The Future of Fast Charging Infrastructure for EV in the USA

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<u>**Abstract**</u>

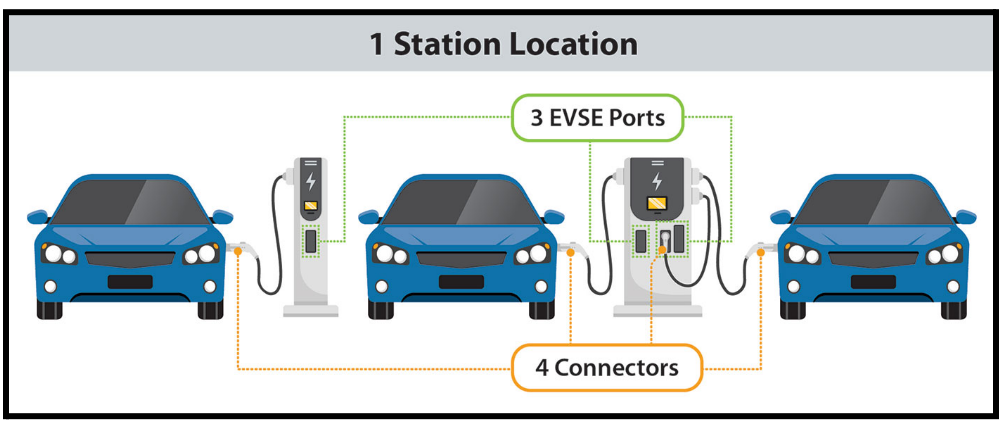
This project will focus on the DC Fast Charging infrastructure currently available in the US. The technology behind the DC fast chargers will be looked at in comparison to traditional level 1 and 2 chargers. Then, the feasibility of the current state of fast charging will be determined as well as the profitability of commercial fast charging stations. Finally, the economic impact will be discussed in relation to traditional forms of fossil fueling.

<u>**Introduction**</u>

Within the world of EV charging, the efficiency, and speed or charging has progressively improved over the years. The official term, "DC Fast Charging" was given to the most efficient and powerful charging type available today. Compared to its previous generations, "Level 1 charging", and "Level 2 charging", the output has almost quadrupled in strength whilst continuing to be beneficial to the environment.

<u>**Technical Section**</u>

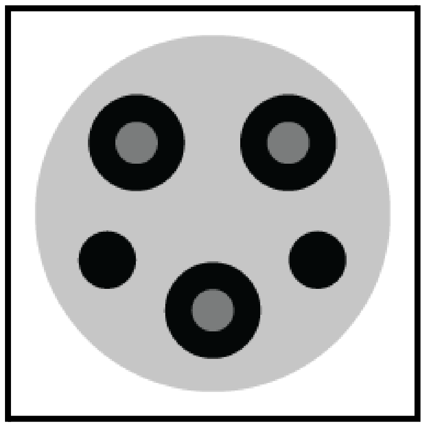
An EVSE, or Electric vehicle supply equipment port (as shown in the figure below), is a port that provides power to charge electric vehicles through a connector. A charging post is able to hold one or more EVSE ports, to charge one or more cars. The location of charging is called a station, which would be able to supply enough power for multiple charging posts to allow simultaneous charging of several vehicles at the same time. A study in 2020 stated that 15% of all ESVE ports in the U.S. were DC fast chargers [4].



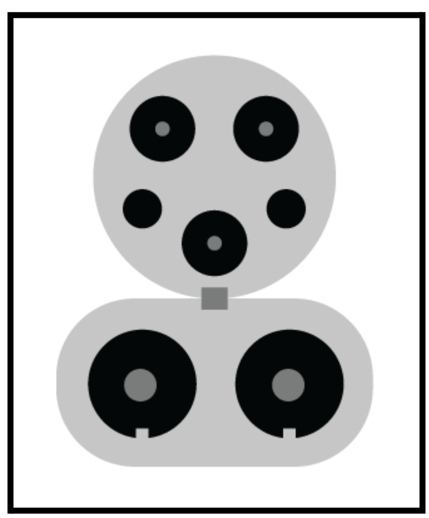
The process of charging includes the following steps: Driving the electric vehicle to the charging station, and plugging in the adapter/connector. Similar to getting gas at the gas station, the process is easy, however, the wait is much longer. Charging times vary based on the car's battery, the current state of the battery (full/half/empty), the capacity, and the type of charging. The charging rate was the main issue in the past with other types of EV charging until DC Fast Charging was introduced in recent years. With the previous-generation charging models (Level

