Electric Car?

350PPM
Capitalist Solutions to Climate Change

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Written October 2020.

Introduction

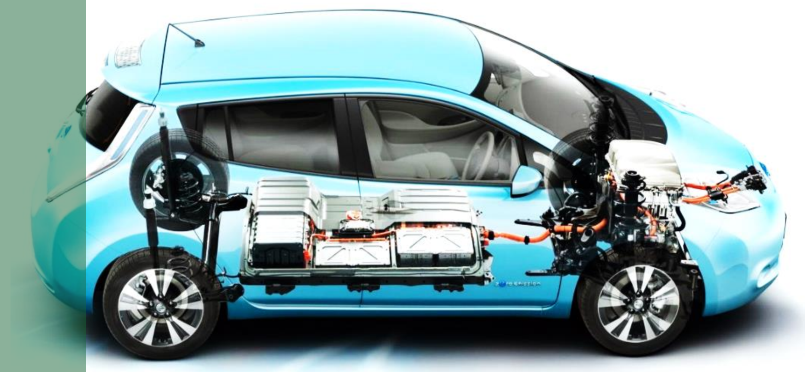
This report aims to help answer the question '*should my next car be electric?*'. As some readers may have found already this is not a straightforward question, nor is there a single, simple answer for all.

For starters, there are several types of car that are included as 'electric vehicles' (EVs). Fully electric EVs are propelled only by an electric motor - or several - and consequently are 'fuelled' solely with electricity. By contrast, hybrid EVs use both an electric motor *and* internal combustion engine, and are fuelled with petrol or diesel, as well as electricity if the hybrid is a plug-in.

Secondly, there are many facets to an answer to this question. The critical considerations are:

- **Cost** - EVs are generally more expensive to buy than conventional equivalents, even including the available UK government subsidy, with no really cheap EVs currently on the market. On the other hand, EVs typically have much lower running costs, especially fully electric versions.
- **Range and recharging** - fully electric EVs have a limited range before they must be plugged in to recharge, a process that takes a lot longer than refuelling a conventional car. This makes them ideal for a subset of potential owners - those who don't often make long journeys (or own another, longer range car) and have access to a private charging point. For longer journeys, the public recharging infrastructure is not yet comprehensive but is growing rapidly. Hybrid EVs offer an alternative for those needing a longer range.
- **Environmental impact** - a key advantage of fully electric EVs is their complete lack of tailpipe emissions, eliminating a significant health risk near roads. They do, however, emit greenhouse gases during their manufacture and, if derived from fossil fuels, the generation of electricity used to recharge them. In general though, across their lifecycle fully electric EVs are *today* considerably greener than conventional cars. And are only likely to become more so in the future. The environmental picture is less compelling for hybrids, with owner behaviour key for plug-ins.

Beyond their green credentials there are plenty of other reasons why you might buy an EV, all of which we explore inside. These include their almost universally impressive driving performance, the inclusion of hi-tech features - such as limited self-driving - and often funky, futuristic designs.



Contents

Types of EV

In this section we outline the types of EV available on the market. Note that all sections have a short version and then a skippable longer version.

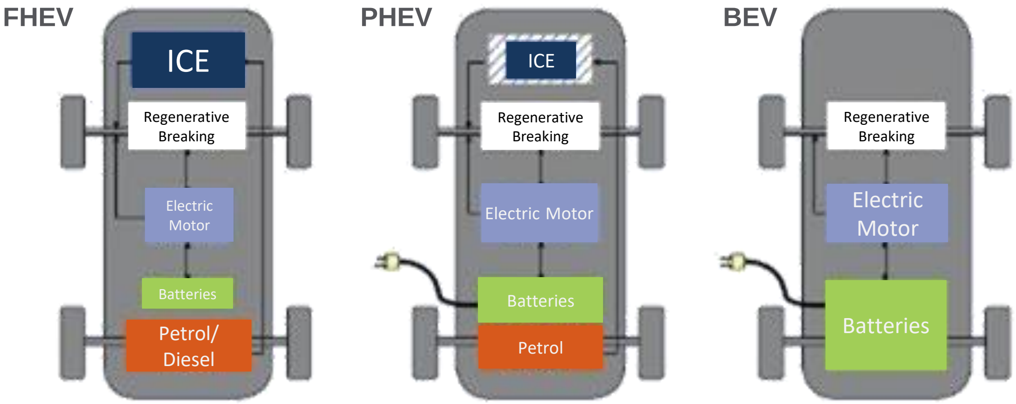
Short Version

There are two main types of EV, each with associated acronyms which will be used with impunity throughout this document:

- **Battery EVs** (BEVs), also known as 'fully' or 'pure' electric vehicles. BEVs rely solely on electricity stored in rechargeable batteries to power one or more electric motors. This makes them quiet, efficient, emissions-free and responsive. However, they have a limited range and you have to plug them into the grid to recharge the batteries, a lengthy process. BEVs - in fact all EVs - recoup energy through regenerative braking, a process which converts the car's movement into electricity.
- **Hybrid EVs** (HEVs) derive power from some split between a liquid fuel and electricity. This gives them some of the features of BEVs, while retaining some of the range and emissions associated with conventional internal combustion engine vehicles (ICEVs). The main types of hybrid are:
  - **Full hybrid EVs** (FHEVs), also known as 'conventional' or 'self-charging' hybrids. FHEVs have a small electric motor and batteries alongside an internal combustion engine (ICE). They can drive solely on electric power, but only for a few miles, at low speeds. Mostly they rely on the engine, or engine and electric motor acting together. You don't need to plug in FHEVs to recharge them, you simply fuel with petrol or diesel as normal.
  - **Plug-in hybrid EVs** (PHEVs) have a larger motor and batteries than FHEVs. This means they have a longer (~30 miles) and faster electric-only mode during which they're BEV-like and beyond which they're FHEV-like. You plug in PHEVs to recharge them, as well as fuelling them with petrol.

Going from FHEV, to PHEV, to BEV, the engine is scaled down and then removed in BEVs, while the electric motor and batteries are scaled up. See diagram below.

Skip this section and go straight to things to consider when buying an EV, or read on for more detail.



Example BEV - BMW i3.
Motor at back,
batteries in middle.

Battery Electric Vehicle (BEV)

Battery EVs (BEVs), also known as 'pure' or 'fully' electric vehicles, replace a combustion engine powered by fossil fuels with an electric motor - or several - powered by electricity stored in rechargeable batteries. A BEV is 'refuelled' by plugging it into an external source of electricity to recharge the batteries. **Figure 1** shows the main components. Note that BEVs don't have an exhaust system as they don't need one - they have no tailpipe emissions. We explore BEVs' green credentials in detail later.

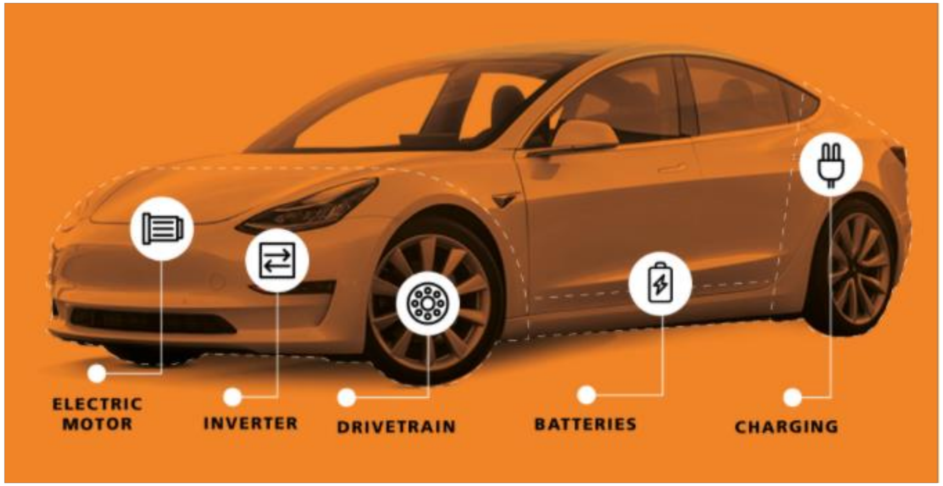


Figure 1 - key components of a BEV. Image source: EDF.

To add a little detail about the components shown in **Figure 1**:

Batteries - store the electricity required to run the BEV, electric motor(s) included. Most if not all BEVs use lithium-ion batteries, positioned low in the mid-section of the vehicle. The battery capacity is given in kWh (a unit of energy). This is equivalent to the size of the fuel tank in a conventional ICEV and determines how far the car can travel without recharging - the range.

BEVs have an official range of ~100-350+ miles depending on model. As we get into later, the official range is usually an overestimate.

Charging socket - allows for external charging of the battery. We go into detail about charging later but to outline BEVs can potentially be charged at home or work, or at a growing network of public charging points. Recharging is a much slower but cheaper process than refuelling an ICEV, with three speeds of charging available - **slow**, **fast** and **rapid**. Very roughly speaking, slow charging is at least an overnight process (~10+ hours), fast charging takes less than ten hours, and rapid charging about an hour.

Inverter - converts DC electricity coming from the battery to AC electricity used by the motor(s).

Electric motor - supplies rotational power to the drivetrain, with the motor power given in kW, BHP or PS. Some BEVs use two motors to drive the front and back wheels independently. Use of electric motors make BEVs cleaner, quieter and fundamentally more efficient than ICEVs, with fuel-to-wheel efficiency of ~85% for a typical BEV, compared to ~30% for a typical petrol car. Efficiency is helped by the ability of electric motors to operate in reverse as generators. This gives BEVs the ability to recuperate energy, charging the batteries when the vehicle slows. This is known as **regenerative braking** and can reduce net energy usage considerably, especially in stop-start traffic and going downhill. Electric motors have other advantages, such as the ability to provide instant torque (rotational force) and constant high torque at low speeds. This means BEVs have inherently good acceleration.

Drivetrain - transmits power from the motor(s) to the wheels. BEVs tend to have a single-speed transmission with no gearbox. BEVs are therefore similar to a conventional automatic in that you don't have to change gears. It's more than this though - there simply aren't any gears to change. BEVs can therefore accelerate smoothly, rather than lurching through gear changes.

In general, BEVs have a simpler design than ICEVs, with roughly 90% fewer moving parts, reducing maintenance requirements considerably.

Hybrid EV (HEV)

ICEVs derive their power from a liquid fuel; BEVs from electricity; hybrid EVs (HEVs) derive their power from some split between a liquid fuel and electricity in an attempt to get the best of both worlds - some BEV-like function but a longer range. Note that, unlike BEVs, which reduce complexity compared to ICEVs, hybrids go the other way, adding complexity and potentially weight and cost as well. HEVs still need to shift between gears like ICEVs but this is usually done automatically.

At the highest level, hybrids are classified as having either a parallel or series configuration. This distinction tells you what the liquid fuel or electricity is powering. **Series hybrids** only use electric motors to drive the wheels, making them similar to BEVs. However, they also have a small combustion engine that can be used as a generator to recharge the battery, if required. By contrast, **parallel hybrids** can drive the wheels using power from *both* an electric motor *and* a combustion engine, including simultaneously. Most hybrids on the market are parallel hybrids. More detail on series and parallel HEVs.

Although an important distinction, a more commonly encountered classification system for hybrids is shown in **Figure 2**, below left. Here hybrids are classified as micro, mild, full or plug-in. This nomenclature may not be used by all manufacturers exactly like this. As we move from micro to mild to full and then plug-in hybrids, the power available from the batteries and of the electric motor(s) are scaled up - adding various electric functions as detailed below - while the combustion engine is scaled down. This was illustrated well 2 pages back. Therefore, the 'higher' hybrids have lower tailpipe emissions potential, though real-life emissions will vary, as explored later.

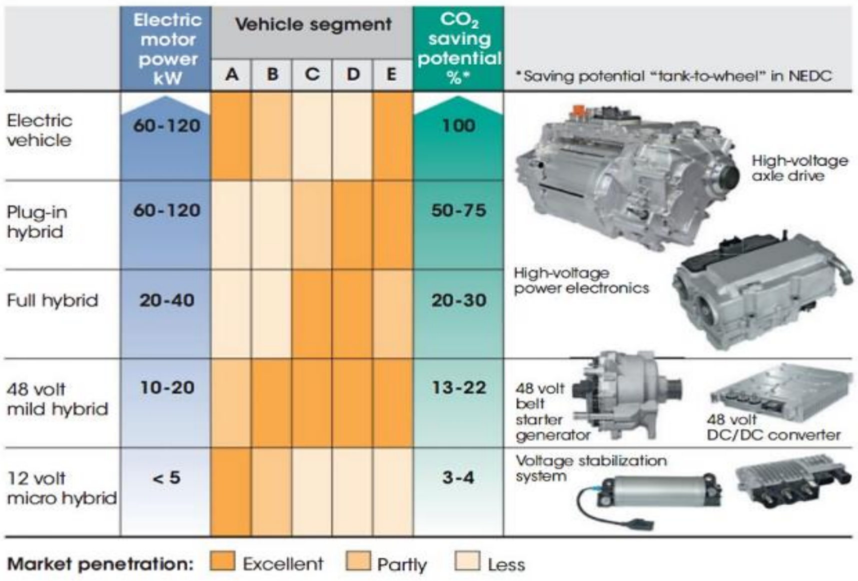


Figure 2 - types of HEV. Source: x-engineer. Vehicle segments defined.

