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FINANCE & STRATEGY

ARE BATTERY ELECTRIC VEHICLES ALWAYS THE GREENER CHOICE?

PART 2:
Comparison of Lifetime CO_2 Emissions Between Petrol & Fully Electric Vehicles

By Annelisa Hussey | Rachel Lennox-Warburton | Matteo Bianciotto

In Part 1 of this series of articles, we demonstrated that Battery Electric Vehicles (BEVs) might not be as green as you think. In this article we examine whether a BEV is truly greener than its equivalent petrol vehicle.

Battery Electric Vehicles vs Petrol Equivalents

In Part 1 of this series of articles, we demonstrated that Battery Electric Vehicles (BEVs) might not be as green as you think.

The electricity used to charge a BEV is often generated using CO2-producing fuels, so the energy mix used for the production of electricity in a particular country is very important in determining whether a BEV indirectly produces as much CO2 emissions as an equivalent vehicle with a petrol Internal Combustion Engine (ICE).

Before a mass rollout of BEVs in a country, it is important to consider its energy mix and whether any other investments need to be made, for instance, switching from coal to cleaner fuels, before BEVs will truly be greener than a petrol-powered car.

In this article we examine whether a BEV is truly greener than its equivalent petrol vehicle. To answer this question, we considered three categories of BEVs and compared them to a similar rated petrol car. The categories and cars considered in this article are summarised in the table below.

Figure 1: BEVs & ICE cars by category

Car Fleet Reviewed

Small	Medium	Luxury
Fiat 500e 24 kWh vs Fiat 500 1.2l Petrol	Citroen e-C4 50 kWh vs Citroen C4 PureTech 130	BMW iX3 80 kWh vs BMW X3
Nissan Leaf 40kWh vs Nissan Micra Visia	Hyundai IONIQ Electric 40kWh vs Hyundai i30	Jaguar i-pace EV400 90 kWh vs Jaguar XE D200
Peugeot e-208 50kWh vs Peugeot 208 PureTech 75		Tesla Model 3 Long Range Dual Motor 74 kWh vs FORD Mustang Fastback 2.3 EcoBoost 290PS

In our analysis and subsequent conclusions, five factors were considered:

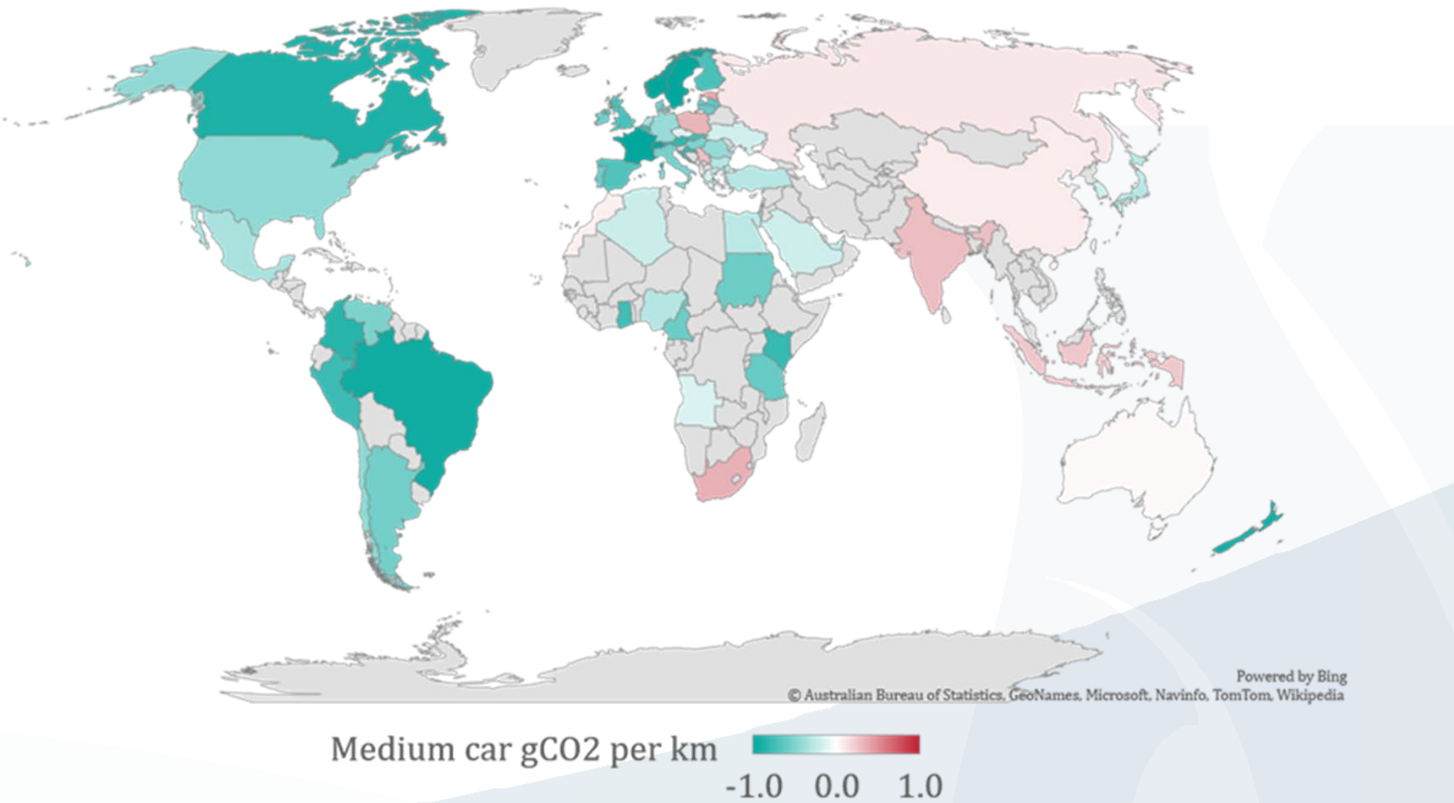
- What is your country's energy mix?
- How big a battery do you need?
- How long will you keep your BEV?
- When do you charge?
- And how much will it cost you?

