# EV lover, she'll take your heart because it's greener

## A lifecycle comparison between electric and combustion-engine cars

European Equities
November 2021

Federated Hermes International

www.hermes-investment.com
For professional investors only

## Summary

This paper is the first in a series of insights on decarbonising the auto sector. To assess how much greener an electric car is than its petrol equivalent, we calculated the lifetime emissions of a car powered by an internal combustion engine (ICE) and an equivalent battery electric vehicle (BEV).

Our findings indicate that:

An average ICE vehicle emits

**35 tons**

of $CO_2$ over a typical 15 year,

**150,000km**

lifetime

BEV emissions over the same timeframe range widely from

**9.5** to **32 tons,**

being highly dependent on how electricity is generated in the country in which the vehicle is operating

Given that the average person emits approximately

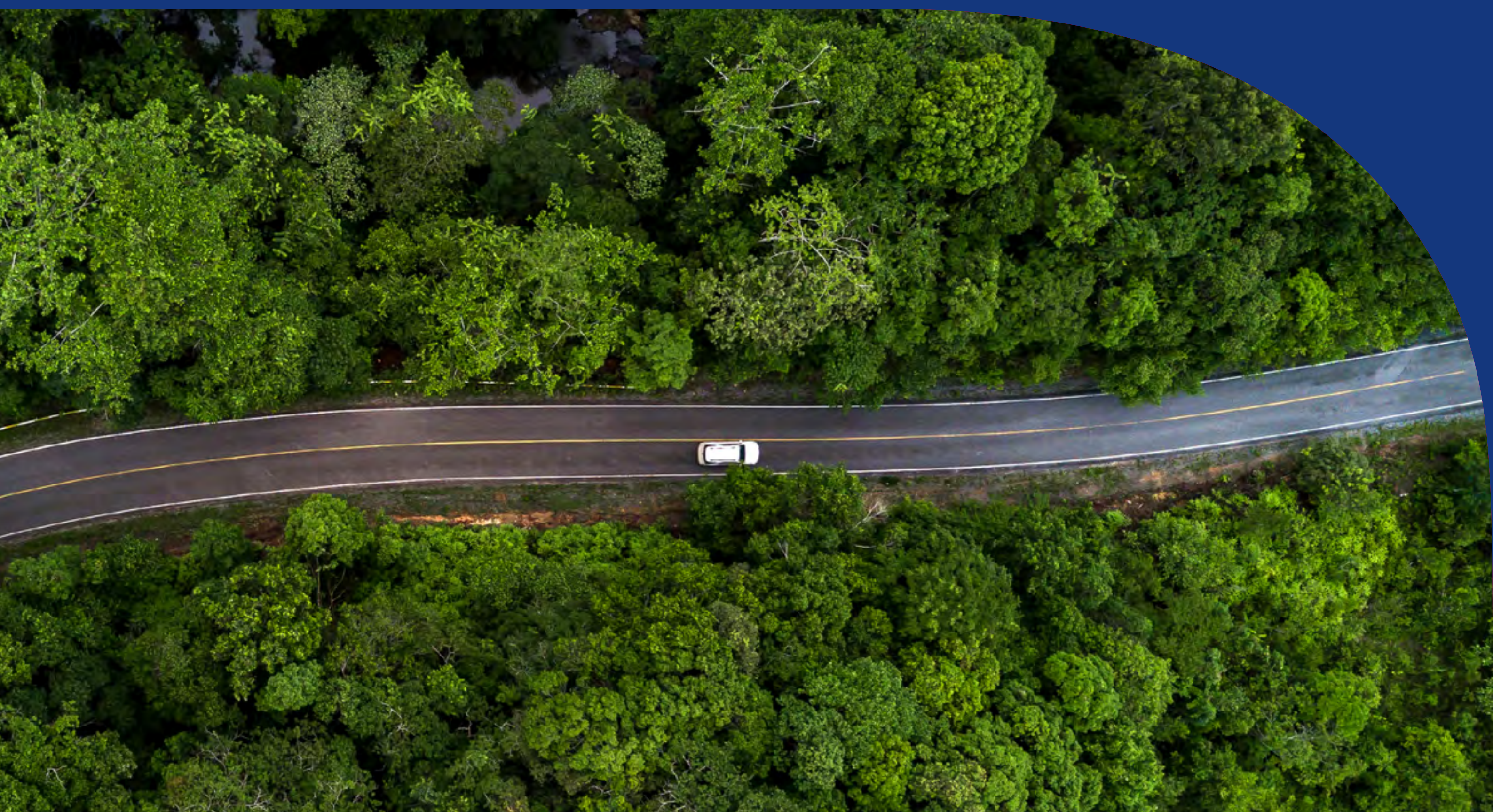
**10 tons**

of $CO_2$ per year, the nearly

**2.5 tons**

per year allocated to driving an ICE vehicle represents an important decarbonisation opportunity

The existing situation in some countries already provides the opportunity for a BEV to significantly reduce an individual's overall emissions. However, improvements in terms of the growing market share of renewable energy would enable BEVs to have an even higher impact.



# Introduction

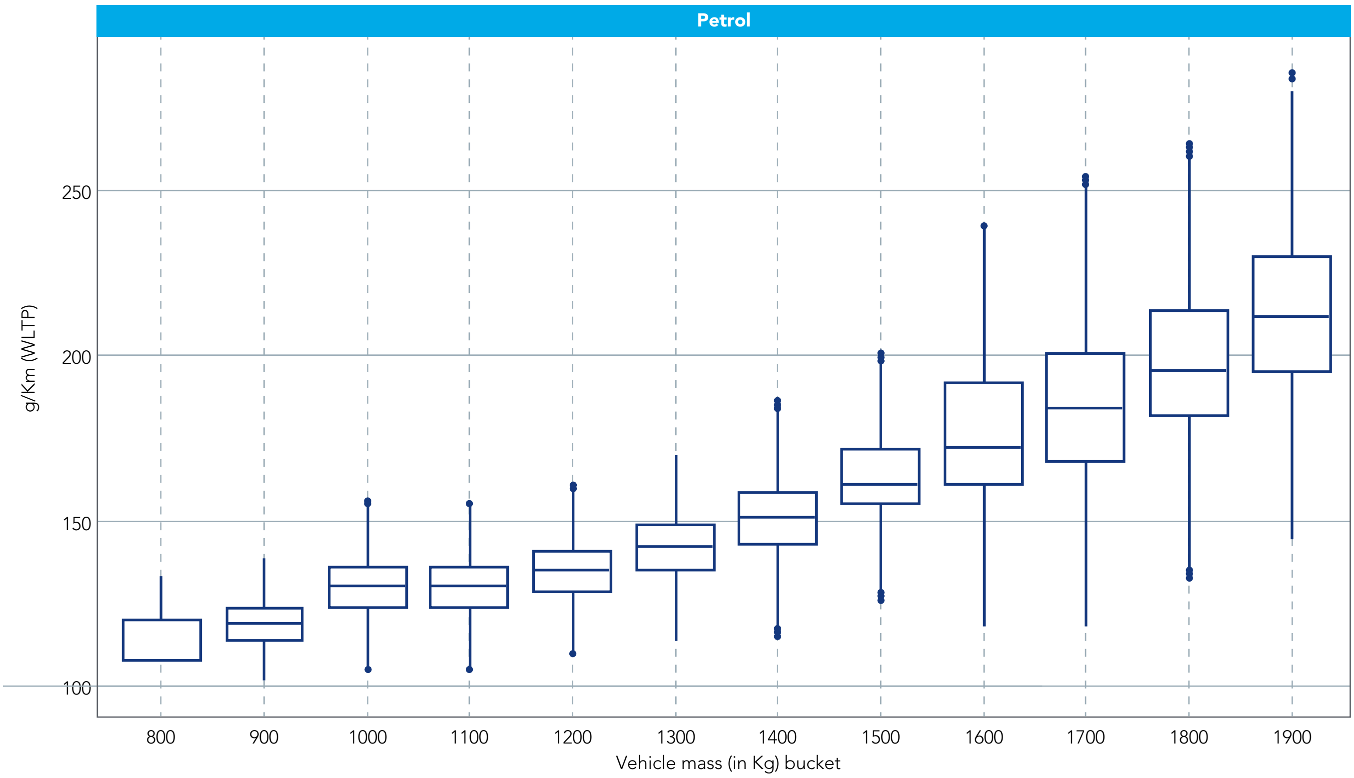
## Road transport is one of the largest contributors to global warming, accounting for 12% of global $CO_2$ emissions[1,2]. Its decarbonisation will therefore have a significant impact in the fight against climate change.

