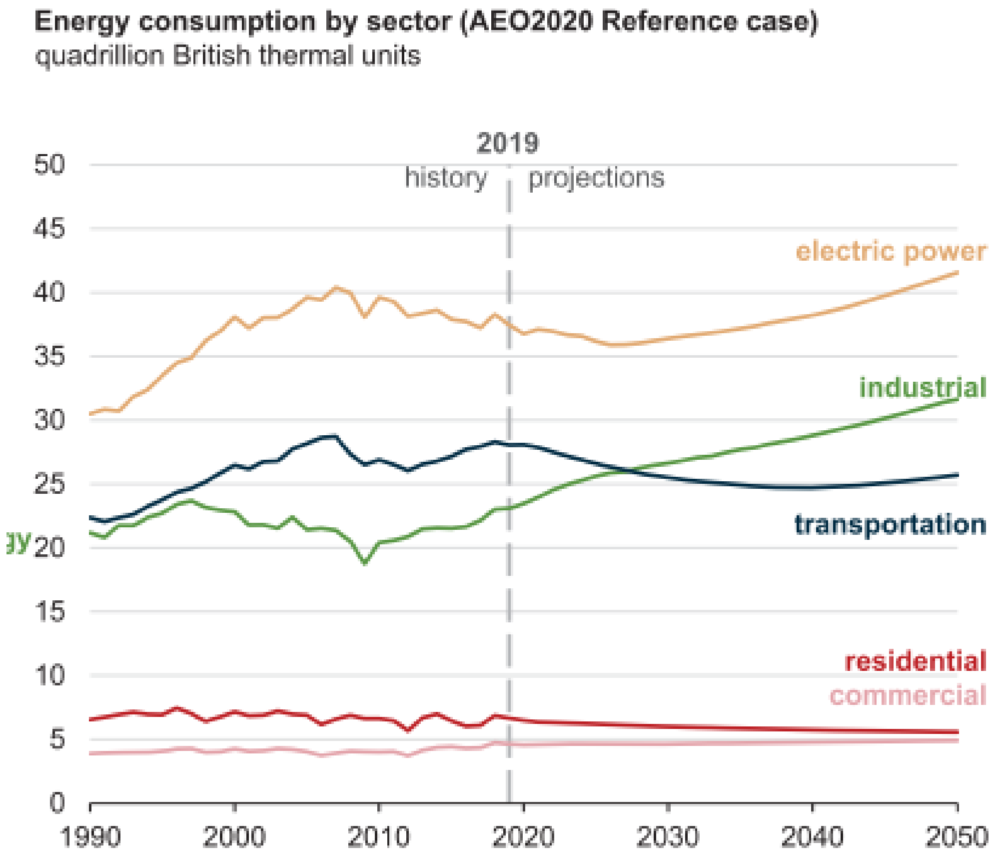

Figure 4. US energy consumption by different sectors including transport

Socio-economic impact of EV

Electric Vehicles can have positive and negative economic impact on our society. However, positive economic impact can outweigh the negative impact. Switching to EV can add a new job to the market and generate demand for existing jobs. It can create additional economic development opportunities by improving a quality of life, reducing energy spend and decreasing our dependence on fossil fuels. The growth of EV in markets might cut the jobs in the oil industry, however development of EV require a lot of people for research and development, manufacturing, and production. Growth of EV also can induce the job in other sectors like electricity development, battery development and so on. Early challenges with EV adoption are the problem of adequate charging stations but as the number of vehicles increases charging infrastructure increases. Another important impact of EV is that it reduces the use of fossil fuel which is the non-renewable source of energy. Sooner or later people must find an alternative to fossil fuel since it is supposed to be exploited completely one day. So EV can be an important alternative to gasoline vehicles. Furthermore, most of the country does not produce fossil fuels; they export the oil completely. Electric vehicles reduce the reliance on foreign oil and those countries can use the electricity produced by themselves to run the vehicles which help them to boost their economy and quality of life. This saves their money going outside the country for the purchase of fossil fuels. Electric vehicles can help to decrease the electricity utility bill by balancing the demand of electricity between data and night. This might reduce the average cost of electricity. Another important thing is that the use of EV can help to improve people's health. Gasoline vehicles produce harmful gases like CO, SO2 which always have an adverse effect on human health. However, electric vehicles have almost zero tailpipe emissions. When we compare the per gallon of gasoline with electricity to run the same type of vehicle, electricity average price is cheaper in the USA (*Saving on Fuel and Vehicle Costs | Department of Energy*, n.d.). In figure5 we can see the cost of fueling EV is $1.15 in the US whereas the cost of fueling vehicles with regular gasoline is 2.25. So, the cost of electricity is almost half of the gasoline. So, if we can reduce the capital cost of Electric vehicles, we can have a higher positive impact on our society and economy.

