Your Essential Guide to Buying an Electric Car in 2021

This is the long form of the following December 2020 article of the same name on RTE Brainstorm:
https://www.rte.ie/brainstorm/2020/1215/1184581-electric-cars-buyers-guide-2021-ireland/

This draft (Version 2, 17-12-2020) presents additional discussion on direct and indirect carbon emissions and vehicle specifications. The added material is highlighted below. Feel free to contact the author at john.hayes@ucc.ie if you have any comments, questions or queries.

What a year for electric cars! If we could ignore Covid 19, 2020 would definitely have been the Year of the Electric Car!

Your EV options have been multiplying throughout 2020 and into 2021, with almost 100 vehicles on the market ranging from **battery-electric vehicles** (**BEV**) to **plug-in hybrid-electric vehicles** (**PHEV**) to **hybrid-electric vehicles** (**HEV**). We have visited all the dealers and researched the electric vehicle (EV) options for you if you are looking to buy in 2021. We have seen the much-anticipated arrival of the Volkswagen ID.3 on our shores. Citroen, Opel and Peugeot have all entered the EV and PHEV markets. 2021 will see the launch of the Ford Mustang Mach-E, a power car classic of automotive lore. Honda, Lexus and Mazda are launching BEVs. Cupra, a Volkswagen brand, and MG Motors, the classic English brand now owned by the Chinese, will enter the Irish market in 2021 to sell EVs. Toyota have a new RAV4 PHEV. Audi have the sportback EVs, while Mercedes and Toyota are each launching new people-carrier BEVs.

First, let's check out the headlines from 2020.

The real news has been elsewhere. Driven by Covid 19, all things EV have seen the most extraordinary stock market rise. Tesla CEO, the indomitable Elon Musk, has become the 2nd richest person on the planet. Tesla Inc. is now valued at over half a trillion dollars, almost as much as all the other automotive companies put together. Elon's other company SpaceX even took astronauts to the International Space Station and then returned them safely home.

We have been seen a competing EV technology get traction (if you pardon the pun) on the stock market, with Nikola and its hydrogen fuel cell EV technology becoming a darling of the markets. A Toyota fuel cell bus has even been driving the streets of Dublin in late 2020.

Is this the great EV stock market revolution, or the biggest stock market bubble since the dot.com era of the 1990s or the Dutch Tulips bubble of the 1630s? Only time will tell- we'll be sure and revisit the topic in the 2025 or 2030 Essential Guide.

We had an election in this country in February. The new Irish government, with the Greens on board, have changed the vehicle registration tax (VRT) levels in order to discourage conventional petrol and diesel vehicles. The old levels were put in place when the Greens were last in government in 2008 to encourage diesel. The new government target is to get us into 1 million electric cars by 2030. That's very ambitious, but as you'll see below, the manufacturers are responding and the choices are increasing.

Advantages and Disadvantages of EVs

Let's first note the advantages and disadvantages of all EVs. First, EVs are more efficient than the equivalent petrol or diesel car, and so require less energy to run, and emit less carbon and other toxic pollutants. Second, the BEVs and PHEVs can be fuelled by renewable energy from the electricity grid, which reduces our dependence on imported fossil fuels and our related carbon emissions. Third, EVs have automatic transmissions, making them easy and quiet to drive, with fast accelerations due to the electric motor. Fourth, an amazing feature of an EV is regenerative braking; the electrics can slow down the car and recharge the battery rather than use the brakes. Fifth, charging the BEV or PHEV using a night-time electricity rate costs only about 1.5c/km! The rate is about twice as high for day-time charging, and over three times as high using the ESB fast-charging rate. You will likely install a charger- this can cost several hundred euro, but it does come with a €600 grant from SEAI to reduce the cost. BEVs have a motor tax of €120. A HEV, such as the Toyota Corolla, costs about 7c/km and comes with a motor tax of €170. On the carbon side, we'll see that BEVs have indirect emissions due to the electricity grid. Later, we'll provide estimates of the carbon emissions to contrast and compare the different technologies.

