A Review on the Various Benefits of Electrical Vehicles

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1 Abstract

In this review, we go over the various benefits of driving an electric vehicle. Specifically, the benefits that relate to the environment, public health and cost savings and give an indepth review of each. To accomplish this, we look at vehicle data recorded by car rental company ZEROCAR, as well as other trusted sources such as census data and other data sets offered by Statistics Canada. We were able to show the significant benefits to the environment, public health and cost savings using these data sources. This shows us that using an electric car instead of a gas car does indeed make a difference in these aspects, and is worth making the consideration to switch.

2 Methodology

ZEVA pulls data from ZEROCAR's vehicles every 10 seconds from the Tesla API, and aggregates into trips. One trip is essentially a period of activity of the car, going from idle, to not idle back to idle again. The following are some insights gained from the data on those trips.

2.1 Data Collection and Methodology

Total Kilometers	66943.915
Average Daily Total Kilometers	449.288
Max Daily Total Kilometers	1288.864
Min Daily Total Kilometers	47.510
Number of Trips	8701
Average Trip Kilometers	7.695
Max Trip Kilometers	162.371
Min Trip Kilometers	0

If we collect data from the time period spanning back to October 13, 2022.

Total Kilometers (All users)	182317.397
Total Kilometers (Car Renters)	100930.040
Average Daily Total Kilometers (All users)	753.377
Average Daily Total Kilometers (Car Renters)	417.066
Average starting charge level (for all users, Tesla)	38.056
Average ending charge level (for all users, Tesla)	78.535
Average starting charge level (for all users, Level 1)	54.746
Average ending charge level (for all users, Level 1)	71.113
Average starting charge level (for all users, Level 2)	78.188
Average ending charge level (for all users, Level 2)	86.529

Data that was not from ZEROCAR was scraped from external sources instead. In this review specifically we mainly used Statistics Canada data. The following are samples from tables used:

Geography	December	January	February	March	April
Calgary, Alberta	124.2	128.6	125.5	132.2	145.1
Vancouver, British Columbia	164.1	179.3	183.3	183.0	188.9
Victoria, British Columbia	160.4	173.4	178.6	180.9	184.9

Table 1: Sample section from the table of gas prices, in cents, from January 1990 till April 2023. Since the prices are already in cents, the values were directly used with no other conversions

Products and product groups	Dec. 2022	Jan. 2023	Feb. 2023
Electricity	185.7	186.8	186.8
Estimate Step 1 energy charge /kWh	$0.0950	$0.0955	$0.0955
Estimate Step 2 energy charge /kWh	$0.1408	$0.1416	$0.1416

Table 2: In the present section, we rigorously delve into a detailed analysis of the Consumer Price Index (CPI) for British Columbia [1], encapsulating the progression of the monthly percentage change observed from March 2015 to April 2023. The foundational index, designated as 100, is seriously predicated on the Cost Price Index as it was formalized in the fiscal year of 2002. This index serves as a critical tool in the calculation of the electricity price for the region. Specifically, a multiplicative operation involving the index and the electricity price obtained from the British Utilities Commission [2] can estimate the electricity price for British Columbia.

2.2 Assumptions Made in Analysis

2.2.1 Environment Saving

There are two main assumptions made. The first assumption is that there are as many humid regions as dry regions in BC. This assumption allows us to take a simple average of the carbon absorbed by trees in the dry areas and humid regions instead of taking a weighted average. However, the dry region tree carbon absorption was 9.1 tons and humid was 11.1 tons which were quite close anyways. Another assumption is that the majority of forests landscape restoration in B.Bernal et al. had a similar amount of trees as many government regulations, including BC (around 2000 trees per hectare).

2.2.2 Health Saving

There are again, two main assumptions made here. The first assumption being that the average health effects recorded in New York would be similar to what can happen across Canada, being that the life years or lives lost per ton of NOx released would be the same in Canada, as it is in New York. Another assumption made is that the population of Canada follows a normal distribution, meaning that the majority of people would have the same as the average commute estimated by the census data.

2.2.3 Cost Saving

The first assumption made is that the gas and electric prices do indeed follow either a linear or polynomial line. Both of these assumptions are backed up with high R^2, both being above 0.85. Another assumption that was made was that the daily drivers of ZEROCAR followed the general public. This was also backed up by comparing with the equivalent census data and seeing that they are indeed close. Additionally, the evaluation of electric vehicles was predicated solely on the Model Y Performance Version. One other assumption made (to the benefit of gas cars) is that maintenance prices will remain constant as time goes on, meaning we won't see significant jumps in motor oil or transmission fluid prices as time goes on. This assumption was made because no helpful data on historical motor oil and transmission fluid prices were available.