Indeed, regulators around the world have been enforcing ever-stricter auto emission standards since the early 1990s. Vehicle manufacturers have responded with more efficient combustion engines, better catalytic convertors, and innovations such as stop-start technology.

However, we are now at the point where targets are too strict to be met with more efficient combustion engines alone. For example, in the EU, manufacturers now need to meet a fleet *average* of 95g/km of $CO_2$,[3] yet there are no petrol or diesel cars on the market than can achieve less than 100g/km (see Figure 1).

**Figure 1:** Distribution of vehicle emissions from cars registered in the EU by vehicle mass as at 2020, based on the WLTP standard[4]

Variance of emissions profile of petrol vehicles vs. their mass



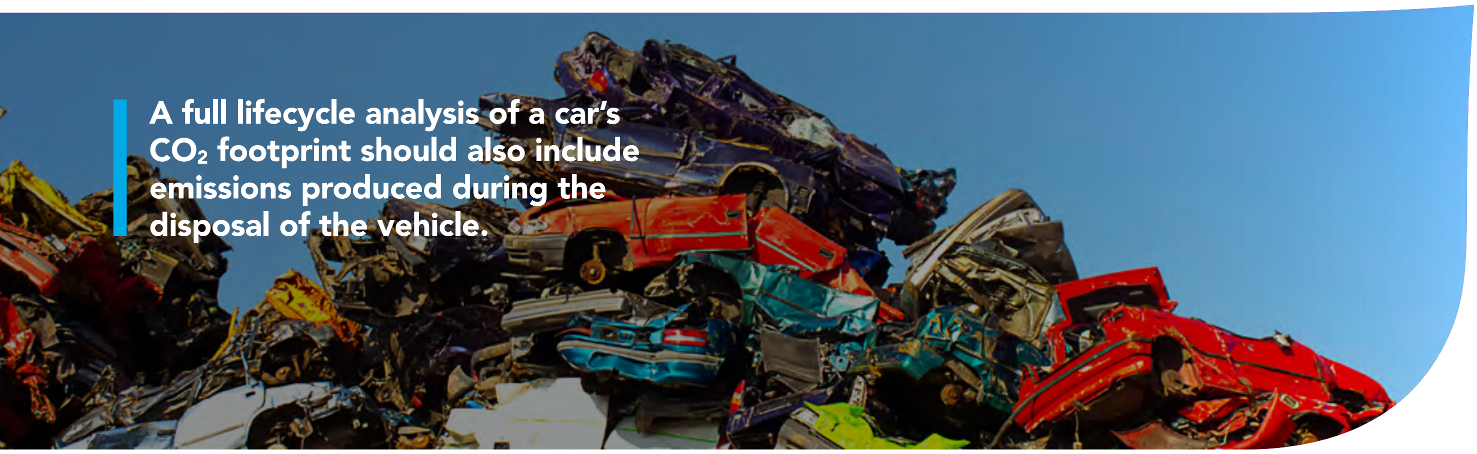


[1] "Everything You Need to Know About the Fastest-Growing Source of Global Emissions: Transport", Shiying Wang and Mengpin Ge, published by the World Resources Institute as at October 2019. https://www.wri.org/insights/everything-you-need-know-about-fastest-growing-source-global-emissions-transport

[2] Sims R. et.al , 2014: Transport. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[3] "REGULATION (EU) 2019/631 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 April 2019. Setting $CO_2$ emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011", published by the EU Publications Office as at 17 April 2019. EUR-Lex – 32019R0631 – EN – EUR-Lex (europa.eu)

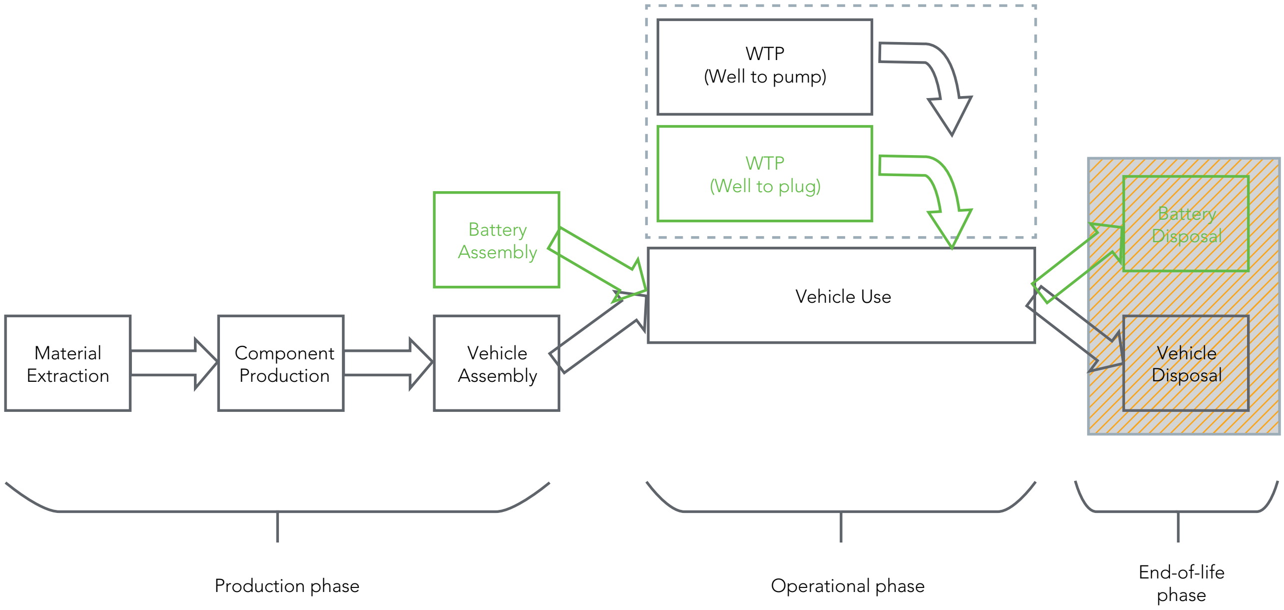
[4] Data from: https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-20.




With regulatory pressure mounting, the industry has turned to electric vehicles, both hybrid and fully electric, to get their average emissions down. But how much lower (if at all) is the lifetime $CO_2$ footprint for a BEV compared to an equivalent ICE vehicle? When we see a Tesla wafting silently past leaving no exhaust fumes, it's easy to imagine such a vehicle is dramatically better for the environment than a growling muscle car belching a cloud of black smoke in its wake. However, while a BEV is undoubtedly much better for the immediate environment in terms of noise and air pollution, at a global level the picture is far more nuanced.

The lifetime $CO_2$ footprint of a vehicle results from three phases, which are shown graphically in Figure 2.

**Figure 2:** ICE vs BEV lifecycle footprint (green boxes indicate BEV additional steps)




Source: Federated Hermes, using the GREET model (See https://greet.es.anl.gov).

**Production phase:** $CO_2$ is produced in the extraction of raw materials from the earth, the processing of these materials, their formation into components, and assembly into the complete car. Although ICE cars and BEVs share a lot of materials and components, there are some major differences that result in a significantly different $CO_2$ footprint from this phase.

**Operational phase:** The operational phase refers to the useful life of the car as a means of transport. For an ICE vehicle we need to consider not only the exhaust emissions it produces but also the $CO_2$ emitted in extracting, processing and refining the oil into petrol or diesel and transporting it to the petrol station. The latter are called 'well-to-pump' or 'well-to-tank' emissions.

- Electric cars don't emit any $CO_2$ when driving around. However, $CO_2$ may have been emitted in the production and supply of the electricity the car uses – these are called 'well-to-plug' emissions.
- In addition, both petrol and electric cars emit some particulate matter from the tyres and brakes during operation. However, the amounts are relatively small and need dedicated investigation, so we have excluded them from this analysis.