1, and 2 charging) providing a voltage of about 120, or 200-240, charging an average car would take several hours for a full charge. Equalling charging rates of 2-5 and 10-20 miles of driving, respectfully, per hour of charging. With the newfound adapters and charging stations, the DC Fast Chargers have significantly improved their voltage range to about 200-1000 volts, and being able to achieve maximum current levels of 350 Amperes, and maximum power levels of 350 kilowatts. This rate translates to about 320 miles per hour of charging, meaning that most electric vehicles would now be able to charge to about 80% capacity in that time [3].

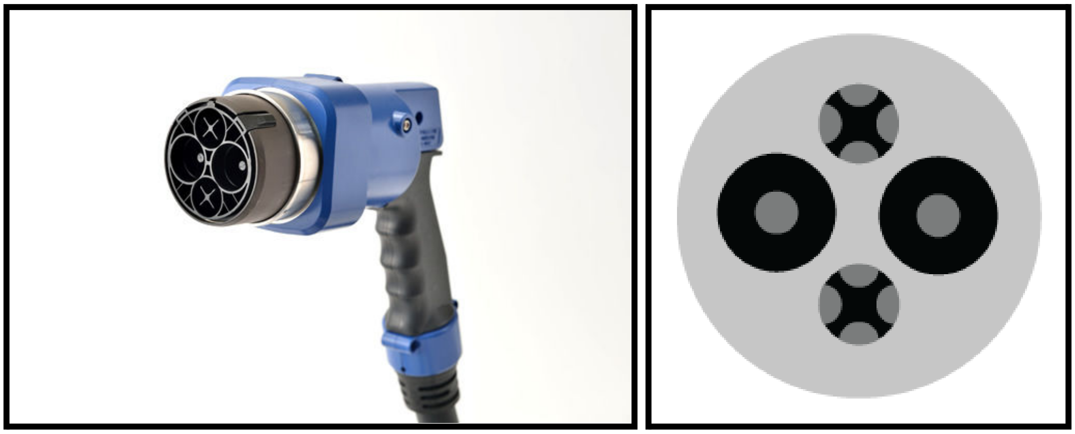
Recalling the changes in charging adapters over the years, initially, a J1772 connector (as shown in the figure below) was used in the Level 1 and 2 charging stations, while only providing the 120-240V of output. As a result of the need for higher speed charging, three new types of adapter connections were introduced with the abilities of DC Fast Charging. These included the CCS connector, CHAdeMO connector, and the Tesla connector.



The first advancement in the connector types was the "CSS connector" (as shown in the figure below), or "J1772 Combo", since it was a slight advancement from its predecessor, the J1772 connector. The difference between the two is that the CCS connector has the same J1772 connection, however provides two extra pins directly below to allow the increased output flow. Therefore, this connector can be used for Level 1, Level 2, and DC charging, and will adjust the charging speed based on the vehicle connected.



Today, the most common connector stated by the U.S. Department of Energy, is the "CHAdeMO connector" (as shown in the figure below), and is a DC charging standard for electric vehicles, built by the "CHAdeMO Association". This company has become a global organization in the world of electro mobility as they also provide seamless communication between the car and the charger [4].



One electric vehicle company, named Tesla, has an even simpler process when arriving at their "Supercharger Stations". Firstly, Tesla operates the largest collection of EV charging stations in the world (30,000+), with over 1600 of them being DC fast charging compatible, and decided to make them exclusively compatible with only Tesla cars. Integrated into their built-in software, Tesla cars allow users to travel long distances worry-free by making the best use of every mile. A unique route to the destination is created, including stops at fast chargers on the way based on the car's expected range, allowing a simple and seamless driving experience [10].

