Benefit - Cost Analysis -
The Implementation of a Tesla Supercharger in Lakeland, Florida.

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Abstract

In North America, most electric vehicles follow the same universal plug in style. These are more accurately put into three levels: Level 1 (120 volts AC), Level 2 (208-220 volts AC), and Level 3 DCFC (480 volts AC) charging. The alternative to at home charging is public chargers that charge at a significantly higher rate. The purpose of this Benefit-Cost Analysis is to assess the desirability of implementing Tesla charging stations and access the alternative options for City of Lakeland, and Polk County, and state residents in Florida.

Decision to be Analyzed & Literature Review

Tesla Batteries

Tesla states that its battery packs were designed to outlast the cars. The average usage of private passenger cars in the U.S. is 17 years and roughly 200,000 miles (322,000 km). The mileage in Europe is lower - about 130,000 miles (209,000 km). So, we have the first indication that the batteries should last longer than that. Battery capacity is above 85% (on average) after 150,000-200,000 mile After selling more than 1 million electric cars, Tesla's battery degradation data shows that vehicles with mileage between 150,000-200,000 miles (241,000-322,000 km), on average, still have more than 85% of initial battery capacity the battery degradation is below 15%. This is pertinent to the owners of Tesla vehicles because the rate at which their batteries degrade over time is minimal compared to the mileage of the lifetime usage of the vehicle.

A group of Tesla owners on the Dutch-Belgian Tesla Forum are gathering data from over 350 Tesla vehicles across the world and frequently updating it in a public Google file located here: (https://docs.google.com/spreadsheets/d/t024bMoRiDPIDialGnuKPsg/edit#gid=0).

There is previously reported data, but Tesla has since added many more vehicles and those vehicles have been driving a lot more and therefore completing more battery cycles. The data clearly shows that for the first 50,000 miles (100,000 km), most Tesla battery packs will lose about 5% of their capacity, but after the 50,000-mile mark, the capacity loss levels off and it looks like it could take a long time for a pack to degrade by another 5%. This trend suggests that the average battery pack could cycle through over 186k miles (300k km) before coming close to 90% capacity.

When it relates to electric vehicles, battery degradation means not only the loss of battery capacity but also the loss of range over time. This is one of the main concerns of new electric car buyers and can vary greatly based on several factors like battery cell chemistry, battery management system, and usage. Tesla has historically been able to limit degradation to industry-low levels due to its robust battery management system. Real-world data showed that Tesla battery degradation was less than 10% after over 160,000 miles (257,500 km). Interestingly, Tesla used to not clearly cover battery capacity degradation in its warranty until it launched Model 3. With an update to its warranty earlier this year, Tesla now covers all battery capacity degradation in all of its vehicles with a limit of 70% capacity for up to 8 years or 100,000 to 150,000 miles depending on the model. Based on the previously mentioned data, it looks like Tesla won’t have to honor too many warranty battery replacements due to accelerated battery capacity degradation.

Public and Private Charging

Level 1 charging is the default EV charging option. It is accessible to all electric vehicles and all locations that have a standard power outlet. The issue with Level 1 charging is that it is relatively slow. Typically they are 12-16 amps which translates into 2-6 miles of range per hour, and it is commonly referred to as trickle charging.

For faster charging, homeowners can upgrade to Level 2 chargers. These use a 240-volt power outlet, the same as those used by some air conditioners or clothes dryers. Level 2 charging is a lot faster than Level 1 charging, providing 14 to 35 miles of range per hour by taking advantage of the circuit's higher amperage. These charging cords are traditionally sold as a separate add-on for your EV. Because some homes might not have a 240-volt outlet, homeowners may need to work with an electrician to get one installed. You'll want to ensure that the circuit supports a high enough amperage to allow your charge to operate at its peak output to charge your car as fast as possible. For pretty much every EV brand except Tesla, Level 2 chargers use a J1772 port. Tesla has their own Level 2 charging port, however, all Tesla's come with a J1772 adaptor for charging. So, all EVs should be able to take advantage of most public Level 2 charging stations.

Unlike the first two options which use residential AC current, DC fast chargers ,often called Level 3 chargers, use DC current. Because Level 3 chargers provide DC current, they bypass the on-board charger and directly charge the EV's battery meaning that it charges faster providing current to the battery itself rather than going through secondary systems.This allows for very fast charging speeds: they can provide 100 miles of range per hour or more. While Level 3 chargers are fast, manufacturers warn that you should not rely on them as your main charging source. The large amount of power that fast charging stations use can damage your EV battery's health, and potentially shorten its lifespan. It's recommended to only use fast-charging if you need it for long-distance travel or if you are pressed for time. Level 3 chargers are not feasible for home use, as they require special utility connections, hardware, wiring, and permits. They also have extremely high setup and energy costs. You'll only find Level 3 DC charging stations along highways or in other public areas.

In addition to the aforementioned Level 2 stations, the DOE says there are now 3,653 DC fast-charging stations in the U.S., 813 of which are for Teslas. But those numbers don't tell the whole story. First, knowing there's a station doesn't mean you know how many plugs are available; some may have a dozen plugs while others have just one or two. Second, vehicle connectivity is simply one aspect of public charging. After all, gas pumps will work with any car, but you still need to pay for the fuel. And that's where charging networks come in.

Most EV manufacturers include a Level 1 EVC cord set so that no additional charging equipment is required. As a general rule, Level 1 recharging will add approximately four miles of travel per hour. Level 1 charging is the most common form of battery recharging and can typically recharge a EV's batteries overnight; however, a completely depleted EV battery could take up to 20 hours to completely recharge (Groover Combs et al, 2020).

Level 2 recharging will supply up to approximately 15 miles of travel for one hour of charging to vehicles with a 3.3 kW onboard charger, or 30 miles of travel for one hour of charging for vehicles with a 6.6kWh on-board charger. Level 2 EVC utilizes equipment specifically designed to provide accelerated recharging and requires professional electrical installation using a dedicated electrical circuit. Level 2 equipment is available for purchase online or from retailers that sell other residential appliances. A completely depleted EV battery could be recharged in approximately seven hours using a Level 2 charger (Groover Combs et al, 2020).

DCFC recharging will add approximately 80-100 miles of travel with 20-30 minutes of charging. The DCFC EVC converts AC to DC within the EVC equipment, bypassing the car's charger to provide high-power DC directly to the EV's traction batteries through the charging inlet on the vehicle .While the power supplied to EVs by all DCFCs is standardized, there is not uniform agreement on the connector that is used to connect the charger to the vehicle (Groover Combs et al, 2020).