The principal disadvantage of EVs relates to the range of the BEV. However, battery size has been increasing while cost has been reducing, and so a BEV range of greater than 400 km is common in many models. We know that the battery degrades with time. Therefore, the range could drop in half in several years under severe weather conditions, such as driving at highway speeds with the heating on in cold sub-zero winter days. Second, serious environmental concerns remain for the batteries related to the energy and carbon intensity of manufacturing, to the recyclability, and to the sourcing of key materials. These concerns are being addressed for the long-term sustainability of EVs. That said, serious environmental concerns have to be addressed for all options of mechanized transportation. The BEV has the additional key advantage of eliminating toxic tail-pipe emissions.

A little bit on indirect CO_2 emissions

One of the challenges for EVs is that the battery can result in significant additional indirect carbon emissions during manufacturing. The good news is that these manufacturing emissions have been reducing. For the typical driver of a BEV, it can take about 2 years of driving before the lower indirect carbon emissions due to driving has paid off the excessive manufacturing emissions of the BEV. However, over a ten-year period, the BEV can significantly reduce the total emissions due to the combined manufacturing and driving when compared to its fossil-fuel competitors. This is largely because the electricity generation powering the driving is becoming a lot cleaner, with the elimination of coal and peat as the energy sources and the embrace of gas, wind and solar. The challenge over the next decade is to keep reducing the carbon emissions due to the manufacturing.

Our knowledgeable UCC colleagues, Paul Deane and Brian Ó Gallachóir, tell us that significant reductions in carbon emissions are planned for the Irish grid over the next decade. The historic values of grammes of carbon dioxide per kilowatt-hour, gCO_2/kWh, published by SEAI, and the predicted values, provided by Paul, are plotted in Figure 1. The kilowatt-hour or kWh is the unit of energy used both for our household electricity consumption and for electric vehicle batteries. The number of electrical kWh to drive a kilometre, kWh/km, is published for each BEV. We are going to convert this number to gCO_2/km based on electricity from the Irish grid. You can then compare the indirect emissions of BEVs with the emissions of conventional or hybrid vehicles, also published as gCO_2/km. We are going to use a value of 220 gCO_2/kWh, based on predicted values for carbon emissions by the Irish electrical grid over the next ten years to 2030. The number for 2020 is higher at about 312 gCO_2/kWh. The predicted number of 2030 is a lot lower at 118 gCO_2/kWh.

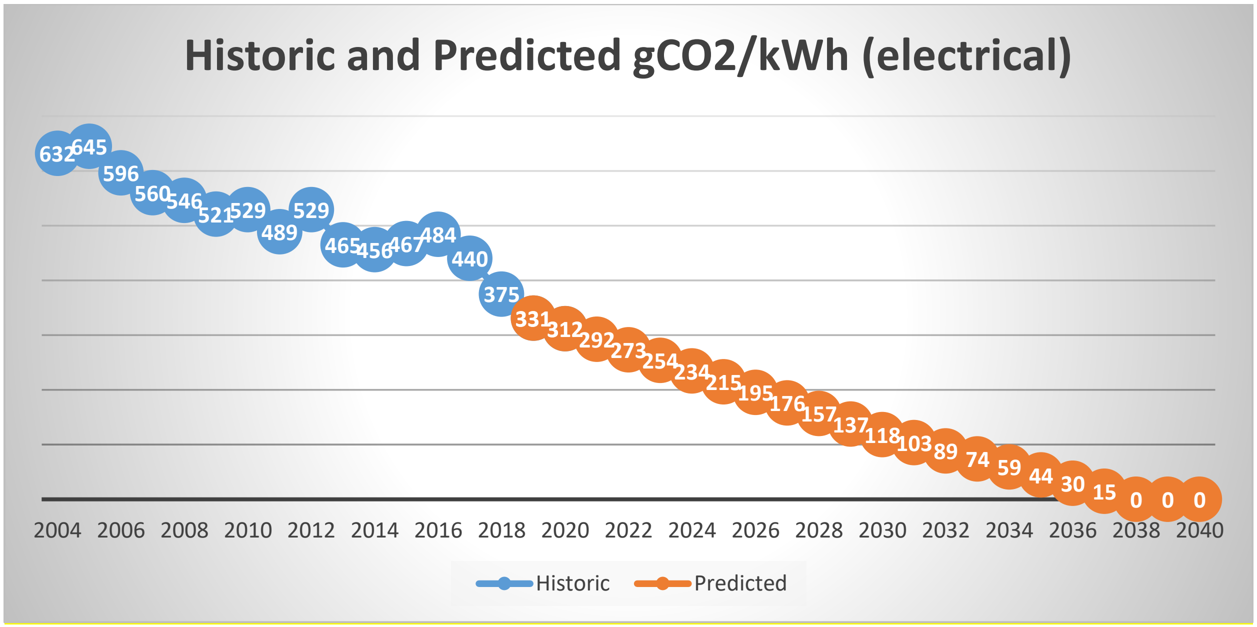

Figure 1. Historic and predicted carbon emissions over time for the Republic of Ireland.