Looking now at each hybrid in turn, and the electric functions they add…

Micro hybrids are essentially ICEVs but add certain energy and emissions saving functions, also available on all higher EVs, namely: **idle stop/start** - automatically switching off the internal combustion engine when the vehicle is stationary - and **regenerative breaking**, mentioned earlier as a useful feature of BEVs.

Mild hybrids (MHEV) add **electric torque assistance** on top of the functions mentioned for micro hybrids. This means the electric motor can provide additional torque to the wheels alongside the combustion engine, improving the overall torque response of the powertrain. Mild hybrids are sometimes described as simply 'the next generation' of ICEVs and are becoming increasingly common. As they are not greatly different from ICEVs we say little more about about micro or mild hybrids.

Full hybrids (FHEV), also called 'conventional' or 'self-charging' hybrids, can operate for a limited range in **electric-only mode**. In this mode the internal combustion engine is switched off and the vehicle is powered solely by the electric motor. Due to battery limitations, this mode is only possible at very low speeds and only for a few miles; more typically, FHEVs use both power sources or just the combustion engine.

For those who want to dig a little deeper, **Figure 3** shows the key components of a FHEV and where the power flows in its various modes. Note that all types of hybrid can self-charge their battery to some extent while driving along, as shown in **Figure 3**, diagram (c).

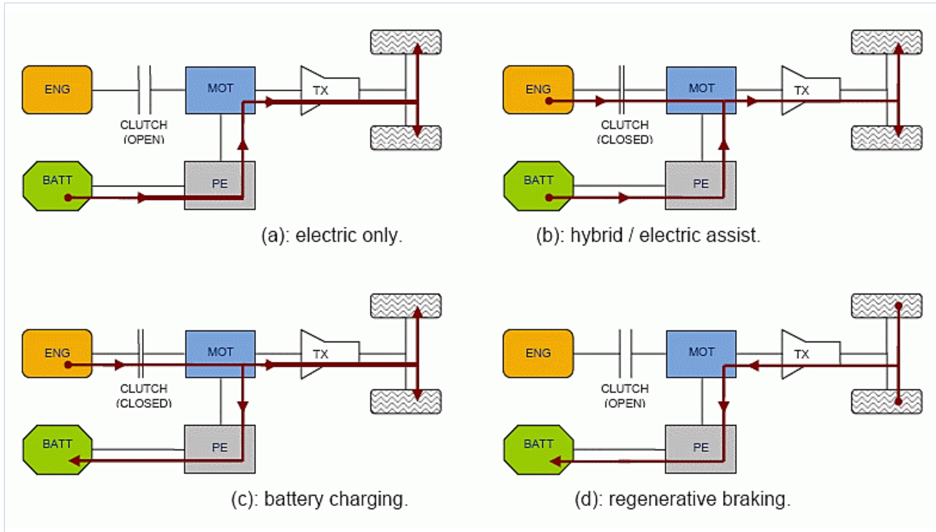


Figure 3 - the key components of a parallel configuration FHEV and the modes in which it can operate. Source: x-engineer.
Legend: ENG - internal combustion engine, MOT - electric motor/generator, TX - transmission, BATT - high voltage battery, PE - power electronics module (MOT controller).

Plug-in hybrids (PHEV) scale up the electric motor such that they cannot rely solely on self-charging as lower forms of HEV can. They therefore add an electrical socket to externally recharge their larger batteries, though you still refuel them with petrol as well - they are dual fuel. The advantage of such a setup is that the overall range is not greatly compromised compared to ICEVs, but the electric-only mode can function at much higher speeds, and over a longer range than FHEVs - 20-40 miles is common. PHEVs demand more from their owners than other hybrids as they require regular recharging in addition to standard refuelling. Plus, although PHEVs *can* automatically control their power split, some PHEVs include various driver-activated modes such as a forced electric-only mode, a battery charging mode, or a mode that saves the battery charge for a specific part of the journey.

The driving performance and emissions of a PHEV will vary depending on the battery charge and which vehicle mode is activated, which, as we get into later, may be different from the one the user selected. If the batteries run out, a PHEV doesn't grind to a halt like a BEV would, it just becomes FHEV-like and a lot less green. However, running without any petrol is not an option as it can damage the battery, according to Toyota for their PHEVs.

Figure 4 adds to **Figure 2,** summarising the electric functions available with the different types of hybrid. Learn more about hybrids here.

Functions	Type of Hybrid			
	Micro	Mild	Full	Plug-in
idle stop/start	*	*	*	*
electric torque assistance		*	*	*
regenerative breaking	*	*	*	*
electric-only mode			*	*
battery charging (while driving)	*	*	*	*
battery charging (from grid)				*

Figure 4 - distinguishing between the types of hybrid vehicle by the electric functions they can perform. Source: x-engineer.

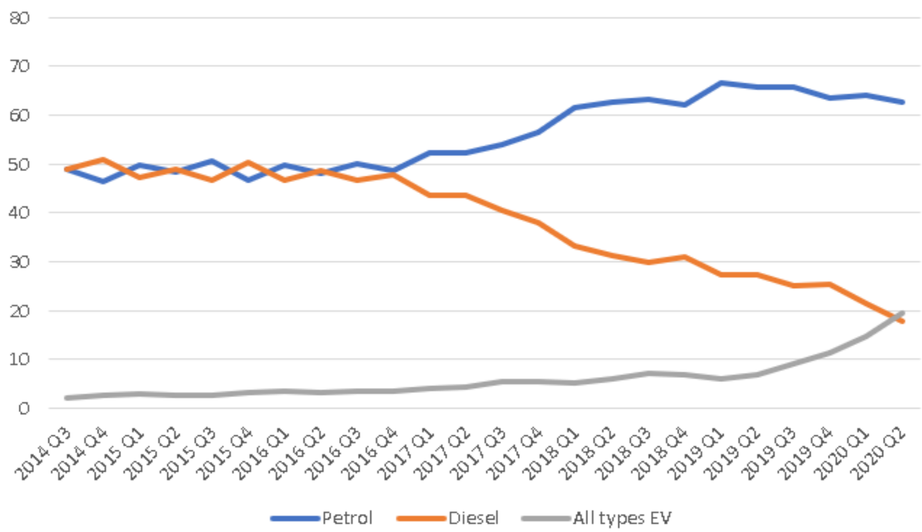


Figure 5 - % new car registrations in GB by fuel type. Source: [DfT and DVLA]().

Bestselling Types of EV

Added together, all types of EV currently account for roughly 20% of new car registrations in Great Britain, with EVs picking up market share particularly rapidly since the start of 2019. See **Figure 5**, left. Interestingly, **Figure 5** shows EVs overtaking diesel ICEVs in Q2 2020, precipitated by the [Dieselgate scandal]().

Figure 6, below left, separates out the 'All types EV' line of **Figure 5**. Non-plug-in hybrids have been most popular historically, having sold over ~600,000 to the end of Q2 2020. PHEVs have sold ~180,000 and BEVs ~130,000, both with a much more recent take-off in sales. REXs * are really a footnote in terms of sales. **Figure 7**, below, then combines all the plug-in types of EV and compares them with the non-plug-in EVs. Over 320,000 plug-in cars have been sold in GB to September 2020. We cover [the bestselling EV models]() later.

* A PHEV in series hybrid configuration is called a range-extended EV (REX). This is a BEV with a small combustion engine to recharge the battery only, not propel the car.

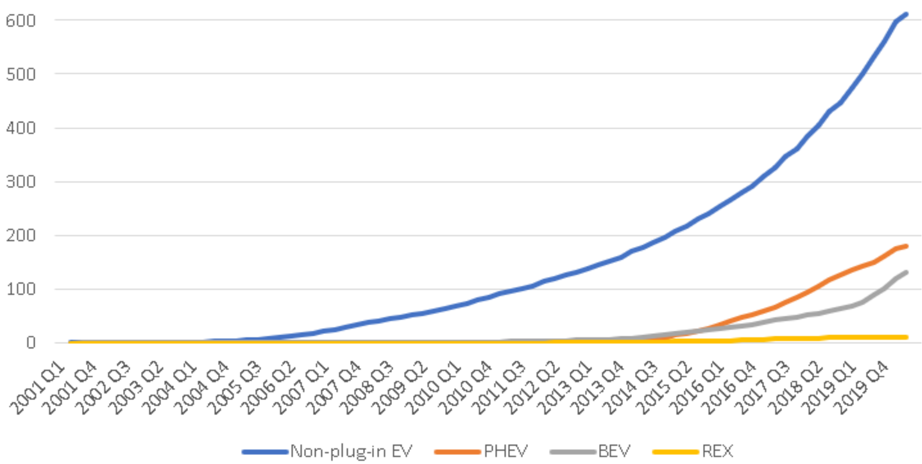


Figure 6 - thousands of cumulative new EV registrations in GB by EV type *. Source same as **Figure 5**.

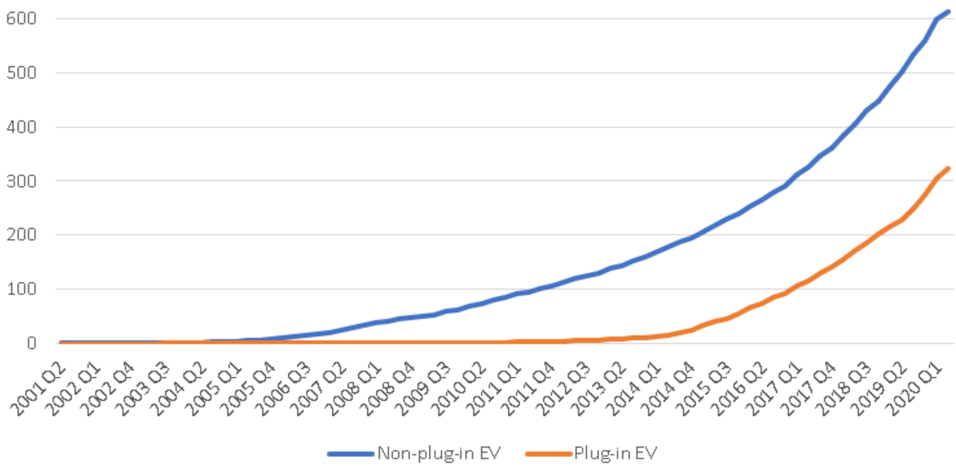


Figure 7 - thousands of cumulative new EV registrations in GB by plug-in status. Source same as **Figure 5**.

Critical Considerations

Having laid out what we mean by EV we now begin answering the question '*should my next car be electric?*'.

To help in the decision-making process we've divided our answer into 'critical' and 'other' considerations. Critical issues have the potential to make someone answer '*hell no, my next car should definitely not be electric*', regardless of all other considerations. We've included environmental impact, range and recharging, and cost as critical – you may not agree with this.

Environmental Impact

Short Version

In general, **BEVs are considerably better for the environment than ICEVs and all forms of HEV, especially if charged with 100% renewable electricity**. PHEVs have the potential to be the greenest form of hybrid, if kept charged and driven non-aggressively. For an individual environmental rating on over 60,000 cars of all types go to Next Green Car.

Looking at BEVs in more detail…

- The tailpipe emissions from ICEVs contribute both to air pollution near roads, which is potentially damaging to human health, and to global climate change.
- BEVs have no tailpipe emissions with which to contribute to air pollution near roads. They also generate less noise pollution.
- However, BEVs are likely to have higher emissions from their manufacture than ICEVs, mainly due to the batteries, and, if generated from fossil fuels, have emissions associated with the production of electricity used for their recharging. Lifetime emissions are therefore key.
- Lifetime greenhouse gas emissions are today significantly lower for BEVs than ICEVs in most cases. Using a 2019 average UK electricity mix, the lifetime emissions per kilometre for a Nissan Leaf - one of the bestselling BEVs - are about three times lower than the average ICEV.
- The Nissan Leaf's lifetime emissions can be further reduced by about a third by recharging using 100% renewable electricity.
- Looking forward, the average carbon intensity of electricity is expected to fall considerably as countries make progress towards climate change targets. By contrast, the carbon emitted from burning a gallon of petrol or diesel cannot be reduced. This implies that the BEV emissions advantage (when charging with an average electricity mix) is only going to increase.
- It is possible to make the argument that **the greenest thing to do is to switch to a BEV *immediately***; the carbon debt is quickly paid back.

Skip to the next critical consideration about range and recharging.

Why ICEVs are Bad for The Environment

ICEVs are considered worse for the environment than BEVs chiefly because of their tailpipe emissions. **Figure 10**, below, shows the approximate composition of ICEV exhaust, which differs depending on whether the fuel is petrol or diesel. Whilst some of these exhaust components are harmless (N_2, O_2 and H_20), other components are either greenhouse gases - contributing to global climate change -, airborne pollutants - potentially damaging to human (and other organism) health -, or have other detrimental effects, such as the production of secondary pollutants, which may have their own impacts. The potentially harmful components are (* *means important*):

Carbon dioxide (CO_2) * - the main greenhouse gas.