**End-of-life phase:** A full lifecycle analysis of a car's $CO_2$ footprint should also include emissions produced during the disposal of the vehicle. If it was just left in a barn to rot this element would effectively be zero, but with 100 million cars reaching the end of their lives every year that is neither practical nor desirable. The process of recycling materials from a vehicle actually results in additional $CO_2$ emissions. However, the next generation of cars that incorporate these recycled materials will have a lower production footprint as a result. Unfortunately, there aren't yet enough electric vehicles reaching end-of-life for this to have any impact. What's more, during the phase of EVs displacing ICE cars, new EV production will significantly outnumber old EVs being retired each year. Given this, we have left the end-of-life $CO_2$ footprint at zero when calculating the overall footprint of this generation of EVs.

# Lifecycle analysis: our assumptions

As you can see from Figure 1, ICE and BEV vehicles have many common elements in their production footprint. However, there are also several key differences which can significantly impact the total footprint of the vehicle. The end-of-life phase is also shown, but as already discussed we will not take it into consideration in our calculations. We will therefore include the footprint at production, maintenance (fluids and wheel replacement), and operation.

For our comparison, we have taken an 'average' ICE car and an equivalent BEV. The mass of our average ICE car is 1,500kg, which equates to a 5-door Volkswagen Golf. Our equivalent average BEV is assumed to have a 64kWh battery, a size typically found in mid-size, mid-spec electric cars such as the Kia e-Niro, Hyundai Kona, or VW ID3. We have allowed an additional average weight of 296kg for this. The 1,500kg average mass does not include the wheels (or the spare) or the lead-acid battery. The total weight of our example ICE vehicle would therefore be 1,558kg with all components included, while our example BEV would weigh 1,842kg.

We have assumed an average vehicle lifespan of 15 years and average mileage of 10,000km per year. This results in an average lifetime range of 150,000km, which is a number frequently used in similar automotive lifecycle assessment (LCA) analyses (albeit these mostly focus on traditional petrol fuelled vehicles)[5,6]. There will always be examples of extremely high mileage (such as the infamous 5,000,000km Volvo[7]) where the production $CO_2$ footprint can be 'amortised' over a large number of miles. However, there are also plenty of 'garage queens' that only get wheeled out for auto shows.

Our assumptions are summarized in Table 1.

**Table 1:** Our assumptions of an 'average' ICE and BEV vehicle, and the lifetime operation

| Assumptions | ICE | BEV |
|---|---|---|
| Body weight (kg) | 1,500 | 1,500 |
| Battery/Wheels weight (kg) | 46 | 342 |
| Total weight (kg) | 1,546 | 1,842 |
| Battery capacity (kWh) | | 64 |
| Lifetime distance (km) | 150,000 | |
| Well-to-Plug/Pump (g/km) | 37 | 0-190* |
| Tailpipe emissions (g/km) | 160 | 0 |

* Dependent on country energy mix.

[5] "Data gathering and analysis to improve the understanding of 2nd hand car and LDV markets and implications for the cost effectiveness and social equity of LDV $CO_2$ regulations," published by Transport & Mobility Leuven, CE Delft, TNO and Element Energy for the European Commission, DG Climate Action, as at May 2016. https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/2nd_hand_cars_en.pdf;

[6] Carbon Vehicle Partnership, Life Cycle $CO_2e$ Assessment of Low Carbon Cars 2020-2030, August 2018. https://www.zemo.org.uk/assets/reports/CONFERENCE%202013%20Final%20Report_Lifecycle%20CO2%20Assessment%20of%20Low%20Carbon%20Cars%202020-2030_PEJuly2013.pdf

[7] "World record Volvo hits 5 million km", published by Unique Cars Magazine as at 14 August 2016. https://www.tradeuniquecars.com.au/news/1608/world-record-volvo-hits-5-million-km

## The GREET model

We have used the GREET (Greenhouse gases, Regulated Emissions, and Energy Use in Transportation) model from the US Department of Energy's Argonne National Laboratory for the $CO_2$ calculations[8]. This has a lot of flexibility to model for specific examples.

The GREET model is a widely used LCA model, aimed at estimating the lifecycle emissions from material extraction and production as well as vehicle manufacturing. It contains a significant number of vehicle/fuel systems and is constantly updated. GREET's petroleum model uses data from a number of refineries covering the majority of US production. It also uses energy balance and emission factors instead of reported emissions from individual assets. In general, and for the purpose of this analysis, we used the GREET2 2020 version and compared a conventional ICE passenger car against a full BEV.

The GREET model allows for a plethora of different scenarios, vehicle configurations, and energy mixes, but as explained above we have used an average car for each type. While there are certainly cases our analysis does not cover (such as comparing a lightweight ICE vehicle to a much heavier BEV, or a very old ICE car to a highly efficient BEV made of lightweight alloys), we believe the overall results when including such cases would be similar. In terms of energy mixes and average emissions, the default GREET model is based on US figures, however, we have introduced our own estimates as well as data from the International Energy Agency to generalise.

**The GREET model allows for a plethora of different scenarios, vehicle configurations, and energy mixes, but as explained above we have used an average car for each type.**

## Production stage

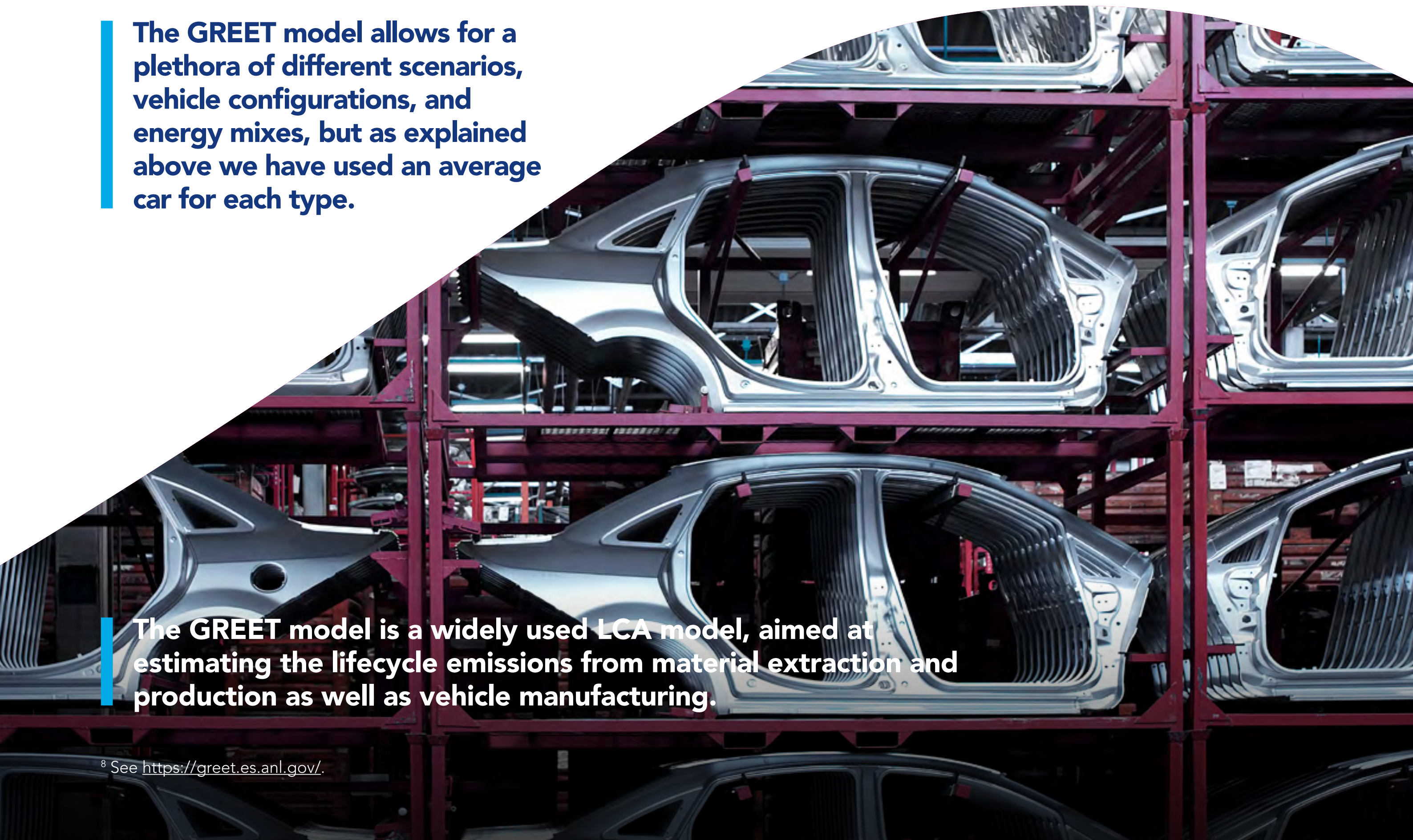
Taking all this into account, our 'average' ICE car has a production $CO_2$ footprint of 5.5 tons. Table 2 shows the breakdown of the footprint by vehicle component.