Don’t forget to plug in your PHEV!

The desirable feature of a PHEV is that they typically can cover 50 km in electric-only mode. That is great as 50 km is about the average daily drive in Ireland, which means that many of your miles can be electric only. If you have a PHEV or are getting one, drive as much as possible using electricity from the grid- otherwise the environmental benefits will not be fully realised. The carbon emissions can be 3 to 4 times greater when running the vehicle off the engine compared to being in electric mode and running off the battery, your fuel costs will also be a lot higher.

Estimating the EV Emissions

This is a complex field but we certainly can make an attempt to estimate the total CO_2 emissions for some vehicles based on the latest numbers. The most recent International Energy Agency (IEA) report gives numbers for the life-cycle greenhouse gas emissions from the manufacturing of an average mid-size car [3]. Examples of such cars would be the Toyota Corolla HEV and the Hyundai Ioniq BEV. For this study, we assume ten years of driving at 15,000 km per year for a total of 150,000 km.

As a starting point, we will simply add the manufacturing emissions to the direct or indirect driving emissions. The various figures are as shown in Figure 2. The BEV 40 means a BEV with a 40 kWh battery, and this vehicle results in about 8,700 kg of CO_2 emissions during manufacturing. The indirect emissions due to the BEVs come to 5,250 kg, which is 150,000 km at 35 gCO_2/km, a representative value for a BEV. Thus, the total emissions for the BEV 40 is 13,950 kg. As the battery size increases, the manufacturing emissions also increase, rising to as high as 12,000 kg to manufacture a vehicle with an 80 kWh battery (BEV 80), with total emissions of 17,250 kg.

The manufacturing emissions for the PHEV come to about 7,400 kg. We'll use the emissions published by the US EPA for the Kia Niro PHEV as representative. We assume 60 %, or 90,000 km, of the driving is electric with 44 gCO_2/km and 40 %, or 60,000 km, is in hybrid mode at 113 gCO_2/km. This results in total emissions of 18,140 kg.

Next, we consider a HEV and use the emissions for the Toyota Corolla HEV. This car comes with about 6,500 kg of manufacturing emissions. Adding tailpipe emissions of 15,300 kg, based on 102 gCO_2/km, bring the total emissions to 21,800 kg. Finally, we consider two conventional vehicles and use 6,000 kg for the manufacturing. The published values are 119 gCO_2/km and 122 gCO_2/km for the VW Golf petrol and diesel vehicles, respectively. The petrol vehicle thus has the highest total emissions at 24,300 kg.