Carbon monoxide (CO) - potentially harmful to health. Breathing in carbon monoxide reduces the ability of blood to carry oxygen and can cause symptoms ranging from mild and 'flu-like' all the way through to death at high concentrations (only likely to happen in an enclosed space).

Nitrogen oxides (NOx) * - potentially harmful to health; nitrous oxide (N_2O) is a greenhouse gas. They react with certain hydrocarbons to produce low level ozone, a greenhouse gas and primary constituent of smog. Breathing nitrogen oxides or ozone can cause respiratory and other health impacts. Nitrogen oxides also contribute to the formation of particulate matter and acid rain.

Hydrocarbons (HC) - some potentially harmful to health. Benzene (C_6H_6) in particular is carcinogenic and long-term exposure has been linked with leukaemia. However, it is present in limited amounts in exhaust emissions.

Particulate matter (PM) * - microscopic particles of solid or liquid matter suspended in the air - potentially harmful to health. Smaller particles can pass deep into your lungs, potentially leading to respiratory or heart problems. Modern diesel cars are fitted with Diesel Particulate Filters (DPF) to reduce the emission of these particles.

Sulphur dioxide (SO_2) - potentially harmful to health, though it exists at a low concentration. Contributes to the formation of particulate matter and acid rain.

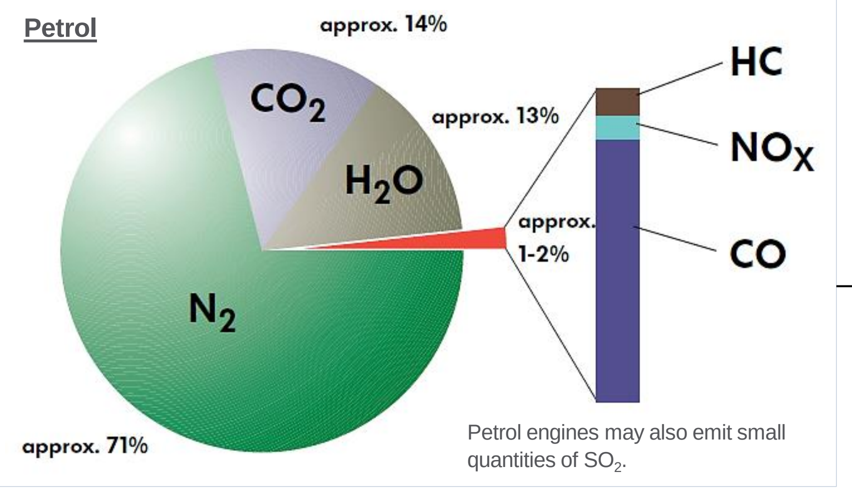
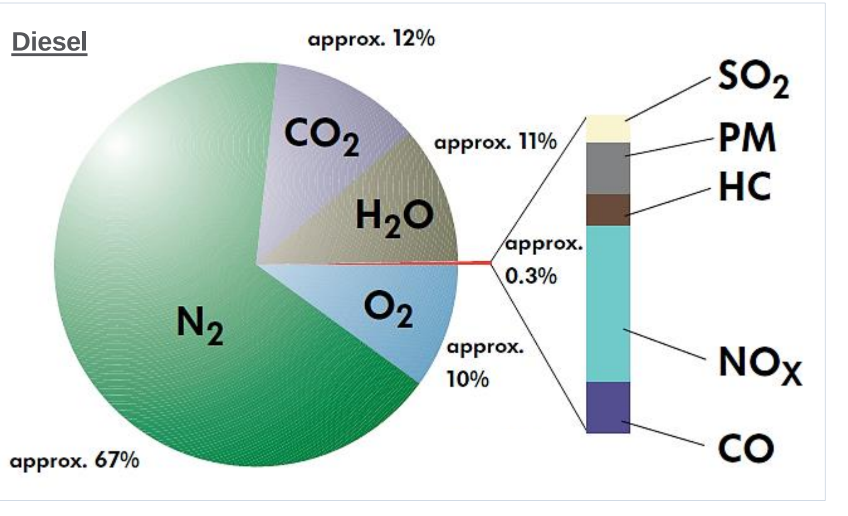


Figure 10 - ICEV exhaust composition. Image source.

— Petrol

Diesel —



UK Harm of ICEV Emissions

The evidence suggests that the combined effect of all the ICEVs on our roads is having a considerable impact on the environment and human health, together with an associated financial impact on society and individuals. Looking at the UK…

According to government statistics, **road transport use is the largest source of territorial UK greenhouse gas emissions**, accounting for more than 25% of total emissions. Whilst emissions from energy generation have fallen by over 60% since 1990 - as wind and solar have come into common usage - road transport emissions are roughly the same. This is not compatible with net-zero ambitions.

Figures from the Royal College of Physicians (RCP) suggest that around 40,000 early deaths in the UK each year are attributable to outdoor air pollution, as are a range of non-fatal illnesses. Through reduced productivity and an added burden on the health service, the annual cost is estimated at approximately £20 billion. Although not the only source, motor vehicles are a major source of air pollution. In particular, the exposure of people living near roads to high levels of particulate matter and NOx emissions is highlighted as a key health risk. One of the main recommendations from the RCP is to 'promote alternatives to cars fuelled by petrol and diesel'.

Although the UK government is phasing out the manufacture of ICEVs by 2040 (though this is likely to be moved up), this is arguably much too late.

Comparing Environmental Impact

As BEVs do not combust fossil fuels, they have no tailpipe emissions and therefore, clearly, are less polluting than ICEVs **at point of use**. They are also quieter at lower speeds, see this link for more. BEVs are a key way of reducing both local air and noise pollution near roads. However, BEVs do potentially have emissions associated with the production of electricity used for their recharging. If derived from fossil fuels this will create greenhouse gas emissions and have a local air pollution impact, though this local impact should be lower than ICEV pollution near roads (given population proximity). And, of course, all vehicles have emissions associated with their manufacture. For a fair comparison of the total environmental impact, we therefore need to consider the **lifecycle emissions** - those created throughout the lifetime of the car *and* fuel. For an individual lifetime environmental rating on over 60,000 cars go to Next Green Car. **Figure 11** shows the lifecycle stages for an ICEV and its fuel.

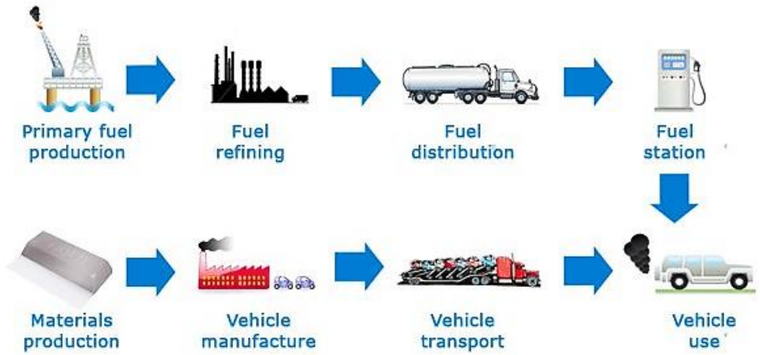


Figure 11 - the lifecycle of an ICEV and its fuel. All lifecycle stages create emissions. Vehicle disposal is not shown, but also creates emissions. Image source: Next Green Car.

Carrying out lifecycle emissions comparisons is tricky. Problem one is that we need accurate figures for the fuel-efficiency and emissions of vehicles. Official figures, derived from standardised lab testing, are not necessarily reflective of figures obtained in the real world. With the introduction in 2017 of the Worldwide Harmonised Light Vehicle Test Procedure (WLTP), which replaces the New European Drive Cycle (NEDC) in the EU, these discrepancies are expected to be reduced by around half but will still be present, according to Next Green Car. Existing alongside WLTP a new test standard called Real Driving Emissions (RDE) has been introduced in Europe. This is performed on the road, not in the lab, see **Figure 12**, overpage. **It is figures from RDE or similar testing that should be used to compare vehicles**, if available. Manufactures usually quote the WLTP figures.

Figure 12 - lab-based rolling-road testing, left, versus Real Driving Emissions (RDE) testing, right. Image source: [Next Green Car].

Problem two is that it is not easy to get accurate figures for the emissions associated with car manufacture, both of individual components and the final assembly process. Car companies, in general, do not provide such figures. In addition, emissions from producing the same car in two countries will differ if they are produced using electricity with a different carbon intensity.

Assuming we have accurate inputs we can then attempt to make a comparison. But there are many comparisons we could make, with many variables we could change that might strongly impact the results, for example:

- Which cars we are comparing, their size being one important factor.
- How we assume a car is driven over its lifetime. This is partly imported from how the car is tested to establish emissions figures, but we can vary things like miles driven.
- How we calculate the emissions associated with the electricity used to recharge the BEV. For example, one issue is do we use the average grid carbon intensity in a given country, or something different? It would be reasonable to assume that EV owners are more likely to charge their cars with renewable electricity, either because some of them have solar panels on their houses, or are using public charging points that may be powered by renewable sources. But how do you quantify this?

A more complete set of factors [can be found here]. What all this complexity means is that (a) it's quite hard to match real life and (b) there is no single estimate of relative environmental impact that applies everywhere under all circumstances. We look next at one specific comparison in the UK.

UK Lifecycle Greenhouse Gas Emissions

Figure 13 shows the output of [an analysis by Carbon Brief], comparing the lifetime greenhouse gas emissions of a Nissan Leaf, the bestselling BEV in Europe in 2018, with the average UK ICEV and a FHEV with the best available fuel economy at the time. It is assumed that an average UK electricity mix is

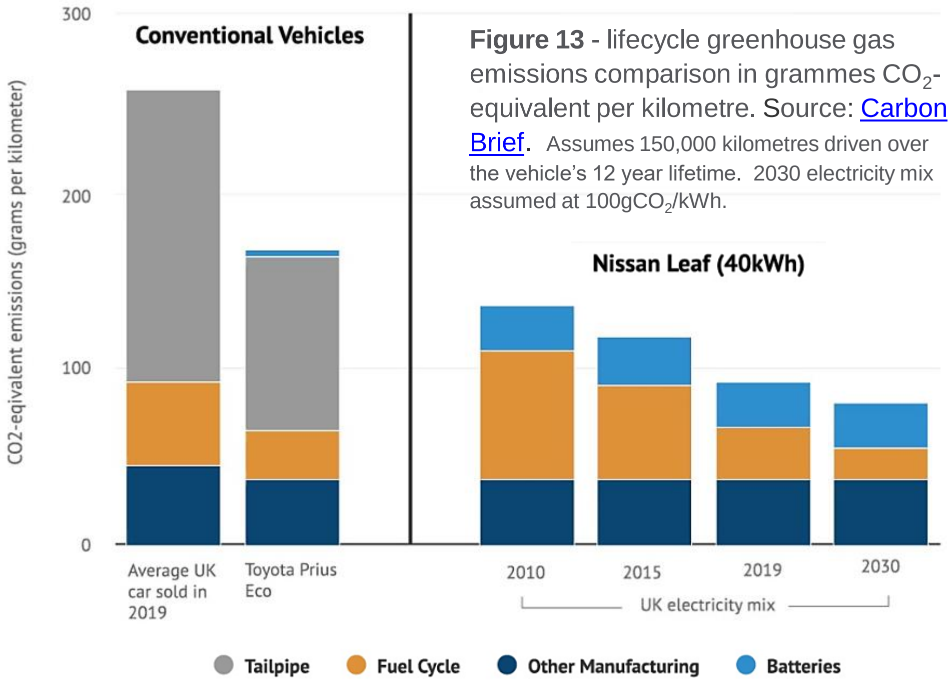


Figure 13 - lifecycle greenhouse gas emissions comparison in grammes CO_2-equivalent per kilometre. Source: [Carbon Brief]. Assumes 150,000 kilometres driven over the vehicle's 12 year lifetime. 2030 electricity mix assumed at 100gCO_2/kWh.

used for recharging the EV and that 150,000 km is driven over the twelve-year life of the cars. **Figure 13** illustrates some key points, which it is not unreasonable to apply more generally:

- Tailpipe emissions are by far the largest source of emissions for the average ICEV. The BEV saves some two to three tonnes of CO_2e each year in use.
- For the BEV the largest source of emissions is its manufacture.
- The BEV generates more emissions than an average ICEV in its manufacture, with battery production the main difference *. However, it pays back the extra emissions after less than two years.
- Using a 2019 average UK electricity mix **the lifetime emissions per kilometre for the BEV are about three times lower than the average ICEV**. The FHEV has just under double the BEV's emissions.
- If charging the BEV today using a 100% renewable source its emissions are cut by just under a third.
- As countries decarbonise electricity generation to meet their climate change targets the average grid carbon intensity will fall, reducing both recharge and manufacturing emissions for BEVs (battery manufacture is very electricity intensive).
- While manufacturing emissions for ICEVs may also fall slightly with the grid carbon intensity, the carbon emitted from burning a gallon of fuel cannot be reduced (though fuel efficiency *may* be improved slightly). This means that **the emissions advantage that BEVs have over ICEVs is only going to increase**.

One of the more startling conclusions of this analysis is that **you could replace an average ICEV with this BEV and be saving emissions after less than 4 years**. See **Figure 14**.