3 Analysis

3.1 Environment Saving

The evaluation of environmental savings is done in comparison to what a tree can also do in the same time period. We begin with trees in north America, on average being able to absorb 10.1 tons of carbon per hectare per year [3]. Based on BC's recommendations for planting trees, we have 2000 trees per hectare [4]. This gives us 4.39kg of carbon per tree per year. Thus daily we have an estimate of 14g of carbon. Now, if we look at the driving behaviour mentioned in section 1, we have a daily total average of 449.288mi(724.205km). We also have that per kilometer, cars emit 208g of carbon [5]. For each km, a Tesla model Y uses 181 Wh [6], which would emit approximately $15gCO2e/kWh \times 0.181kWh = 2.715g$ carbon [7]. This then follows that we save on $724.205km \times (208-2.715)gCO2e/km = 148668.42g$ of carbon emissions. **This is equivalent to what 10619 trees absorb in a day**, or based on our 2000 trees per hectare estimate, or equivalently 5.3 hectares filled with trees.
Note: If we switch to the daily average from last October, the daily average is 468.127 (753.377 km). This is equivalent to what 11,046 trees can absorb within a day, equivalent to 5.5 hectares filled with trees. **In total, ZEROCAR has saved approximately 37427026.8 grams (37 tons) of carbon dioxide**, calculated as 182317.397 km $\times(208-2.715)$g/km.

3.2 Health Saving

Kheirbek et. al, were able to find causal links to fine particulates emitted by traffic and various health issues in New York [8]. They found that with 43,934 tons of NO_x emitted into the air, there were 320 deaths caused by it (with confidence interval bounds of 220 to 420), this gives us an estimated 1 death per 104.6 tons. There is also 5850 life years lost (with confidence interval bounds of 4020 and 7680) and 720 (95 % CI: 380, 1050) hospitalizations. Further, according to Stats Can, there are 152,685 electric vehicles registered (as of 2021) [9]. Also, according to Stats Can, we have an average commute distance of 8.7km [10]. Finally, the upper limit for NO_x emissions by the government is 0.2g/km [11]. Now with all values set up we calculate either lives lost or deaths with the following: let the value we wish to compute be ℓ. Note that ℓ would be based on 43,934 tons of NO_x emitted. Thus with this, we just need to calculate the emissions saved by electric vehicles. Utilizing the 152,685 EVs registered, along with a daily commute average of 8.7 we have $152,685 \times 8.7 \times 2 = 2,656,719$km (there and back). Utilizing the upper limit for NOx emissions as an estimate for each car, we have $2,656,719 \times 0.2 = 531343.8$g of NOx per day. This gives us 0.531 tons of NOx per day, or 193.815 tons per year. Now recall that our value ℓ takes the form of:

$$\ell = \frac{x}{43934 \text{ tons of NOx}} \times 193.815 \frac{\text{tons of NOx}}{\text{year}}$$

Simplifying leaves us with:

$$\ell = x \times 0.0044$$

where x is the number of life years lost or lives lost and we are left with ℓ being the amount of lives or life years saved in a year. This finally leaves us with the following values:

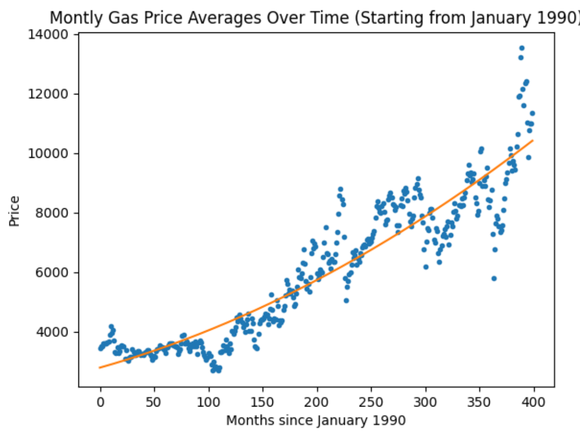
Lives Lost (estimate)	1.408
Lives Lost (upper limit)	**1.848**
Hospitalizations (estimate)	3.168
Hospitalizations (upper limit)	4.620
Life Years Lost (estimate)	25.740
Life Years Lost (upper limit)	**33.790**
People Affected (estimate)	4.576
People Affected (upper limit)	6.468

