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P2_7 Electric Vehicles vs Internal Combustion Vehicles

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Abstract

There is much debate over the carbon footprints of electrical vehicles (EV) versus internal combustion engine vehicles (ICE). In this paper, we estimate the net CO_2 emissions for the average ICE to surpass that of EVs at $\sim 25,000$ km driven, with the worst EVs requiring $\sim 74,000$ km and the best EVs requiring $\sim 16,000$ km, concluding that EVs always surpass ICEs in their lifetimes.

Introduction

The world is currently facing a growing climate crisis, with a key solution proposed being the shift to Electrical Vehicles (EV) over traditional Internal Combustion Engine (ICE) vehicles. The answer to the question 'which vehicle is better for the environment?' may be obvious to many, but there are a lot of factors which contribute to these vehicles' environmental impact. However, we decided the most straight forward way to address the issue was to model the CO_2 emissions for the two types of vehicle to compare their environmental impact over their lifespans. Specifically, this meant addressing the CO_2 emissions during manufacturing, and then whilst the vehicles are driven.

Data and Calculations

We began by researching the initial CO_2 emissions generated during vehicle manufacture. This includes emissions from mining and transporting raw materials, refinement, and final vehicle assembly. The average net CO_2 emissions during these processes for ICEs varies massively depending on the source used, so in the process of researching the data, we used CO_2 and CO_2e (CO_2 equivalent) ratings interchangeably. We found an estimate of an standard ICE vehicle to be 5.6 tonnes [1]. Whereas for EVs, we found this process was more environmentally impacting, with 8.8 tonnes emitted on average, again with huge discrepancies in various sources for the data [1].

Next, we considered the process of emitting CO_2 during vehicle usage. Since EVs use electricity from the national grid, their CO_2 emissions are directly tied to the emissions generated by their countries' power grid. For the UK, this is approximately 256 g/kWh [2]. We then needed to convert this into an amount of CO_2 per km. Some research found that the efficiency of EVs lithium ion batteries in a Volkswagen e-up! is 0.117 kWh/km [3]. We were then able to estimate the emissions per km for an EV as:

$$(256 \text{ g/kWh}) \times (0.117 \text{ kWh/km}) = 29.952 \text{ g/km}$$

Assuming no losses in the national grid and or when charging the vehicle, this can be taken as the average emissions of EVs.

For ICEs, the CO_2 emissions are more straight forward to source as they have emissions tests done on their engines. The average for ICE cars was found to be 177.5 g/km [2][4]. We then used these average g/km values to be the gradients on our plot, while the initial CO_2 emissions for manufacturing these vehicles were used as the initial offsets on the y axis.

To constrain this model, we attempted to source some 'worst case' and 'best case' data for EV manufacturing, rather than average, and plot these graphs as well. Manufacturing for small EVs such as the Renault Zoe is likely to cause only ~ 7.66 tonnes of CO_2 emissions [5]. On the flip side, long range EVs such as the Tesla model 3 can be responsible for approximately 15 tonnes of CO_2 emissions in manufacturing [6].

Results and Discussion

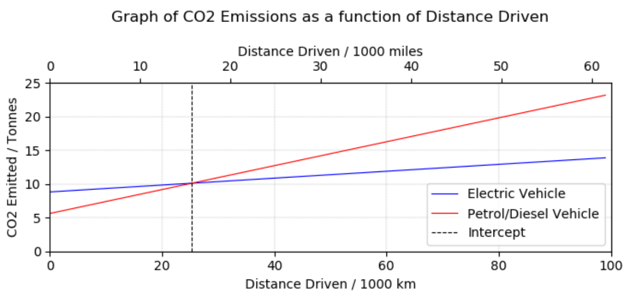

Figure 1: The graph compares the CO_2 emissions of the average EVs to ICEs as a function of distance driven.

Figure 1 shows the CO_2 emissions of the average EV and ICE as a function of the distance travelled. The gradient of incline of the ICE is steeper than that of the EV, but with a lower offset due to the manufacturing emissions. This results in an intersection point on the graph where the ICE matches the emissions of the EV and then proceeds to have higher lifetime emissions for the rest of the graph. We estimate that after travelling a distance of $\sim 25,000$ km (about 16,000 miles) the EV will match the lifetime emissions of an ICE, with any further distance travelled giving the EV lower next emissions.

Figure 2 shows the results of estimating the worst and best case scenarios for EVs. The graph on the left shows long range EVs cause the intercept to reach $\sim 79,000$ km to break even with ICEs, whereas the best case graph on the right shows there is no intercept, with small EVs reaching more eco-friendly at a lower $\sim 16,000$ km.

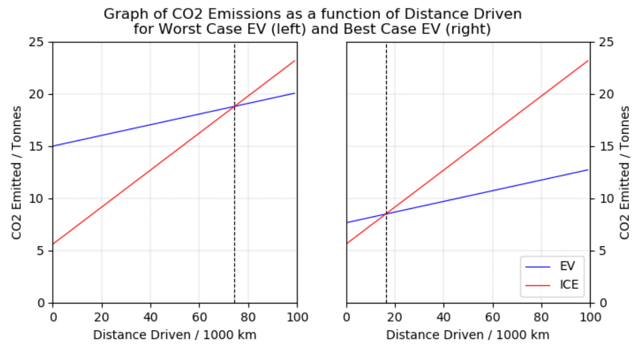

Figure 2: Graph comparing the CO_2 emissions of the best/worst EVs to ICEs as a function of distance driven.

Conclusion

We investigated the required distance an EV would need to travel to have total net emissions lower than a car powered by an ICE. On average, this distance was found to be $\sim 25,000$ km, with the worst EVs requiring $\sim 74,000$ km and the best EVs $\sim 16,000$ km. These values can vary greatly when sourcing different manufacturing CO_2 emissions. However, the variations do not change the key point that EVs always beat ICEs over lifetime emissions.

References

[1] `bit.ly/3m4h5XC` [Accessed 29th October 2020]

[2] `bit.ly/379u4TN` [Accessed 7th October 2020]

[3] `bit.ly/3oNhEXI` [Accessed 29th October 2020]

[4] `bit.ly/3oTsOKB` [Accessed 5th October 2020]

[5] `bit.ly/3nfcXW8` [Accessed 11th October 2020]

[6] `bit.ly/2LmUqsN` [Accessed 11th November 2020]