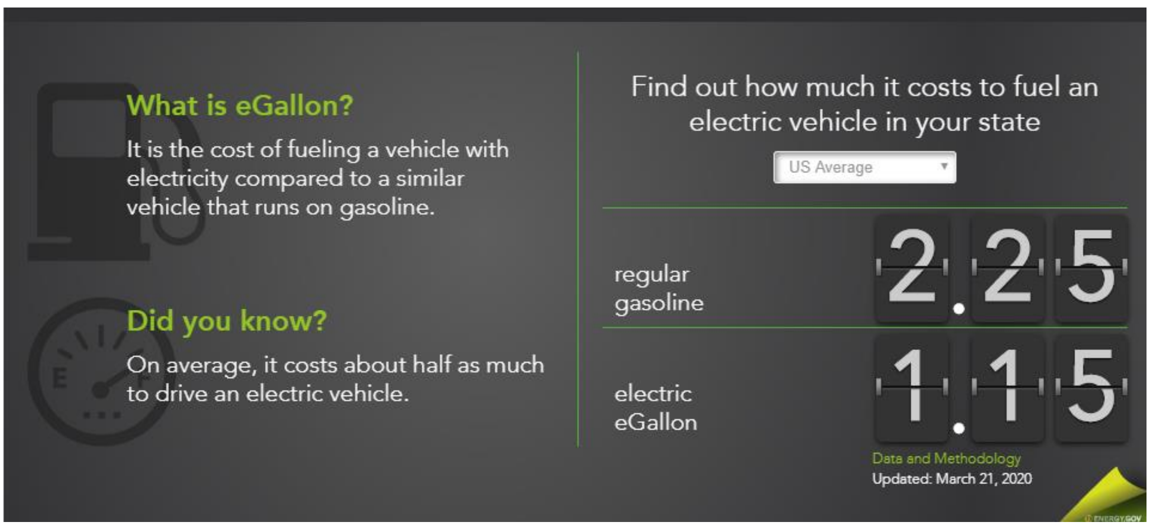

Figure 5. Electric vehicles charging cost equivalent to regular gasoline

One social barrier of EV is that for the usage of electric vehicles, drivers are not convinced that EVs are better than some of the currently available conventional vehicles (Donateo et al., 2015).

Environmental impact of EV

Global warming and climate change are the one of the major problem worlds facing. Transpiration sector contribute the higher portion of carbon emission (*The Annual Energy Outlook explores long-term energy trends in the United States*, n.d.) which is shown in figure 6 where we can see all most 2 billion metric ton CO2 emission is from transportation sectors which is really a serious concern for the environment. Therefore, Electric vehicle is considered as clean energy vehicles with no tailpipe emission like that of fossil fuels vehicles. If we could replace the gasoline vehicles with Electric vehicles, then we can reduce the CO2 emission by huge amount (Sioshansi et al., 2010).