Looking to the future, the Environment and Climate Change Canada have proposed regulations that will require that at least 20 percent of new vehicles sold in Canada will be zero emission by 2026, at least 60 percent by 2030, and 100 percent by 2035 [12]. Taking this future look a step further and considering, at each time step, how many lives would be saved assuming that the net percentage of electric cars sold also matches the net percentage of electric cars on the road. Currently, about 10% of cars on the road are electric. Thus, we have that our figure of 152,685 cars being electric is because of that 10%. Thus to project our estimates to higher and higher percentages, we simply multiply the value calculated at 10%, by $x \div 10$, where x is the projected new percentage. This leaves us with:

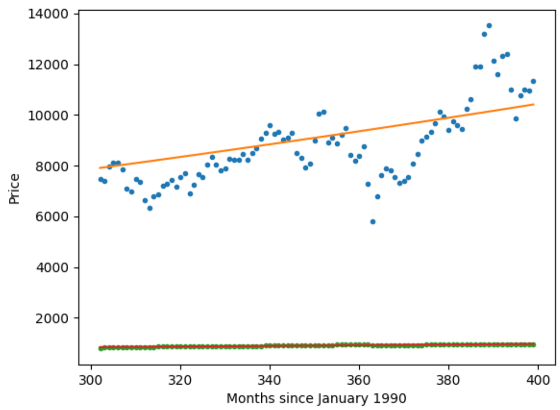
Saved Variable	present (10%)	2026 (20%)	2030 (60%)	2035 (100%)
Lives Lost (estimate)	1.408	2.816	8.448	14.080
Lives Lost (upper limit)	**1.848**	**3.696**	**11.088**	**18.480**
Hospitalizations (estimate)	3.168	6.336	19.008	31.680
Hospitalizations (upper limit)	4.620	9.240	27.720	46.20
Life Years Lost (estimate)	25.740	51.480	154.44	257.400
Life Years Lost (upper limit)	**33.790**	**67.580**	**202.74**	**337.900**
People Affected (estimate)	4.576	9.152	27.456	45.760
People Affected (upper limit)	6.468	12.936	38.808	64.680

3.3 Cost Savings

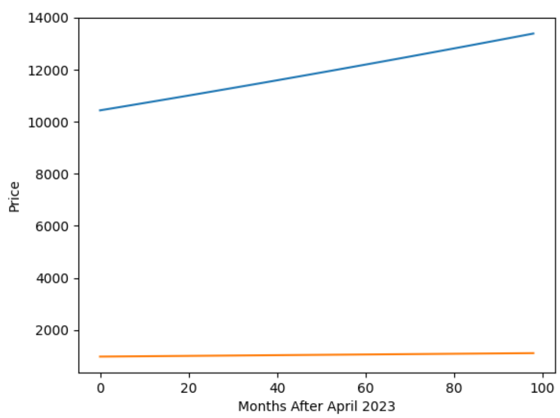
We begin with a projection of gas prices over time with a polynomial as such:

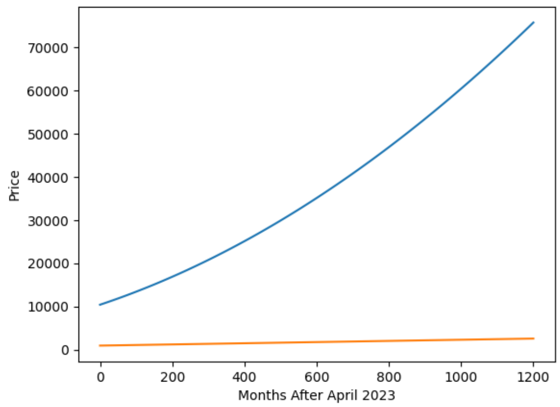


This model has an R^2 value of 0.87, which means that our model fits the behaviour of gas prices quite well. Using this model, as well as a similar one for electric prices (with an R^2 value of 0.86), we do some predictive analysis in this section.



In the graph above there is a collection of prices of both electric and petrol, along with a polynomial that fits the points (on average). The bottom red line and green dots represent average electricity prices each month over time from 2016 March to April 2023 (based on electricity prices in BC) [13]. The above orange line with blue dots represents the gas prices over the same time length [14]. On the next page, using the polynomial that was fit to the prices, we project future savings.