One of the most revolutionary changes is that of Tesla's very own supercharging network, which represents a large market for both Electric Vehicles and a high demand for charging stations (US Department of Energy, November 2015). The increase in charging stations directly reflects consumer demand for Electric Vehicles. As there is an increase in electric vehicles purchased, there is going to also be an increase in demand for chargers as there needs to be more means for consumers to charge their vehicles outside of '"in-home" charging.

An increase in purchases of Electric Vehicles, the demand for open charging stalls at the stations will also increase. Electric Vehicles and Charging Networks are complementary products. Therefore, as we see the gradual movement away from fossil fuels, electricity as a renewable energy source is increasing in usage and demand. Level 2 and DCFC chargers are going to see an exponential rise in demand due to more electric vehicles being in the market. More consumers are going to want their cars to be charged from these stations, and they will want it to be done incredibly fast. As a result, we will likely see an increase in DCFC chargers and their charging capabilities across the state.

One of the common reasons for choosing EVs is due to the price of gas versus the power consumption. A consumer's willingness to pay for the Electric Vehicle and the costs to charge factors into the demand for Tesla's charging stations and the ability to have a plugin that works at home for cars, as consumers are treated to more Electric vehicles in the market. This will be discussed more in depth later on.

Alternatives to Public Charging Stations

The alternatives to having public charging stations involve having residential private charging stations, at home charging stations and renewable energy power charging stations, at home. The direction for public charging stations is to pay a per kilowatt charge and with Tesla, paying for the charge varies on the package and model year of purchase. For at home charging stations, the costs vary based on the age of the house and community and electrical wiring of the house, which can cost up to an additional $1,000 (Albrecht 2019).

In addition, the Governor of Florida awarded 27 contracts to build charging stations along the I-95, I-4, I75 and I-295 highways (Calvan 2020). Florida will implement EV chargers at Florida's Turnpike service plazas. Based on another state level direction, California has instead imposed a mandate that the entire automotive industry in California transition to selling only EVs by 2035, effectively forcing the consumer market into action.

Demand and Elasticity of Demand for Cars

The analysis for which this paper was created does not actually need elasticity of demand for cars, electric vehicles, or fueling or charging stations. By briefly discussing the elasticity of demand for automobiles, we are able to paint a better picture of the market that creates demand for electric vehicle charging stations and Tesla Superchargers in particular.

Measuring the elasticity of demand for any good is a difficult process, with cars, however, this task becomes incredibly difficult. Cars typically only change prices with the release of the next year's model which can have anywhere from minor comfort and trim updates every year to major body and technology overhauls every three to five years. Because the price of a specific new vehicle only changes when a new model is released, it is difficult to track the change in price needed to calculate the elasticity. Even though we know the different quantities sold each year and the price, since each year is technically a different product, we are not able to compare across model years. It is also not practical to compare a vehicle of one model year to other versions of itself (e.g. base vs sport vs luxury) because each trim level is competing in slightly separate markets. A consumer looking to buy a base model vehicle of one brand is most likely compared to other brands' base models and not a sport or luxury model. Although it may be the case that one vehicle's luxury trim level is compared to a higher end vehicle's base model. Nevertheless, this has not stopped people from finding the elasticity of demand for both specific vehicles and vehicles by class.

Using standard and nested logit models, Qin (2014) estimates the elasticity of a compact internal combustion vehicle, such as the Jaguar XF, to be .022 within group and .0015 across group. As a luxury vehicle, the XF's elasticity will be relatively low and changing the quantity available would not affect the price as much and may in fact increase it if that means that sourcing the appropriate number of materials is more difficult. The Jaguar XF itself has an own-elasticity of .0004 and a cross-elasticity of -6.22 with consideration to other vehicles in the group. Continuing with examining entry level luxury vehicle brands, we see within group elasticities as low as .429 for Audi and as high as 1.260 for Jaguar and as low as .0002 for Jaguar and high as .0017 for Mercedes-Benz and BMW across group (Qin, 2014). In 2019, (Xing et al., 2019) estimated the own-price elasticity for gasoline vehicles to be -2.761 and -2.751 for battery electric vehicles. When analysing just the Tesla Model S, they found an own-price elasticity of -2.37 and a cross-price elasticity average of .005 with other vehicles in the group (Xing et al., 2019).

Willingness to Pay

Calculating willingness to pay, the maximum price at which a consumer will buy a product, like calculating elasticities, is a science. As when calculating elasticities, it is important to take into account the vehicle trim level, but also now associated costs such as fuel or electricity, fueling or charging station availability, and climate impact sensitivity. Tanaka et al. found that American consumers were willing to spend $49.84 for each percent decrease in fuel costs and $21.5 for every 10 miles added to the total range of the vehicle (Tanaka et al., 2014). While these may seem low, it is important to note that the willingness to pay is an upfront cost while the potential savings are over the lifetime of the vehicle. For those consumers for whom carbon emissions were a concern, they were willing to pay $29.00 for each percent decrease in emissions. Because charging an electric vehicle takes considerably more time than fueling an internal combustion vehicle, the charge time must also be considered when calculating willingness to pay. Hidrue et al. found that consumers were willing to pay between $425 and $3250 per hour reduction in charging time and that to reduce a 50 mile recharge from 10 hours to one hour, consumers were willing to pay $5646. They suggest that range anxiety, long charging times, and higher entry prices were consumers' main concerns (Hidrue et al., 2011).

Asides on Willingness to Pay: Ownership Cost and Fuel Savings

As cemented in American culture as cars are, every car owner has a rough idea of how much maintenance and ownership costs will be before purchasing a new internal combustion engine vehicle. In late February of 2020, Investopedia did a brief overview of the least expensive way to own a Tesla Model S 85D, a middle of the line Model S. They found that at the end of five years, the cost of ownership is just over $100k (Page, 2020). Taking advantage of all available offers and calculating fuel and maintenance savings and selling the vehicle back to Tesla brought the five year cost to just under $44k which is about $730 per month (Page, 2020) The cost of purchasing a new Jaguar Xf is $72,950 on the sticker for a model most similar to a Tesla Model S 85D. According to Kelley Blue Book, the equivalent five year old Jaguar XF in good condition could be sold for between $30k and $35k. Assuming the best, the five year cost would be brought down to $38k for five years which is about $583 per month before gas and maintenance costs. A 2019 article on CleanTechnica compared Tesla Model 3 and Honda Civic costs over five years. Each vehicle was compared at three different equivalent trim levels. With as many as possible variables constant, the deciding factor was the cost of fuel vs electricity (Shahan, 2019). Across the five different comparisons of low, moderate, and high gas and electricity prices, they found that the five year ownership costs were roughly equivalent between the two vehicles (Shahan, 2019).