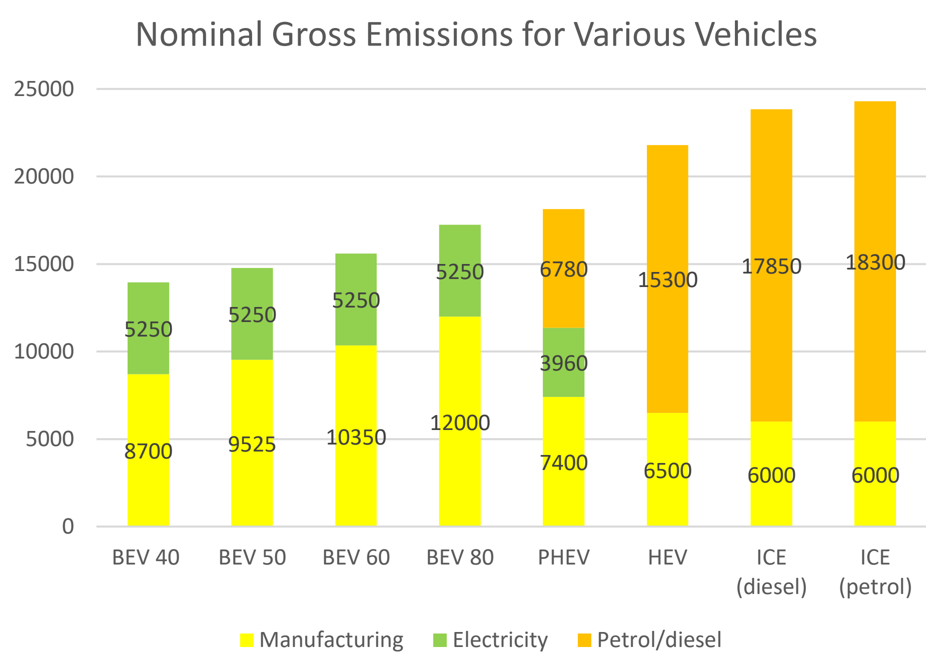

Figure 2. Nominal emissions manufacturing (yellow), electric grid (green) and fossil fuel (orange) for mid-size vehicles based on 150,000 km over ten years, with manufacturing numbers based on IEA 2020 report.

This simple study shows that a 2021 BEV, with a medium-sized battery and with typical yearly mileage, can have significantly less total emissions, about ten metric tonnes, than an equivalent vehicle powered by fossil fuels. One can reasonably expect that the smaller the vehicle, the lower are the total emissions. Conversely, larger SUV-type vehicles will have higher emissions. Based on Figure 1, we can see that further improvements in the electrical grid will reduce the indirect driving emissions (in green) significantly over the next few decades.

There are many challenges for EVs going forward. The environmental payoff is dependent on a number of factors. The electric grid has to get cleaner; this has been happening in Ireland and will continue. The country of manufacture of the vehicle can be a significant factor, as many of the industrial countries, such as China, have a high dependency on coal. Coal comes with pollution and health issues and mining deaths. Natural gas provides a key cleaner energy source for many countries, but the associated fracking and methane leakages are problematic.

Sourcing of raw materials has been controversial, especially for lithium and cobalt, key ingredients of the lithium-ion battery. Battery manufacturers are working to reduce cobalt content and replace it with nickel, while more sustainable sources of lithium are also being developed.

The competitive existing fossil-fuel technologies have also being getter cleaner, but they also come with high penalties. Illness and deaths related to particulate matter and other toxic tailpipe emissions are high globally, and the reaction to this has been a significant part of the push to EVs.

The EV List for Early 2021

The following alphabetical list is a starting reference for EVs on the market in early 2021. The vehicle type is shown as coupe (c), crossover (x), estate (e), hatchback (h), liftback (l), saloon (s), people carrier (P) or SUV (V).

Please note that there may be errors or omissions, and that there will be variations due to delivery charges, etc. New vehicle launches are fast and furious in the EV world, and so check with the dealers as to prices, new and premium models, and variations for 2021 and beyond!

The standardized WLTP values are published in Ireland for range and mile per gallon (mpg), and so are used here, but we do note that there can be varying interpretations of the test values.

Reference [4] is a very good information source on BEVs. You can also reference the US EPA website [5] for very useful comparisons of vehicles across emissions and fuel economy. Reference [6] is a very informative site on EVs.

Battery EV:

Each BEV comes with the following information: price, battery size, range, an estimate of the average gCO_2/km emitted by the Irish electrical grid to power the car over the next ten years, and the time for an acceleration from zero to 100 km/h (which provides an insight to vehicle power and torque relative to the vehicle mass). EVs can have very fast accelerations.

Audi e-tron Quattro 50 (V) €72,211, 71 kWh, 333 km, 50 gCO_2/km, 6.8 s;

Quattro 50 (sportback) €75,197, 71 kWh, 333 km;

Quattro 55 (V): €82,004, 95 kWh, 405 km, 50 gCO_2/km, 5.7 s;

Quattro 55 (sportback): €89,016, 95 kWh, 405 km.

BMW i3 (h, four-seater) €37,466, 42 kWh, 308 km, 34 gCO_2/km, 7.3 s;

Mini Cooper (h, four-seater) €27,349, 32.6 kWh, 234 km, 33 gCO_2/km, 7.3 s.

Citroen C4 (x) 50 kWh; 350 km, 36 gCO_2/km, 9.7 s.

Ford Mustang Mach-E (x) 75.7 kWh, 450 km, 36 gCO_2/kg, 6.9 s.