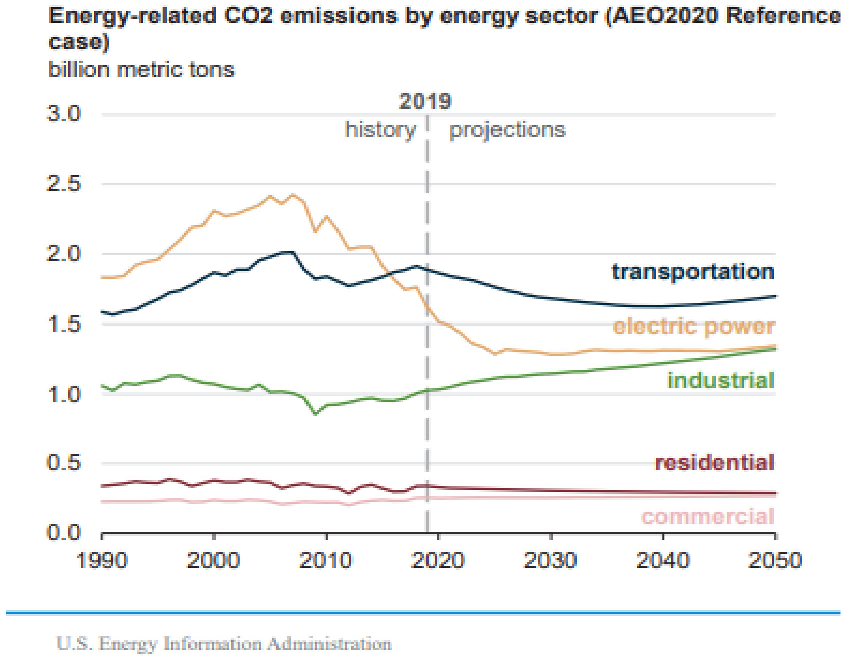

Figure 6. CO2 emission by different sectors including transport in billion metric ton

However, EV's are considered as zero tailpipe emission vehicles, Plug-In vehicles Hybrid Vehicles can run using gasoline, so we need to consider the emission during gasoline mode. Furthermore, another important thing to consider is emissions from the electricity generation system. In figure 7 we can see that natural gas and coal covered the highest percentage of electricity generation in the US which means they have high CO2 emission, whereas renewable fuels like solar, wind, hydro have very low CO2 emission.

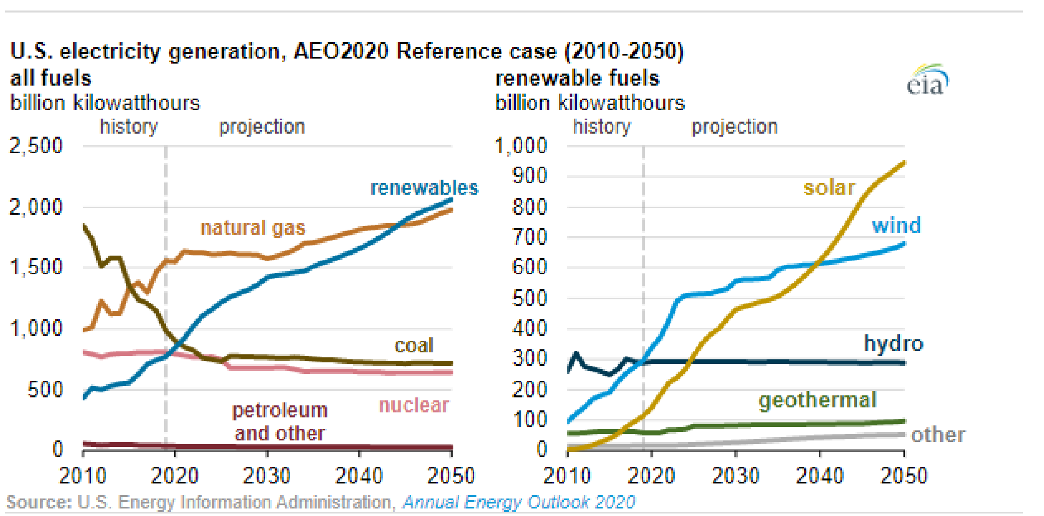

Figure 7. US electricity generation history and projection

Therefore, the source of electricity to charge a vehicle has an effect on emission from electric vehicles. If we have more electricity generated from coal and natural gas than that of renewable sources like hydro, wind, solar, we will have more CO2 emission per unit charge of electric vehicles. Figure 8 shows the amount of annual CO2 emissions by different categories of vehicles (*Alternative Fuels Data Center: Emissions from Hybrid and Plug-In Electric Vehicles*, n.d.).