What Is Your Country's Energy Mix?

Each BEV has an efficiency expressed in kWh per km. For the medium BEVs presented above, ratings agencies state 0.18 kWh/km for the Citroen e-C4 and 0.153 kWh/km for the Hyundai IONIQ. This, however, does not include losses during transmission and charging. For the purpose of this study, we have assumed charging losses at 10% based on electric transmission loss data by country from the International Energy Association (IEA).

Using the underlying 2018 energy mix, by country, we compared BEVs with their petrol equivalent on the basis of grams of CO_2 per km. The map below shows the average of the medium BEVs and petrol cars listed above. For those countries highlighted in green, the BEV emits less CO_2 per kilometre than the equivalent petrol car. On the other hand, for countries highlighted pink/red, it would be better to have a car fuelled by petrol.

Figure 2: Medium BEV vs its corresponding petrol engine version - CO2 g/km differential



In this chart, countries that have emissions twice as bad as an equivalent petrol vehicle would be highlighted dark red. The score in the legend is calculated as electric vehicle emissions less equivalent petrol vehicle emissions, with the result then divided by the petrol vehicle emissions.

Many countries, including Poland, China and South Africa, have a current energy mix that would make driving a BEV “less green” than driving an equivalent ICE petrol car.

How Big a Battery do You Need?

BEVs use large batteries, with capacities ranging between 24 kWh in the small Fiat 500e to 90 kWh in the luxury Jaguar i-pace EV400. In comparison, a standard AA battery has only 3.75 Wh of capacity i.e. 24,000 times smaller than those used in the Jaguar.

The distance a BEV can travel on one charge is highly dependent on the battery size, with a Fiat 500e being able to travel 90 miles vs the Jaguar's 225 miles. This means that in a similar manner to larger petrol cars having greater petrol consumption, larger BEVs use larger batteries.