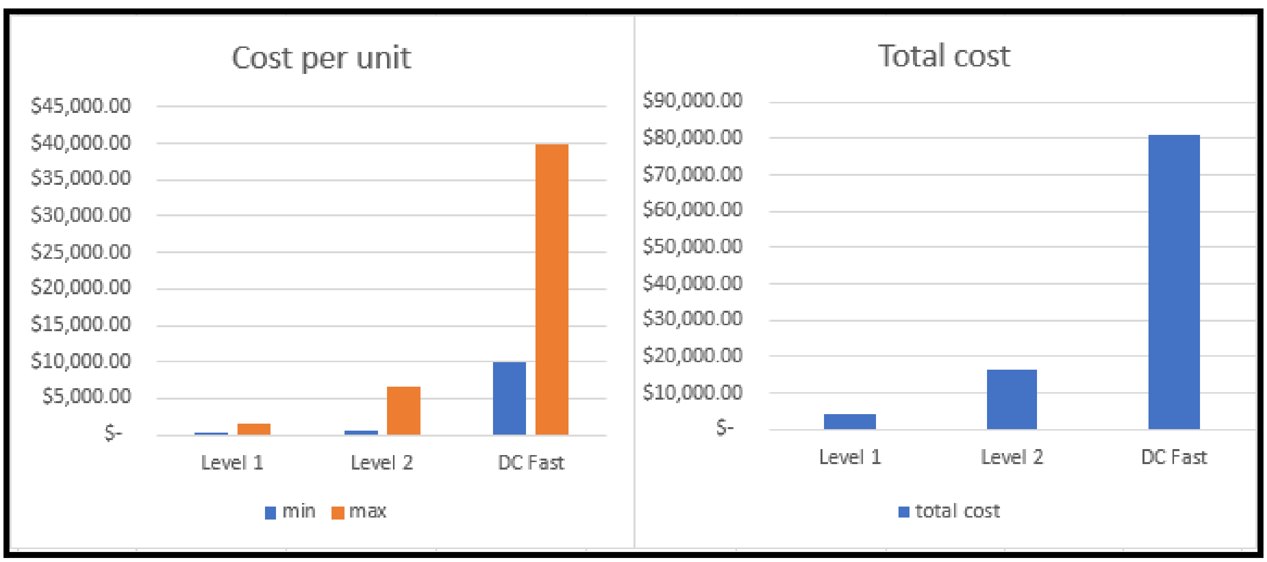
The "Tesla connector", (as shown in the figure below), is the main connection type per all Tesla motors vehicles. The maximum charging rate of this connector can go up to 250kW, therefore being able to deliver a sufficient amount of power per time period.

The battery capacities of the electric vehicles also come into play as the larger the battery, the more power it can hold, and thus, the more miles. The size of an electric vehicle's battery in the U.S. ranges from about 30 - 200 kWh, with an average size of 70-80 kWh per vehicle. The benefits of electric vehicles versus gasoline vehicles will be discussed later in the report.

As much as the increased speed of DC fast chargers save time, there are several limitations to using this type of charging. Those include higher losses of power for charging a battery, a limit of charging to a maximum of 80% its battery capacity (to prevent overcharging), the quicker degradation of the battery over time, and the inability to install residential DC fast chargers as a result of the high power requirements.