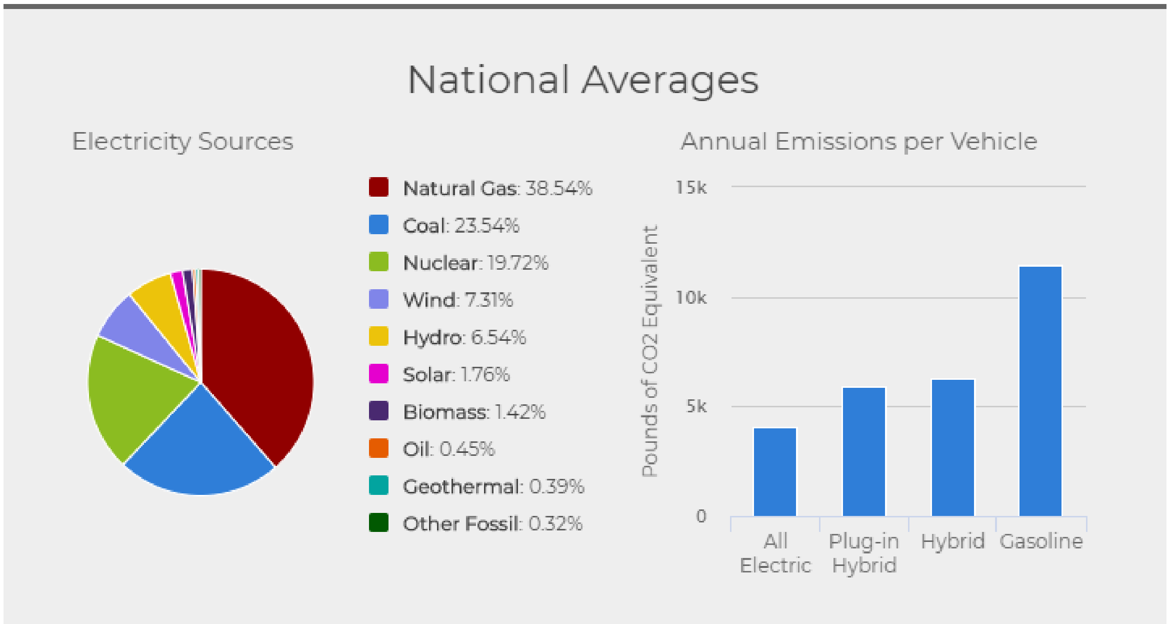

Figure 8. US electricity generation graph and CO2 emission for different type of vehicles

Different policies for EV

Energy sectors policies and Government polices always play an important role for the adoption of the electric vehicles. The one who are in business of oil may never want EV to boom. There is a Zero-Emission mandate, which is special provision in the clean air act. This act allows states to either follow federal law for vehicles emission or adopt laws of California regulation. In 2010 California adopted new regulation which require 15 percent of new vehicles sales in 2025 with Zero emission vehicles. There are different financial incentives, including tax credits and tax exemption to decrease the cost of electric vehicles and encourage people to adopt new technology. The U.S. federal government has initiated a tax credit for plug-in electric vehicles (PEVs) purchased after December 31, 2009 (Eia, 2017). Many other states in US are using rebates, tax exemptions, and tax credits to motivate EV purchases.