Asides on Willingness to Pay: Road Trip Time Comparisons (Trip time and distance measured with Google Maps)

For many people across the country, the ability to drive long distances to visit relatives for holidays, drive to school out of state, or simply like to vacation in far away places is of the utmost importance. For example, Gus drives back and forth between his home in Framingham, MA and his apartment near Florida Polytechnic University several times each year. Like an electric vehicle owner would, he meticulously plans out his route. Rather than optimizing charging times, Gus optimizes distance between gas stations and has a heavy bias towards BJ’s, Costco, and Sam’s Club gas stations. Because fueling time is negligible, he tries to get as far as possible between stops without running out of gas. Gus knows that he starts to get fuel anxiety at 315 miles, when his fuel needle is well below empty. His planned route from Lakeland to Framingham has five essential gas stops, with a sixth just before arriving home so that he has a full tank the next day. The average distance between gas stations is 221 miles with a maximum of 261 miles.

Using Tesla’s trip builder, we can compare trips from Lakeland to Framingham with a Model 3 Performance which has a range of 315 miles, similar to Gus’ maximum willing travel distance. The Tesla trip has 10 essential supercharger stops with an eleventh close to home, so that the two trips are as similar as possible. Even if Gus did own an electric vehicle, it is unrealistic for him to install even a Level 1 charger at home that would have access to the charging port on a car, thus the need for the charging stop close to home. The average distance between superchargers is 130 miles with a maximum of 180 miles. Even though the Tesla stops more frequently to charge, Gus’ trip is still 13 miles longer due to suboptimal routing towards his preferred gas stations. The Tesla’s driving time is also shorter by roughly 18 minutes. The differences between the Tesla and gas trips constitute less than 1% of the total trips. This seems wrong, and it is because it does not take into account fueling or charging times. The Tesla trip builder estimates a total of 4.8 hours will be spent charging. Assuming a total time of five minutes per gas station that Gus stops at, that means that Gus' trip will take more than four hours less than the Tesla's trip.

The Tesla trip builder also estimates gas savings at $32. However, on closer inspection, we find that Gus has a lower dollar per mile driven and the gas savings are less than the $32 estimated. Assuming that the gas costs saved are directly related to charging times, we find that for each dollar saved we are spending nine minutes at a supercharger which comes out to $7.87 per hour after adjusting for time Gus would have otherwise spent at a gas station. In 2011, Hidrue et al found that consumers were willing to pay $425 to $3250 up front for each hour decrease in charging time to full. Just after fifty-four total hours of charging and roughly 17,600 miles of driving, Gus would have saved enough money to break even with his initial investment of $425. Over the lifetime of the vehicle, until the cost savings per hour can meet the consumer's willingness to pay per hour charging, it does not make sense for consumers to choose a Tesla over a traditional gas vehicle for long trips.

Quantitative Analysis on Data from Users and Contextual Meaning

To obtain more data, the team looked at some data provided by current Model 3 owners. For continuity purposes, the owners of the Blue Model 3 have Long-Range Dual Motors, with 19" Sport Wheels, and have Autopilot (Tesla Motors, 2020), all of which have factors on driving and utility for the driver. However, do note that the total value of the car is nearly $60,500 (Tesla Motors, 2020) and Tesla requires a down-payment of $1,000. In comparison, the average new vehicle in 2019 was roughly $40,000. More on these comparisons later.

The first set of data below was calculated and taken from John Kraus, one of the current Model 3 LR Dual Motor owners we spoke with. John's old data provides an interesting insight into the home charging prices in comparison to supercharger prices.

To completely fill-up the vehicle at home, he spends roughly $9.00. "At-home costs" are based strictly off the cost per kilowatt hour that the given utility company charges for. This is different from the Supercharging network (and potential referral program promotion), which users directly pay Tesla for their charging. This charge has quite the contrast to what owners of combustion vehicles face per fill-up. Assuming that the average tank size of a car is 14 gallons (average between 12 and 16 gallon tanks) (RocketHQ, 2020), and that gas costs are currently anywhere between $2.00 a gallon to $3.50 (AAA Insurance, 2020), it could take a consumer between $28-$49 to completely fill their vehicle(which is comparable in size of the vehicle, EPA estimates on range, and fuel economy). This is nearly 3 - 5.4 times the amount an electric vehicle driver, who charges strictly at home, faces. The data is further broken down into subdivisions to see more insights.

Home charging	
Miles per dollar	34.91
Dollars per mile	$0.0286
Average cost to add full rated miles (322)	$8.8887
Percent per hour	6.52
Miles per hour	20.24

Table 1: Home Charging Data from John Kraus for his Tesla Model 3 LR Dual Motor

However, these values significantly increase with the supercharging capability. Do note that a better value of the average cost to add full rated miles (322) should truly lie within the $16-$20 range. John's numbers are currently skewed as he calculated these values including the "free miles of charging" he earned from the use of Tesla's referral code program. This referral code program is used strictly at the supercharging networks. Even using the maximum end of this range, an owner of the vehicle is not paying as much as they would if they have stayed with their electric vehicle. This data is also further broken down into subdivisions to see more insights.

Supercharging before reimbursement	
Miles per dollar	25.59
Dollars per mile	$0.0391
Average cost to add full rated miles (322)	$12.0259
Dollars per minute	$0.2455
Miles per minute	6.28

Table 2: Supercharging Data from John Kraus for his Tesla Model 3 LR Dual Motor

With this in mind, Trevor Mahlmann also shared his data in regards to his Tesla Model 3, named Cobalt. For Trevor, on average he is able to obtain a charge from 0-80% in roughly 6-6.5 hours at home. However, as mentioned in the Level 1 charging literature review, this amount of time is highly dependent on what kind of charger you buy. Average percentage gained per hour is roughly 10%. A different method in determining costs, in comparison to John, Trevor's costs per KwH is roughly $0.055/kWh.

At home charging costs is roughly $4 for a full charge off-peak and roughly $20 for an on-peak charge. DCFC chargers are anywhere ~2-3 and 5-6 times the price of normal electricity. However, similar to John Kraus and Andrew Kaylor, these costs are justified due to the acknowledgement of the required infrastructure and that it is still cheaper than to fill-up a tank of gas.