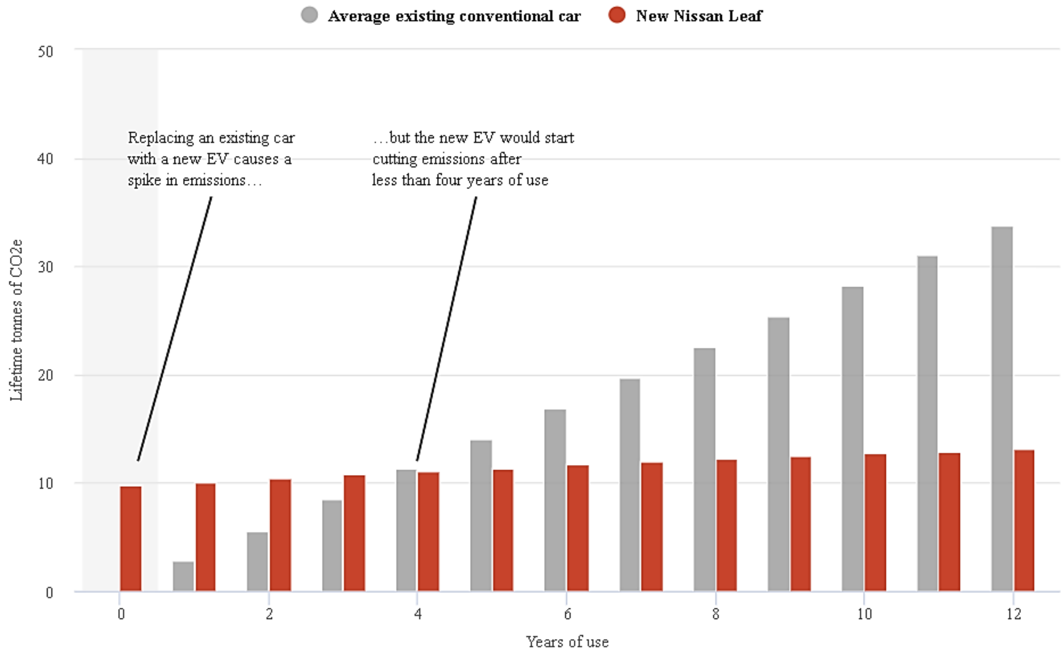


Figure 14 - Cumulative greenhouse gas emissions for an average existing ICEV versus a new Nissan Leaf. Source: [Carbon Brief](). Assumptions same as Figure 13, with added assumption of average UK electricity carbon intensity in 2019 for year one and gradual improvement towards a 2030 target of 100gCO_2/kWh and beyond.

As PHEVs offer a ~20-40 mile electric-only range you might expect that - as **Figure 2** implies - they should perhaps create emissions closer to BEVs than FHEVs. However, looking at real-world data the group Transport & Environment concluded that official data for PHEVs massively underestimate tailpipe emissions and that PHEVs - as they are actually used - sit closer to ICEVs than BEVs, though still slightly better than FHEVs. Apparently many owners rarely charge their cars - a completely avoidable issue - meaning they are effectively driving a heavy FHEV. In addition - and also partially avoidable - some/all PHEVs automatically kick-in the combustion engine on cold days, or if the driver accelerates hard, even if the car is in electric-only mode. Buyer beware.

* There are local environmental and human rights concerns associated with the extraction of some elements used for EV battery manufacture, e.g. cobalt.

Range and Recharging

Having considered environmental impact, which gave us arguably one of the most important reasons for owning an EV - especially a BEV -, in this section we cover all aspects of charging an EV. Such considerations potentially provide one barrier to EV ownership, with cost, discussed in the next section, providing another.

Short Version

Range - BEVs typically have a range of ~100-350+ miles, depending on model. This is limited compared to ICEVs. Overall range should not be a problem with hybrids, though the limited electric-only range of PHEVs requires regular recharging for greenest and cheapest use.

How refuelled - other than FHEVs, EVs lack the simplicity of ICEV refuelling. BEVs and PHEVs are plugged in to recharge; FHEVs are not. FHEVs and PHEVs also take petrol/diesel. Charging guides for bestselling plug-in EVs.

Where recharged - EVs are best recharged at home (and/or work, if available) using a dedicated charging point, though public charging points can be found at ~12,000 locations in the UK, operated in regional or national networks by multiple companies. Unfortunately, it is not possible to plug any EV into any charger - there is reasonable but not universal compatibility. Depending on location, finding local, compatible, available, public charging points may not always be possible. Map of public EV charging points | Guide to public charging networks | Guide to charger and connector types.

Recharge time - recharging a BEV takes a lot longer than refuelling an ICEV. Very loosely speaking, slow charging - usually done at home - is at least an overnight process (10+ hours), fast charging takes less than ten hours, and rapid charging - only available in limited public locations - about an hour. PHEVs charge quicker due to smaller batteries. Home charging time and cost calculator | Public charging time and cost calculator.

Recharge cost - recharging a BEV can cost a fraction of refuelling an ICEV. For home charging a Nissan Leaf this fraction starts at approximately a third and drops to a twelfth if charging overnight on the best EV tariff. Public charging is far more expensive, though can still be considerably cheaper than ICEV refuelling, with the price dependent on speed. PHEVs recharge for less than BEVs. We compare total fuel costs in the next section.

Consequently, to own a plug-in EV *as your only vehicle* ideally requires that:

- **Your daily driving mileage is limited to the range of the EV**, or potentially double the range if you have suitable charging at work. For a PHEV it is best if your driving is mostly limited to the electric-only range.
- **You have a garage or off-street parking area** where a private charging unit can be installed and recharging performed (or access to residential on-street charging, or - at a stretch - suitable local public charging).
- **You don't mind planning longer journeys**, taking recharge locations and time into account.

Skip to the next critical consideration about cost.

ICEVs have a long range - median 412 miles - and refuelling is a relatively quick and simple process. The range and refuelling picture is different for EVs as follows…

Range

BEVs have a more limited range than ICEVs - typically ~100-350+ miles. Refuelling therefore has to happen more frequently. While overall range should be less of an issue for hybrids, they have a limited electric-only range, which for PHEVs means they need to be recharged frequently to reduce emissions and cost. Factors affecting EV electric-only range include:

- Nominal battery size (kWh).
- Useable battery size (kWh). This may be less than the nominal battery size due to upper or lower charge restrictions used to protect against potential damage and extend battery life. Useable battery size is likely to shrink over time, reducing the range. EVs tend to have a battery warranty that covers extreme range deterioration.
- Starting charge of the battery (% of fully charged).
- Efficiency of the EV at converting stored electricity into distance driven (KWh per 100km). This can be converted to and compared with the mpg of a ICEV, or, better, used to compare the efficiency of EVs. This may be given as a single number but in reality will vary depending on:
    - Driving type (city/motorway/etc.) - due to regenerative breaking, EVs tend to do better in stop-and-go driving, with city typically better than motorway fuel efficiency (reverse of ICEVs).
    - Topography - downhill is particularly good for EVs, again due to regenerative breaking.
    - Variations in weather - range can be considerably lower in winter versus summer (a third less for a Renault Zoe).
    - Vehicle physical load and any additional electrical load e.g. climate control.

Note that the efficiency of ICEVs is also affected by these factors, it's just that their range is longer to begin with so this matters less.

Manufacturers often have a widget where you can play around with these factors to see how they impact the range. See **Figure 15** for an example from Renault. In general, manufacturers give WLTP range, introduced in the previous section, which is likely to be higher than you get in practice. You really want the Real Driving Emissions (RDE) range, or similar. This should be more realistic.

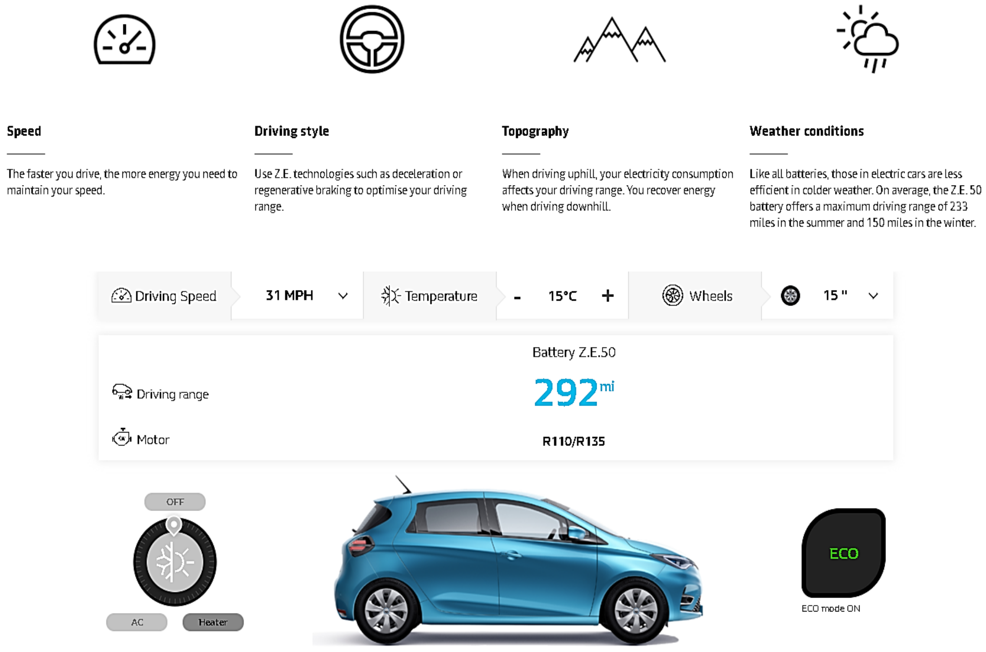


Figure 15 - manufacturer widget for demonstrating the various factors that affect the range of the Renault ZOE, a BEV. Play around with it here.

Recharging Overview

In this section we look at recharging BEVs and PHEVs, an inherently safer process than ICEV refuelling, though it takes much longer to complete and can be performed at different rates depending on the power of the charger, usually measured in kW. Recharging can potentially be performed at home (and any other private charging points to which you have access, such as at work) and at suitable public charging points. We look at home and public charging separately shortly. Remember that PHEVs are also fuelled with petrol.

Factors Impacting Recharge Time

There are three main speeds of EV charging point - **slow** (3kW – 6kW), **fast** (7kW, 22kW), and **rapid** (~43kW+), with the fastest speeds only available at public locations. Other than the speed of the charging point, factors affecting recharge time include:

- The current state of battery charge (% of full charge).
- Useable battery size (kWh). Larger batteries take longer to recharge but give you a longer range.
- Power of the on-board chargers (kW). EV models can charge at different fast and rapid speeds depending on what chargers have been fitted, with some PHEVs unable to rapid charge.
- Other factors include ambient temperature, in-vehicle energy load, and the charging rate slowing down as the maximum charge is reached as often happens with rapid charging.

For a rough charge time estimate divide the size of the uncharged portion of the battery by the lower of the power of the relevant on-board charger and the charging point power.

Connectors and Compatibility

Each charging point has an associated set of connectors which are designed for either low- or high-power use, and for either AC or DC charging. Rapid charging typically uses a DC current, the rest, an AC current. **Figure 16** shows the main types of connector. Some are used for one charging speed only, others across charging speeds.

Figure 16 - the main types of EV charging cable connectors. Rapid chargers use CHAdeMO, CCS or Type 2 connectors. Fast and slow chargers use Type 2, Type 1, Commando, or 3-pin plug outlets. Image source.

For some charging points the cable is attached to the charger (tethered). For other chargers the EV driver supplies the cable (untethered). Rapid chargers are tethered, the others can be either. **Figure 17**, on the next page, shows a common untethered EV charging cable.

Unfortunately, there is not universal compatibility between EVs and chargers - **you can't plug any EV into any charger**. Some of this is deliberate - Tesla chargers only work with Tesla cars, for example. Plugging into completely the wrong type of charger is largely enforced by the physical differences between connectors - you would have to work rather hard to plug a connector into the wrong socket on your EV or a charger.

Figure 17 - type 2 to type 2 EV untethered charging cable. One end goes in the car, the other in the charger. Simple. This cable can be bought in 5m and 10m long versions.

In addition, the majority of EVs and charging points have built-in computers to manage the charging process and prevent you overcharging. This means you can plug in to a compatible charger with a power rating above that at which your car is designed to charge - it just slows down to match your EV.

Compatibility is reasonable though, and improving. Most new UK EVs use a Type 2 socket for slow or fast charging and a CCS inlet for rapid charging. Type 2 units are by far the most common public charging standard and most owners will have a cable with a Type 2 connector charger-side.
[More detail on charging point speeds and connectors](#).
[Access charging guides for the bestselling plug-in EVs](#).

Getting Charging Right

Unlike refuelling an ICEV - assuming you don't confuse petrol with diesel or blow yourself up - it is very much possible to charge an EV in a sub-optimal way. For PHEVs, remembering to charge the battery at all seems a step too far for some. As mentioned previously, batteries will naturally lose capacity over time - equivalent to your fuel tank shrinking - but to extend their life as much as possible suggestions include: (a) keeping them charged between 50% and 80% capacity; (b) avoiding extreme hot and cold; (c) not charging straight after a long drive; (d) not relying on rapid charging very often.