**Table 2:** Production $CO_2$ footprint for an average ICE vehicle

| Production element | $CO_2$ footprint (grams $CO_2$) | Weight (kg) | % of Emissions |
|---|---|---|---|
| **Components** | **4,173,004** | **1,558** | **75%** |
| Powertrain System | 614,482 | 230 | 11% |
| Transmission System | 310,684 | 95 | 6% |
| Chassis (w/o battery) | 1,014,597 | 381 | 18% |
| Body | 2,117,044 | 794 | 38% |
| Other (wheels, etc) | 116,197 | 36 | 2% |
| **Batteries** | **4,813** | **22** | **0%** |
| Lead-Acid Battery | 4,813 | 22 | 0% |
| **Assembly** | **673,449** | | **12%** |
| Vehicle Assembly | 673,449 | | 12% |
| **Fluids** | **676,971** | | **12%** |
| **Grand Total** | **5,528,237** | **1,558** | **100%** |

Source: Federated Hermes (internal analysis), GREET2 2020.

In comparison, our BEV has a significantly larger production $CO_2$ footprint of 8.5 tons. The breakdown by component is shown in Table 3, while Figure 3 shows the production emissions profile in terms of the materials used.



**The GREET model is a widely used LCA model, aimed at estimating the lifecycle emissions from material extraction and production as well as vehicle manufacturing.**

[8] See https://greet.es.anl.gov/.

**Table 3:** Production $CO_2$ footprint for an average BEV

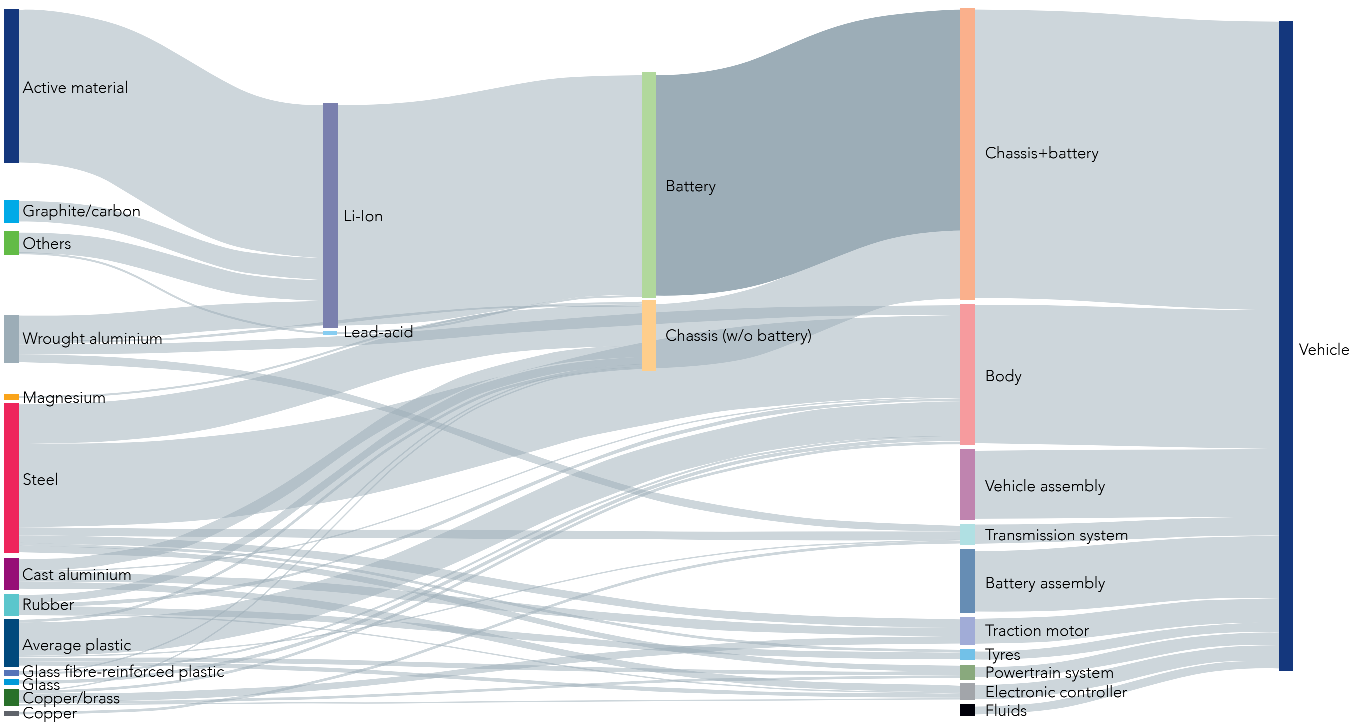
| Production element | $CO_2$ footprint (grams $CO_2$) | Weight (kg) | % of Emissions |
|---|---|---|---|
| **Components** | **4,134,110** | **1,536** | **49%** |
| Powertrain system | 182,063 | 68 | 2% |
| Transmission system | 275,164 | 84 | 3% |
| Chassis (w/o battery) | 966,738 | 363 | 11% |
| Traction motor | 361,464 | 140 | 4% |
| Electronic controller | 215,304 | 88 | 3% |
| Body | 2,017,181 | 756 | 24% |
| Wheels | 116,197 | 601 | 1% |
| **Batteries** | **2,800,012** | **306** | **33%** |
| Li-Ion battery | 2,795,199 | 296 | 33% |
| Lead-Acid battery | 4,813 | 10 | 0% |
| **Assembly** | **1,456,395** | | **17%** |
| Battery assembly | 782,946 | | 9% |
| Vehicle assembly | 673,449 | | 8% |
| **Fluids** | **112,473** | | **1%** |
| **Grand Total** | **8,502,990** | **1,842** | **100%** |

Source: Federated Hermes (internal analysis), GREET2 2020.

One more aspect we need to investigate in the production phase, is the key elements that are contributing to the $CO_2$ profile of the manufacturing of the car. For a battery electric vehicle, this is shown graphically in Figure 3, where we outline all raw materials that are required, from steel to rubber, and how these stack up to the total vehicle's $CO_2$ footprint. In this case we highlight the significant contribution the Active Material (the Lithium for the battery) which is very comparable to the contribution of steel.

**In this case we highlight the significant contribution the Active Material (the Lithium for the battery) which is very comparable to the contribution of steel.**

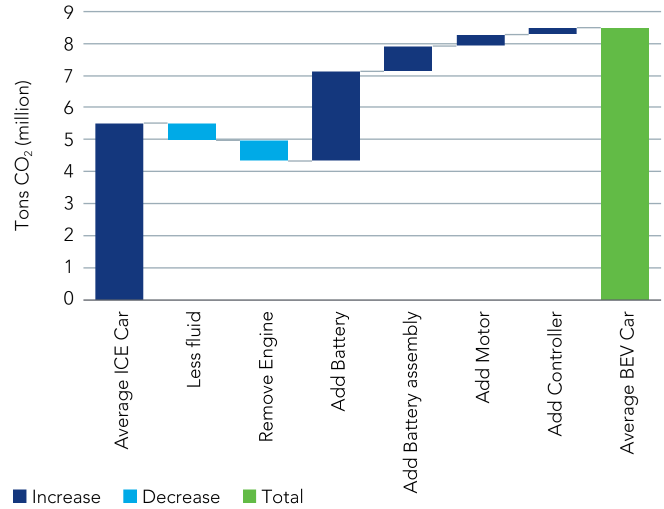
**Figure 3:** Breakdown of the production emissions profile of an average BEV




Source: Federated Hermes (internal analysis), GREET2 2020

The difference is explained in Figure 4. A BEV saves 600kg of $CO_2$ from not having an engine, transmission and fuel tank, as well as a further 560kg of $CO_2$ due to the lack of engine fluids across the vehicle's lifetime. However, an additional $CO_2$ footprint is created by the battery, electric motors and invertors. Thus, before the cars have even been driven, the BEV already has a $CO_2$ footprint which is three tons larger than the ICE car.