Electric Vehicles in different sectors

Electricity in agriculture comes in variant aspects. Such as farm buildings, irrigations systems, crop treatment, product processing, and storage. Machinery in agriculture is still heavily reliant on petroleum. Designing a driving system for tractors are different from and automobile. For example, tractors are usually designed to have various agricultural implements for off-road working attached, so they require more weight to work at a lower speed and range of acceleration. Moreover, the electric motor should be able to apply a high torque at a low speed. The electrification of agricultural driving systems leads to increased efficiency, flexibility, productivity, and performance. In addition, the overall farm performance can be enhanced by improving operator comfort and increasing machine power. In recent years, a number of tractor manufacturers have adapted their equipment to operate with electrical power and alternative fuels, such as biofuels, solar panels, and hydrogen FCs. Therefore, the focus in this area will be on electrical drives in the future. Factors such as the high cost of battery production and the availability and convenience of fossil fuels have placed limitations on the large-scale utilization of electric vehicles.

Many studies have focused on sustainable and environmentally friendly energy sources to replace conventional fossil fuels. Results showed that the hybrids energy emissions were approximately 17% lower than a comparable diesel engine tractor. In addition, they found that the high cost of life cycle micro-electric tractors is due to vehicle batteries and their replacement costs. Therefore, batteries form and important part of the integration. The poor durability of electric batteries and long recharging times have reduced the ability of electric cars to gain a long-term market presence. These characteristics have placed limitations on the utilization of batteries in tractors, which require large amounts of energy within short time periods (Ghobadpour et al., 2019).

Unlike urban vehicles, agricultural and mining vehicles usually operate far from the electrical network and fuel station. Therefore, providing energy to these areas increases the cost of farming. In this case, an independent on-site renewable energy power supply system can provide a meaningful alternative while helping to satisfy the farm energy demand or sell electricity to the local network. In addition, this can help to increase the efficiency and reduce the dependency on fossil fuels.

Biomass, solar, and wind are the most widely available alternative renewable energy sources that can be produced with current technology on a commercial scale. In a major effort to transition from non-renewable to renewable energies, biomass is one of the most promising energy sources. For example, there are three main categories of resources: agricultural waste from product residues, food waste, and forest bioenergy resources. These can also be used to produce other energy sources such as biodiesel, bioethanol, biomass pellets, and bio-methane gas. A study found that on-farm biogas energy production is financially viable for small-sized dairy and swine farms when the total annual indirect benefits are over $10,000. With that, biogas can be also produced on farms as an important renewable source for producing hydrogen or electricity for utilization in future electric vehicles (Ghobadpour et al., 2019).

Population projections show an increase of 7.5 billion in 2017 to 10 billion by 2050, increasing agricultural production is expected to continue. Automated machines in agricultural have certain technological and information requirements. Regardless of the importance of automation in agriculture, it faces more limitations here than in other industries. Some limitations are the dependency of the type of operation, environmental conditions may affect sensor observation, work spaces are large, ground surfaces can change daily, and low cost systems are required. However, the environment is commonly simpler than for open road autonomous vehicles. The field dimensions and set of fields are well defined, as well as the area that is planted or requires planting for a particular product. Furthermore, boundaries and obstacles are fixed, and the areas of passage for vehicles are clear. Recently, several major tractor manufactures have started to examine prototype autonomous tractors using various technology. For example, a John Deere concept offers auto-steering vehicles with agricultural management systems that reduce driver errors and pass overlaps, resulting in improved fuel efficiency. Other companies, such as Case New Holland offer similar systems. Although these products are up on the market. The uptake of them are slow due to costs, reluctancy to change, and the reliability of GPS systems (*Enhancing safety in underground mines with electric vehicles*, n.d.)**.**

Although it may seem we are a long way from electrical machinery in agriculture and mining, the continuous research and development of robotics and automation in the manufacturing world will improve the realization of automation for farm and mining machinery.

Electric Vehicles US Current State, Future Forecast and Market Overview

In the US, electric vehicles are becoming more and more popular and are expected to sell at an exponential rate. 2018 was the biggest year for electrical vehicles as the sales increased 81% from 2017. By the end of 2018 there was about 1.1 million electric cars on the road while still only contributing 22% to the global electric vehicle fleet. The leading manufacturers of electric vehicles in the United States is Tesla, followed by GM and Nissan, who together contribute 62% of the total electric vehicle sales. The growth of electric vehicles on the road from 2011 through 2019 is shown in figure 9.