Charging at Home

The existence of practical home charging is a key advantage of plug-ins over ICEVs, even more so in the age of Covid-19. Home charging may be slower than

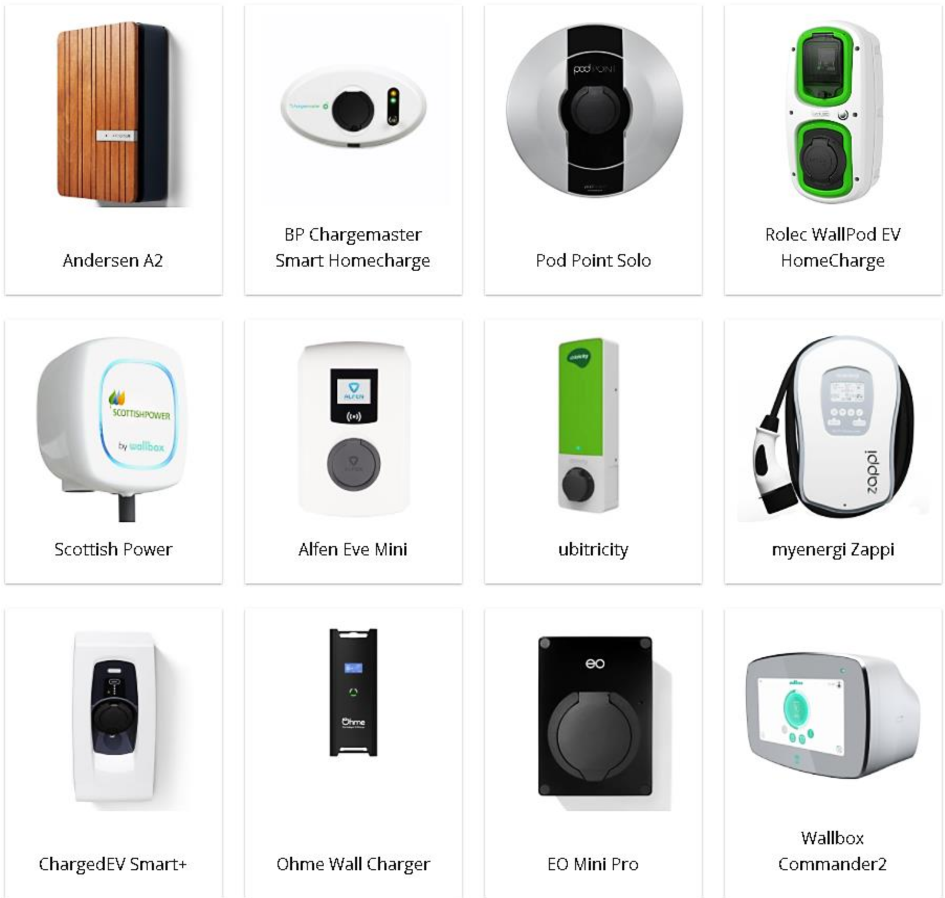


Figure 18 - some of the popular EV home charging points. [Link through to the manufacturers from this Zap-Map webpage](#), the source for this image.

public charging but it is potentially a lot cheaper, especially overnight when a car is often sitting there doing nothing anyway. It is very convenient to wake up with your car recharged, ready for use.

Home charging is, however, not available to everyone. You need to own your house (or have a cooperative landlord) and you need a garage or off-street parking area where a private charging unit can be installed. If you don't have off-road parking there is limited residential charging available in some areas, or you could charge at work, if available, or at local public charging points - covered in detail shortly - though this is nothing like as convenient as charging at home.

Although it is possible to charge an EV using a standard 3-pin mains socket, for reasons of speed and safety a dedicated charging unit, installed by an accredited installer, is strongly advised. As we cover later, this is not a major cost. Some new cars even come with the charger installation as part of the deal.

Around 40 manufacturers provide charging units suitable for residential use - examples of popular models are shown in **Figure 18**, on the previous page. At the bottom of **Figure 18** you can link through to an interactive version that takes you to the relevant manufacturer's website. Typically the units are wall-mounted, as shown below. Most suppliers provide two power rating options: 3kW (slow charging) or 7kW (the bottom end of fast charging). Expect to pay more for the 7kW option which, if the car has a fast on-board charger, reduces the charge time significantly, as demonstrated over page.

Here's a link to a home charging time and cost calculator, which works out the charge time and cost for a specific make and model of EV. Examples on the next page.

Charge Time

As mentioned previously, there are a number of factors that will determine charge time. To give some idea of charge time we'll use two common EVs - a Nissan Leaf BEV (40kWh battery) and a Mitsubishi Outlander PHEV (12kWh battery). Here are the home slow and fast charging times for both:

	Slow 3kW (0-100%)	**Fast 7kW** (0-100%)
Nissan Leaf	14 hours	6 hours
Mitsubishi Outlander	5 hours	3.5 hours

Note that the Leaf is limited to 6.6kW fast charging, while the Outlander is limited to 3.7kW fast charging. Other EVs may not be limited in this way.

Charge Cost

Charging cost in pence is worked out using: charging power (kW) x charging time (h) x electricity cost (p/KWh). The electricity cost will vary depending on your electricity tariff. To give some idea of cost we use the same two EVs as before. Note that the Outlander also has a petrol cost, not included here. We look at total fuel costs in the next section.

	Cost/kWh	**Cost to charge** (0-100%)	**Cost per electric mile**
Nissan Leaf	16p	£6.40	4 p
Mitsubishi Outlander	16p	£1.90	7 p

These costs per electric mile compare very favourably to ICEVs, which cost roughly 12-15p per mile to refuel, according to Zap-Map. This is due to the high efficiency of EVs and the low taxes on electricity. However, we have assumed an electricity cost of 16p/kWh, which is something like an average electricity cost in the UK. Much cheaper costs - down to ~4p/kWh overnight - are available using an electricity tariff designed specifically for EV owners. See a list of EV energy tariffs. Note that EVs use a lot of electricity to recharge, so your electricity bill will go up substantially if home charging. This is just a cost showing up in a new place - you still save considerably more by not having to buy petrol. As you might hope, it is possible to automatically charge only during the hours when it is cheapest on your chosen tariff.

Charge Emissions

As we explored earlier, if you care about the green credentials of your EV then the carbon intensity of the electricity used for recharging is critical.

EV specific electricity tariffs tend to feature a renewable energy promise, with the supplier matching energy used by the customer with electricity from renewable sources. This means that those tariffs not only reduce cost, but also emissions. Note that some supposedly 'green' tariffs are greener than others and that some green tariffs are for general (non-EV) customers and therefore won't have the time of use element, important for reducing charging costs.

As an alternative to using grid-supplied electricity you may have the option of installing a home solar and battery storage system. In theory this means you could charge your EV using your own 100% renewable electricity. It may not be that easy to do in practice and this option has a very high upfront cost, but the option is there for the wealthier enthusiast. More here.

Vehicle-To-Grid

EVs, especially large numbers of them acting in unison, provide an innovative way for grid operators to balance local electricity supply and demand; this must must match in real-time. The technology for this exists already - charge points can be bidirectional (they can export to the grid as well as importing from it) and respond to the signals necessary to make such a system automatic. A number of trials are on-going. One day this may provide a way for EV owners to earn some extra money. Simpler versions of this are already in use, with, for example, EV owners earning money by charging at specific times as requested by their electricity supplier or local grid operator.

Public Charging

On average most EV owners use the public charging network once a week, according to Zap-Map. Zap-Map runs a live map of public charging points. This network is significant and growing, if not yet comprehensive, see **Figures 19** and **20**. Greater London has the most charging points followed by the South-East and Scotland; the areas with the fewest charging points are Wales and Northern Ireland. A mix of slow, fast, rapid and ultra-rapid (100-350kW) charging points are available, with fast chargers most common.

34359	19702	12449	462
Connectors	Devices	Locations	Last 30 Days

Figure 19 - numbers of public charging points in the UK, as of 2nd October 2020. Source: Zap-Map.

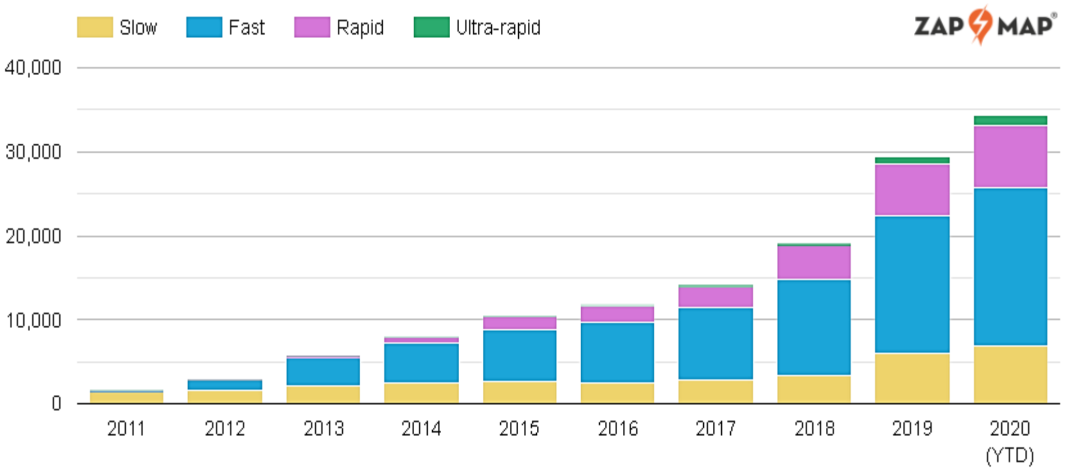
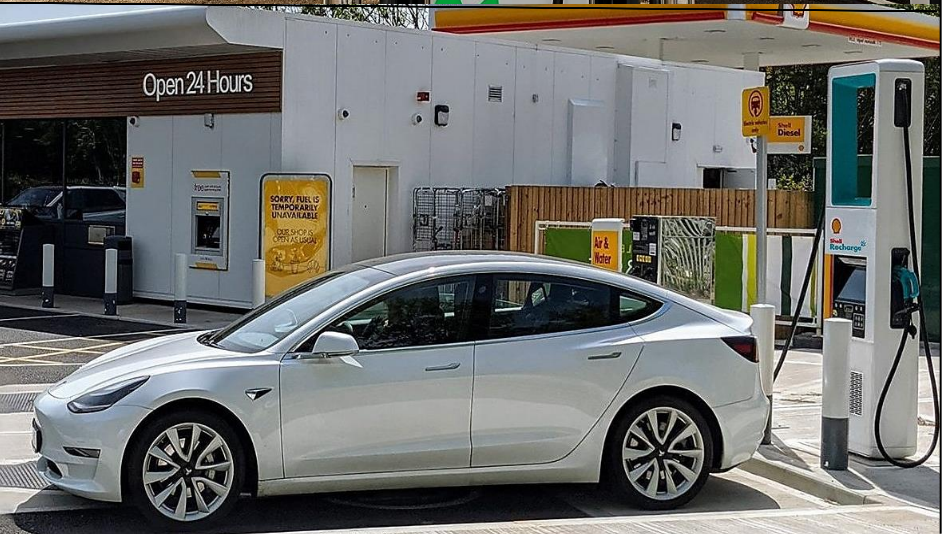


Figure 20 - number of UK public charging connectors by speed, as of 2nd October 2020. Source: Zap-Map.



Fast chargers tend to be found at destinations where you are likely to be parked for an hour or more, for example, car parks, supermarkets and leisure centres. Rapid chargers tend to be found at motorway services or locations close to main routes, as are the relatively rare ultra-fast chargers. Here's a link to an EV-specific public charging time and cost calculator.

As we mentioned earlier, not all EVs can rapid charge and you can't plug an EV into any charger, but you can likely find compatible locations directly from your EV's Sat Nav, or you can use a site like Zap-Map. Zap-Map also has a route planner. Note that you are not guaranteed to be able to get a charge at a given location. This might be because the connectors are all already in use (and unlike petrol pumps may stay occupied for hours) or the connector you want is out of operation (which can be more problematic than a given petrol pump being out of operation). We covered running out of electricity and petrol in the last section. In this unlikely event you just phone for roadside assistance.

Charging Networks

Another complication is that what we have called 'the public charging network' is in fact composed of distinct regional and national networks owned and operated by different companies. The largest by market share are: Polar, ubitricity, Pod Point, ChargePlace Scotland, Source London, Charge Your Car and the Tesla Destination and Supercharger networks. Learn more about each public charging network.

These networks vary in size, cost, access requirements and the services they offer. Other than the Tesla networks, which only work with Tesla EVs, networks generally try to cater across makes of EV, as well as charging speeds.

Most networks need/allow a user to register details beforehand. Once a member, you have access to all charging points in that network. Some networks require an RFID card to use them, others a mobile app, while an increasing number offer contactless pay-as-you-go charging; monthly subscription is the other common payment option. Charging networks are similar to phone networks in that different providers offer access to the same thing for slightly different prices and packages. You pick the one that gives you the best coverage in your area, at the best price (and you also might want to check their charging emissions). One thing to consider is that if using more than one you have the slight inconvenience of managing multiple apps and subscriptions.

As an example of a public charging point, **Figure 21**, right, shows a fast 7kW Pod Point charger, the sort of charger you might find at a train station, supermarket or golf club.