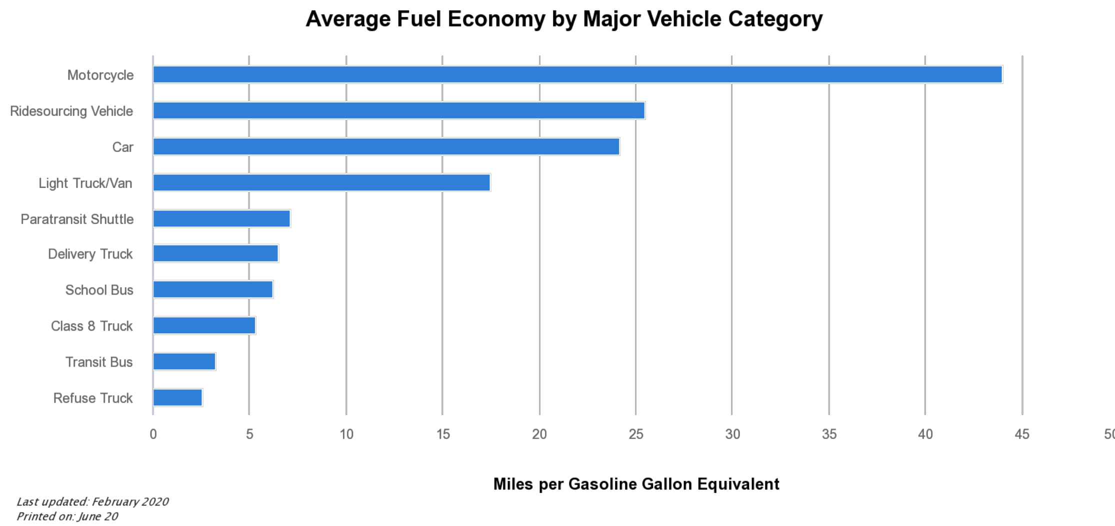
Here you can see the blue line (gas) grows at a faster rate than the electric (orange) line. **It is projected that a full tank will cost approximately 12 times as much as a full battery in 8 years.**

Another aspect of cost savings is to look at a similar analysis in the lens of daily usage. Looking at a list of daily drivers of ZEVA, one is able to see that on average, each client drives 8.302 miles (13.36 kms) per day, which is quite close to the census estimate of 17.4 kms. Further, based on ZEVA, we have an efficiency of 0.173 kwh/km. This is computed with total battery percentage difference divided by total odometer difference, and assuming the vehicle has a 75kwh capacity which is the standard for model Ys as such:

$$\frac{\sum_{t \in \text{trips}} (t_{\text{sp}} - t_{\text{ep}})}{\sum_{t \in \text{trips}} (t_{\text{eo}} - t_{\text{so}})} \times \frac{1}{100} \times 60$$

Where t_{sp}, and t_{ep} are the starting and ending battery percentage for each trip, and t_{eo} and t_{so} are the starting and ending odometer readings for each trip. This calculation being a total ratio thus includes energy gained back during regenerative braking, and additional energy expended using things like the media console and climate control. Further, this value is close to what is reported in fueleconomy.gov, which reports it at 28kwh/100mi or 0.174 kwh/km. This gives us an approximate range of 431.03km. With an average daily commute of 13.36kms, **it will take approximately 32 days to drain the battery with everyday use**. With similar driving behaviour, but higher battery range, such as with a model S, one can expect to see 43 days.

Now lets look at gas vehicles:



Here we have an average efficiency of 24.2mpg, or 10.3 km/L. With an average fuel capacity of 60L we have a total approximate ranage of 618kms. Using the same daily average of 13.36kms, **it will take approximately 46 days to empty your tank**.

Charging one model-Y battery to full would cost a homeowner \$10.56 (based on BC power prices, assuming level 2 at 14.08¢/kWh). With the assumption that the average size of a gas tank is 60 litres, a full tank of gas would cost approximately \$116.79 (based on the average historical gas price for Vancouver, BC from Statistics Canada between May 2022 and April 2023, which is 194.65¢/L), almost an 11-time difference!

Another thing to look at is maintenance cost of a car as well. With gas cars, there are more costs related to maintenance with things like oil changes, transmission fluid changes and other repairs, which electric cars do not need. Using CAA maintenance cost estimates for various cars and averaging it out, we have that on average, maintaining a car costs \$791.02 per 10,000 kilometers. This gives us an estimated 8¢ per kilometer. Using the ZEVA estimated behaviour of 13.36 kilometers per day, we can estimate saving \$390.11 a year on maintenance.

