An Economic Comparison between Gasoline and Electric Cars

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Although I like the concept of electric cars and hope to drive one someday, there are a number of practical considerations that are often omitted by electric proponents. Popular myth is that electric cars would be very cheap to operate compared to gasoline. Any popular belief is almost a certainty to be wrong. It is much better to use science and mathematics to calculate what is real. The following is such a calculation that compares the cost of a gallon of gasoline with its electrical equivalent at the time of this writing. The details and method are shown so that appropriate revisions can be made in the future.

A gallon of gasoline (with no ethanol added) produces approximately 114,100 BTUs of thermal energy when burned. Converting to the metric system a BTU is 1055 joules. For reference, a joule is one watt of power for one second or the energy required to lift one pound about nine inches. An example is a 100 watt light bulb that 100 joules per second. The energy in a gallon of gasoline is 114,100 * 1055 = 120,380,000 joules.

From thermodynamics the efficiency of any thermal engine is $(1 - T_{Low}/T_{High}) * 100\%$ where T_{Low} and T_{High} are the low and high temperatures (in kelvins) of the thermal process. In short, energy is extracted from the high temperature and exhausted at the low temperature. The temperature difference is related to the amount of work accomplished by the engine. For practical operating temperatures the gasoline engine has an efficiency of about twenty five percent. The only way to improve that would be to increase the high temperature or reduce the low temperature but that gets into materials survivability issues. None of the various snake oil schemes advertised to boost engine efficiency accomplish either. Contrary to popular myth there is no tightly held secret or conspiracy to force low efficiency gasoline guzzling engines on us. Thus, the net useful energy that can be extracted from a gallon of gasoline for automotive use is around 0.25 * 120,380,000 or 30,094,000 joules.

Electrical energy is often measured in kilowatt hours which is the unit seen on everyone's electric bill. A kilowatt hour is 1000 * 60 * 60 = 3,600,000 joules.

For purposes of discussion I will assume a hypothetical electric motor has an efficiency of 80 percent and that the battery has an efficiency of 70 percent and that the charging system has an efficiency of 90 percent. Thus, the amount of electrical energy that would have to be purchased from the utility company to net the equivalent of one gallon of gasoline would be 30,094,000 / (0.8 * 0.7 * 0.9) = 59,710,000 joules. These various efficiency factors are plucked out of the air but are in the ball park of reality. Feel free to adjust the calculation with factors you like better.

As of this writing gasoline sells for $3.00 per gallon (A complicating factor that I will mention and then ignore is that modern gasoline typically contains up to ten percent ethanol which has only 76,100 BTUs per gallon. The result is that the net energy content of this blend is approximately 110,000 BTUs per gallon.). The current rate for electricity is around $0.11 per kWh. With this information we can now compare the joules per dollar factor for each form of energy.

The net joules per dollar for a gasoline car is 30,094,000 / 3.00 = 10,031,000.

The net joules per dollar for an electric car is (3,600,000 / 0.11) * (30,094,000 / 59,710,000) = 16,495,000.

In terms of value for this application, electricity is the winner. For comparison purposes we can now compute the cost of an electrical equivalent of a gallon of gasoline as 59,710,000 * 0.11 / 3,600,000 = $1.82. However, this does not include the Federal ($0.184) and state taxes (ranging from $0.08 for Alaska to $0.455 for California, for my home state of Alabama it is $0.202) built into the price of a gallon of gasoline. The average total tax across the United States is $0.47 per gallon – a value that is presently too low for necessary road maintenance and needs to be increased. One way or another each user of an electric vehicle should be paying this as it supports road building and maintenance. Thus, the real price for an electric equivalent gallon of gasoline is $2.29. At present there are too few electric cars on the road to bother with but this tax would have to be collected somehow in the future should electric cars become common.

This price comes as a shock to many who have been led to believe that an electric car would only cost dimes per day to operate. Selective accounting can make anything look inexpensive. It is a common tactic for advocates of anything to show attractive numbers without showing how they are determined. Many are gullible and fall for that. I advocate for reality and gladly show my calculations for two reasons – (1) so the reader can check and make revisions should there be disagreement with some of my numbers and (2) so that these calculations can be updated as numbers change in the future.

At the present state of battery technology a “good” battery can store about 300,000 joules per kilogram. A “great” battery can store about 1,000,000 joules per kilogram. A “super” battery (still under development) can store about 3,000,000 joules per kilogram. These numbers should improve in coming years. A good question is what mass battery would be needed to store the equivalent of a gallon of gasoline. Using my values from above, the energy storage would be 30,094,000 / 0.8 = 37,618,000 joules. This would require a mass of 125 kg (or about 275 pounds) for “good” battery technology. A ten gallon equivalent would weigh 2,750 pounds! It looks promising that batteries of the future will bring this down considerably to practical levels. But such batteries will not be widely affordable for some time. A general statement concerning present day electric cars is that the battery holds roughly the equivalent of one gallon of gasoline.

Astute readers will observe that I am omitting the cost of the battery. That is a significant factor in the total cost of an electric car. The battery will only last for a small number of years and then require an expensive replacement. Because prices are changing rapidly I will not show the amortization of battery cost into the total picture. It is more complicated and has a spread of results depending on how an individual uses the car. But be advised that it is high and gasoline at even $4.00 is cheap in comparison.

The consideration of pollution is important. The dominant form of electricity generation in the United States is the burning of coal. Thus, an electric car shifts the pollution from the vehicle to the coal plant. That is an excellent factor for congested smog saturated areas. The coal plants operate at respectable efficiencies and have means to minimize pollution far better than what is practical for a gasoline vehicle. The only other option is nuclear as hydro-electric and other nature driven systems are limited in what they can produce. Thus, shifting to electric cars would result in a net reduction in pollution. That is worth something.

Another benefit of electric cars is that the electrical energy is produced within the United States and not imported. This reduces the weakening effect on the dollar from imports and reduces the effect of various instabilities around the world on our transportation.

A "full-size" electric car is highly impractical today as its range would be only about twenty miles or so. Practical electric cars at present must be small and thus can haul limited passengers and cargo. Such cars today have a range of around fifty miles. A car is much more than the cost to operate. The car must also have the necessary utility such as hauling passengers and cargo. Otherwise, low operating cost is meaningless. The small size contributes to a higher probability of injury or death in any kind of accident compared to a gasoline car. Electric cars also have a premium price tag and the break even operating time is years and in some cases longer than the life of the car. For these reasons I have no interest in electric cars today. I consider them to be toys for the rich. But as in the past, toys for the rich eventually become practical for the common person. At such time I will buy an electric car.

The shift to electric is best done via natural growing cost disadvantages for gasoline and improving cost advantages for electric with advances in technology. That is best handled at the private industrial level like all of our technology from the past. We must remember that governments are comprised predominantly of people who would never be able to make it in the private sector. Thus, governments do not have the competence to manage or direct such a transition. Government involvement would only increase the cost and delay the result contrary to popular socialist myth.