Charge Time

To give some idea of charge time, we use the same two EVs we did for home charging - a Nissan Leaf BEV (40kWh battery) and a Mitsubishi Outlander PHEV (12kWh battery). Here are the fast 22kW and rapid 50kW charging times for both:

	Rapid DC 50kW (0-80%)	Fast AC 22kW (0-100%)
Nissan Leaf	40 mins	6 hours
Mitsubishi Outlander	25 mins	3.5 hours

Note that the Leaf can charge at 50kW rapid DC, but only 6.6kW fast AC, while the Outlander can only charge at 22kW rapid DC and 3.7kW fast AC.

Charge Cost

Cost depends on the speed of charging - faster, more expensive - and which network provider is running the charging point. There are some free charging points in the UK (e.g. the Zero Carbon World network), while others charge for use. When they charge this is mainly done on a per kilowatt hour (kWh) basis. This element of the cost can vary from a couple of quid to £6 - £7 for 30 minutes of rapid charging (around 100 miles of range). A couple of network providers charge extra fees, which can include any of the following:

- One-off registration fee, which is normally £10 – £20.
- Monthly fee, varies.
- Connection fee, 50p to £3.
- Cost per hour to charge - used to discourage people leaving the cars plugged in.

If we assume a rapid charge cost of 30p/kWh - roughly double the home charging cost without a cheaper EV tariff - rapid charging our two example cars costs the following:

	Cost/kWh	Cost to charge	Cost per electric mile
Nissan Leaf	30p	£9.60 (0-80%)	7.5 p
Mitsubishi Outlander	30p	£2.70 (0-100%)	13.8 p

Figure 21 - a Pod Point 7kW public charging point.

Cost

We covered recharging costs as part of the preceding section. In this section we look at all the costs associated with owning an EV. Purchase costs potentially provide another barrier to EV adoption, while low running costs provide another advantage of owning an EV.

Short Version

Purchase Costs

Whilst most sizes and styles of car can be found in BEV and HEV forms - if not all from the same manufacturer - there are no really cheap EVs on the market, particularly in the case of PHEVs. See our two page picture list of selected bestselling BEVs.

Where a manufacturer offers versions of the same model in multiple forms the ordering of prices is roughly **ICEV<FHEV<<PHEV<BEV**, with FHEVs more similar in price to ICEVs than BEVs, which are in turn similar to PHEVs. The purchase cost for BEVs is currently reduced by £3000 by a government subsidy in the UK. Even so, you pay a premium for a BEV or PHEV. The cost of a home charger for plug-ins is reduced by up to £350 by the Electric Vehicle Homecharge Scheme, meaning getting one is not a major extra expense.

Running Costs

EVs - especially BEVs - have the potential to be much cheaper to run then ICEVs, though are still likely to be more expensive on a total cost of ownership basis. The main saving comes from fuel costs, especially if plug-ins are charged at home. Using an average domestic electricity price the savings are considerable with **FHEVs very roughly 25%, PHEVs ~50%, and BEVs ~70% cheaper than comparable ICEVs**. As covered earlier, this saving can be improved by up to an additional ~75% for BEVs by home charging overnight on the best EV tariff. Fuel cost calculator (compares any two cars) | Journey cost calculator (compares electric with other car).

Other EV running cost reductions include:

- Lower or zero car tax - UK BEVs pay no private car tax and HEVs pay lower tax than ICEVs, most noticeably in the first year of registration. Company tax is also reduced. Car tax calculator | Company car tax calculator.
- Reduced servicing costs for BEVs - evidence from fleets shows that BEVs can reduce total service, maintenance and repair costs by more than half when compared to ICEV alternatives. HEVs, on the other hand, are likely to be more expensive than ICEVs to maintain.
- Zero London congestion charge - low emission vehicles pay no congestion or ULEZ (Ultra Low Emission Zone) charge.

Insurance costs are broadly similar for EV and ICEV models. While EVs tend to be in a higher insurance group than a comparable ICEV, the drivers themselves are often considered lower risk. New EVs tend to be well covered by warranties, including a long battery warranty.

Skip to the next section on other aspects to consider when buying an EV.

Purchase Costs

Choice

Although not the overwhelming choice available for ICEVs, most major manufacturers offer at least one BEV and one hybrid. A few manufacturers specialise in BEVs only - Tesla, for example. Looking across manufacturers, electric options are available across most styles and sizes of car, though market penetration varies by market segment. Overall there are 205 plug-in models available in October 2020 (plus variants), according to Next Green Car. On the next two pages we present a non-comprehensive selection of BEVs, ordered from low to high purchase cost. As you might expect, you tend to pay more for increased range. On the page after that we list the bestselling EVs and suggest resources for helping pick a particular EV.

One of the key reasons for the lack of EV adoption is the lack of really cheap EVs on the market. Using figures from an October 2020 Autotrader search, the cheapest new BEVs are ~£17,000, PHEVs ~£27,000 and non-plugin hybrids (including mild hybrids) ~£12,000. Nearly new cars are cheaper by several thousand. Note that with some EVs the battery is owned on a lease basis, adding an extra fixed monthly cost; this is becoming less common.

Relative Cost

All types of EV tend to be more expensive than ICEV equivalents, whether new or second-hand. The fundamental reason is that they are more expensive to make, largely due to the cost of the batteries and, for hybrids, also the multiple drivetrains. Prices are coming down fairly rapidly though, with batteries costs having fallen almost an order of magnitude in the past decade. Tesla are predicting another halving in the next 3 years. In the second-hand market, prices are supported by factors such as high demand and most EVs not being that old.

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In the case of FHEVs, manufacturers who make a lot them - such as Toyota - are able to use economies of scale and price them more or less on a par with ICEV equivalents, with the differences more obvious for smaller models. By contrast, PHEVs and BEVs are often considerably more expensive than ICEV equivalents, though the difference is mitigated to some extent by only offering them in higher trim levels and well equipped with lots of hi-tech features, as covered later.

Figure 22 shows some examples of models offered by manufacturers in multiple forms. The ordering of prices is roughly **ICEV<FHEV<<PHEV<BEV**, with FHEVs more similar in price to ICEVs than BEVs, which are in turn similar to PHEVs.

	ICEV	BEV	PHEV	FHEV
Hyundai IONIQ	-	30950	30250	23840-25000
Hyundai Kona	17505-26830	29900-35900	-	23160-24920
Kia Nero	-	29595-33850	30265	24900-27100

Figure 22 - on the road prices for 3 models of car available in multiple forms (includes government grant for BEV). Prices from Next Green Car, 10/2020.

The purchase costs of new BEVs - but not hybrids - costing up to £50,000 are reduced by £3000 by the UK government's Plug-in Car Grant. See list of eligible vehicles. You don't need to claim this - the money is taken off automatically by the dealer. Currently this grant is expected to be available till at least financial year 2022/23.

Charger Purchase

Another subsidy, the Electric Vehicle Homecharge Scheme reduces the cost of home charger installation for eligible plug-ins by up to £350. Find an accredited installer. Typically a 3kW unit will cost between £250 and £500, while a 7kW one will cost between £450 and £800. It is worth remembering that new EV buyers may be eligible for a discounted or free charging point as part of a manufacturer-backed perk. There are also EV-focused electricity tariffs that offer similar schemes.

Note that there is a workplace equivalent of the Electric Vehicle Homecharge Scheme - the Workplace Charging Scheme. More about workplace charging.

SMART EQ forfour
Type: BEV, city car
Cost (OTR, £): from 17,785
NGC environmental impact: 19/100

Battery size (kWh): 17.6
Official range (miles): 81
Official webpage
Charging Guide: Zap-Map
Review: Next Green Car

VW e-up!
Type: BEV, city car
Cost (OTR, £): from 20,195
NGC environmental impact: 18/100
Battery size (kWh): 36.8
Official range (miles): 159
Official webpage Charging guide
Review: Next Green Car
See also: Seat Mii Electric, Skoda CITIGOe; these share a platform.

Mini Electric
Type: BEV, supermini
Cost (OTR, £): from 24,900
NGC environmental impact: 21/100
Battery size (kWh): 32.6
Official range (miles): 144

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

MG ZS EV
Type: BEV, SUV
Cost (OTR, £): from 25,495
NGC environmental impact: 23/100
Battery size (kWh): 44.5
Official range (miles): 163

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

Peugeot e-208
Type: BEV, supermini
Cost (OTR, £): from 25,715
NGC environmental impact: 21/100
Battery size (kWh): 50
Official range (miles): 211

Official webpage
Charging Guide: Zap-Map
Review: Next Green Car, Autotrader

Renault Zoe
Type: BEV, supermini
Cost (OTR, £): from 26,170
NGC environmental impact: 23/100
Battery size (kWh): 52
Official range (miles): 238-245

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

Nissan Leaf
Type: BEV, small family
Cost (OTR, £): from 26,845
NGC environmental impact: 21/100
Battery size (kWh): 40-62
Official range (miles): 168-239

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

Vauxhall Corsa-e
Type: BEV, supermini
Cost (OTR, £): from 27,665
NGC environmental impact: 22/100
Battery size (kWh): 50
Official range (miles): 205

Official webpage
Charging Guide: Zap-Map
Review: Next Green Car, Autotrader

Kia e-Nero
Type: BEV, SUV
Cost (OTR, £): from 29,595
NGC environmental impact: 23/100
Battery size (kWh): 39-64
Official range (miles): 180-282

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

Hyundai Kona Electric
Type: BEV, SUV
Cost (OTR, £): from 29,900
NGC environmental impact: 21/100
Battery size (kWh): 39.2-64
Official range (miles): 180-279

Official webpage
Charging Guide: Zap-Map
Review: Next Green Car, Autotrader

Hyundai IONIQ Electric
Type: BEV, large family
Cost (OTR, £): from 30,950
NGC environmental impact: 20/100
Battery size (kWh): 38.3
Official range (miles): 194

Official webpage
Charging Guide: Zap-Map
Review: Next Green Car, Autotrader

BMW i3
Type: BEV, supermini
Cost (OTR, £): from 33,025
NGC environmental impact: 19/100
Battery size (kWh): 42.2
Official range (miles): 188

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

Tesla Model 3
Type: BEV, executive saloon
Cost (OTR, £): from 40,490
NGC environmental impact: 22/100
Battery size (kWh): 60-75
Official range (miles): 254-348

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

Audi e-tron
Type: BEV, SUV
Cost (OTR, £): from 60,650
NGC environmental impact: 34-39/100
Battery size (kWh): 71-95
Official range (miles): 176-252

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

Jaguar I-PACE
Type: BEV, SUV
Cost (OTR, £): from 65,195
NGC environmental impact: 30/100
Battery size (kWh): 90
Official range (miles): 292

Official webpage
Charging guide: Zap-Map
Review: Next Green Car, Autotrader

Porsche Taycan
Type: BEV, sports cabrio
Cost (OTR, £): from 83,580
NGC environmental impact: 31/100
Battery size (kWh): 79.2-93.4
Official range (miles): 252-287

Official webpage
Review: Autotrader

Bestselling EV Makes and Models

Figure 23, below, shows the bestselling UK cars from 2017-2020 that are defined as ULEVs (Ultra Low Emission Vehicle). A ULEV is defined as having less than 75 grams of CO_2/km from the tailpipe, as measured in official tests. In general this includes BEVs and PHEVs, but not other hybrids as they are more polluting. As this is a quick moving market, in **Figure 24**, below right, we also list the bestselling ULEVs in Q1 2020. The constituents and ordering are different from **Figure 23**. The Tesla Model 3 was the most popular model in Q1 2020, selling over 5000 units, roughly double the number of Nissan Leafs sold. EVs have carried on selling well since, in spite of, or perhaps in part because of, Covid-19.