**Figure 4:** How the additional emissions add up in a BEV versus an ICE vehicle




Source: Federated Hermes(internal analysis), GREET2 2020.

## Operation stage

Tailpipe emission figures may be familiar to readers, as they can be found on a car's specifications sheet. The variation between the largest and smallest emitters is considerable; for example, a Citroen C1 1.0i emits 109g/km (or 175g/mile), whereas a Bentley Continental GT clocks up a whopping 396g/km (or 637g/mile).

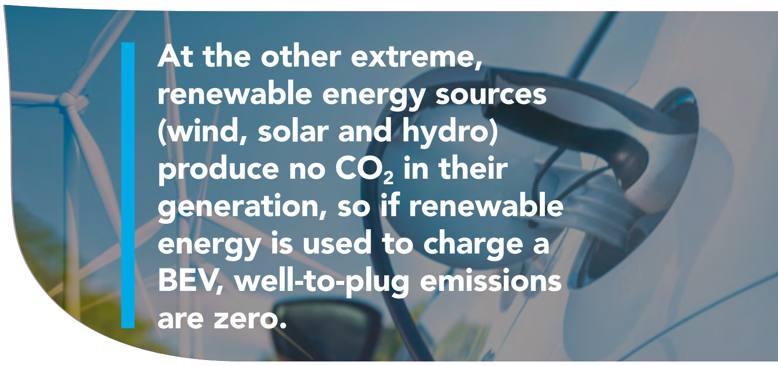
However, as well as the $CO_2$ emitted during the operation of the car, we also need to consider the $CO_2$ emitted to 'fuel' the car. The petroleum market is a global one, so well-to-pump $CO_2$ emissions don't vary much between countries; the GREET model calculates them as 37g/km (or 60g/mile). So, the total $CO_2$ emitted per kilometre for these two cars would be 146g and 433g respectively. Our 'average' car emits 160g/km at the exhaust pipe for total $CO_2$ emissions of 197g/km.

Our 'average' car emits

**160g/km**

at the exhaust pipe for total $CO_2$ emissions of

**197g/km**




Of course, our estimate of the tailpipe emissions is not necessarily applicable to other regions. For instance, in the US the average ICE vehicle emits 250g/km (as well as driving longer distances)[9]. Similarly, in China, the emissions for an average ICE vehicle are 232g/km[10]. However, these differences would not distort our conclusions; if anything they strengthen our thesis.

It's worth noting that well-to-pump emissions are relatively small compared to emissions produced during the actual operation of the car.

Coal is the dirtiest source, creating the equivalent of

**240g/km** followed by oil at

**220g/km** and natural gas at

**104g/km**

The $CO_2$ emissions during operation for a battery electric vehicle are zero. However, as with an ICE vehicle, we need to incorporate the emissions generated in getting the 'fuel' (in this case electricity) into the car in the first place (these are referred to as 'well-to-plug' emissions). For BEVs, different power generation sources have very different emission levels, so well-to-plug emissions can vary considerably. Using the GREET model, we illustrate the impact of the energy source used to charge the vehicle's battery in terms of grams per mile of $CO_2$. Coal is the dirtiest source, creating the equivalent of 240g/km, followed by oil at 220g/km and natural gas at 104g/km). At the other extreme, renewable energy sources (wind, solar and hydro) produce no $CO_2$ in their generation, so if renewable energy is used to charge a BEV, well-to-plug emissions are zero[11].

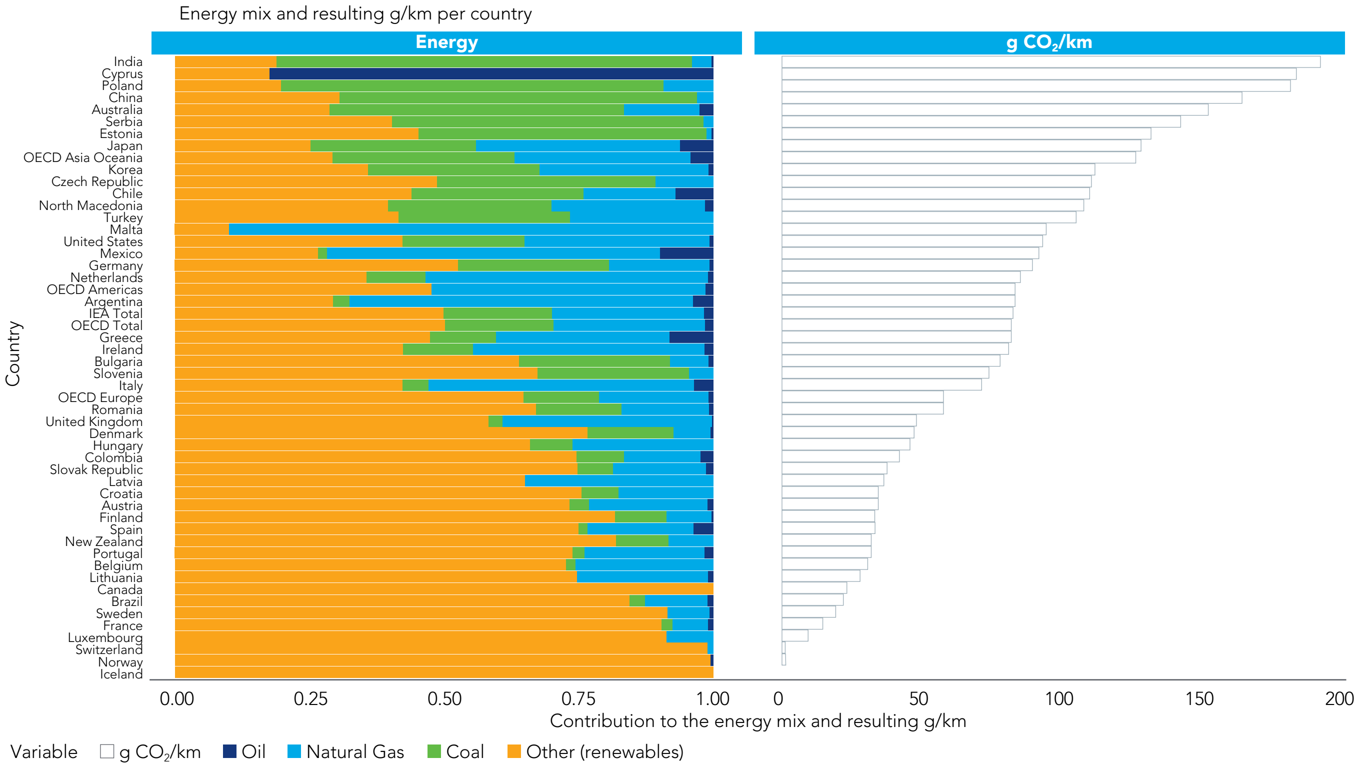
This variability means that, in contrast to the relatively consistent well-to-pump emissions for ICE cars globally, well-to-plug emissions for electric cars vary considerably depending on the local electricity generation mix. Figure 5 shows the energy mix in different countries, along with the resulting impact on the country's well-to-plug emissions profile, expressed in grams per kilometre.

[9] "Greenhouse Gas Emissions from a Typical Passenger Vehicle", published by the United States Environmental Protection Agency as at March 2018. https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle.

[10] Provincial Greenhouse Gas Emissions of Gasoline and Plug-in Electric Vehicles in China: Comparison from the Consumption-Based Electricity Perspective Yu Gan, Zifeng Lu, Xin He, Chunxiao Hao, Yunjing Wang, Hao Cai, Michael Wang, Amgad Elgowainy, Steven Przesmitzki, and Jessey Bouchard

[11] We have not included the $CO_2$ emitted in the construction of renewable energy assets since these costs are amortised over their working lifetimes and would thus be very small in terms of grams per mile. However, we do acknowledge their presence.