There is a ~10% difference between the Level 2 charging network / KwH than at home, off peak. These prices become exponentially higher when comparing off-peak to DCFC, as it is roughly five to six times the cost. Off-peak is ~$0.05 / kWh and Supercharging is $0.25-0.30. The main reason for the increase in price? Speed.

Supercharger networks are incredibly effective at providing consumers a very fast ability to recharge their vehicle. Tesla's Version 3 Supercharger network can provide a vehicle 250 miles of range within nearly 20 minutes; Version 2 Supercharger Networks take just over 30 minutes of charging time. At home charging takes at least twelve times longer.

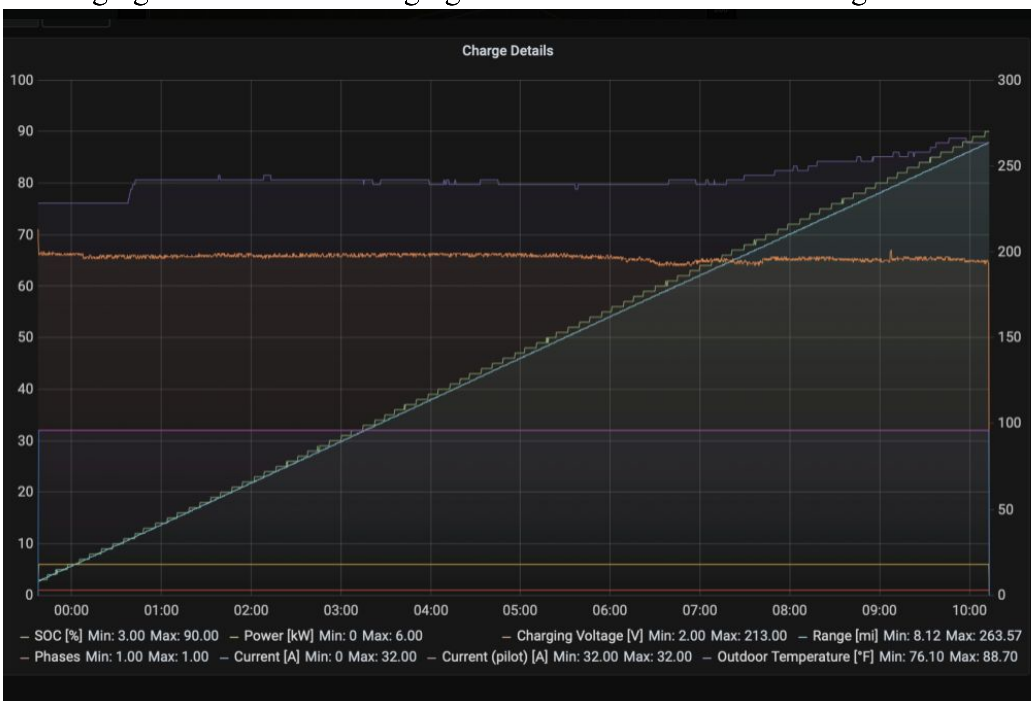

Figure 1: AC Charging from Trevor Mahlmann for his Tesla Model 3 LR Dual Motor over 10 hours at 6kWh (Level 1 Charging)

This graph depicts what is occurring to the vehicle under AC charging over roughly 10 hours at 6kWh. This is most equivalent to what we refer to as Level 1 charging, which often occurs overnight while the consumer is sleeping. 250 miles are added within 10 hours of plug-in. This means roughly 0.4167 miles of driving capability is added every minute of charge time. This is incredibly slow, however is the cheapest option for a consumer due to electricity rates being lower than supercharging rates.

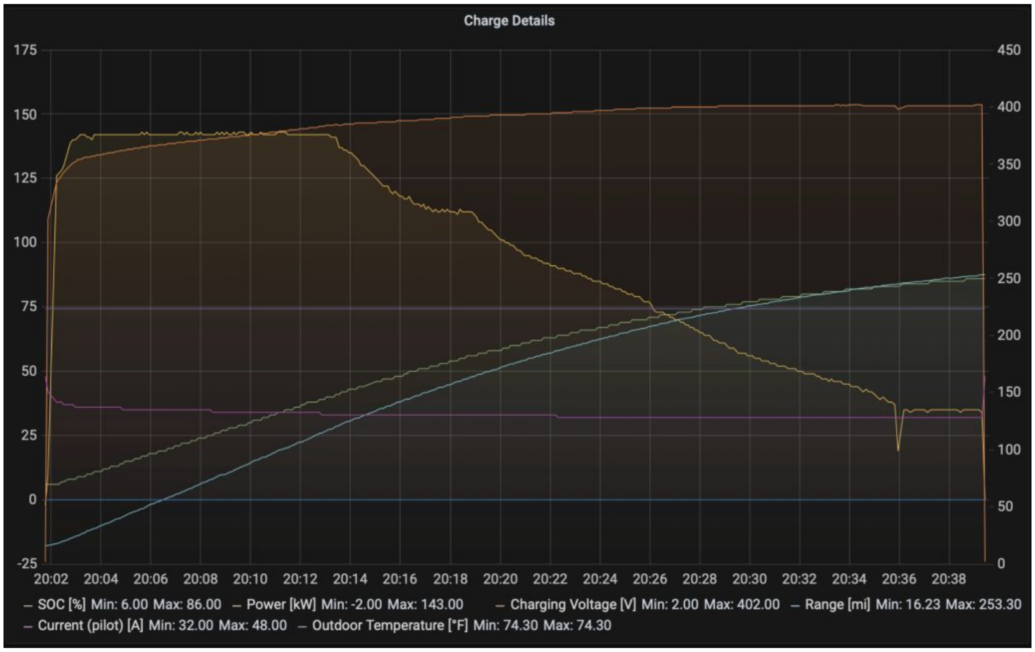

Figure 2: Supercharging Details for Trevor Mahlmann's Tesla Model 3 LR Dual Motor over 36 minutes at 150kWh (Level 2 Charging)

This graph depicts what is occurring to Trevor's vehicle under DCFC - Supercharging, V2 150kW during peak time at a charger. This is most likely equivalent to what we refer to as Level 2 charging. 250 miles are added within 36 minutes of plug-in. This means roughly seven miles of driving capability is added every minute of charge time. This is quite a decent rate of charge, but certainly takes a decent amount of time.