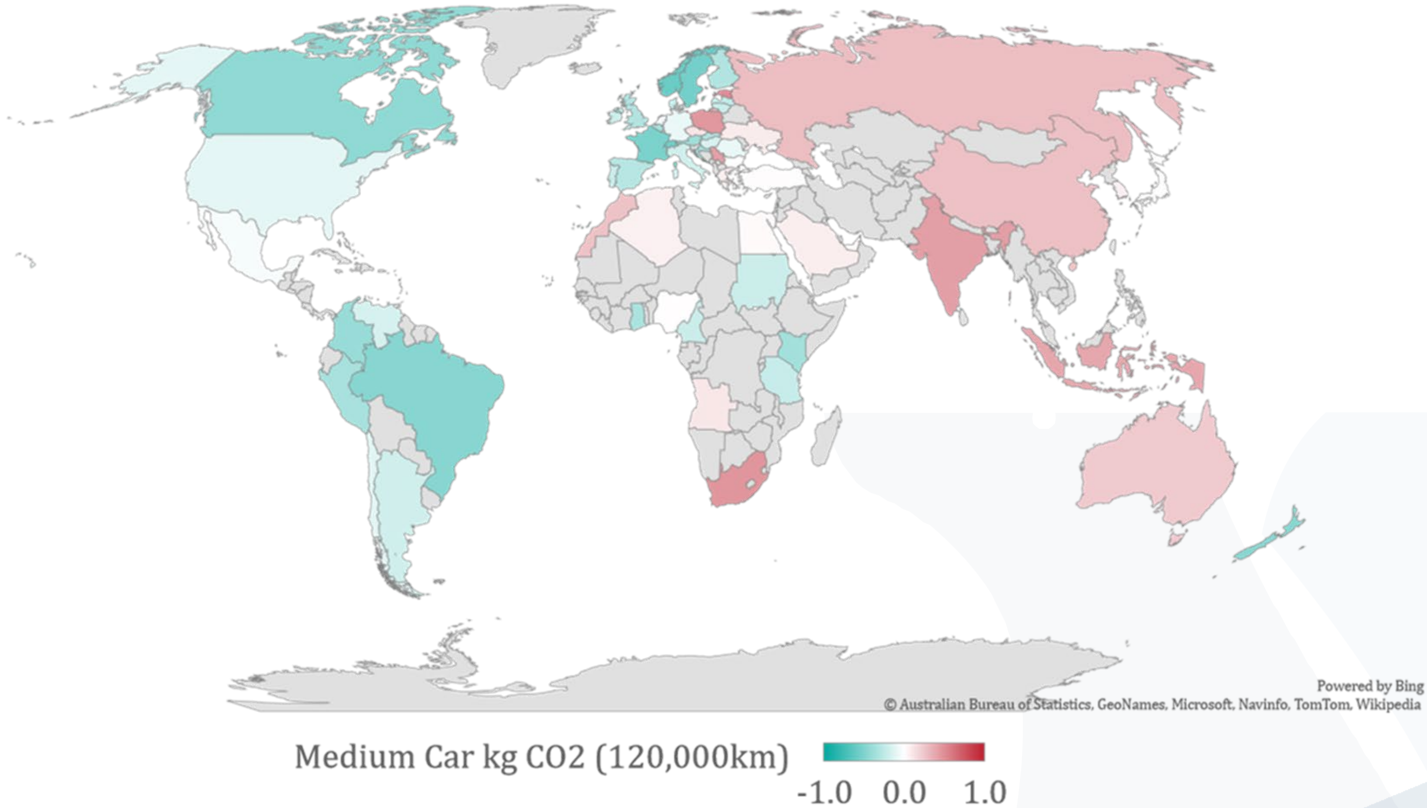
Battery production consumes large amounts of natural resources, including lithium, cobalt, nickel and manganese. The reserves of these metals are finite and unless an economically viable method of recycling is implemented or alternative battery technology is developed, they will one day be exhausted.

Mining the materials and manufacturing the battery produces a considerable amount of CO_2 during production, transport and electricity consumption. According to *S&P Global Market Intelligence*, 77% of the world's 455 GWh battery output is produced in China, a country with a less favourable energy mix. According to a 2017 paper produced by Romare and Dahlof, batteries produced in Asia create 150 to 200 kg CO_2 emissions per kilowatt-hour of battery capacity.

Focussing on the two medium BEVs presented above, battery production alone accounts for c.7,900 kg CO_2 emissions per vehicle. When these emissions are added onto the lifetime of a BEV, electric cars suddenly look less green.

The map below again compares medium BEVs against their petrol counterparts. This version of the map now includes emissions from battery production for BEVs, as well as the emissions from crude oil production and fuel refining for petrol cars, which is 31gCO_2/km according to the Energy Information Administration (EIA). When compared to map above, running a BEV in many countries becomes less favourable with respect to CO_2 emissions (i.e. the countries have swung into the red). This is the case for Morocco, Saudi Arabia, and Ukraine, among others.

