EVs and the Future of Automobiles:

A Price-Point Comparison of Electric and Gas Automobile Drivetrains

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Abstract

Electric vehicles are gaining traction in automobile manufacturing as a possible alternative to gasoline vehicles, yet the primary vehicle available at this point is largely at a medium or higher price point. To get a sense of the future of the car industry, I examined how a single vehicle, powered differently, might compete in the commercial market. My original hypothesis was that the electric car, while being much easier to assemble due to its fewer components, will perform worse at a low price range, ultimately hindering car buyers from choosing this option, despite the need to find a solution for both climate change and rising gas prices. As I discovered, the electric car was not easy to assemble, but “easier” than a gas engine as I was unable to even assemble an engine (in a prior experiment). The electric car did perform worse at a lower price range, and because it is not feasible to make a lower price point electric vehicle, partially due to performance issues, the research suggests that the hindrance of purchasing lower-cost electric vehicles is largely due to economics.

Background: History and Purpose

The vehicle market has always played largely into the American economy. Historically, Americans used cars as status symbols as well as transportation in a way that Europe and other smaller countries did not. The last time we saw a large change in the market was the introduction of assembly lines to the manufacturing process of automobiles, notably the Model T with Henry Ford (Gross 12). We are on the cusp of seeing such a major change with the possible switch to electric-powered vehicles - it is important to ascertain how this will affect buying cars from an economic standpoint - will an electric vehicle at a lower price point perform as well as the lower price point gas-powered vehicle at the current state of technology? We have seen more expensive or luxury brands offer electric cars but not everyone can afford those.

Motor vehicles were first introduced in the late 19th century as an alternative to horsepower. “German visionary Karl Benz is credited with creating the very first car to be powered by the internal combustion engine; he wasn’t the first man to create a vehicle that could run independently of horses. That honor fell to Nicolas Cugnot of France, with his steam car.” (Cheetham 6). Cugnot “built a three wheeled, steam-driven vehicle for the purpose of pulling artillery pieces” which was revised and caused “the first automobile accident when it ran into a wall” (Gillespie 1). One of the original horseless carriages in the early 20th century was a machine created by Oliver Evans in 1772 - his design could propel itself by steam power. Steam power continued apace and in 1851 the American Steam Carriage Co. was established, with a fleet of vehicles capable of reaching up to 15 mph” (Cheetham 6). Steam was an obvious choice as it was being used to power boats and trains.

However, steam-powered vehicles could not be used easily for personal transportation due to their heaviness, lack of speed, and expense (Cheetham 6). Alternately, electric vehicles were easy to drive on city streets and where electric power stations were available so plenty of people living in cities bought them. Their range was limited, though, and like steam-powered vehicles, they were heavy, slow, and additionally, electricity was expensive (Balesco). Outside of cities where roads were not always paved and electricity was more difficult to find, EVs were not popular (Balesco). However, with the invention of a fuel-powered engine at the end of the 19th century, the possibility of personal transportation beyond a horse-drawn vehicle became more than a vision. “In 1890, America’s first successful internal combustion engine, designed by Charles Duryea … powered a vehicle independently” (Cheetham 6). By the early 20th century, many automobiles came with three types of engines: steam, gasoline, and electric (Balesco). These three types were competitive at first but a preference for gasoline engines prevailed:

> “Most motorists wanted the freedom to travel anywhere. Gasoline cars satisfied that demand; they were faster and less expensive than electric cars, and they could travel many more miles between refueling stops. A gasoline station could be located anywhere

> – on or off the electric grid -- simply by installing a tank and a hand-operated pump and ordering wholesale gasoline deliveries in tank trucks. Refueling a gasoline car took minutes instead of hours needed to recharge batteries. Sales of gasoline cars far exceeded sales of electric cars by 1905. Electric cars all but disappeared from the market by 1920." (Balesco)

Americans crave freedom and power, two things the gasoline-powered automobile in the early 20th century could give them.