Honda e (h) €29,995, 35.5 kWh, 222 km, 222 km, 38 gCO_2/km.

Hyundai Ioniq (s) €32,250, 40.4 kWh, 311 km, 30 gCO_2/km, 9.7 s;

Kona (x) €39,650, 67.5 kWh, 484 km, 32 gCO_2/km, 7.9 s.

Jaguar I-Pace (x) €85,780, 90 kWh, 470 km, 48 gCO_2/km, 6.4 s.

Kia Niro (x) €36,700, 67.1 kWh, 455 km, 35 gCO_2/km, 7.8 s;

Soul (x) €35,300, 67.1 kWh, 452 km, 35 gCO_2/km, 7.9 s.

Lexus UX 300e (x) €60,430, 54.3 kWh, 305 km.

Mazda MX-30 (x) €31,795, 35.5 kWh, 200 km.

Mercedes Benz EQC (V) €82,590, 85 kWh, 417 km, 49 gCO_2/km, 5.1 s;

EQV (P) 100 kWh, 363 km, 61 gCO_2/km, 12.1 s.

Nissan Leaf (h) €27,595, 40 kWh, 270 km, 45 gCO_2/km, 7.9 s;

e+ €35,539, 62 kWh, 385 km, 40 gCO_2/km, 7.3 s.

Opel Corsa (h) €26,854, 50 kWh, 330 km, 36 gCO_2/km, 8.1 s.

Peugeot 208 (h) €26,853, 50 kWh, 339 km, 36 gCO_2/km, 8.1 s;

2008 (V) €31,262, 50 kWh, 331 km, 36 gCO_2/km, 8.5 s.

Renault Zoe (h) €26,990 50 kWh, 395 km, 38 gCO_2/km, 11.4 s.

Tesla Model 3 (s) €47,990, 50 kWh, 430 km, 33 gCO_2/km, 5.6 s;

Model S (s) €85,990, 95 kWh, 652 km, 39 gCO_2/km 3.8 s;

Model X (V) €94,990, 100 kWh, 561 km, 44 gCO_2/km 4.6 s.

Toyota Proace (P) 75 kWh, 330 km.

Volkswagen ID.3 Life (h) €32,157, 58 kWh, 425 km, 34 gCO_2/km, 7.3 s;

ID.3 Touring (h): €41,175, 77 kWh, 542 km, 36 gCO_2/km, 7.3 s;

ID.4 1st (c): €41,428, 77 kWh, 500 km, 40 gCO_2/km, 8.5 s.

Hybrid EV:

Each HEV comes with the following information: price, fuel economy in mpg, and published gCO_2/km tailpipe emissions, and the time for an acceleration from zero to 100 km/h.

Ford Mondeo (s, e) €35,878, 51.4 mpg, 126 gCO_2/km, 9.2 s.

Honda CR-V (V) €40,895, 41 mpg, 156 gCO_2/km.

Hyundai Kona (x) €29,045, 52.3 mpg, 122 gCO_2/km, 11.2 s.

Tucson (V) €35,995, 48 mpg, 133 gCO_2/km.

Toyota Corolla (h, s, e) €27,630, 62.8 mpg, 102 gCO_2/km, 10.9 s;

Camry (s) €41,995, 53.3 mpg, 120 gCO_2/km, 8.3 s;

C-HR (x) €31,195, 57.7 mpg, 110 gCO_2/km, 11 s;

Highlander (V) €63,995, 42.8 mpg;

Prius (l) €36,330, 61.4 mpg, 104 gCO_2/km, 10.8 s;

RAV 4 (X) €37,970, 50.4 mpg, 127 gCO_2/km, 8.4 s.

Yaris (h) €24,255, 72.4 mpg, 88 gCO_2/km, 9.7 s;

Yaris Cross (x);

Lexus ES300h (s) € 49,950, 51.4 mpg, 125 gCO_2/km, 8.9 s;

LC (c) €126,890, 43.9mpg, 145 gCO_2/km, 5.0 s;

LS (s) €145,420, 30.7 mpg, 207 gCO_2/km, 5.4 s;

NX300h (x) €56,660, 37.7 mpg, 170 gCO_2/km, 9.2 s;

RX450h (V) €83,995, 34.5 mpg, 185 gCO_2/km, 8 s;

UX250h (x) €40,820, 51.3mpg, 124 gCO_2/km, 8.5 s.