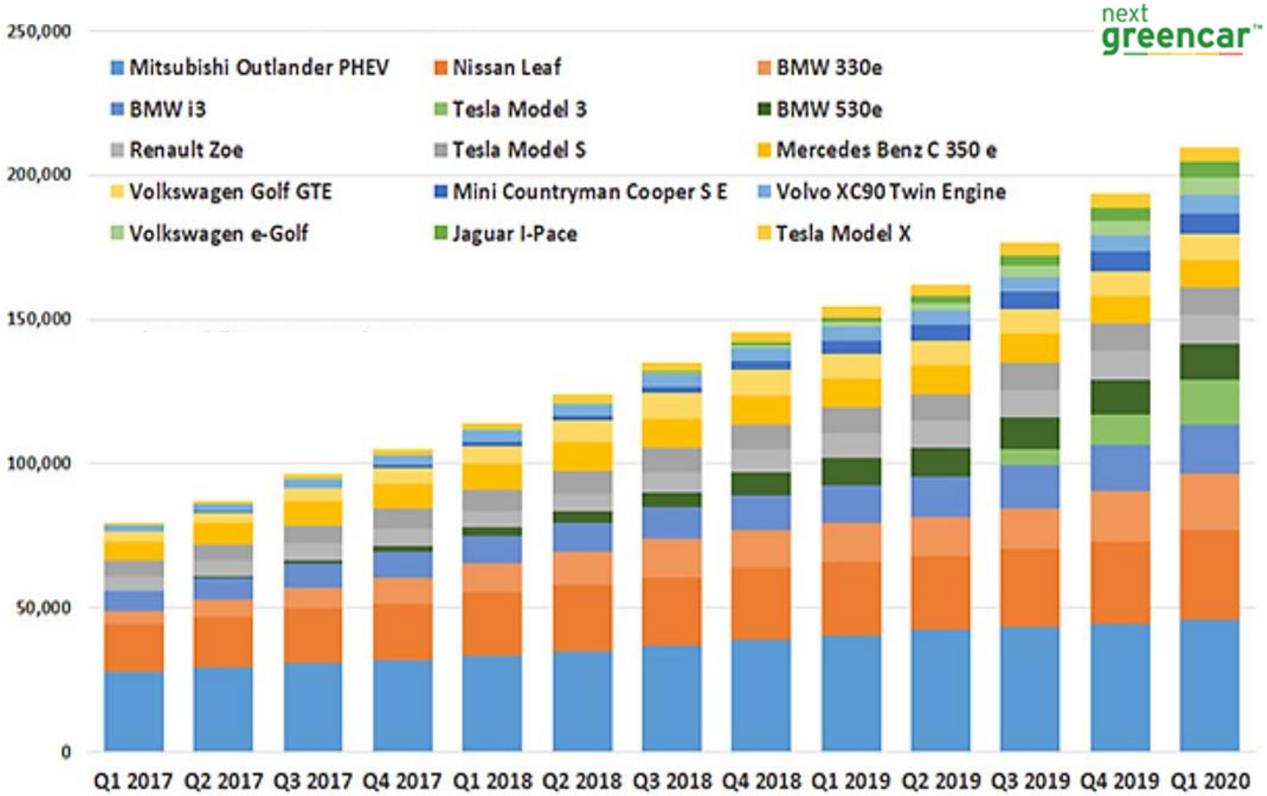


Figure 23 - bestselling ultra-low emission cars by model 2017-2020. Source: Next Green Car.

Picking an EV

For help picking a make and model try, for example, the car selector at Electric Car Home, or the new car search and car comparison features at Next Green Car, or look at reviews on AutoTrader. One way of identifying value is to look at the purchase cost relative to the range of the EV.

Car	Type
Tesla Model 3	BEV
Nissan Leaf	BEV
BMW 330e	PHEV
MG ZS EV	BEV
Mitsubishi Outlander	PHEV
Volkswagen e-Golf	BEV
Jaguar I-Pace	BEV
Peugeot e-208	BEV
Range Rover Sport P400e	PHEV
Audi e-tron	BEV
BMW i3	BEV
Kia Niro PHEV	PHEV
Mini Countryman Cooper S E	PHEV
Kia e-Niro	PHEV
Porsche Cayenne E-Hybrid	BEV
Volvo XC50 Twin Engine	PHEV
Volve XC90 Twin Engine	PHEV
Audi A3 e-tron	PHEV
Mini Electric	BEV
Hyundai IONIQ Electric	BEV

Figure 24 - ordered list of bestselling ULEV cars in Q1 2020 in the UK. Bestselling at top. Source: Next Green Car.

Running Costs

Car Tax

UK private vehicle tax is based on the CO_2 emissions of the vehicle, with differences most notable in the first year of registration.

Newly registered BEVs pay no vehicle tax at all, saving up to £2175 in the first year, compared with the most polluting cars, and at least £140/year from the second year onwards compared to non-BEVs.

PHEVs likely pay £0-15 in the first year, depending on emissions, and pay £140 thereafter, a £10 discount to the standard ICEV rate. This assumes the car has a list price of less than £40,000. Above this a £325 premium applies from years 2-6. HEVs pay more in the first year.

For businesses, company car tax is also linked to CO_2 emissions, so is lower for EVs. Businesses operating EVs can also receive a tax break through the system of Enhanced Capital Allowances (ECAs).

Calculate the tax for a specific EV:

Car tax calculator

Company car tax calculator

Fuel Costs

Comparing fuel costs between ICEVs and the various types of EV is not straightforward. EVs will be cheaper but quantifying exactly how much is a challenge. To recap and expand on why:

- The available electricity price can range from as little as 4p/kWh to 30p/kWh or more, depending on where and how fast EV recharging is performed. By contrast, the available petrol and diesel costs should be similar everywhere. Both will vary over time.
- Calculations tend to use an average vehicle efficiency - mpg, or kWh per 100km - which may not reflect the actual driving done. If using an average efficiency it should be derived from real-life driving, not lab testing.
- PHEVs are particularly problematic as you have to assume how much time is spent powered by electricity and how much by petrol. This can vary from mostly on electricity to mostly on petrol, depending on how driven and charged.

To give some idea of relative costs we use the online journey cost calculator from Zap-Map, and look again at the cars of **Figure 22**, which exist in multiple forms. Results are shown in **Figure 25**. Assumptions made in these results include an average UK electricity price of 16.5p/kWh, an average petrol price of 106.6p/litre, real-life vehicle fuel efficiency estimates and PHEVs spending half their distance in electric-only mode. Full assumptions and exact calculations are specified here.

pence/mile	ICEV	BEV	PHEV	FHEV
Hyundai IONIQ	-	4	6.1	8.6
Hyundai Kona	13.4	4.2	-	9.3
Kia Nero	-	4.5	7.7	8.8

Figure 25 - fuel cost in pence/mile for 3 models of car available in multiple forms. Cheapest variant used. Prices from Zap-Map's Journey Cost Calculator, 10/2020.

As you would expect, the cost per mile ordering is **ICEV>FHEV>PHEV>BEV**, with BEVs by far the cheapest. As we stated in the charging section, home charging costs can be a quarter of this assumed electricity price, meaning **Figure 25** is a solid underestimate of the home-charged running cost advantages of plug-ins versus non-plugins.

Clearly, the amount you save on fuel costs by switching to an EV depends on how far you drive. To give some idea, let's assume you drive 20 miles a day for a year (7300 miles in total). Even assuming the high average electricity price, relative to the petrol version of the Hyundai Kona you would save £675 by driving the BEV version, and £303 by driving the FHEV version. This - together with the other savings mentioned in this section - are still unlikely to take the total cost of ownership of a given BEV below a similar ICEV. We are assured this day is coming soon.

London Congestion Charge

For drivers in London another major running cost benefit for EVs is available as part of the Congestion Charge scheme. All electric cars - defined as vehicles that emit up to 75g/km CO_2, meet at least Euro 6 emissions standards, and have a minimum electric-only range of 20 miles (full list here) - pay no congestion or ULEZ (Ultra Low Emissions Zone) charge, though vehicles need to be registered and pay an annual £10 fee. For daily commuters this could save over £3500 a year.

Insurance

Insurance costs are broadly similar for EV compared to ICEV models. While EVs tend to be in a higher insurance group than comparable ICEVs, the drivers themselves are often considered lower risk. There are a number of insurance firms - both general and specialists - available that will provide cover for EV drivers. More detail about EV insurance here, including differences between EV and ICEV insurance.

According to comparethemarket.com, the average annual car insurance premium is £755 (March 2020). Equivalent figures for a few popular models of EV are shown in **Figure 26**.

Car make and model	Average annual premium **
Hyundai IONIQ Hybrid Premium SE	£481.69
Nissan Leaf Tekna	£553.65
Smart Forfour Passion	£717.19
Tesla Model 3 Performance AWD	£1,223.33

Figure 26 - average insurance costs for the most popular electric cars. Source: comparethemarket.com.

**Average price amount based on the top five quotes from Compare the Market data from 1 March 2020 to 1 June 2020. The average is based on all variations of the vehicle model and uses risk data from people with different age ranges, addresses and driving histories. You may find a cheaper or more expensive quote based on your circumstances.

Maintenance

According to Zap-Map, evidence from fleets shows that 'BEVs can reduce total service, maintenance and repair costs by more than half when compared to ICEV alternatives'. However, most EVs are too new to the market to have picked up any clear trends in terms of reliability or maintenance costs later in life. In any case, reliability is likely to be a function more of manufacturer than car type.

In general, BEVs should require less maintenance than ICEVs due to:

- Far fewer moving parts.
- No need for oil changes, spark plug replacements and more.
- Brake pad replacements being less frequent because regenerative braking significantly reduces the wear on brakes.

BEV servicing is therefore likely to be simpler and less frequent than for ICEVs. Tesla, for example, says its cars should generally be serviced on an as-needed basis - presumably meaning if something goes wrong - and do not require annual maintenance, with more involved checks recommended every two years or less frequently.

The picture is somewhat different for hybrids, due to their inherent complexity and retained combustion engine. It is reasonable to expect hybrids to be more expensive to maintain than ICEVs or BEVs, with annual services necessary for the combustion engine.

Although certain EV-unique repairs (e.g. battery replacement, if not owned on a lease basis) have the potential to be quite expensive, to encourage adoption new EVs tend to be well covered by warranties, with up to three separate warranties included covering the car as a whole, the EV-dedicated components, and the battery. The Nissan Leaf, for example, currently comes with a 3-year whole car warranty (or 60,000 miles), a 5-year EV dedicated components warranty (or 60,000 miles), and an 8-year battery capacity loss warranty (or 100,000 miles).

Other Aspects

Having covered the elements we consider critical in answering the question 'should my next car be electric?', we now move on to other aspects. These things aren't necessarily less important but are unlikely to put you off getting an EV altogether, quite the opposite.

Short Version

Safety

There is no reason to believe that EVs are fundamentally less safe than ICEVs for occupants.

While not unique to EVs, EVs often come with the most advanced safety features on the market (e.g. blind spot and rear cross traffic warning, emergency auto-breaking and lane keeping assist).

Due to reduced engine noise EV drivers should be hyper-aware of pedestrians. Some BEVs have an external noise generator for low speeds.

Driving Experience

EVs have an appreciably different driving experience from ICEVs, for both the driver and passengers. This is usually seen as a positive thing.

BEVs are quiet, accelerate smoothly - no need to change gears, manually or automatically - and very responsively, especially at lower speeds, with handling improved by a low centre of gravity (and by two independent motors for some EVs). Hybrids have some of these advantages, especially in electric-only mode, and can be more responsive at higher speeds.

Regenerative breaking reduces the required amount of pedal control, with some EVs effectively allowing for single pedal control.

High-Tech Features

EVs come with a range of hi-tech features, not all unique to EVs but some being pioneered in them. These include:

- Fewer physical buttons and increased use of digital touchscreens, displays and external cameras.
- Remote control and monitoring of various on-board features using an app. Examples include charging, climate (allowing for pre-conditioning of cabin temperature before you get in) and Sat Nav (allowing for preloading of locations).
- Autonomous driving functions. No commercially available EVs can fully drive themselves - yet - but this is where we are possibly headed. Currently offered functions include auto parking, auto summon (automatically retrieving a car from a parked position), auto driving within a lane, auto lane change, as well as the automatic accident avoidance functions mentioned above.

Skip to the answer to the question asked at the start of this report.

Safety

There is no compelling reason to believe EVs are any less safe than ICEVs. A limited review of the available research suggests that electric and hybrid cars are potentially more crashworthy than ICEVs, though BEVs are more likely to be involved in accidents involving pedestrians.

If we look again at our set of cars that exist in multiple forms (used in **Figures 22** and **25**), the Euro NCAP safety ratings are identical across forms, though not all the vehicles have a rating. Euro NCAP testing explained. Look up NCAP ratings for a particular EV.

On the plus side, BEVs don't use flammable petrol/diesel and have reduced roll risk due to the batteries typically lowering the centre of gravity. Plus, while not unique to EVs, EVs often come with lots of high-tech safety features.

On the negative side, there have been over-publicised reports of a few BEVs catching on fire, with the massively larger number of ICEV fires going largely unnoticed. While batteries do present a fire risk, everything is done to minimise a fire happening at all, the scale of any fire, and the associated risk to passengers, both in normal operation and during a crash. For example, battery cells are cooled, separated and housed in a tough casing, see **Figure 27**, right. A fuel tank is often made of only fairly thin metal or plastic.

EVs do use higher voltages than ICEVs, introducing a new risk. However, EVs are designed to minimise the consequences of this risk in the event of a crash, and for maintenance and repair purposes this is only really a question of establishing safe working practices.

One final safety concern specific to EVs is their quieter operation - pedestrians are less likely to hear an EV than a ICEV. However, many EVs can be made to emit extra noise externally at low speeds. This will shortly become mandatory for new EVs in the EU. In any case, extra care needs to taken when driving an EV in pedestrian areas.