Automobile design can be thought of as two parts: the outer body and the inner machine. "Early motor cars comprised a rolling chassis–the engine, frame, suspension system, wheels, and steering mechanism supplied by an automotive manufacturer–and the body and passenger compartment, often designed and built by a coachbuilder" such that the two parts were often not built together (Adler 11). It is easy to see why early cars were referred to as "horseless carriages" since the outer design was the work of a coachbuilder.

Initially, cars were luxuries only owned by the wealthy. "In its nascence the automobile was embraced … as an iconoclastic symbol of industry, progress, and velocity" (Adler 10). One of the major turning points in automobile manufacturing was Henry Ford's determination to "build a car for the multitudes" (Cheetham 7). "Mechanization and mass production were the determinant factors in the boxlike bodywork of the commercially successful Model T" (Adler 12, and fig. 2). Ford designed both the vehicle, particularly its body, as utilitarian and with his new design of a production line, historically changed mass transportation. (Cheetham 7).

As early as the 1940s, mass produced fuel injected cars were causing noticable environmental issues like air pollution (Balesco). America did not produce enough gasoline for these cars and we had to resort to importing oil, creating a dependence on other countries' exports.

While car manufacturers changed design in the post-war boom of the 1950s and 60s, the next major change came with the economic downturn of the 1970s. High-performance engines set in mass-market shells, aka “muscle cars” were popular until politics and economics forced a change. In 1965, Ralph Nadar published a book titled, *Unsafe at Any Speed: The Designed-In Dangers of the American Automobile*, which called out car manufacturers for unsafe design and practices (Adler 22). Congress passed the 1968 National Safety and Motor Vehicle Act and “[b]y the 1970s, safety legislation was becoming ever more stringent and the post-Vietnam War oil crisis meant economy engines were becoming much more important” (Cheetham 9). American automobile owners “discovered that bigger isn’t better, especially when there isn’t any gasoline” (Adler xii). Safety features and lower running costs became the primary driver of vehicle manufacturing in the 1970s, a turn from the larger power cars due to cultural and financial concerns.

The pendulum swung back to more powerful cars with the onslaught of SUVs, but with no real design change. By the late 20th century, various sectors of the government, scientists, and some manufacturers began realizing that electric-powered vehicles could be a solution to increasing pollution, greenhouse gasses, and dependence on exported oil (Balesco). What we are seeing now is the powerful impact of the global climate crisis - similar to the 1970s with the reaction to high oil prices but on a grander scale, the need for a redesign of the engine to run on electric power instead of fossil fuels is pushing manufacturers to rethink their vehicles.

For a lot of reasons, we are seeing climbing fuel costs again like in the 1970s. As the fuel costs go up, people start looking for ways to avoid those costs. In addition, the “longer gasoline prices remain high…the more they affect consumers’ expectations about future prices” (Orszag). With the economic downturn in the mid-2000s, consumption of cars fluctuated. “That price threshold was exceeded again in the spring and summer of 2006 and yet again through much of 2007. Since 2005, the sale of cars relative to light trucks has increased, after declining for several decades. After stagnating for a comparable period, the average fuel economy of new cars has increased, as has that for light trucks” (Orszag). As expected, “Market shares for leading categories of light trucks—especially SUVs—went the opposite way, dipping as gasoline prices rose" (Orszag). "All major car categories—from two-seaters and subcompacts to large sedans and wagons—have gained market share as the price of gasoline has risen, with gains of between 4.5 percent and about 9 percent for every 60 cent increase in the price of gasoline above $2.30 per gallon. At the same time, the market shares of all types of light trucks, from minivans and SUVs to pickup trucks and passenger or cargo vans, have fallen by 4 percent to 6 percent" (Orszag).