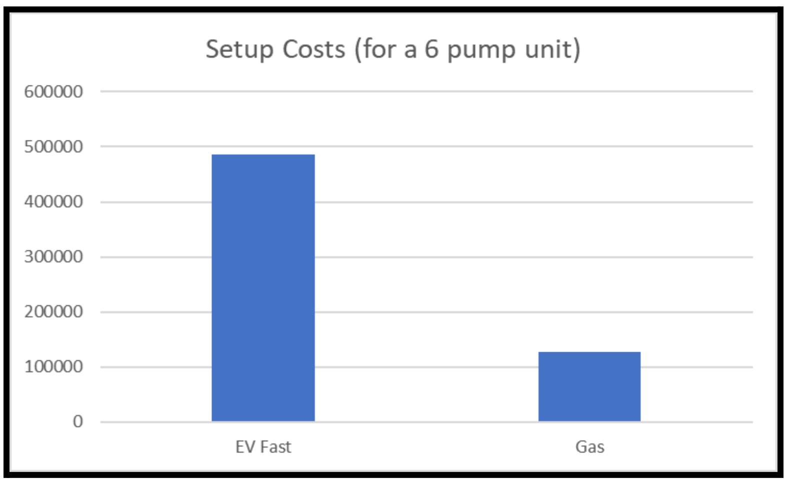
<u>Economic section</u>

Similar to any infrastructure change, looking into the cost of fast charging infrastructure for electric vehicles is important when determining its feasibility. The economic impact of charging electric vehicles can be broken down into two categories; the cost of the electricity and the cost of the charging equipment. When looking specifically at fast charging, the latter is more important to consider. There is currently a large barrier of entry when it comes to installing level 3 DC fast charging stations when compared to installing level 1 or level 2 charging stations. Level 1 stations cost $300-$1500, level 2's cost $600-$6500 and fast charging stations cost $10,000 to $40,000. This is just the price range for the physical hardware, the installation costs also scale up at the same rate. Level 1 stations cost up to $3000 to install, level 2's $12,700, and fast charging stations up to $51,000 [2]. The reason for such a drastic increase in price when upgrading to a fast charging station is mostly due to the need for increased electrical service at the point of installation. Unlike level 1 stations, which can often be plugged into existing electric infrastructure, fast charging stations need their own custom inputs to provide the necessary power. This tacs on additional materials and labor costs which, as shown, can drive the price of installation up drastically.

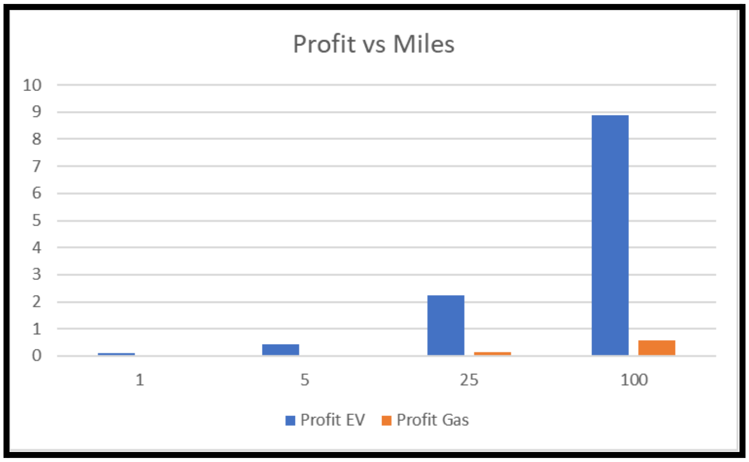


That puts the cost, on average, of installing a DC fast charging station at 20 times the cost of a level 1, and 4.9 times the cost of the level 2 at $81,000. At this price point, fast charging is currently too expensive for most individuals to install the necessary equipment in their own house or property. While this is a drawback, it does not mean fast charging is completely unviable. Very few people have the ability to fill their own gas tank at their house and that never stopped the progress of powering combustion engine vehicles. Basic level 1 and 2 charging stations can still be used in the home, when speed of charging is less important, leaving room for fast charging to become a commercial business similar to traditional gas stations. That brings up the question of would fast charging “gas stations” be profitable? To answer that, we must look into two different areas; how does the cost of an EV charging station compare to a traditional fueling station,and what is the cost/profit per unit of fuel for both stations.

Using the mean value of $30,000 per unit, a cost comparison between an EV charging station and a regular gas station can be found. Assuming a 6 pump setup, this puts the cost of equipment at $180,000 [6]. Adding the installation fee of $51,000, this brings the total cost of a 6 pump station to $486,000. In comparison, a typical gas station pump costs between $16,000 and $21,000. Using the average of $18,500, and an average installation cost of $2,750, this brings the total fossil fuel 6 pump station to $127,500.