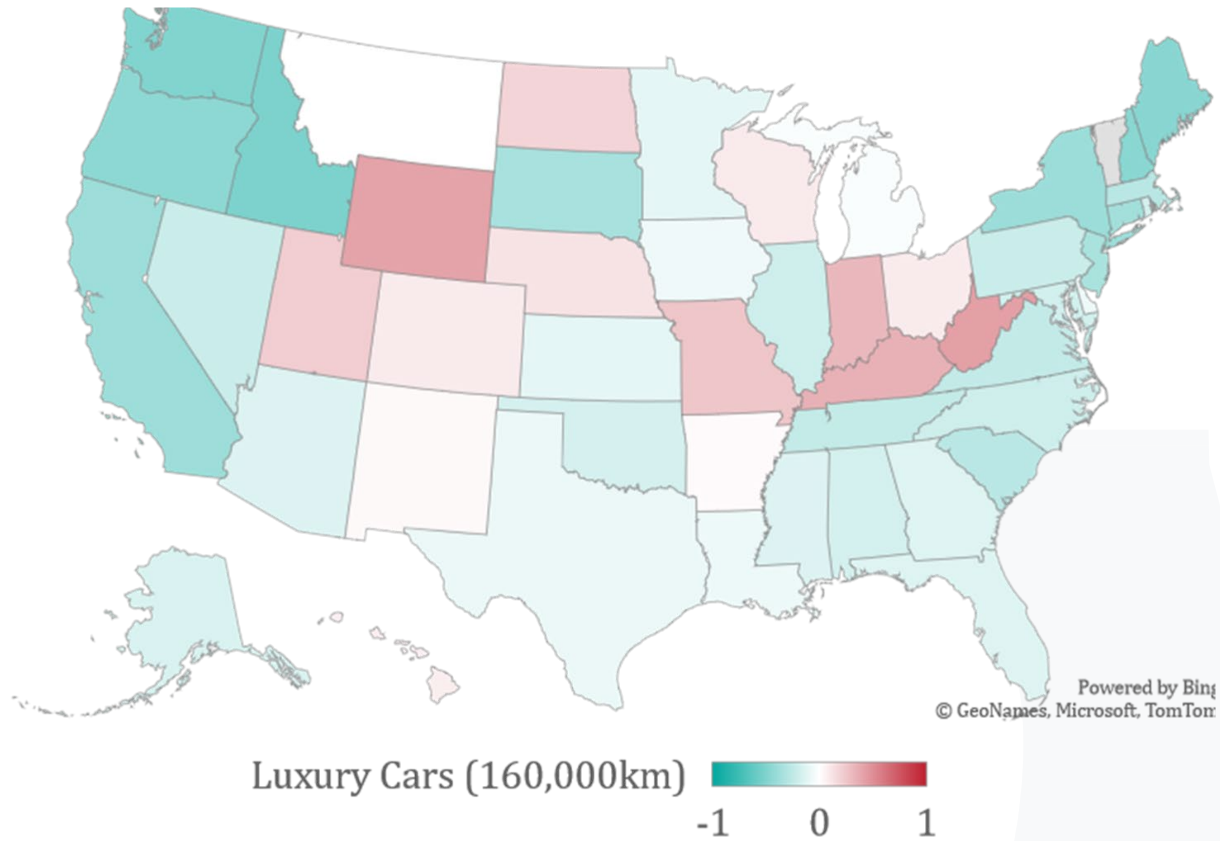
Figure 3: Medium BEV *vs* its corresponding petrol engine version – kg CO_2, taking into consideration battery & fuel lifetime emissions



Unless there is a breakthrough in battery production efficiency, countries will need to find ways to reduce CO_2 emissions from power generation, not only to make sure that each kilometre driven produces less $C0_2$ than using a modern ICE, but also to offset the substantial emissions generated during the process of producing the batteries.

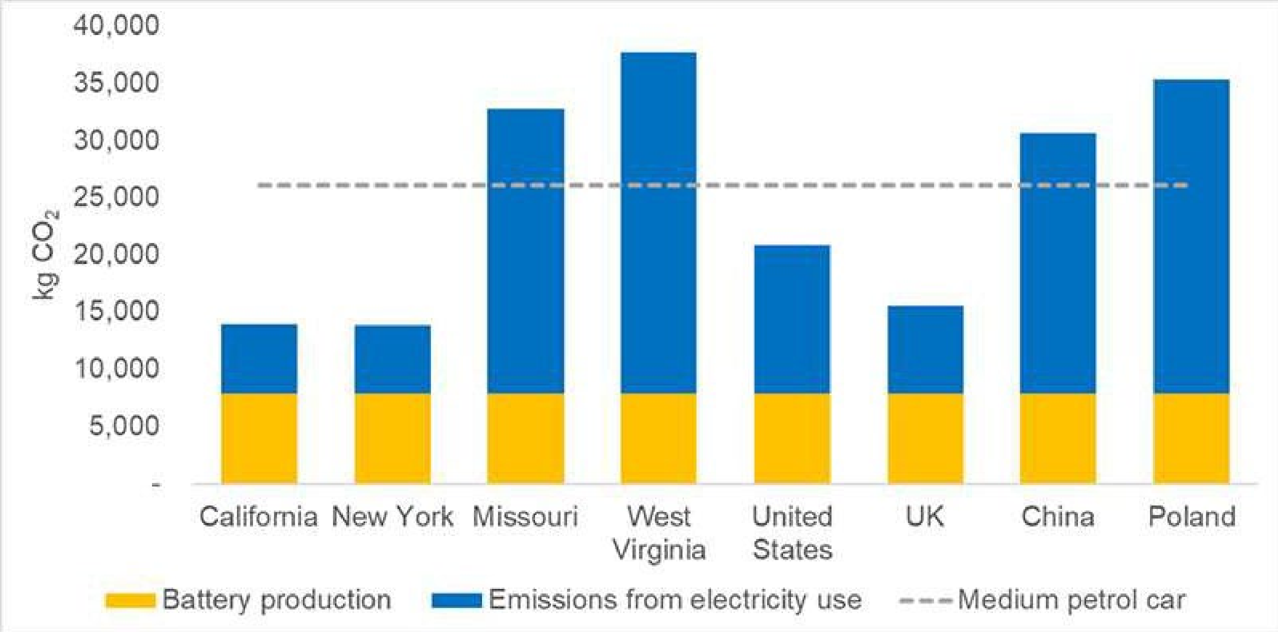
The energy mix can, however, vary greatly within countries, depending on how the electricity grid is managed. The United States appears green in both of the world maps above. Looking closer, however, the situation varies enormously on a state-by-state basis. The map below presents how the operation of BEVs and ICE cars in the luxury car category compares in different parts of the US. Although the overall picture for the US is green, a fair number of states are, unfortunately, in the red.