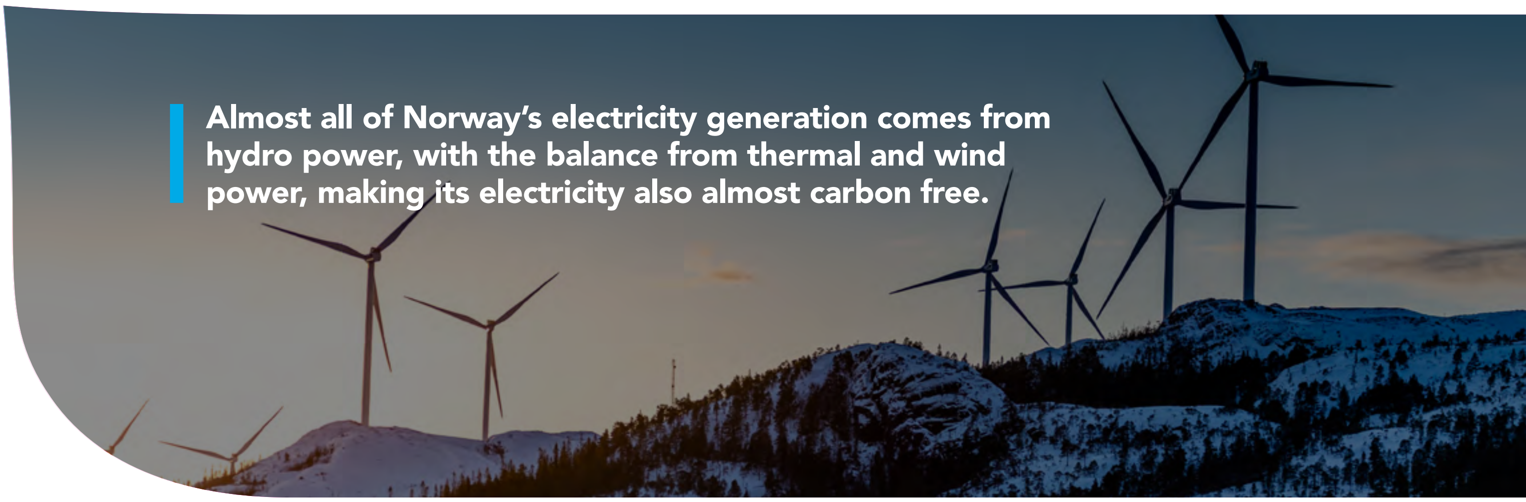
**Figure 5:** Impact of the current energy mix of countries on well-to-plug emissions for BEVs (data is from IEA, YTD until April 2021)




Source: Federated Hermes (internal analysis), IEA, September 2021.

As can be seen, countries with a high proportion of coal or oil in their energy mix, including Poland, China and India, generate more than 160 grams of $CO_2$ per kilometre. This means that BEVs run in these countries have an emissions profile which is comparable to that of traditional ICE vehicles. Poland generates over 80% of its electricity from fossil fuels, with the vast majority of this from coal. Although this is a significant improvement from the situation a decade ago, it does mean that it has one of the worst $CO_2$ footprints for electric cars in the world – ironic given Poland's ambitions to be one of the leading producers of electric car batteries in Europe. This prompts the question: should EV penetration be encouraged in countries with a high proportion of fossil-fuels in their energy mix, or should more effort be placed first on decarbonising these countries' electricity supply?

In contrast, countries with very high renewable energy penetration, such as Sweden, Denmark or Finland, have a much more appealing profile of less than 60 grams per kilometre. Switzerland's electricity generation sector is dominated by nuclear and hydro, and so is virtually carbon free. Similarly, almost all of Norway's electricity generation comes from hydro power, with the balance from thermal and wind power, making its electricity also almost carbon free. As a result, running electric cars in these two countries truly does offer net-zero motoring – if you exclude the production footprint.



# Total $CO_2$ footprint

Armed with the $CO_2$ figures for production and usage, we can now compare the total lifecycle emissions for ICE and electric cars. As we have seen, the $CO_2$ production footprint for BEVs is higher than for ICE cars, but BEVs typically emit less $CO_2$ when in use. There is therefore effectively a 'breakeven' point, in terms of mileage, beyond which an electric car will have lower total lifecycle emissions than an ICE vehicle.

As a reminder, we have assumed:

- The average distance covered over the lifetime of a vehicle is 150,000km
- For an ICE car, we have calculated an average well-to-pump footprint of 37 grams of $CO_2$, and assumed average exhaust emissions of 160 grams of $CO_2$ per km

Based on these figures:

- An average ICE car would have a lifetime $CO_2$ profile of 35 tons, 84% of which would be generated during the operational phase of the vehicle
- On the flip side, an average BEV with a 64KWh battery, operating in the United States[12], would generate 22 tons of $CO_2$, with 62% of that emitted during operation
- In Europe, the same vehicle would generate 17 tons, with 50% emitted during operation

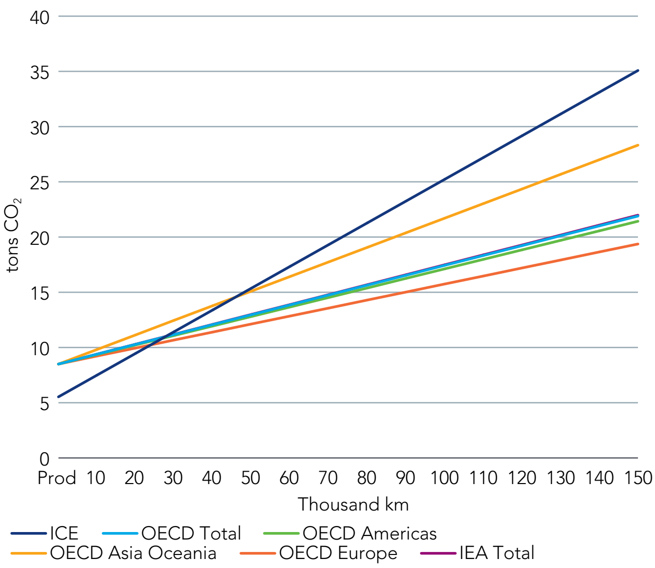
To illustrate the impact of the different energy mixes, Figure 6 and Figure 7 show the lifecycle $CO_2$ profiles of an average ICE car and an average BEV in different regions. Once again, we have used the GREET model for the well-to-pump data, as well as the translation between energy generation and $CO_2$

The average distance covered over the lifetime of a vehicle is

**150,000km**

production. In terms of the carbon emissions for the ICE car during operation, we have used an average $CO_2$ profile of a vehicle in Europe using the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) methodology, as at the latest data cycle[13]. The energy mixes, and thus the translation to grams of $CO_2$ per km comes from the IEA.

**Figure 6:** Cumulative $CO_2$ emissions profiles of an ICE vehicle vs a BEV in different regions, showing breakeven point for different energy mixes




Source: Internal analysis, GREET2 2020 and IEA 2021.

In Table 4 we show the lifetime emissions profile of a BEV in various regions, comparing these with the profile for a typical internal combustion engine car. The latter is based on the assumption of emissions of 160g/km for all ICE vehicles in all regions.

**Table 4:** Summary of lifetime emissions profile

| | ICE | BEV OECD Total | BEV OECD Americas | BEV OECD Asia Oceania | BEV OECD Europe | BEV IEA Total |
|---|---|---|---|---|---|---|
| Production (tons $CO_2$) | 5.53 | 8.50 | 8.50 | 8.50 | 8.50 | 8.50 |
| Operation (tons $CO_2$ per 150,000 km) | 35.08 | 21.90 | 21.43 | 28.32 | 19.37 | 21.98 |
| Approximate 'break-even point' | Not applicable | 28,000km | 27,000km | 46,000km | 24,000km | 38,000km |

Federated Hermes (internal analysis), GREET2 2020.

Of course, ICE vehicles differ to some extent across regions (for instance those in the US have higher average tailpipe emissions than European ones). If we introduce appropriate operational emissions by region, total lifetime emissions for a typical ICE vehicle and BEV for the United States, Europe and China are shown in Figures 7a and 7b below respectively.

[12] It should be noted that the average ICE in the United States emits more than 165g/km, but we kept this value for this analysis

[13] As found here: https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-20.