Plug-in Hybrid EV:

Each PHEV comes with the following information: price, battery size, range in electric-only mode, and the time for an acceleration from zero to 100 km/h. We don't use the published WLTP figures here as they do not separately break out the emissions when driving in electric or hybrid mode. You can estimate the vehicle emissions in electric or hybrid mode by comparing the PHEV of interest to the figures for an equivalent BEV or HEV type. See also [5] for US EPA data on fuel economy and emissions on the models which are also sold in the US.

Audi Q5 TFSI e Quattro (V) €59,065, 14.1 kWh, 40 km, 5.3 s;

Q7 TFSI e Quattro (V) €83,250, 17.3 kWh, 42 km;

A7 TFSI e Quattro (sportback) €77,550, 14.1 kWh, 40 km.

BMW 225xe (h) €39,667, 10 kWh, 56 km, 6.7 s;

330e (s) €43,235, 12 kWh, 60 km, 5.9 s;

530e (s) €53,134, 12 kWh, 56 km, 6.1 s;

745e (s) €90,023, 12 kWh, 58 km, 5.2 s; i8 (c);

Mini Cooper Countryman (x) €42,950, 9.6 kWh, 51 km.

Citroen C5 (X) €38,995, 13.2 kWh, 55 km, 8.9 s.

Ford Kuga (V) €34,600, 14.4 kWh, 56 km, 9.2 s.

Jaguar E-Pace (x) €65,195, 13.6 kWh, 55 km, 6.5 s;

F-Pace (V) €67,460, 13.6 kWh, 53 km, 5.3 s.

Kia Niro (x) €31,850, 10.8 kWh, 48 km, 10.8 s;

Xceed (h) €29,650, 8.9 kWh, 48 km, 11 s.

Land Rover Range Rover Sport (V) €87,705, 13 kWh, 41 km, 6.7 s.

Autobiography (V) €140,965;

Defender (V) €78,085;

Discovery Sport (V) €61,645;

Evoque (V) €59,225;

Velar (V) €79,275;

Vogue (V) €122,820.

Mercedes Benz E300de (s, diesel) €57,720, 13.5 kWh, 48 km, 6.0 s.

E300e (s, petrol) €55,825, 13.5 kWh, 50 km, 5.7 s;

S560e (s).

Mitsubishi Outlander (V) €39,900; 13.8 kWh, 45 km.

Opel Grandland X (V) €38,695, 13.2 kWh, 60 km, 6.1 s.

Peugeot 3008 (V) €37,550, 13.2 kWh, 60 km;

508 (s) €37,800, 11.8 kWh, 40 km.

Seat Leon (h) €32,695, 13 kWh, 60 km.

Skoda Superb (s) 13 kWh, 55 km, 7.7 s.

Toyota RAV4 (V), 18.1 kWh, 65 km.

Volkswagen Golf (h) €41,805, 13 kWh, 64 km;

Passat (s) €41,260; 13 kWh, 60 km.

Volvo S60 (s) €57,995, 11.6 kWh, 56 km, 4.6 s;

90 (s) €64,995, 11.6 kWh, 51 km, 5.1 s;

V60 (e) €54,998, 11.6 kWh, 58 km, 4.6 s;

V90 (e) €62,927, 11.6 kWh, 58 km, 5.9 s;

XC40 (x) €44,995, 10.7 kWh, 45 km, 8.5 s;

XC60 (x) €66,028, 11.6 kWh, 51 km, 5.9 s;

XC90 (V) €77,420, 11.6 kWh, 48 km, 5.8 s.

John Hayes is a senior lecturer at University College Cork and previously worked in the automotive industry. He is the lead author on *Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles* by Hayes and Goodarzi, and published by John Wiley & Sons in January 2018. Car enthusiast Gerard Foran and UCC engineering graduate Conor Healy worked with John on this article.

References

[1] https://www.rte.ie/brainstorm/2019/1211/1098528-your-essential-guide-to-buying-an-electric-car-in-2020/

[2] https://www.rte.ie/brainstorm/2019/0808/1067595-the-second-coming-of-the-electric-car/

[3] International Energy Agency, *Global EV Outlook 2020*.

[4] https://ev-database.uk/

[5] United States EPA comparison website: https://www.fueleconomy.gov/

[6] https://chargedevs.com/