Figure 4: Luxury BEV *vs* its corresponding petrol engine version - kg CO_2 differential, taking into consideration battery & fuel lifetime emissions



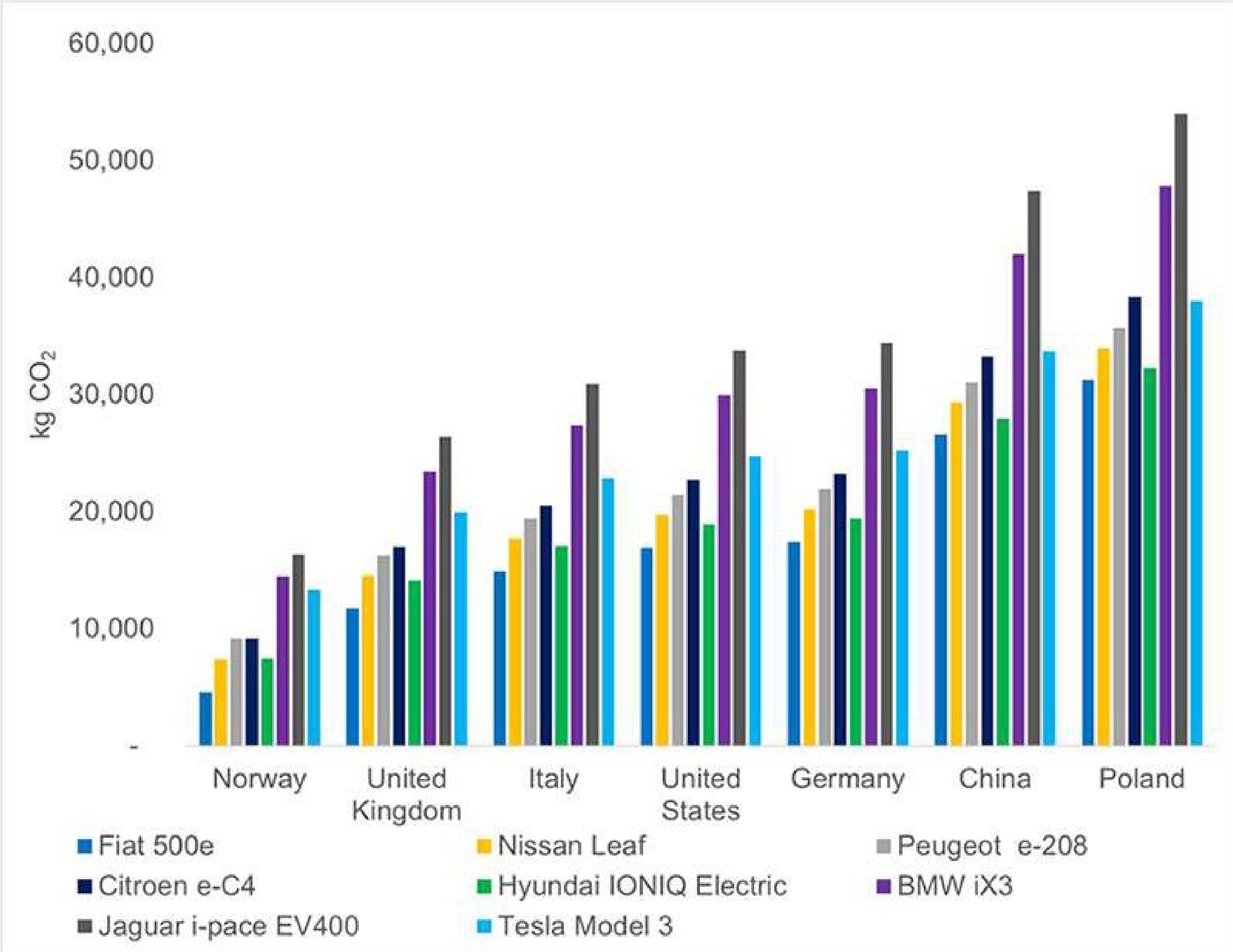
In fact, many states compare with the worst offenders globally. The chart below shows how medium category cars compare with equivalent petrol-powered cars in some states of the US, as well as elsewhere around the world. Using a vehicle lifetime assumption of 160,000 km, in Missouri and Virginia for example, a medium BEV would produce more $C0_2$ emissions than a comparable medium ICE car.