In the early 20th century, both steam and electric vehicles were tried and then rejected because of their weight, their slow speeds, and lack of ability to go further distance. Electric vehicles only worked well in cities where electricity was available and to some extent that is still true. But with technology, especially new battery technology, electric vehicles are worth considering again. "Consumer Reports says the average life expectancy of a new vehicle these days is around 8 years" (Weisbaum). Autotrader, an online company that buys and sells used cars says, "electric cars typically last longer than vehicles with gas engines. There are fewer maintenance appointments to worry about, and EVs don't have engines or multi-speed transmissions, so they don't have problems with those parts" (Electric). According to a 2022 Canadian study using an 8-year lifespan for cars, during each of which the car gets driven approximately 20,000 kilometers, an electric car is significantly cheaper than a gas car (True). This is assuming 2021 gas prices too due to the recent gas price surge, but if that surge is to continue, which is likely, the gap will be even larger. (Halper). "Yet despite the lower sticker price of the conventional car, the Kona's EV model is a lot cheaper when all is said and done, with a $56,000 lifetime cost compared to $71,100 for the gas version" (note the use of Canadian measurements and monetary units) (True). Higher-end electric cars do not come with any cost reductions when it comes to charging or maintenance despite the higher price tag, and while you might expect the range to increase with the price it does not correlate. The only change from low to high prices in electric cars is the features and the branding, which also correlates with gas cars.

With rising gas costs and with the current concerns about climate change, the time is right for us to consider electric vs. gas engines. The current issue, however, is the cost (Naughton). Electric vehicles at a higher price point are emerging; our premise for this study is to consider lower-cost electric vehicles and their viability. So like Henry Ford wanting to bring the Model T to a wider population, the time is ripe for studying whether lower-cost vehicles could be a viable option for the masses.

The primary comparison in America comes down to the almighty dollar. A cost analysis alone will not determine what the populace will purchase, but it provides a strong indicator. For our study, I compared the manufacturing design, process, and product quality between a low-price point vehicle using a gas-powered drivetrain and the same vehicle using an electric-powered drivetrain to determine what the pros and cons of gas powered vs. electricity-powered vehicles are at a lower-price point. I examined the power consumption rates of gas engines and electric motors, the industrial engineering of car manufacturing, studies that show the emerging solid-state batteries, the historical markets for both types of vehicles, and the history of vehicles, including how they have impacted both the American economy and social psyche of American culture, among others as well as the possible future implications of electric vehicles on climate change.

As climate change and rising gas prices continue to increase interest in electric vehicles, the ability to have EVs at a lower price point without sacrificing transportation quality will influence the automotive industry but the lower price point electric vehicles are not feasible for the typical American buyer, at least not yet.

The Build

In order to keep the costs low, we decided to build a frame for the vehicle rather than purchase one. This decision then required us to learn how to weld. During this fabrication/design process we located materials, including steel tubing for the frame, steel rods for axles and steering wheels, electric motors and battery setup, and engine, as well as the pieces for assemblage. I kept a bill of materials (even where we borrow or scavenge pieces) of the items to ensure the vehicle stayed within a particular price point. I also tracked hours spent assembling each vehicle, for labor cost comparison and hiccups in manufacturing where one drivetrain added difficulty in fabrication, again for a comparison basis.

In order to do the comparison, we needed two different drivetrains; a gasoline engine uses a spark plug to ignite the gasoline within a combustion chamber pushing a piston that lays on a camshaft to turn the explosive energy into linear motion into rotational motion that is then directed to the differential (U.S. Dept of Energy - Gasoline), whereas an electric vehicle uses energy from a battery to power electromagnets inside motors that cause a rotational motion that gets diverted to the transmission (U.S. Dept of Energy - Electric). These different engines are the critical difference between electric and gas vehicles - the drivetrain.