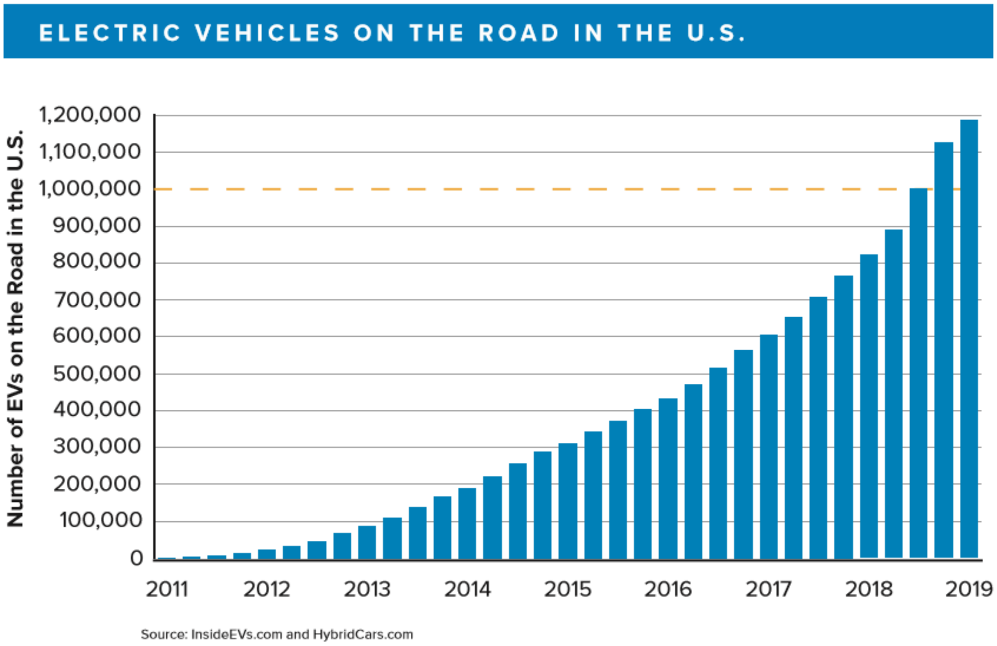

Figure 9. HEVs EVs on the road in the US (*Electric Transportation*, n.d.)

A major holdback to the electric vehicle industry is the price. With electric vehicles being relatively new technology, the sales price of an electric vehicle is more expensive. With a higher price, the sales of electric vehicles are not to the high numbers the US would want. In figure 10, the projected price drop of a car, crossover, and sports utility vehicle are shown (*Electric Vehicle Advocacy and Education - Plug In America*, n.d.).

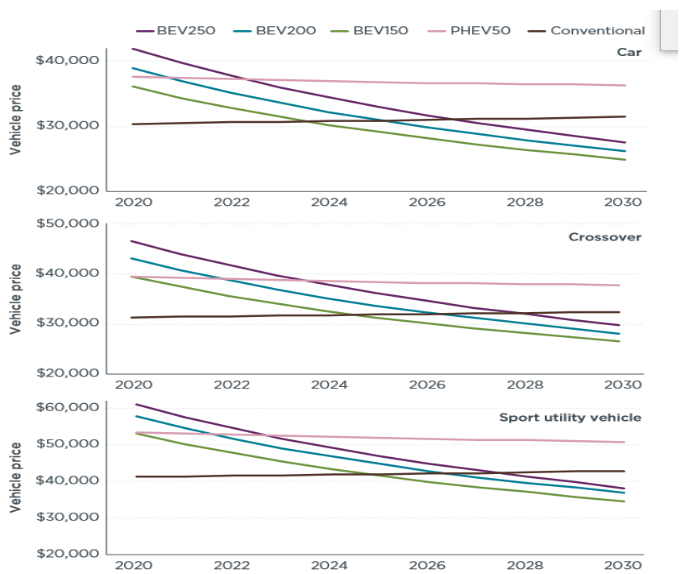

Figure 10. Price Projection of Electric Vehicle

With the expected price drop of electric vehicles in the future, the increase in EV production, and cheaper vehicle usage, the United States electric vehicle industry is projected to be on the rise. In figure 11, the estimated car sales projection is shown along with the sales share, which shows what percent of total vehicles sold are electric (Lutsey & Nicholas, 2020).