Figure 5: CO_2 emissions over the lifetime of a medium BEV



Generally, the smaller the car the better, due to the smaller battery. It is therefore very important that personal usage requirements be considered before purchasing a BEV. If you plan to use the vehicle in predominantly urban areas, and simply for grocery trips and school runs, a smaller car should be selected. The chart below compares BEVs in a number of countries, again assuming a lifetime of 160,000 km.

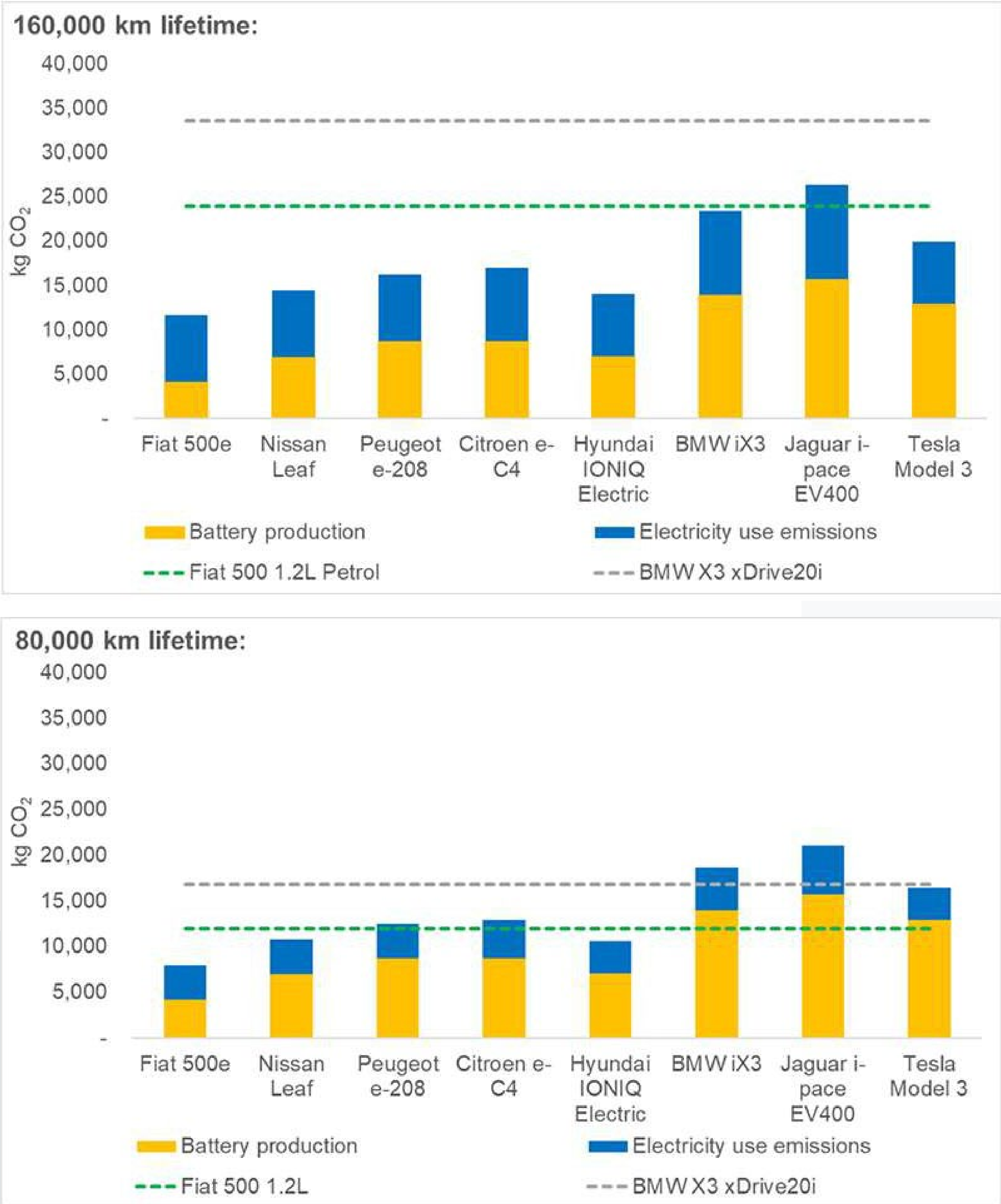
Figure 6: Comparison of BEV CO_2 emissions across various countries



How Long Will You Keep Your BEV?