The first major problem we hit when designing the car was a power difference between the drivetrains. Power is fundamentally how much work something can do in a given time, so for any tests to be substantial the two drivetrains needed to have roughly the same power. We already had our Engine picked out: a Predator 212cc, so it was a matter of finding electric motors with comparable power. The Predator was said to have 6.5 HP or roughly 4850 watts of power, so we scoured Amazon, eBay, eBay motors, Allie Express, and numerous other sites of varying reliability. It wasn't easy to come close to 4850 watts at a reasonable price. 5000-watt motors will run you roughly $1000, which would undermine the economical pricing we were aiming for. We finally settled on using two 2000-watt motors in tandem to achieve 4000 watts and that we would adjust our data accordingly.

The project was drawing on much longer than expected, extending "labor costs." Then we made the breakthrough and got the gas car running. And it ran well excluding one major oversight. Our centrifugal clutch was never disengaging. After consulting Mr. Allen and Mr. Wellford, we determined that our accelerator was always ever so slightly pulled, getting the engine just over the speed needed to engage the clutch. The electric car provided challenges as well from mismatched unit systems to motors turning the wrong way. Once working however, it proceeded to break another four times. Each time I had to repair it stronger than it had been before in the hopes it would last the next time. The electric car was much more challenging to assemble than the gas with more troubleshooting and without additional labor as I was working alone at this point.

Once assembled, I tested the vehicles for speed, range, torque, horsepower, stability, and safety to compare these aspects and the qualities of each drivetrain. I also considered the earlier information regarding any manufacturing ease/difficulties regarding lower price point of both gas-powered and electric-powered vehicles.

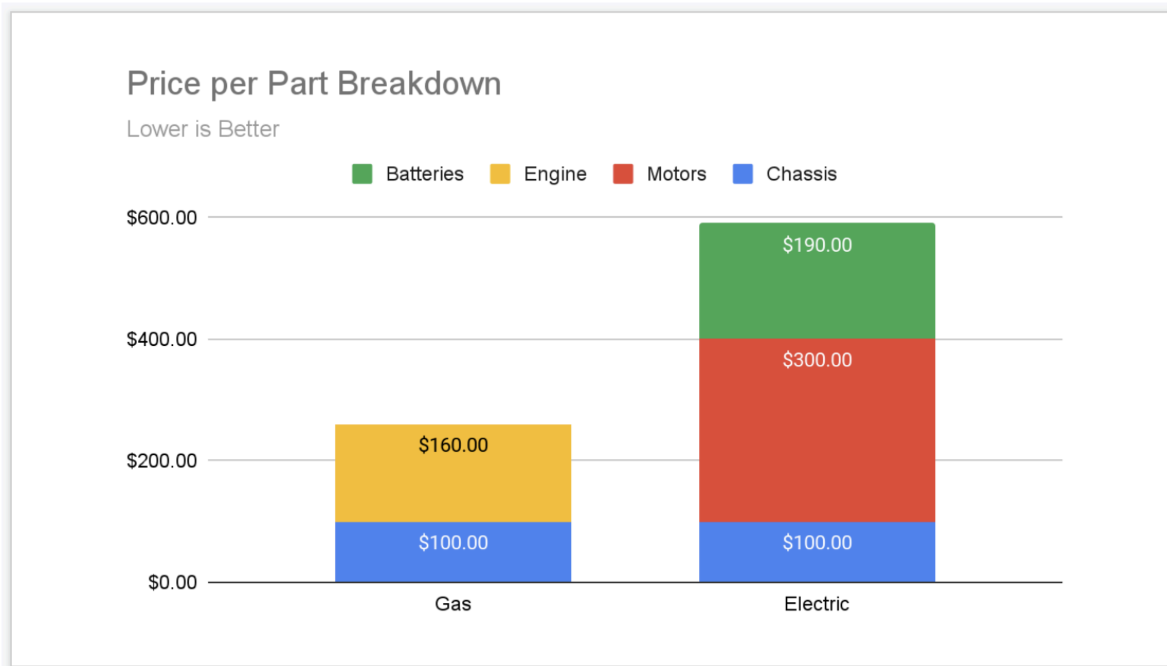
The Testing

We tested the two model cars for various commonly compared statistics. The performance data of the cars fit with the research on industry models. Electric cars generally have better acceleration, and ours did too. Similarly, EVs have considerable losses in top speed and range with a higher general weight. These data points we collected align our economic models with the predicted results from the industry standards. Considering our data fits so well into the predicted data helps ensure that the industry models will persist into lower-costing cars.