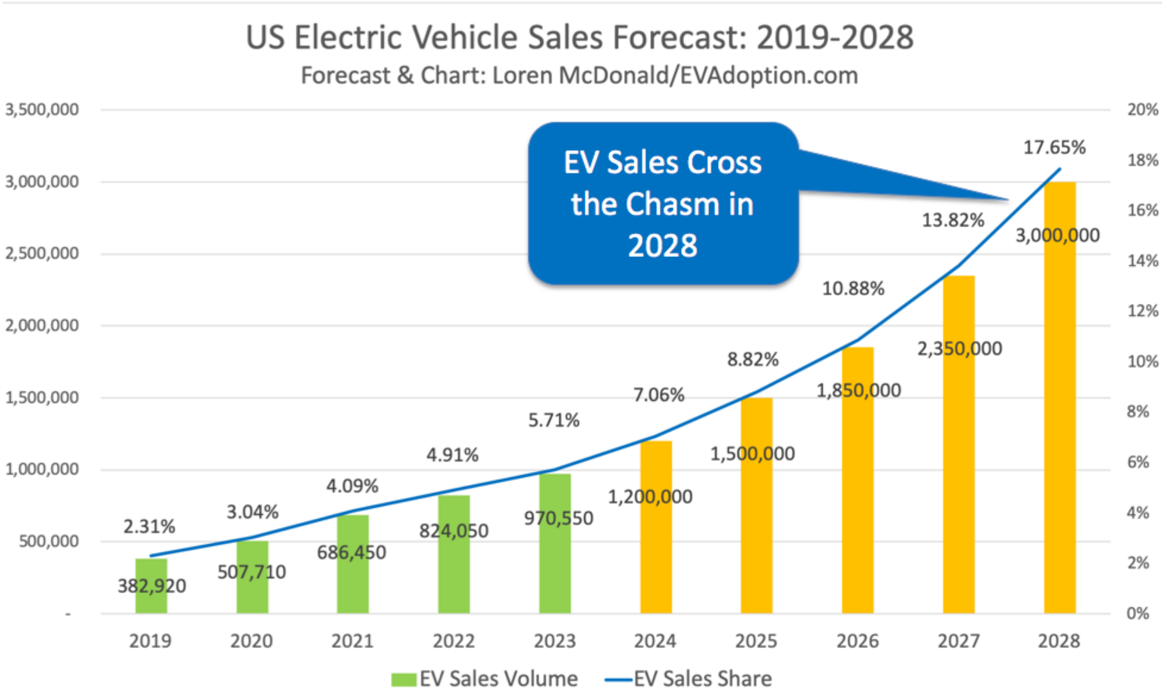

Figure 11: EV sales projection

Challenges to the Adaptation of Electrical Vehicles.

While electrical vehicles seem like the best option there are a few challenges preventing them from producing and selling them at higher rates. The first problem lies in the batteries. With cobalt being a big element in the battery, a big supply is needed. 60% of the world cobalt supply is consumed up with batteries already. Changing from gas powered vehicles to electric means more batteries being used with a limited supply. A replacement material for cobalt has not yet been found. Another problem with the batteries is the storage capacity. With many people traveling long distance in their vehicles, EVs batteries can support between 100-250 miles on a single charge, then must be charged for a long period of time. This puts a damper on long distance travel using electric vehicles. The second problem is the current price of electric vehicles. With high prices, most people choose the more affordable option of buying a gas-powered vehicle. In figure 12, the chart shows the income range of people that are buying electric vehicles, with the majority of sales coming from the $125,000 to $149,999 range. This is a problem as the middle class and lower-class individuals are not purchasing electric vehicles which is the majority of US citizens.