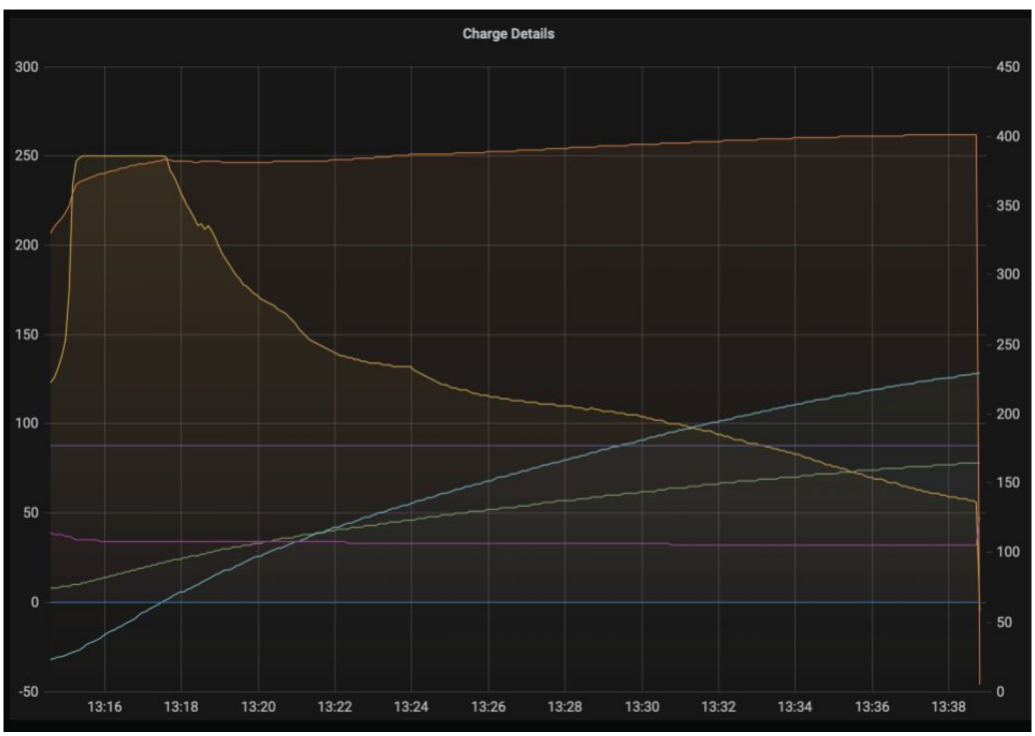

Figure 3: AC Charging from Trevor Mahlmann for his Tesla Model 3 LR Dual Motor over 22.5 minutes at 250kWh (Level 3 Charging)

This graph depicts what is occurring to the vehicle under DCFC Supercharging - V3 at 250kW. This is most equivalent to what we refer to as Level 3 charging, and is the fastest rate at which EV's can be charged today. 250 miles are added within minutes of plug-in. This means roughly 11.363 miles of driving capability is added every minute of charge time. DCFC Supercharging at the V3 stations, charging at 250kWh is significantly more expensive however is lightning fast compared to AC Level 1 charging.

Overall, the DCFC Supercharging - V3 at 250kW provides an incredible ability for the vehicle to recharge in a very faster manner. However, as mentioned, the rate at which the consumer must pay for this convenience is roughly five to six times higher than the cost of charging at home, at a very slow 6 KwH off-peak. For the consumer, the best way to charge, strictly monetarily speaking, is to solely charge at home, which is why nearly 80% of all EV owners do so. However, to minimize the amount of money spent and time charging, it is best to combine a mixture of at home charging and supercharger usage.

For the sake of argument, let us assume that the new Tesla is bought for $60,500, the charging costs for *charging only by the supercharger network* are $16 to obtain a fully charged vehicle, and has maintenance costs of $200 per year. In comparison, a new gas-powered vehicle is purchased for $40,000, has maintenance and repair costs of $600 per year (AAA Insurance, 2020) an average tank size of 12.5 gallons, has an average estimated miles per gallon of 20 mpg (enabling 250 miles per gallon), and gas costs $2.60 per gallon. Both scenarios have the consumer filling up their vehicle, with electricity and gas respectively, traveling 250 miles, and filling up once a week. It would take nearly 17 years for the price of the gas car to exceed the cost of the electric vehicle, should the consumer solely use the supercharger network at that rate, holding everything else constant. This was calculated by taking the initial cost of the vehicle plus the sum of maintenance costs and fill up costs each year. Excluding factors such as the Autopilot, Full-Service Driving Capabilities, and other perks of owning a Tesla, unless the consumer is wanting to keep the vehicle far past the average period a car is held for and about six years after the average lifespan of a vehicle, simply the costs of owning an electric vehicle do not make sense and cannot be justified by the money alone.

Initial Cost	Maintence Costs	Fillup Costs			20 mpg vehicle	250 miles	per week									
60500	200	832		1032	12.5 gallons per week											
40000	600	1690		2290	gas price of $2.60											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
61532	62564	63596	64628	65660	66692	67724	68756	69788	70820	71852	72884	73916	74948	75980	77012	78044
42290	44580	46870	49160	51450	53740	56030	58320	60610	62900	65190	67480	69770	72060	74350	76640	78930

Table 3: Lifetime ownership costs for a Tesla Model 3 an average consumer vehicle

The Myth of Range Anxiety - (hint: it's a lie)

According to John, Andrew, and Trevor, there is no thought of range anxiety or worry when comparing their Tesla's to their gas-powered vehicles. Being a Tesla customer means you have access to 3rd party charging plus the 20,000 Tesla stalls. Natively, Tesla's on screen display (OSD) will provide info on the quantity of public superchargers available real time. While the data reported on availability is highly accurate, some chargers do have issues and that's entirely understandable. However, Andrew mentioned that the speed and availability were very reasonably accurate enough to feel comfortable with planning his route. Some may claim that their result in the middle of nowhere may not feel like a lie, however, this is more a direct result of poor route planning by the driver rather than the capability of the vehicle (both electric and internal combustion, for this matter).

There is full-confidence in Tesla Superchargers being available for charging, but other networks much less so. A supercharger stall stands tall and Tesla signs the spots well to prevent people from parking there. Additionally, the charging network is almost seen as superior to a gas station because they put them frequently near good food options versus gas stations, so consumers can get bathrooms and also good food options /amenities, instead of nasty bathrooms and poorer food options in and near typical gas stations.

The only pitfall is that it can be challenging to determine wait times when charging was at full capacity, but this was not a frequent occurrence fortunately. Most stops are within 20 minutes, which is confirmed by the data above, just enough to make it to the next charging location. Charging while low is “better bang for the buck” as far as return on investment (ROI) on time investment goes; therefore the vehicle typically runs between 5-10% and 70% charge.