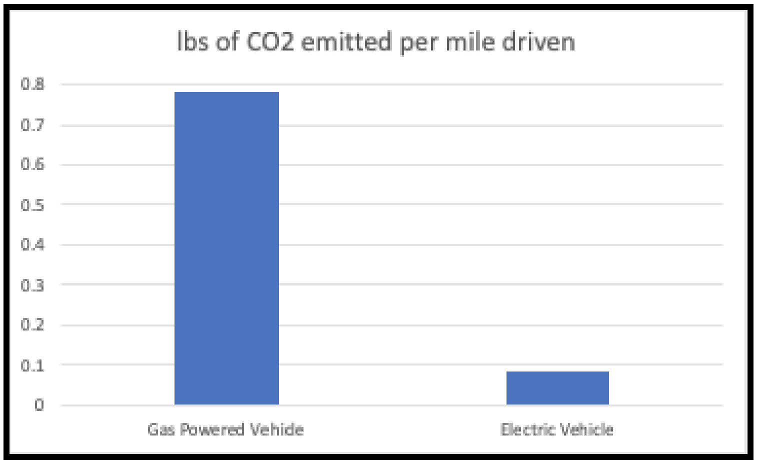


The profit per unit sold is an important metric when determining the feasibility of a business. Traditional fossil fuel gas stations in the USA average a $0.15 profit per gallon of gas sold [8]. An average car holds 12 gallons of gas and gets 25.4 miles per gallon [7]. This means the station owner will make, on average, $1.80 per car and that car will be able to drive 305 miles. This means the average profitability for gas stations is $0.0059 per mile driven. This metric will allow for the comparison between fossil fuel station profitability and EV fast charging station profitability. Calculating the cost and profit for EV fast charging is a little more complicated. One company cites their price for using fast charging stations at $0.35 per minute. The average EV can get 70 miles per 20 minutes on a fast charger which makes 3.5 miles per minute. Using a 300 mile range as an estimate, this brings the total charge time to 85.7 minutes which would cost $30. To find the profit made, using an average capacity of 29kWh [9] for an EV battery and the national average of $0.11 per kWh this puts the cost at $3.19 per fillup meaning a profit of $26.81 per car. Divide this by the 300 average miles driven brings the profitability to $0.089 per mile driven. This makes EV fast charging stations an outstanding 15 times more profitable per mile driven than traditional gas stations. This comes at the drawback of higher start up costs and a much smaller customer base.