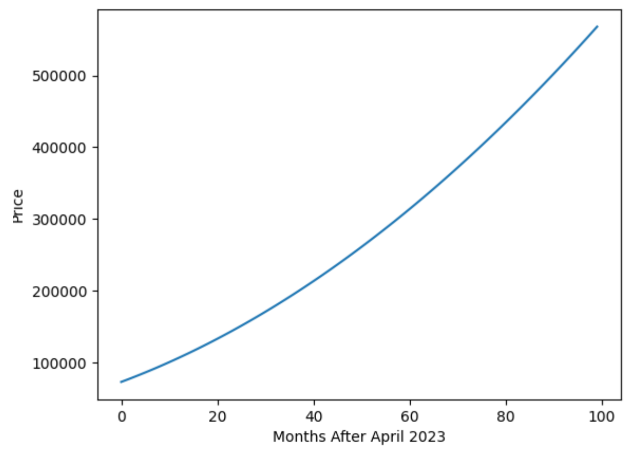
Thus to compute an estimated total by year, we have a total estimated gas cost in a year as \$926.70 (based on 46 days to go empty, and daily driving behaviour of a ZEVA client). Subtracting the equivalent cost of charging and electric car for a year we have 926.70 - 121.13, or \$805.57 saved going electric. Then adding the maintenance cost, **we have a grand total of \$1195.68 saved per year driving electric!**

Of course, as time goes on the gap would widen even more as gas prices continue to rise. We do some predictive analysis in this way using the following formula, derived based on ZEVA recorded driving behaviour:

$$h(x) = \left(g(x)\frac{365}{46} - e(x)\frac{365}{32} \right) + 390.11$$

where x is the year, $g(x)$ is the predicted averaged gas price for the year (adjusted to be the amount needed for a full tank of gas), and $e(x)$ is the predicted averaged electricity price for the year (adjusted to be the amount needed for a full battery).

This gives us the following:



As you can see, as the years go, the rate of cost savings increases rapidly!

References

[1] S. Canada, "Consumer price index, by geography, monthly, percentage change,." [Online]. Available: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000411&pickMembers%5B0%5D=1.26&cubeTimeFrame.startMonth=11&cubeTimeFrame.startYear=2022&referencePeriods=20221101%2C20221101

[2] B. C. U. Commission, "Bc hydro electricity rates." [Online]. Available: https://www.bcuc.com/WhatWeDo/ResidentialEnergyRates#:~:text=BC%20Hydro%20Electricity%20Rates&text=Based%20on%20two%20months%20of,over%201376)%20%3D%20%240.1408%20%2FkWh

[3] B. Bernal, L. T. Murray, and T. R. Pearson, "Global carbon dioxide removal rates from forest landscape restoration activities," *Carbon Balance and Management*, vol. 13, no. 1, 2018.

[4] G. of BC, "Spacing guidebook." [Online]. Available: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silvicultural-systems/silviculture-guidebooks/spacing-guidebook

[5] Transport and Environment, "Analysis of emissions from new cars in 2020." [Online]. Available: https://www.transportenvironment.org/wp-content/uploads/2021/11/2021_11_car_co2_report_technical_annex.pdf

[6] E. Database, "Ev database." [Online]. Available: https://ev-database.org/car/1183/Tesla-Model-Y-Performance

[7] G. Canada, "Table 6 – electricity consumption intensity values (g co2e/kwh electricity consumed)." [Online]. Available: https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system/emission-factors-reference-values.html#toc7

[8] I. Kheirbek, J. Haney, S. Douglas, K. Ito, and T. Matte, "The contribution of motor vehicle emissions to ambient fine particulate matter public health impacts in new york city: a health burden assessment," *Environmental Health*, vol. 15, no. 1, Aug. 2016. [Online]. Available: https://doi.org/10.1186/s12940-016-0172-6

[9] S. Canada, "Automotive statistics," 2021. [Online]. Available: https://www.statcan.gc.ca/en/topics-start/automotive

[10] ——, "Study: Long commutes to work by car," 2021. [Online]. Available: https://www150.statcan.gc.ca/n1/daily-quotidien/190225/dq190225a-eng.htm

[11] transportpolicy.net, "Canada: Light-duty: Emissions." [Online]. Available: https://www.transportpolicy.net/standard/canada-light-duty-emissions/

[12]

[13] Epcor, "Historical electricity rate information." [Online]. Available: https://www.epcor.com/products-services/encor/electricity-plans-and-rates/Pages/historical-electricity-rates.aspx

[14] S. Canada, "Monthly average retail prices for gasoline and fuel oil, by geography." [Online]. Available: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000101