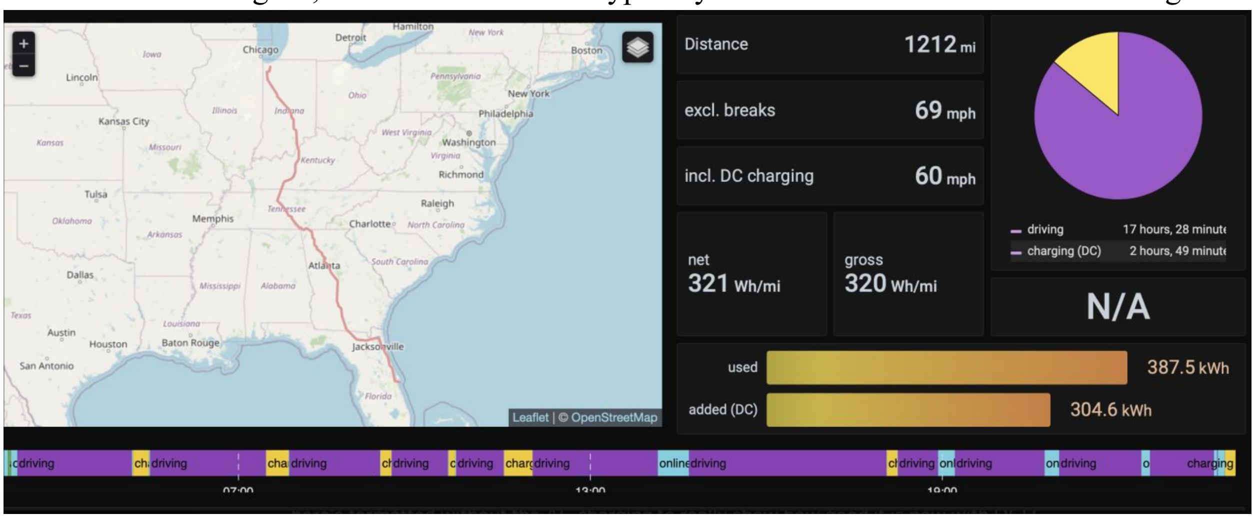

Figure 4: Trevor Mahlmann’s trip to FL from IN in his Tesla Model 3 LR Dual Motor

For instance, this is a track of Trevor’s most recent road trip from Indiana. Out of the twenty hours it took to arrive, only roughly three hours were spent charging alone. This means about 85% of the entire drive was spent solely on the road - this is excellent! Trevor mentioned that when he made his stops, he was not solely just sitting there doing nothing; only roughly thirty minutes of that was true waiting time. The other time was time spent doing road trip activities like stretching his legs, using the restroom, eating, etc. Factoring in everything except thirty minutes, it is mentioned that only 0.025% of the trip was “wasted” due to having to stop and use a Supercharger.

Fundamentally, the concept of range anxiety for an electric vehicle is no different than that of a combustion engine. Those who claim otherwise have falsely made preconceived ideas, and if anything, more supercharger stations available should help reduce that anxiety.

Impacted Parties

For the benefit-cost analysis of having charging stations, we divided the impacted parties into State, County, and Resident levels. The social costs are the sum of the cost to by a car, the cost of waiting for the vehicle to charge, and the cost of electricity. The benefits are the sum of the benefit by the reduction in carbon emissions and the difference the cost of gas and electricity for the same distance driven. Net benefits were then found by simply subtracting the costs from the benefits. Also worth noting is that Tesla covers all implementation, maintenance, and upgrade costs to the Supercharger as they consider it their asset. Therefore, the city and state does not have to pay those costs as they are covered by Tesla themselves. The only need is that the Superchargers are near areas that have the capability for high capacity electric output. This is why they are conveniently located near gas stations and large retail complexes. Tesla also implements solar panels to aid in the reduction of their costs. This information came from Tesla - Fremont Director of Manufacturing - Freddy Rivera.

Calculations and Sensitivity Analysis

	State	***Lakeland***	***Resident***
Social Cost			
Upfront to buy car = $60,500	$0.00	$0.00	$60,500.00
Cost for waiting = $15/hr	$0.00	$0.00	$429,000.00
Cost for electricity = $0.25/kWh	$0.00	$0.00	$7,150.00
Total Costs	**$0.00**	**$0.00**	**$496,650.00**
Social Benefits	-	-	-
Social Benefit in reduction of Carbon Emissions (Standard = 212)	$110,490,584.00	$1,458,984.00	$212.00
Money saved by not buying gas (cost of gas - cost of electricity)	$0.00	$0.00	$23,270.00
Total Benefits	**$110,490,584.00**	**$1,458,984.00**	**$23,482.00**
	-	**-**	**-**
Net Benefits = SB - SC	**$110,490,584.00**	**$1,458,984.00**	**-$473,168.00**

Table 4: Net Benefit Calculations for Current Values

This table indicates the total amount of Social Benefits and Costs for each entity that has standing. The up-front costs to buy a vehicle only pertains to the resident as they are the ones with the asset. The cost for waiting while charging is multiplied by the amount of time to charge per hour, 52 weeks in a year, $15 valued worth of time, and 1,500 cycled charges, the estimated lifespan of a Tesla vehicle, to fully charge. The state and county governments have no standing. The cost for electricity is ultimately always transferred to the consumer for their consumption. The state and county governments have no costs in this because they are already producing electricity for neighboring retail businesses and because Tesla covers all costs of the install, maintenance, servicing, and upgrades to the charger.

For Social Benefits, according to the EPA each consumer, in general, contributes $212 in carbon emissions due to the usage of internal combustion engines. This is assuming that their actions of having a Tesla and using a supercharger forgo all carbon emissions and footprint. The benefits calculated for the county and state are from an extrapolation of data by multiplying by the number of EV owners in each category.

The number of gas stations in FL: 7,043, this gives us a total supply, as charging stations would be used in gas station lots. So with a ratio of 1:74 to users we we can estimate the total amount of EV users in FL using the market ratio, which is 74*(7,043) = 521,182 users in FL. Looking at the Lakeland County level, with 93 gas stations*74 EV users, we can get an estimate of 6,882 total EV users possible in Lakeland.