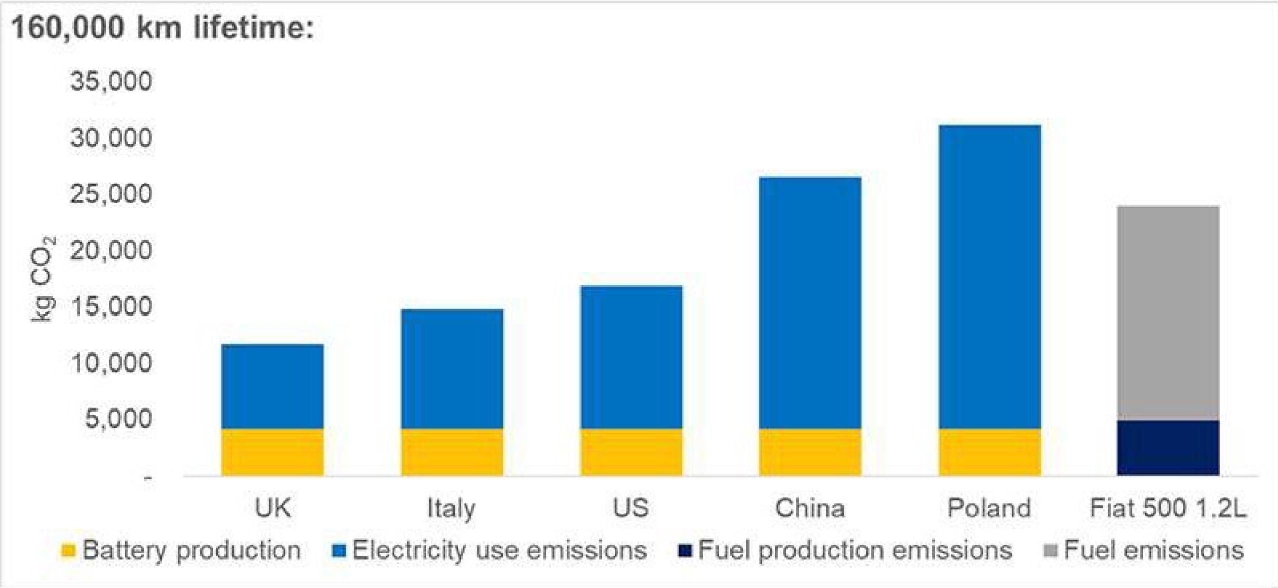
The assumed lifetime of the car makes a difference too. Different countries and regions have different user habits, so for the purpose of this article we have assumed vehicle lifetimes are measured in kilometres driven. Using the UK energy mix, the charts below compare the BEVs across 160,000 and 80,000 kilometres. The proportion of emissions related to battery production is naturally considerably higher in the 80,000 km scenario and, consequently, the relative CO_2 emissions savings when compared to a petrol ICE-powered car are smaller.