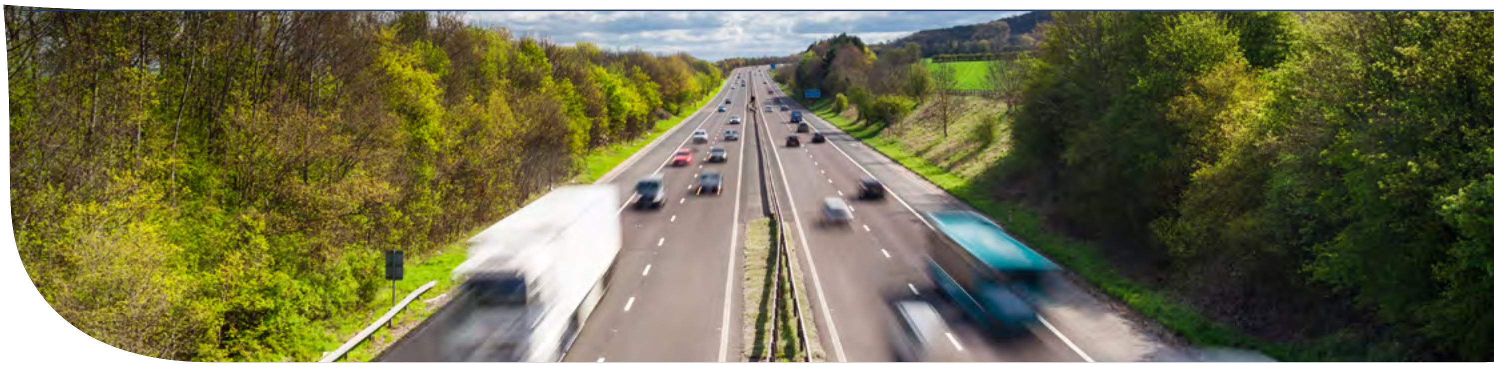
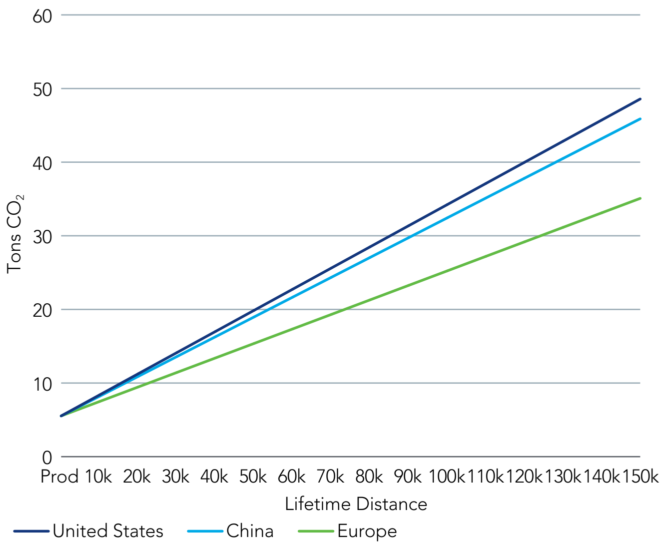
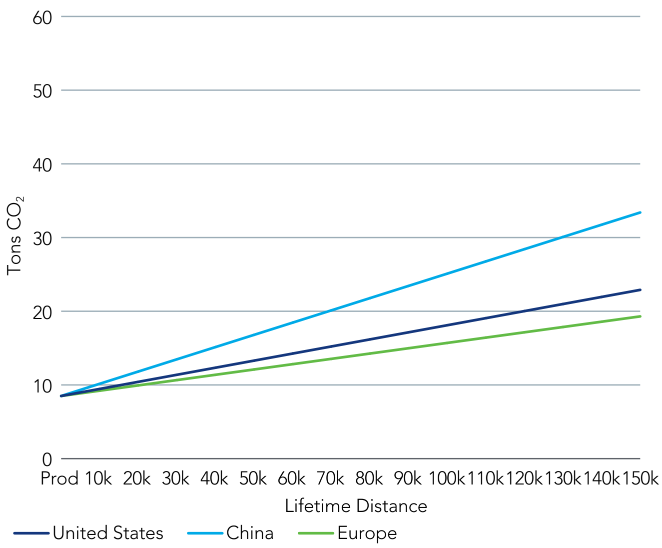


**Figure 7a:** Lifetime emissions profile for an ICE vehicle in US/China/Europe including regional tailpipe emissions




Source: Federated Hermes (internal analysis), GREET2 2020.

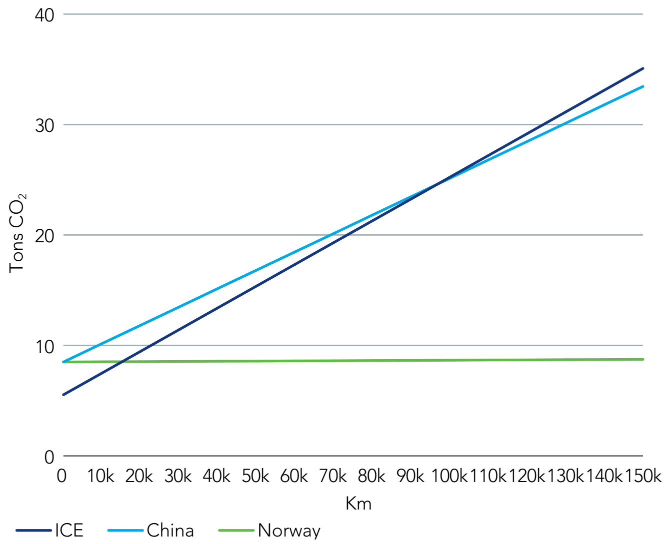
**Figure 7b:** Lifetime emissions profile for a BEV in US/China/Europe




Source: Federated Hermes (internal analysis), GREET2 2020, and IEA.

The proportion of fossil fuel versus renewable energy used to generate electricity in a specific country can vary considerably. This can have a noticeable impact on the emissions profile of a BEV. To illustrate the point, Figure 8 and Table 5 show the cumulative $CO_2$ emissions profiles for an ICE vehicle versus a BEV in China and Norway respectively – two countries which have very different energy mixes.

**Figure 8:** Cumulative $CO_2$ emissions profile of an ICE vehicle vs a BEV in Norway (90% renewables) and China (25% renewables), showing breakeven points




Source: Federated Hermes (internal analysis), GREET2 2020, and IEA.

**Table 5:** Summary of lifetime emissions profle of China (70% fossil fuel), and Norway (1% fossil fuel)

| | ICE | BEV China | BEV Norway |
|---|---|---|---|
| Production (tons $CO_2$) | 5.53 | 8.50 | 8.50 |
| Operation (tons $CO_2$ per 150,000km) | 35.08 | 33.45 | 8.74 |
| Approximate 'Break-even point' | NA | 97,000km | 17,000km |

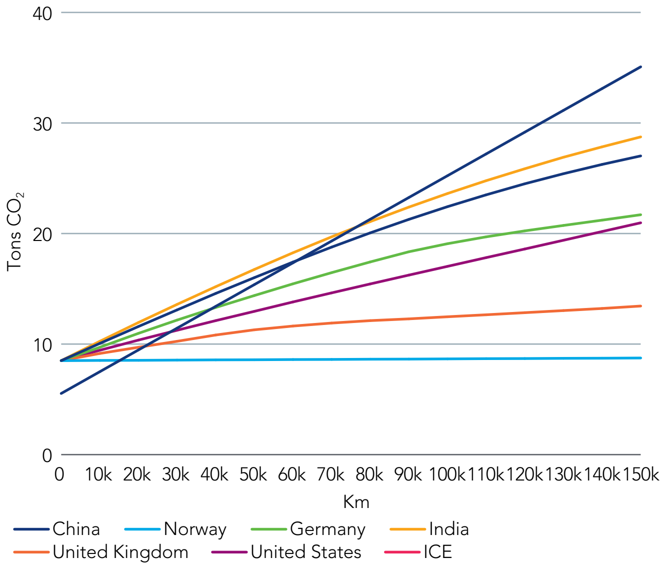
Source: Federated Hermes (internal analysis), GREET2 2020.