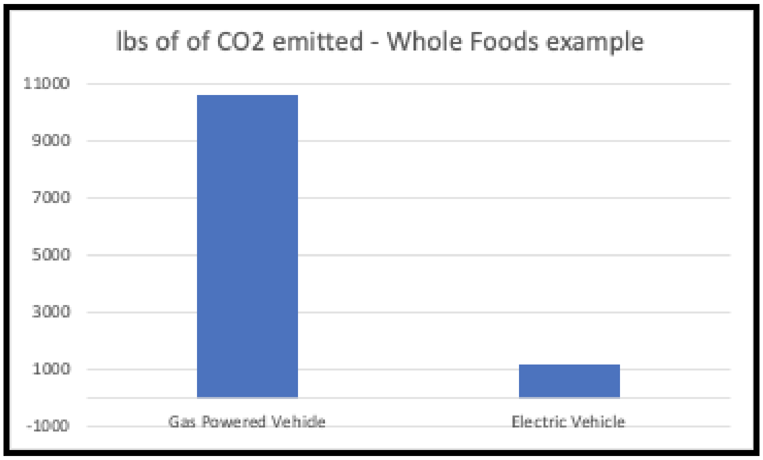


Environmental Section

When attempting to compare the carbon dioxide emissions of electric vehicles to gas powered vehicles, we must find a common unit that can be arrived at through unit conversion. For the sake of simplicity, we decided to compare gas powered vehicles to electric vehicles via "lbs of CO2 per hour." For electric vehicles, we know that the typical range in miles is about 300 miles. Additionally, we know that 1 kWh is equal to 0.85 lbs of CO2 emitted. We also know that the average electric vehicle has a battery capacity of 30 kWh. From there, we multiply the 30 kWh battery capacity by the 1 kWh equivalent (0.85 lbs of CO2 emitted) to get 25.5 lbs of CO2 emitted. To find emissions in pounds of CO2 per mile, we divide the 25.5 by the average mileage distance an electric vehicle's capacity can travel, which is 300. 25.5 divided by 300 gives us 0.085 lbs of CO2 per mile. Now we must calculate the emissions in pounds of CO2 per mile for a gas powered vehicle. For starters, average gas mileage is 25 miles per gallon. The average tank size in the United States is 12 gallons. From there, we can calculate the average miles driven per full tank of gas, which is 25 miles per gallon multiplied by the 12 gallon tank, giving us 300 miles as a result. We also know that the average emissions from a gas powered vehicle per gallon of gasoline is 19.6 lbs of CO2 per gallon of gasoline. We then multiply the 19.6 by the 12 gallon average tank size to get 235.2 lbs of CO2 emitted. Lastly, we divide the 235.2 by 300 miles to get 0.784 lbs of CO2 per mile. As seen in the graph below, gas powered vehicles emit around 9.2 times more pounds of carbon dioxide per mile than electric vehicles emit.



According to an EVgo article regarding electric vehicle (EV) charging stations at Whole Foods stores in the San Francisco, CA area, charging at EV charging locations increased 191% from 2014 to 2015. Similarly, those who charged their cars at these locations showcased a clear preference towards DC fast charging. When given the choice between DC fast charging and level 2 charging, twelve out of thirteen sessions, people chose DC fast charging over level 2 charging. In September of 2015, there were 1452 DC fast charge sessions in total. This amounts to around 45 fast charging sessions per day during the month of September. According to the math above, if we use the 300 mile capacity for an electric vehicle, this means about 1147.5 lbs of CO2 was emitted as a result of those 45 electric vehicles using DC fast charging per day during September 2015. In comparison, if those 45 cars were using gas powered vehicles, emissions would have equaled about 10,584 lbs of CO2. Therefore, if we subtract the theoretical gas powered emissions of September (10,584) from the EV emissions from September (1147.5), then we can estimate that each day an additional 9436.5 lbs of CO2 would be emitted into the atmosphere if these 45 EV charges were gas powered vehicles rather than EVs. What is notable from this is how much more of a preference the DC fast charging option is compared to the slower, level 2 charging station. The availability of DC fast charging stations seems to encourage more people to purchase electric vehicles, thus decreasing the amount of CO2 that is emitted into the atmosphere at a large rate [5].



Of all the Whole Foods in the San Francisco, CA area, there are a total of 13 stores which have DC fast charging stations present. From those 13 locations, it is estimated that as a result of these locations, approximately 8,770,895 miles have been driven on electric vehicles that were charged from these locations. That difference in lbs of CO_2 emissions between gas powered vehicles and electric vehicles is 3,945,274 lbs of CO_2 emissions that were reduced. This is the equivalent of almost 2,000 tons of CO_2 that was voided just from these locations in San Francisco, CA.

Conclusion

In conclusion, fast charging saves time at the expense of high losses of power for charging the battery of an EV. Fast charging also results in a quicker degradation of battery over time on top of higher power requirements making residential fast charging infeasible for the everyday electric vehicle owner. Fast charging stations are 15 times more profitable per mile driven than gas stations. However, fixed/setup costs must be considered as they are larger for EV fast charging stations.This makes them infeasible for home use but feasible for commercial use. When considering whether or not to install a DC fast charging station over a level 1 or 2 station, one must consider the preference and demand of the fast charging stations. A fast charging station is 20 times the cost of a level 1 station and 4.9 times the cost of a level 2. Thus, if the demand is high enough, it would be worth it both economically and environmentally in the long run. Similarly, fast charging stations have increased the amount of people that have and are currently embracing electric vehicles. The ability to fully charge a vehicle in less than an hour has led to more people buying electric vehicles, thus increasing utilization of fast charging stations. Because of this, the more electric vehicles are purchased, the more pounds of CO_2 emissions are avoided by charging a car rather than filling a car up with gasoline.

Citations

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