Cost analysis

Our total costs align just how I expected, with the gas car being significantly cheaper at just $260, and the electric car coming in at more than double that at $590 (Figure 1).

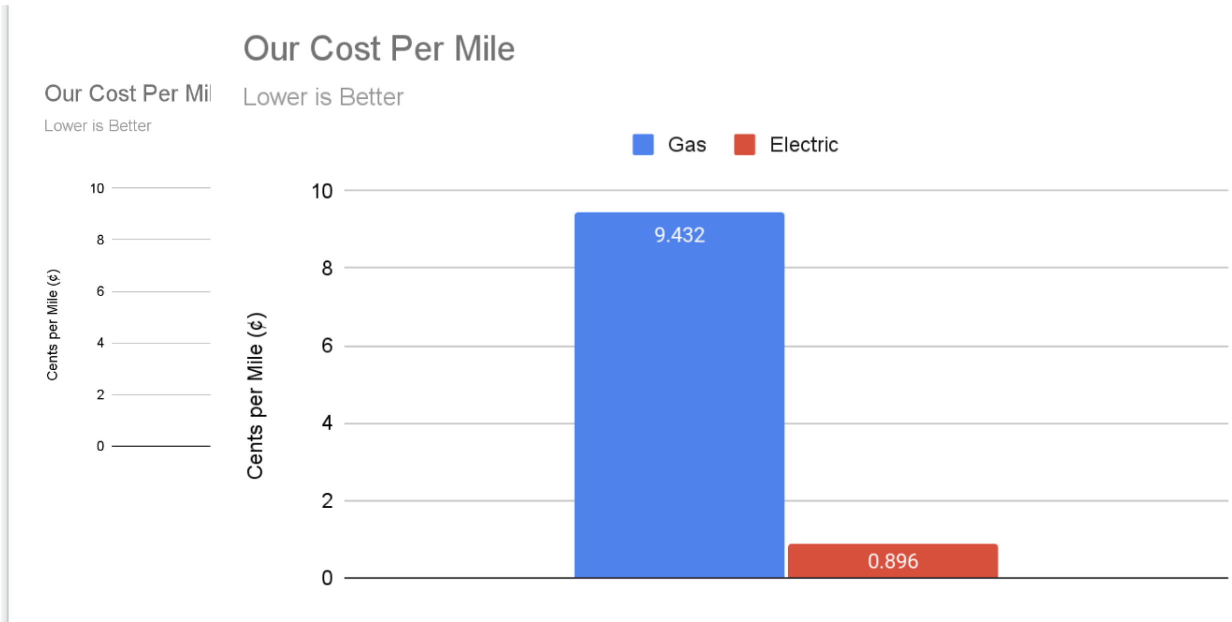
Figure 1



However, after breaking down the costs by parts, the statistics no longer align with the industry's normal projections (König). In most electric cars the batteries are the significant factor for price, and while our batteries did cost more than the engine of the gas car coming in at $190 versus the engine's $160, the real kicker was the two motors which cost $300 (König). This additional cost was likely due to the necessity for two motors caused by the power difference between them and the engine, which helps explain why electric cars on the market do not experience the same problem. Gas engines have been developed much longer than electric motors and part of that development includes research on how to make them cheaper, but as we get into the higher price points their powers balance out with similarly priced motors (Furch). So as the car gets more economically priced, the gas vehicle is able to maintain decent power while the electric vehicle has increasingly negative returns. This also explains our experimental results when it comes to performance - our lower-costing electric car was far worse in performance than the gas-powered car except in niche areas where electric cars are known to be better such as acceleration and their turning radius.