Taking the amount, in dollars, for carbon reduction multiplied by the 6,882 estimate of EV drivers in Lakeland is how Lakeland's benefit is attained. The state's benefit in carbon reduction is attained by taking the 521,182 possible EV drivers and multiplying the $212 dollars by it. The benefits for the resident for ridding their consumption of gasoline is the average of 7.8 gallons, multiplied by $2.6 / gallon, multiplied by 1,500 fuelings (to mirror that of a Tesla), minus the cost for electricity found in the prior section. Taking the Benefits - Costs, we receive the net benefits. For the state the total net benefits of a supercharger is: **$110,490,584.00,** for the county of Lakeland, the net benefits is **$1,458,984.00** and for the average Tesla owning resident the net benefits are: **-$473,168.00.** Clearly, having a supercharger is in the best interest of the state and county. However, the cost of the resident/owner of the EV is so high because strictly due to the individual's value of their time and how long it takes to charge. However, a reduction in the amount of time, primarily due to advancing technology, should aid in bringing these costs down.

The following below is our sensitivity analysis changing the constraints from each section in the benefits and costs:

Default Values are in Green	***Net Benefits***	***% Change Net Benefits from Default***
	Cells in light green are better than default and cells in red are worse than default	*Cells in light green are better than default and cells in red are worse than default*

Key 1: Describes How to Read Tables 5-11

Change in the Time Value	***State***	***Lakeland***	***Resident***	***State***	***Lakeland***	***Resident***
15	$110,490,584.00	$1,458,984.00	-$473,168.00	0.00%	0.00%	0.00%
8.46	$110,490,584.00	$1,458,984.00	-$286,124.00	0.00%	0.00%	39.53%
13	$110,490,584.00	$1,458,984.00	-$415,968.00	0.00%	0.00%	12.09%
50	$110,490,584.00	$1,458,984.00	-$1,474,168.00	0.00%	0.00%	-211.55%
100	$110,490,584.00	$1,458,984.00	-$2,904,168.00	0.00%	0.00%	-513.77%

Table 5: Net Benefits when the Value of Time is Changed

In the table above, it analyzes how much the net benefits change given that there is a change in an individual's value of their time. The numbers show that should a person value their time less, the net benefits for the residents/owners of the EV improve between 12.09% and ~40%. However, should they value their time much higher, like most millionaires and others of high social standing would, the net benefits of charging drastically decrease. Due to the higher cost of purchasing an EV over an ICE vehicle, EV owners are more likely to be those that place a higher value on their time. Changing the value of an individual's time has a significant result on net benefits. The value of time is highly sensitive.

Change in the Cost for Electricity	***State***	***Lakeland***	***Resident***	***State***	***Lakeland***	***Resident***

0.25	$110,490,584.00	$1,458,984.00	-$473,168.00		0.00%	0.00%	0.00%
0.2	$110,490,584.00	$1,458,984.00	-$470,308.00		0.00%	0.00%	0.60%
0.23	$110,490,584.00	$1,458,984.00	-$472,024.00		0.00%	0.00%	0.24%
0.3	$110,490,584.00	$1,458,984.00	-$476,028.00		0.00%	0.00%	-0.60%

Table 6: Net Benefits when the Cost of Electricity is Changed

Holding everything else constant, the team looked at what an impact in the cost for electricity and how that would affect the overall benefits. In the calculations above, the team used an average of $0.25 per Kilowatt hour for charging. This number was a result of conversations with Trevor Malhmann, Andrew Kaylor, and John Kraus. Of course a lower rate per kilowatt hour of charge improves the net benefits for a consumer. However, the rate at which this occurs is marginally low. Should the price increase, consumers are impacted, but not by more than ~$4,000.00. The best thing for consumers would be for the cost-rate of supercharging to decrease over time, which is likely to occur due to more consumers and Tesla's master plan of everyone driving affordable, electric vehicles. The numbers indicate these numbers are not too sensitive.

Change in the Charge Time for 250 Miles	***State***	***Lakeland***	***Resident***		***State***	***Lakeland***	***Resident***
22	$110,490,584.00	$1,458,984.00	-$473,168.00		0.00%	0.00%	0.00%
21	$110,490,584.00	$1,458,984.00	-$453,018.00		0.00%	0.00%	4.26%
20	$110,490,584.00	$1,458,984.00	-$432,868.00		0.00%	0.00%	8.52%
15	$110,490,584.00	$1,458,984.00	-$332,118.00		0.00%	0.00%	29.81%
10	$110,490,584.00	$1,458,984.00	-$231,368.00		0.00%	0.00%	51.10%

Table 7: Net Benefits when the Time to Charge to 250 Miles is Changed

The team also looked at the charging rate. Currently, it takes roughly 22 minutes on DCFC charging to obtain 250 miles from empty. Any reduction in charging time significantly affects the net benefits that consumers experience. A one minute decrease in charging time improves net benefits by 4.26%. Should Tesla be able to have a vehicle that can supercharge within ten minutes, holding everything else constant, the net benefits a consumer would witness would increase by nearly 51%! The team is optimistic that reduction in charging times are likely to occur due to the rapid advancement in battery and charging technologies. Eve though battery capacities will also increase in the future, the technology to charge faster is evolving more rapidly and thus charging times will only ever decrease. These numbers are very sensitive as charging time is one of the largest costs that consumers experience.

Change in the Carbon Offset Value	***State***	***Lakeland***	***Resident***		***State***	***Lakeland***	***Resident***
212	$110,490,584.00	$1,458,984.00	-$473,168.00		0.00%	0.00%	0.00%
100	$52,118,200.00	$688,200.00	-$473,280.00		-52.83%	-52.83%	-0.02%
150	$78,177,300.00	$1,032,300.00	-$473,230.00		-29.25%	-29.25%	-0.01%
250	$130,295,500.00	$1,720,500.00	-$473,130.00		17.92%	17.92%	0.01%
300	$156,354,600.00	$2,064,600.00	-$473,080.00		41.51%	41.51%	0.02%

Table 8: Net Benefits when the Carbon Offset Value is Changed

Another area to investigate was impacts if the ~$212 in Carbon Offset values given by the EPA were incorrect. The values of $100 and $150 were used in case the $212 was an overestimation. The calculated net benefit shows that it nearly has no impact on the resident but drastic impacts for the state of Florida and Lakeland County. Should the value the team went with, the net benefits are negatively affected by nearly 52% and ~30%. The same is true with its opposite. Should the $212 be an underestimation, and a higher value, such as $250 or $300 be more accurate, net benefits increase by ~18% and ~41.5%. The values of offsetting carbon are very sensitive towards the final values.