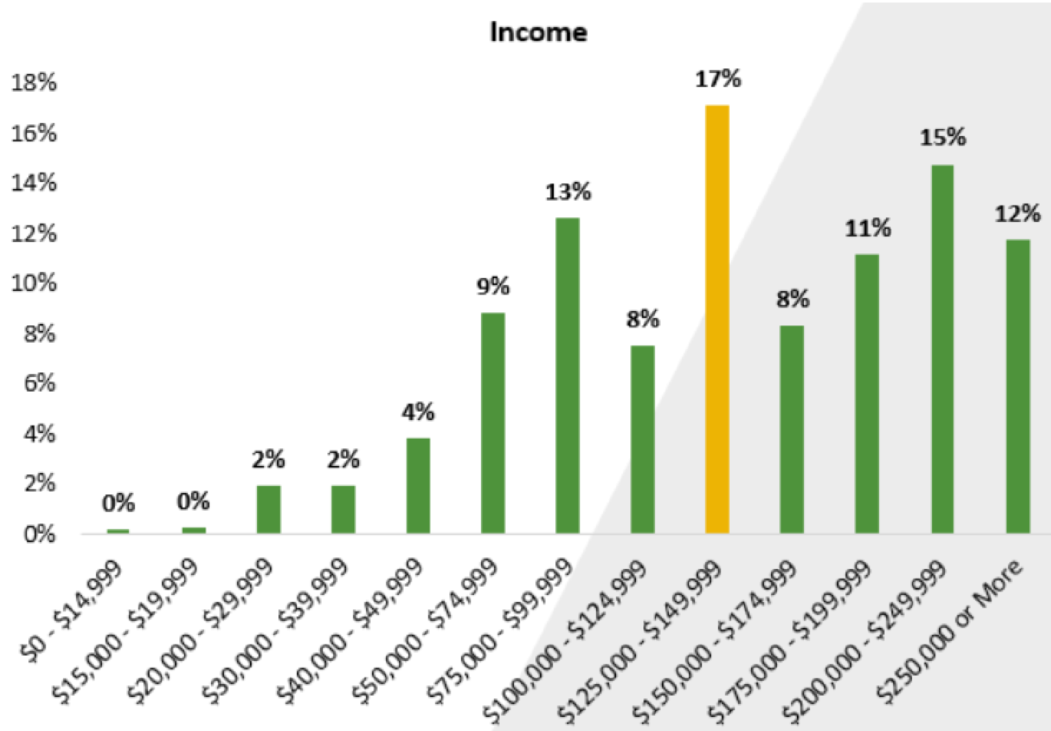

Figure 12. Salary of EV purchasers

Another problem is that gas powered vehicles are becoming more energy efficient and environmentally cleaner than ever before. Gas powered vehicles real world CO2 emission fell to 357 grams/mile while the fuel efficiency rose to 24.9MPG marking the best numbers in history. This is a problem for electric vehicle sales as the majority of the people will look for a reasonably priced car with good gas mileage. As gas powered cars are getting better and cleaner, sales of electric vehicles will not rise as they should.

Discussion and Conclusion

Electric vehicles have been around for a very long time. Dating back to the 1830s electric vehicles have been used for basic travel. Technology for these EVs have improved greatly over the past 20 years with quicker charging, longer travel, and cheaper costs. With such improvements in electric vehicles, sales are projected to rise exponentially in the coming years. Electric vehicles are projected to be the popular and clean car for the United States future. Electric vehicles have great potential to replace gasoline engine in future vehicles in future if companies work on reducing the capital cost of the vehicles and country can increase the charging structure. These vehicles can play a significant role job to address the climate problem and global warming problem if we increase its use. It can also play major role in economic growth of oil importing countries. We have seen oil producing countries like Qatar, UAE, Saudi Arabia have progressed a lot because of oil, however most of the countries in the oil are oil importing. Therefore, these countries prevent money going from outside the country and invest those money inside the countries to boost up their economy.

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