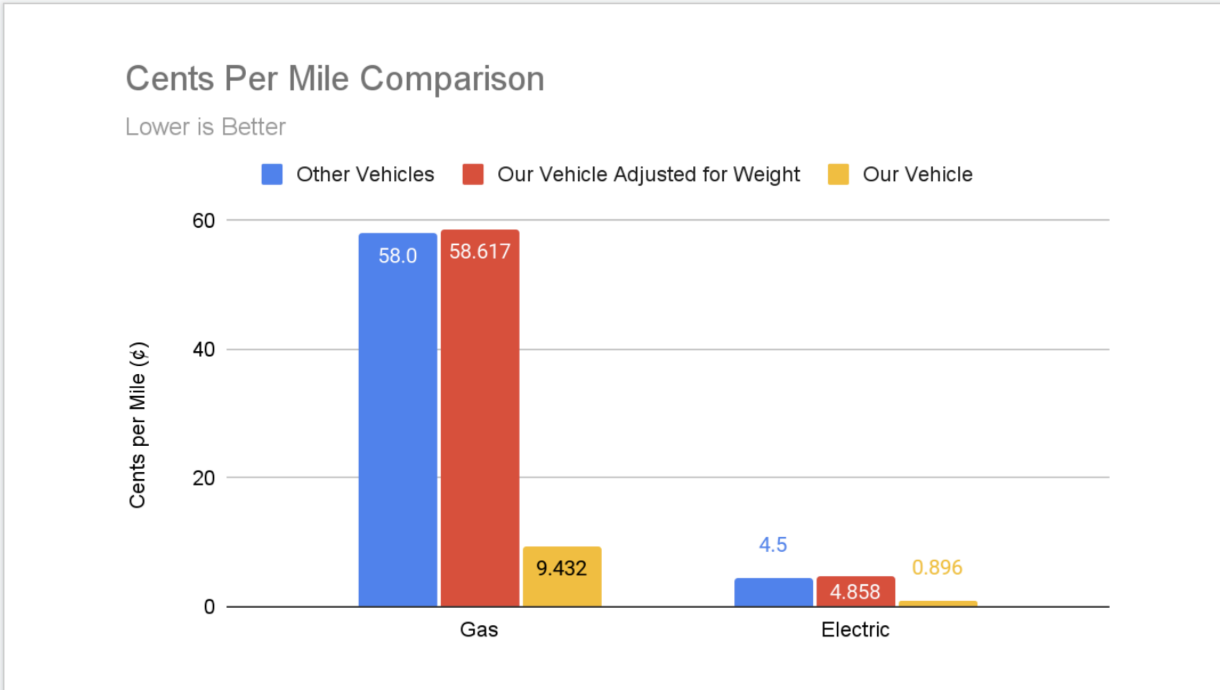
To counter the cost of the equipment, not surprisingly, the economical electric car was 10 times more fuel efficient in price. The electric car cost roughly 0.9 cents per mile driven while the economical gas car costs roughly 9 cents per mile (Figure 2).

Figure 2



While the 10 times difference does align with the industry models, the industry average costs were each close to 6 times as high as our values (König). Electric cars cost on average 4.5 cents a mile and gas cars cost on average 58 cents per day, so why were our numbers significantly better with our cheaper parts than the average cars? After weighing the vehicle with the different drivetrains, I found it was due to weight: the more mass being propelled in standard cars meant more energy needed to do the propulsion and therefore more cost per mile. After finding an average weight for a subcompact SUV to be 2000 lbs I was able to create a ratio of weights with 2000 lbs and our 370 lbs and 320 lbs cars (including 150 lbs driver) that would alter the data to better represent a heavier vehicle (Nealon). Once the data was transformed it better imitated the industry standards coming out as 58 cents per mile for our gas car, perfectly reflecting the industry average, and 4.8 cents per mile for the electric car, varying only by 0.3 cents (Figure 3).