The assumed environmental benefits of BEVs means that governments offer significant incentives to encourage consumers to switch to electric cars. These include both financial incentives such as grants, discounts and toll exemptions, and practical measures such as allocated parking zones and charging bays. However, our analysis shows that in some countries the environmental case for BEVs is less clear cut than might be expected.

That said, the above projections lack a very significant factor which makes the BEV far more appealing, and that is the growing proportion of renewable energy in countries' energy mixes. Taking data from strategic research provider Bloomberg NEF (BNEF) for each country's expected future energy mix, the total $CO_2$ profiles for a BEV would change significantly. Figure 9 shows projected cumulative $CO_2$ emissions for a sample of countries based on estimates of future levels of renewable power generation.

While this analysis may appear to penalise the ICE alternative, it should be noted that the emissions performance of an ICE vehicle is unlikely to change much over its lifetime, since well-to-pump emissions cannot easily be improved. On the other hand, any improvements to the energy mix of the countries in which the BEV operates would have a direct impact on the vehicle's emissions profile.

**Figure 9:** Projected emissions profiles of an ICE vehicle vs. a BEV based on BNEF estimates of future renewable energy share in the energy mix




Source: Federated Hermes (internal analysis), GREET2 2020, BNEF, and IEA.

For instance, in China the latest data indicates only 30% of energy currently comes from renewable sources. However, projections for the country's energy mix would improve its well-to-plug $CO_2$ footprint by 15%. Similar projections would improve the well-to-plug footprint in India by 21%, and in the United Kingdom by 32%.

Many governments have introduced incentives for consumers to purchase BEVs. For example, in the US:

- The Federal Government gives a tax credit of US$7,500 for the purchase of an electric vehicle (provided that the manufacturer has reached 200,000 vehicles sold)[14]
- Individual US states can have additional incentives as well, such as California, which adds $1,000 for a BEV per household[15]

In Europe, all countries provide either grants or tax incentives for consumers. For example:

- France offered a €7,000 grant in 2020 (up to 27% of the vehicle price), which dropped to €6,000 in 2021 and will fall to €5,000 in 2022[16]
- Germany offers a €9,000 grant (falling to €8,000 for cars costing between €45,000 and €65,000)[17]
- Sweden offers a €6,000 grant (with a cap of 25% of the vehicle price)[18]
- Norway is offering a €2,000 grant for vehicles under €50,000 until the end of 2021[19]
- Greece offers a €5,500 grant, as well as a scrappage scheme[120]
- The Netherlands offers a €4,000 grant towards any new BEV[21]
- Interestingly enough, Poland offered only VAT benefits for BEVs and these ended in early 2021[22]

There are several points to note from these results:

1. The $CO_2$ emission reduction achieved by switching from an ICE vehicle to a BEV varies by country. Since materials shortages constrain current BEV production, it could be argued that BEVs should be allocated to countries that will see the greatest benefit. This is unlikely in practice for political reasons and due to the level of coordination required. However, it is interesting that Germany offers an €8,000 grant to save 12 tons of $CO_2$ over the vehicle's lifetime, while the Netherlands save a similar amount of $CO_2$ for half that cost[23].
2. For most countries, it is the operational phase that makes up the majority of lifetime $CO_2$ emissions. By producing cars that are zero emission in the operational phase, car manufacturers have done their part. As fleet emission targets for carmakers become ever stricter around the world, the proportion of EVs is likely to increase rapidly over the next decade. Eventually, a tipping-point will be reached when it will become uneconomical to continue to produce ICE cars. After that, further reductions in the $CO_2$ footprint of cars in the operational phase will largely come from individual countries increasing the share of renewables in their electricity generation mix.
3. As a guide, a 1% increase in renewables can improve wall-to-plug emissions by 2.4g/km when replacing coal, 2.2g/km when replacing oil, or 1g/km when replacing natural gas.

[14,15] Source: https://pluginamerica.org/.
[16-22] Source: https://www.eafo.eu/.
[23] The Netherlands have a lower percent of renewable energy sources than Germany, however Germany has a higher contribution of coal plants in its energy mix. The saving is the difference between the lifecycle emissions of a BEV in each country vs the ICE one.

# Reducing the production $CO_2$ footprint

Focusing now on the production phase, it is easy to see the impact of metals on a BEV's carbon footprint. In Table 6 we show the amount of steel, aluminium, copper, and brass used in an average battery electric vehicle. Again, this production breakdown is based on our previously explained assumptions and can be adapted for any case of vehicle. It should be noted that steel, aluminium, and copper are also used in the production of the lithium-ion battery.

Our calculations show that about 41% of the total production footprint of a BEV comes from the metals used; the main contributor is steel, which accounts for about a quarter of the total production footprint. It is therefore clear that any improvement in the production of steel, whether through using renewable energy in an electric arc furnace or hydrogen in a blast furnace, could significantly reduce the vehicle's footprint. This will be the focus of our second paper in this series.

**Table 6:** Contribution of metals to the production $CO_2$ footprint of a BEV

| Metals | Total weight (kg) | Total emissions (grams $CO_2$) | % Total Weight | % Total Emissions |
|---|---|---|---|---|
| Steel | 890 | 2,159,129 | 49% | 25% |
| Aluminium | 257 | 1,043,406 | 14% | 12% |
| Copper/ Brass | 116 | 319,920 | 6% | 4% |
| **Grand Total** | **1,264** | **3,522,455** | **69%** | **41%** |

Source: Federated Hermes (internal analysis), GREET2 2020.

Once again, our estimates regarding the production of steel are based on the GREET model. This assumes that on average the steel used in vehicle production is 21% hot rolled, 19% cold rolled, and 60% galvanized rolled, with the raw material used 74% virgin steel and 26% recycled. For virgin steel, it is assumed that a blast furnace is used, whereas for recycled steel, the assumption is the use of an electric arc furnace. From an emissions perspective, GREET assumes that the electric arc furnace emits 70% less $CO_2$ than the blast furnace.

# Conclusions

The image of the near-silent electric vehicle leaving behind it little more than a slight disturbance of the air is an appealing one which is undoubtedly contributing to the rapid growth in EV sales. There is a natural tendency to want to reduce the argument to 'electric: good – petrol and diesel: bad'. However, as we have shown, proper analysis emphasises that the situation is more complicated.

We have shown that the carbon emissions during production are significantly higher for electric cars than for combustion-engined cars. Fortunately, there are ways that this can be reduced. From our recent conversations with Tier 1 and 2 auto component suppliers, environmental considerations are having an increasingly important role in contract discussions with OEMs. We are therefore encouraged that there is industry support for decarbonising production. This will be the subject of our next paper, along with the resulting financial implications.

On the operational side, electric vehicles are significantly greener than petrol cars but they still carry a 'hidden' carbon stigma; that of a fossil fuel based charging infrastructure. As we have shown, the lifetime emissions footprint of a vehicle is highly dependent on the country where the vehicle is operating – a country heavily dependent on fossil fuels for electricity production may even yield a higher $CO_2$ profile for the BEV.

Even in cases where countries do not have the greenest of mixes in their electricity generation, there is potential for BEVs to improve their operational carbon footprint in line with the countries' transition to renewable energy; an advantage not available to ICE vehicles as their pollution will actually increase over time.

In conclusion, while there is still a long road ahead to make cars as green as they could be, at least we are headed in the right direction.

Federated Hermes
International

## Federated Hermes

Federated Hermes is a global leader in active, responsible investing.

Guided by our conviction that responsible investing is the best way to create long-term wealth, we provide specialised capabilities across equity, fixed income and private markets, multi-asset and liquidity management strategies, and world-leading stewardship.

Our goals are to help people invest and retire better, to help clients achieve better risk-adjusted returns, and to contribute to positive outcomes that benefit the wider world.

All activities previously carried out by Hermes now form the international business of Federated Hermes. Our brand has evolved, but we still offer the same distinct investment propositions and pioneering responsible investment and stewardship services for which we are renowned – in addition to important new strategies from the entire group.

## Our investment and stewardship capabilities:

- **Active equities:** global and regional
- **Fixed income:** across regions, sectors and the yield curve
- **Liquidity:** solutions driven by four decades of experience
- **Private markets:** real estate, infrastructure, private equity and debt
- **Stewardship:** corporate engagement, proxy voting, policy advocacy

For more information, visit **www.hermes-investment.com** or connect with us on social media:



BD008811 0011637 10/21