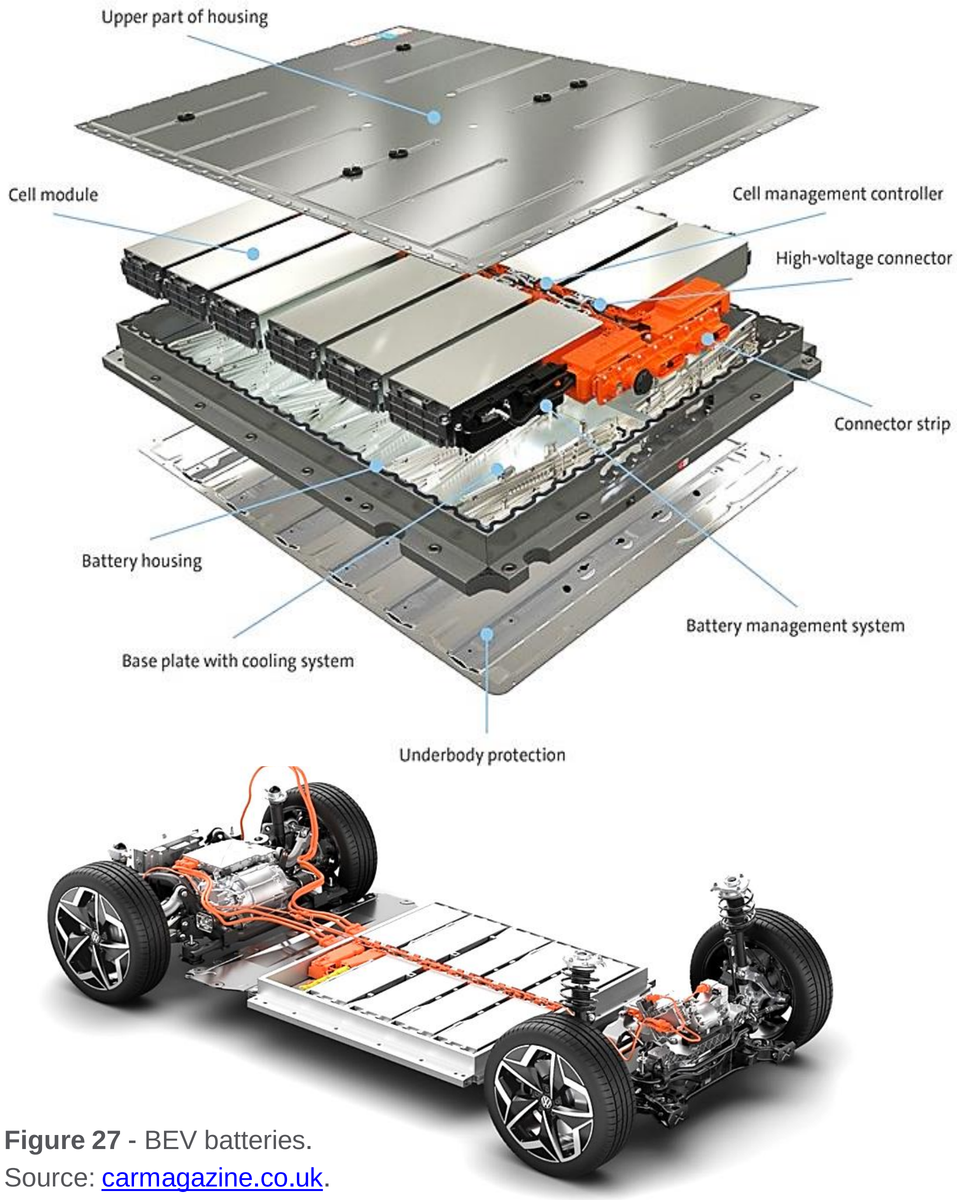


Figure 27 - BEV batteries.
Source: carmagazine.co.uk.

Driving Experience

The experience of driving or being a passenger in an EV is markedly different from being one in an ICEV, with most people seeing this as a good thing - ‘fun to drive’, ‘easy to drive’, ‘low stress’ etc. The most glaring differences are that BEVs typically have:

Quiet and smooth running - BEVs are inherently quieter than ICEVs. On pressing the accelerator, a BEV initially moves in almost total silence, which can be a little disconcerting at first (though, as discussed, noise generators will become standard at low speeds). BEVs don’t have gears so accelerate smoothly without the rev-pause-rev cycle of ICEVs. As the speed picks up, the small amount of ‘engine’ noise that can be heard is quickly masked by wind and tyre noise, which become more noticeable as the speed increases. The honed aerodynamics, designed to maximise EV range, and the use of low-rolling resistance tyres, standard on most EVs, also help to reduce noise levels.

Responsive performance - BEVs have excellent acceleration and high torque, especially at lower speeds. The initial acceleration offered by even standard EVs is often more than offered by many sports cars.

Reduced pedal control - the presence of regenerative braking, offered on most/all EVs, means that ‘braking’ starts even before your foot touches the brake pedal. This reduces the amount you have to physically press the break pedal. Some EVs even have a special mode whereby the regenerative breaking becomes more aggressive, resulting in the car slowing dramatically when you lift off the throttle, essentially enabling single pedal driving.

Decent handling - already mentioned as a safety feature, the battery-lowered centre of gravity usually found with BEVs improves the ride and handling characteristics. Some BEVs - such as those made by Tesla - use two independent motors to control the front and rear wheels, allegedly improving handling, traction and stability control.

For hybrids, the driving experience sits somewhere between ICEV and BEV, with PHEVs more BEV-like, especially in electric-only mode. Hybrids tend to be more responsive than BEVs at higher speeds due to the combination of combustion engine and electric motor. On a less exciting note, some hybrid versions of ICEVs lose out on boot space when areas used for storage (typically under the boot floor) are instead filled with batteries.

High-Tech Features

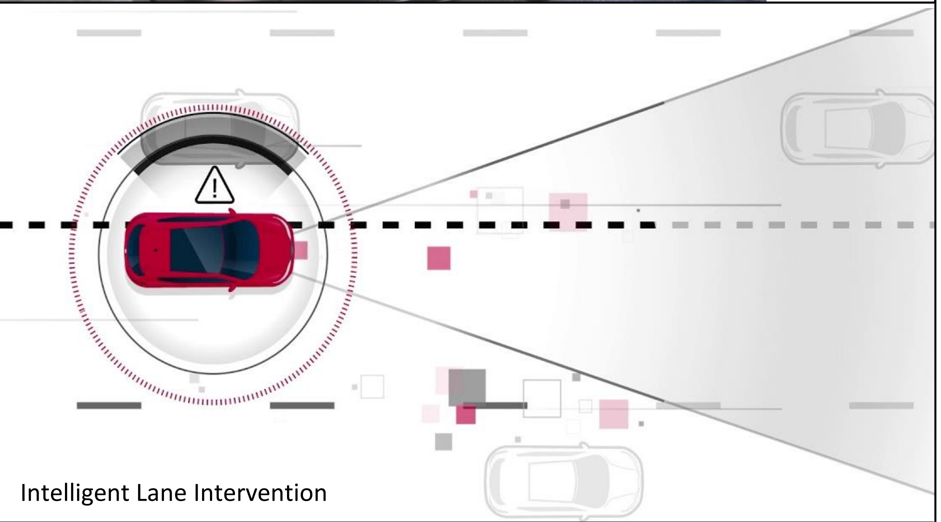
With the odd exception, on the outside most EVs don't look greatly different to ICEVs, if slightly more futuristic looking. On the inside, however, EVs, particularly BEVs, range from slightly different - just minimally incorporating the extra info about battery charge and range that needs to be displayed - to completely redesigned.

Below we show two of the most extreme interiors - the Honda e, left, and the Tesla Model 3, right, both BEVs. The Tesla removes almost all physical buttons and replaces them with one large touchscreen display that controls all media, navigation, climate and other drive and cabin settings. The Honda e keeps a few more physical buttons, but plasters five displays, two of them touchscreen, right across the front of the car. At either side are screens which show the image you usually see from the wing mirrors (which have been removed and replaced with cameras).

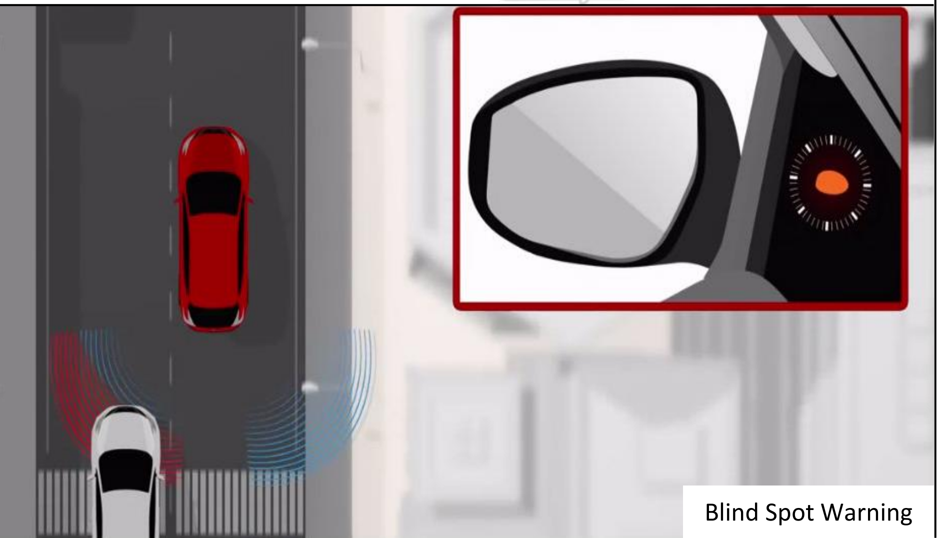
Common to many EVs these two models use an app to provide remote control and monitoring. Common examples of useful things that can be done via app include:

- Charging - scheduling, controlling, checking on progress of, and getting notified about.
- Climate - checking and setting the temperature in the cabin, turning on/off heated seats and steering wheel. Useful for pre-heating a car on a cold morning.
- Using your phone as a key.
- Finding your car, either on a map, or by getting it to flash its lights or honk its horn.
- Interfacing with the car's Sat Nav, e.g. to remotely add destinations.

Rear Cross Traffic Alert



Intelligent Lane Intervention



Blind Spot Warning

Safety and Self-Driving

No commercially available cars can fully drive themselves, though this is clearly a key goal towards which the industry is aiming. Self-driving is not necessarily an EV-specific thing but it is being pioneered in them to some extent and it fits in with their 'futuristic' appeal. Tesla, for example, claim their BEVs already have the hardware to allow full self-driving. There is just the non-trivial-to-say-the-least matter of getting the software correct, which is super-complex given all the edge cases and the consequences of getting it wrong. Meantime, most EV manufacturers are adding a pretty standard set of limited self-driving features to their cars in the name of safety, convenience and coolness.

On the safety side of things, novel warning systems are being introduced as the line of first defence. Examples include **blind spot warning**, **rear cross traffic alert**, **sleepy driver alert** and **traffic sign recognition**, which displays traffic signs on the dashboard. For cases where the driver does not or cannot in the time available respond to prevent an accident, this is when self-driving potentially kicks in. Examples of self-driving safety features include **intelligent lane intervention**, which will automatically direct you back into a lane if you drift out, and **emergency breaking**, which will attempt to stop you crashing into various things such as houses or the backs of cars (some even have 'pedestrian protection').

In terms of self-driving more for convenience than safety, many EVs have some form of **in-lane cruise control** that intelligently maintains a set distance from the car ahead, changing your speed to match, including perhaps coming to a complete standstill and starting off again. This feature may include the ability to automatically steer the car in-lane (on non-wiggly roads), as well as maintaining speed. More advanced systems have the ability to **automatically change lanes**. Taken to the nth degree, this could mean that human-controlled motorway driving is on its way out, though it remains unclear when full self-driving on all roads and in all conditions will appear, if at all.

Self-driving is also getting more advanced for the more mundane task of parking. Moving beyond parking sensors and cameras, some EVs have an auto-parking feature which can complete parallel or perpendicular parking with no driver intervention. Teslas also have a 'summon' feature for retrieving a parked car - you just tell the car to come to your current position on your phone. Nothing could possibly go wrong with that.

An Answer

So, should your next car be electric? It depends. One way - not the *only* way - of answering this is…

If you have the budget, don't mind this car having limited range, are happy with the practicalities of recharging, and want to help the fight against climate change - or otherwise like the idea of an EV - then the answer is an emphatic yes.

For maximum environmental benefit - and lowest running costs, if not necessarily lowest total cost of ownership - your next car should be a BEV, not a hybrid. To minimise ongoing cost and environmental impact you should charge at home overnight on a 100% renewable EV tariff (or use a home solar and storage system).

If a BEV is not appropriate, and your budget will stretch to this, a PHEV is a possibility for a mix of mostly shorter and occasional longer journeys. However, consider first how often you really need a long range and if you couldn't make do with a BEV instead - recharging as you go, renting another car occasionally, or using public transport.

For regular longer journeys the environmental and running cost benefit of a PHEV is lost, so in this circumstance - or for those on a lower budget - a FHEV or an efficient ICEV (we include mild hybrids in this) become stronger options.

Obviously, your willingness to put up with a limited range BEV will be strongly influenced by the availability of another full range car in your household. Experts are predicting that only when single car households are happy to switch in their droves to BEVs will the electric car revolution truly take off.

Timing Your Purchase

If you like the idea of getting an EV, the question then becomes one of timing (and deciding which EV to buy). As mentioned earlier, from a purely environmental perspective **it is possible to make the argument that you should get an EV *right now***. Right now has the advantage of having various subsidies and tax breaks that will not be around for ever. However, right now has the disadvantages of high purchase prices even after subsidy, somewhat limited choice, limited range, and non-comprehensive public charging infrastructure. All these things are expected to improve pretty rapidly. Whether it is worth waiting around for some amount of improvement in one or all of these depends on how much you care about them. To finish let me repeat that if 'saving the planet' is your main reason for getting an EV then all those other factors fade away and right now is the answer - **a BEV, right now**. Hope this document helped.

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