Figure 3



This transformed data demonstrates another reason higher-cost electric cars would be needed to reproduce the same results as a gas car. Yes, in this experiment, cheaper was better, but that's because we skimped out on the necessary luxuries like windshields and doors. When it comes down to it, spending more on a lighter aluminum alloy shell, which happens in a higher-cost vehicle, will vastly offset the additional weight of the heated seats. The weight difference is important for range (König; Naughton). Gas cars have plenty of range, heavy or light, while electric cars have significantly lower ranges, and therefore the importance of lowering the weight is magnified.

Reliability is another area of expense when it comes to vehicles. Maintenance fees can accumulate and cost car owners small fortunes. While we were unable to drive our budget cars until they broke, this price point difference would likely not have changed the trend in data. Gas cars require more frequent, and often more difficult, maintenance because they have more moving parts which cause more frequent stresses and breakages. These additional trips to the mechanic will cost a gas car owner significantly more than the few trips an electric car needs by comparison (Weisbaum). Our more affordable cars would likely have seen a decrease in maintenance fees despite an increase in visits to the mechanic because of their cheaper, and therefore more easily replaceable, parts. On top of that the gas would be decreased further because of the lackluster powertrain. Without a transmission, differential, and driveshaft, our test vehicle had significantly less complexities and therefore less opportunity to break making it cheaper to maintain.

Another area we could not directly test, environmental impact plays more heavily into marketing with minimal cost benefits. Though differing from place to place, many regions have tax reductions for electric vehicles to incentivize the environmentally friendly option (U.S. Dept of Energy - Electric). However, this reduction makes a small dent in the overall cost. More important is the use of green products as a marketing ploy. Lately, there has been a surge of green marketing techniques where a large corporation uses consumer guilt to better push their product. EVs are no exception to this ploy (Simpson). While EVs have their benefits for the environment, they also oversell their worth. The electricity powering any given EV still must be produced in a power plant, and while those could be renewable resources, only 20% of them are (True Cost). Another topic skipped over by the manufacturers is the carbon emissions of lithium mining that occur for battery production. That said, the emissions of an electric car are still half that of a gas. The industry oversells its environmentally friendly truth, but as the world moves toward renewable energies, the prevalence of electric cars will make the transition to a cleaner world easier.

Future Implications

When analyzing the entire economic minefield of such a newly expanding business there are many factors to consider. At a very brief glance, one might determine that EVs are worse and more expensive than gas vehicles, but with a bit more research someone might argue that an EV will make up for that cost over years of ownership with its cheaper fuel and maintenance. However, which one is cheaper isn’t the end of the story. It is my belief that while the future lies with EVs they will not dominate the road until we see a technological breakthrough. While an EV is cheaper than an internal combustion engine vehicle (IBEV) after 8 years of ownership, the initial price hike is not feasible for the younger generations who are shopping for an environmentally friendly alternative to IBEVs. The EVs' largest market demographic is taken off the table because they cannot afford the initial payment. Currently the EV market survives off wealthier backers looking for a luxurious ride. These buyers don't even get to see the long term price benefits of an EV because they buy a new car too frequently. This demographic shift makes EVs lose their biggest pull since money is inconsequential to the wealthy users. The younger generations continue to struggle through the economy left to them and as they grow up the EV market will shrink only offset by any growth the industry sees. These arguments are on top of the inconvenience of charging times and monthly charges for features that come free in an IBEV. That development will be seen within my lifetime. With the development of new batteries rapidly growing, and batteries being the main deterrent of an electric future, the industry will soon hit a major breakthrough as electric cars are able to be produced at cheaper prices. So while an EV may come with its inconveniences today, tomorrow holds a different story.

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