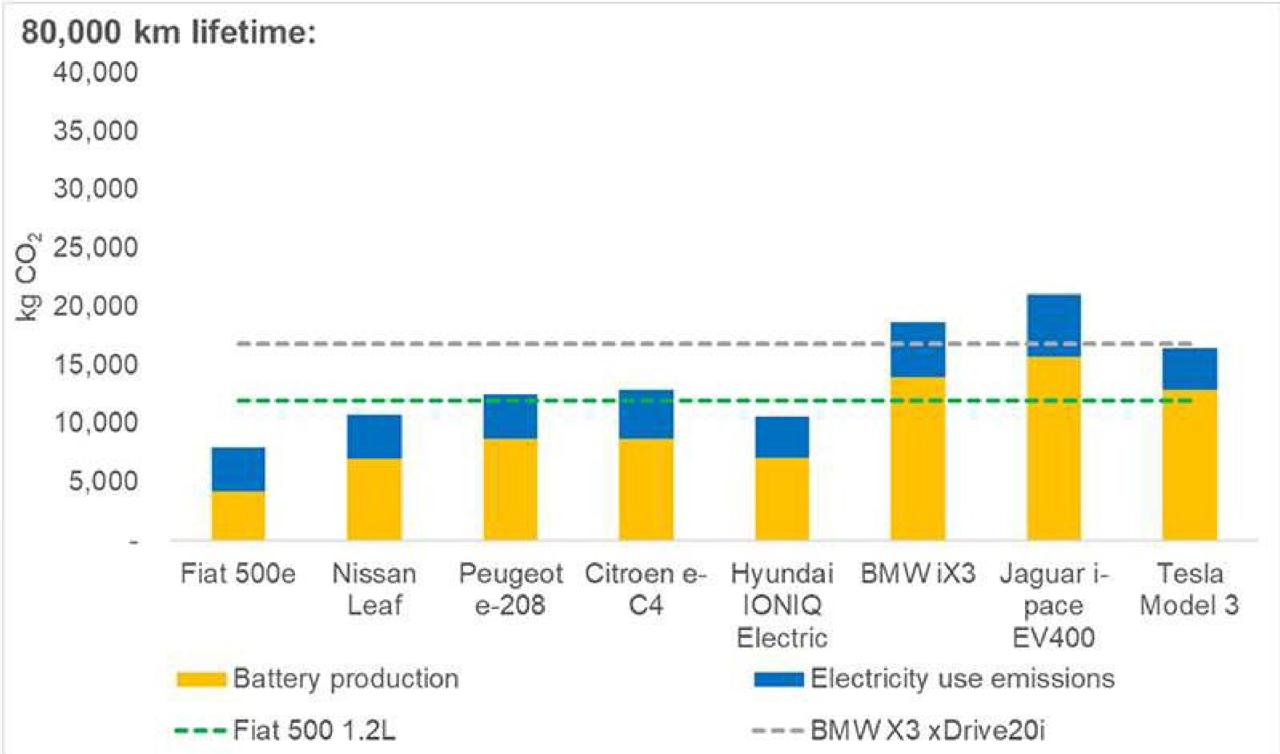
Figure 7: BEV CO_2 emissions – 160,000 km Lifetime vs 80,000 km Lifetime in the UK



The trend can be seen for all countries. In the charts below, a Fiat 500e is compared for both 160,000 and 80,000 km lifetimes.

Figure 8: BEV CO_2 emissions – 160,000 km Lifetime vs 80,000 km Lifetime in several countries





Maximising the BEV's lifetime certainly makes owning one more worthwhile in terms of CO_2 emissions when compared to its ICE car equivalent.

When do You Charge?

The behavioural tendencies of charging are important factors. The energy mix for each country is heavily impacted by the time of day. Renewable energy contributions are often higher during the day, when the sun is shining and solar energy is available. The portion of energy from renewable sources can be substantially lower in the evening, however, where electricity production can generate up to 30-40% more CO_2 when compared to daytime hours (see part 1 of this series of articles).

The optimal charging time for an individual who works from 9am to 5pm each day is often in the evening or overnight, which would mean that a more unfavourable energy mix is powering the BEV. Thus, the actual CO_2 generated by an average BEV may be worse than as presented in the maps above.

Ideally, a BEV owner should charge their vehicle while at work to take advantage of the more favourable energy mix. In some countries though, where there is a tiered tariff system, electricity is more expensive during the day and so this disincentivizes the consumer. From this respect policy and infrastructure need to evolve to allow for individual charging habits to align with minimising CO_2 generated from electricity production.

The Cost of the Vehicle

Battery electric vehicles are generally EUR 10,000 to 15,000 more expensive than their petrol equivalents. The question remains as to whether the owner will recover the extra cost over the life of the vehicle.

This is heavily dependent upon the ratio of petrol to electricity prices in each country. As shown in the chart below, however, for small and medium cars, on the basis of a 160,000 km life, it is apparent that the additional upfront cost of BEVs is not recovered through electricity cost savings. The cost saving for the small and medium categories, with today's fuel and electricity prices from Eurostat, is calculated as EUR 3,500 in Germany and EUR 8,800 in Greece.

In the luxury car category, savings are higher due to the comparatively lower mileage per gallon that luxury cars achieve compared to the smaller cars.

Figure 1: Comparison of the cost savings per vehicle class in each country

In conclusion, the cost benefits of a BEV over an ICE car are unclear. Before purchasing a BEV, individuals should consider four factors. Firstly, whether their country's energy mix is BEV ready; secondly, the CO_2 emissions from the production of the battery; thirdly the planned lifetime mileage; and fourthly whether they can charge it optimally to make use of renewable energy sources. If these criteria cannot be met, an ICE car could be a greener alternative.

OSTERWALD RATHBONE & PARTNERS
FINANCE & STRATEGY

44 Southampton Buildings
London WC2A 1AP
United Kingdom

T: +44 20 3994 0133

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