Percent Change in the Quantity of EV Drivers	**State**	**Lakeland**	**Resident**		**State**	**Lakeland**	**Resident**
0	$110,490,584.00	$1,458,984.00	-$473,168.00		0.00%	0.00%	0.00%
-30	$77,343,408.80	$1,021,288.80	-$473,168.00		-30.00%	-30.00%	0.00%
-20	$88,392,467.20	$1,167,187.20	-$473,168.00		-20.00%	-20.00%	0.00%
-5	$104,966,054.80	$1,386,034.80	-$473,168.00		-5.00%	-5.00%	0.00%
5	$116,015,113.20	$1,531,933.20	-$473,168.00		5.00%	5.00%	0.00%
10	$121,539,642.40	$1,604,882.40	-$473,168.00		10.00%	10.00%	0.00%
30	$143,637,759.20	$1,896,679.20	-$473,168.00		30.00%	30.00%	0.00%

Table 9: Net Benefits when a Quantity of Drivers Switch to an EV

Another constraint observed was the quantity of EV drivers in the state and county. The values on the far left indicate a percent change on our projections. Because these values are a percent change and benefits and costs are being calculated on an individual level, these directly correspond to the percent change in net benefits seen at the county and state level. As such, these values are only as sensitive as the rest of the calculation.

Change in the Gas Cost	**State**	**Lakeland**	**Resident**		**State**	**Lakeland**	**Resident**
$2.60	$110,490,584.00	$1,458,984.00	-$473,168.00		0.00%	0.00%	0.00%
$1.00	$110,490,584.00	$1,458,984.00	-$491,888.00		0.00%	0.00%	-3.96%
$2.00	$110,490,584.00	$1,458,984.00	-$480,188.00		0.00%	0.00%	-1.48%
$3.00	$110,490,584.00	$1,458,984.00	-$468,488.00		0.00%	0.00%	0.99%
$3.50	$110,490,584.00	$1,458,984.00	-$462,638.00		0.00%	0.00%	2.23%

Table 10: Net Benefits when the Cost of Gas Changes

Another constraint worthy of analysis is looking at variations in gas prices. Should the gas prices for the consumer be higher where they live, for instance New York or California, the consumer will save a significant amount of money by switching to electric. Ridding themselves of paying higher gas prices increases their net benefits by ~1-2.25%. However, should gas be significantly cheaper where they live, for instance like Texas and other states in the Midwest, the change of gas cost significantly affects their net benefits. A resulting dropoff between 1.5-4% in net benefits occurs. This could be indicative of why EV adoption is higher in states with higher gas rates, like California and New York, and less adoption occurs in other states, like Texas. However an exterior analysis would be needed to confirm those hypotheses. Ultimately, higher gas prices positively affect the net benefits a consumer experiences by having an EV and utilizing supercharger capabilities.

Change in the Gallons Needed to Drive 250 Miles	**State**	**Lakeland**	**Resident**		**State**	**Lakeland**	**Resident**
7.8	$110,490,584.00	$1,458,984.00	-$473,168.00		0.00%	0.00%	0.00%
5	$110,490,584.00	$1,458,984.00	-$484,088.00		0.00%	0.00%	-2.31%
7	$110,490,584.00	$1,458,984.00	-$476,288.00		0.00%	0.00%	-0.66%
8	$110,490,584.00	$1,458,984.00	-$472,388.00		0.00%	0.00%	0.16%
12	$110,490,584.00	$1,458,984.00	-$456,788.00		0.00%	0.00%	3.46%
15	$110,490,584.00	$1,458,984.00	-$445,088.00		0.00%	0.00%	5.93%

Table 11: Net Benefits when the Gallons of Gas Needed to Drive 250 Miles Changes

Lastly, the team looked at potential variances in the quantity of gas needed to drive 250 miles. Should the car be highly fuel efficient and have incredible miles per gallon, it negatively affects the net benefit a consumer faces - between ~0.66 - 2.3%. However, most of the cars today on the market are not this fuel efficient. Additionally, Tesla's Model 3 and Model S, are capable of driving a much further distance. Though solely an EPA estimate, it is rumored that the Model S can drive over 400 miles before needing a charge - which is incredible for the EV market! Should the consumer be switching over from a less fuel efficient vehicle, such as a Hummer, Jeep, or Cadillac, the estimates are that they are to receive a greater benefit by having an electric vehicle and using supercharging capabilities. The less fuel efficient the vehicle was prior to switch, the greater the net benefits a consumer is set to experience.

Overall, the numbers indicate that it is certainly in the benefit of the Florida state government and Lakeland County to install a supercharger as they only experience benefits from this. All costs are directly covered by Tesla or transferred to the end consumer of the supercharging station. For consumers, they have a negative net benefit. However, this is primarily due to the amount of time needed to wait and the individual's self-proclaimed value of their time. However, this is an area in which the market is moving and battery and charging technology is exponentially becoming better and more efficient. The ideal situation for the supercharger is that of: having a consumer that undervalues their time, pays roughly $0.2-$0.25 per kilowatt hour for charging, an incredibly fast charging capability, high value in the carbon that is offset, an underestimation of EV drivers in the state and county, more expensive gas prices and poor MPG of an older vehicle prompting a change to a Tesla-built electric vehicle. The future is bright for the county and state should they implement this supercharger station.

Conclusion

Overall, there are varying options that the state and county can undertake. The costs for the county and state are nothing as Tesla covers the costs for implementation and views the charger as their asset. The bulk of the costs are primarily on the consumer. However, consumers are leading this market shift and appear to be "ok" or unaware of the costs that they are facing. The biggest costs that consumers experience are a direct result of the amount of time spent charging and their personal value of their time. However, technology will become better and charging times should decrease as Tesla grows. The costs also offset how these decisions affect the derived benefits to the consumer and the planet. Adding more superchargers enables the ability to grow the electric vehicle market and therefore meet future demand. It is best to invest now for the future's sake, rather than investing in the future.

Moreover, the demand for electric vehicles is taking the world and automobile market by storm as climate change becomes more prevalent. This is strengthened by the fact that more companies, almost weekly, are moving towards creating Electric Vehicles and having their products more "green." Tesla is incredibly exclusive due to the capability of the supercharger network and the requirements to charge at one of their stations. Consumers who are buying an Electric Vehicle, specifically a Tesla, at some point will be using the network. To aid in quelling range anxiety and reduce the amount of charging time, more superchargers must be built. Lakeland, and Florida Polytechnic in particular, is in a great location due to their geographical proximity to I-4, a route with lots of demand for vehicle usage. As the future becomes the present, Florida Polytechnic and Lakeland have the ability to become leaders at the forefront of this change and fight against climate change, as well as have their own Tesla Supercharger on campus. Since the bulk of charging is done at home and the benefits that the state and county will experience, it is a "no-brainer" to place a supercharger in Lakeland County.

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