2021: The year of the electric car

The purpose
This is a teacher resource on climate change and green innovation, which you can use to develop your own lesson plans. In 2021 electric cars suddenly became ubiquitous, with adverts appearing online, on billboards, and featuring in primetime commercial ad breaks. This resource has the 3-fold aim of addressing: why electric car sales have rapidly increased in the UK since 2020; where EVs are being bought; and what the future EV market might look like in the twenty-first century. A small pioneer case study will be highlighted near Braintree, in Essex, and Dundee will be celebrated as a city which is fast becoming the cleanest city in the UK.

The specification
AQA GCSE 3.1.1.4. Managing climate change involves both mitigation (reducing causes) and adaptation (responding to change).

Edexcel GCSE 4.5 Case study of a major UK city. The range of possible strategies aimed at making urban living more sustainable and improving quality of life (recycling, employment, education, health, transport, affordable and energy-efficient housing) for the chosen UK city.

OCR GCSE 1.2.6 Case study of one major city in the UK including the influences of: contemporary challenges that affect urban change, including housing availability, transport provision and waste management.

Eduqas GCSE 2.2.2 What are some of the contemporary challenges facing UK towns and cities? Challenges of creating urban sustainable communities in UK towns/cities. The concept of Egan's wheel.

The UN Sustainable Development Goals
In 2015 all UN member states agreed on the 2030 Agenda for Sustainable Development, which consisted of 17 Sustainable Development Goals, commonly known as the SDGs. Number 11 of the SDGs states:

Make cities and human settlement inclusive, safe, resilient, and sustainable.

At present, urban areas are not generally sustainable and a large part of this unsustainability stems from transport. As of 2016, 90% of urban dwellers have been breathing unsafe air, resulting in 4.2 million premature deaths due to air pollution.

Globally, the transport sector is responsible for the release of 8 Gt/year of carbon dioxide (CO₂) emissions, 25% of the global total. A large proportion of this is due to an estimated 1.2 billion cars in operation around the world. Within that global figure are approximately 37.5 million vehicles registered for use on the road in the UK. This figure, both domestically and internationally, is growing year on year. In 2019 92 million motor vehicles were manufactured worldwide. The Internal Combustion Engine (ICE), which is powered by fossil fuels like natural gas, diesel or petrol is the main culprit for increasing CO₂ emissions and declining air quality.

Our carbon emissions must and will be reduced by a shift in public attitude and behaviour (which is already underway). If NetZero is to be realised by 2050, walking and cycling will need to increase and a greater use of public transport (run on renewable energies) will need to occur — running parallel with more efficient engines, low carbon fuels and the electrification of cars.
The background
After successive years of decarbonisation in the UK energy sector, it is now transport which is the number one polluting sector of the UK economy. Transport is lagging behind other sectors and it needs to re-focus in order to achieve NetZero by 2050.

On the next page is a line graph showing UK Domestic GHG emissions from 1990 to 2018. The graph forms part of the incumbent government’s Transport Decarbonising Plan 2020. Within the plan the following reflections are offered:

- Between 1990 and 2018, the UK reduced emissions by over 43% while growing the economy by 75%
- In June 2019, the UK became the first major economy to pass a NetZero law to end its contribution to climate change by 2050
- Transport became the largest emitting sector of GHG emissions in 2016
- In 2018, transport contributed 28% of UK domestic emissions

Additional reflections to run parallel with recent developments in the automotive industry are:

- The UK government plug-in car grant was introduced in 2011 to stimulate the early market for zero emission vehicles, supporting the purchase of more than 285,000 vehicles to date
- In 2012 the Tesla S Model was released with a right-hand drive model arriving in the UK in 2014. Tesla is now seen as “leading the electric race” due to a simplified buying process, superior battery power technology and being innovative and nimble
- In 2017 the Tesla Model 3 was released (arriving in UK showrooms in 2019)
- More cities (Brighton, Bristol, York) plan to ban vehicles completely from their centres as some analysts predict the 2020s “could herald an end to the supremacy of the motor car”
The ICE which requires petrol and diesel has long been known for pollution, and there have been waves of government policies encouraging the public to buy one then the other over time.

Tetraethyllead (lead) was first infused with petrol in the 1920s primarily to prevent piston damage and pre-ignition (when fuel ignites in the cylinder before the spark plug fires) with leaded petrol growing in popularity throughout the mid twentieth century. Increasingly it was discovered that lead was a heavy pollutant linked to cancer, brain damage and hypertension therefore countries began phasing out this polluting fuel. Japan being the first country in the developed world to do so in 1972. The first car to be sold in the UK which was unleaded-only was the Toyota Celica GT-Four. Leaded fuel went from being used in approximately ⅓ of the 22 million cars being driven in the UK in 1993 to a near global eradication by 2011. This was largely spurred on by the UNEP (United Nations Environment Programme) after the 1992 Earth Summit and was based upon an international survey on fuel use by National Resources Defence Council (NRDC).

Since then, diesel fuel has risen in popularity — described as “the cheap way to save the planet” due to marginally lower levels of CO₂. Drivers liked the fuel-efficiency of the diesel engine and the UK government, alarmed by climate change, rolled out advertising campaigns encouraging the public to switch to diesel fuel. A fairly recent example is the cut to diesel fuel duty in 2001 by the then Labour Chancellor, Gordon Brown. Consequently, nitrogen dioxide (NO₂) pollution from diesel fuel has increased, causing thousands of premature deaths. The World Health Organisation announced diesel exhaust fumes as carcinogenic in 2012, placing the fuel in the same category as mustard gas and asbestos.

Car ownership has not diminished in the UK, it is climbing to an expected peak in the mid-2030s. Currently this rise is being fulfilled by petrol fuel cars. Whilst petrol does not emit as much NO₂ as a diesel engine, it is responsible for greater CO₂ emissions.
A new type of car is now gaining momentum in the UK, after being heralded by successive Prime Ministers as a means to reaching net zero in the transport industry: the electric car.

1. Table 1 shows the percentage of diesel, petrol, and electric car sales from 2016 to 2020. Create a line graph using the data in Table 1. When you draw this graph run the x axis from 2016 to 2026 (predicted).

<table>
<thead>
<tr>
<th>Year</th>
<th>Diesel</th>
<th>Petrol</th>
<th>Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>47.72</td>
<td>49.05</td>
<td>3.23</td>
</tr>
<tr>
<td>2017</td>
<td>41.95</td>
<td>53.40</td>
<td>4.64</td>
</tr>
<tr>
<td>2018</td>
<td>31.69</td>
<td>62.36</td>
<td>5.96</td>
</tr>
<tr>
<td>2019</td>
<td>26.66</td>
<td>65.95</td>
<td>7.40</td>
</tr>
<tr>
<td>2020</td>
<td>19.70</td>
<td>62.70</td>
<td>17.60</td>
</tr>
</tbody>
</table>

Table 1 Passenger car registrations in the United Kingdom between 2016 and 2020, by fuel type (%)

2. Extrapolation is an estimation which describes finding a value on a graph beyond the range that was originally measured. It is to infer something. Extrapolate the line for electric car registrations to 2026. Based upon these projections, what level of electric car ownership should be expected for 2026?

3. A living graph describes a graph which places events on a chronology of time, along an x axis. Annotate the 6 pieces of information onto the line graph for the correct year.

4. A living graph encourages students to both select the most important events within a topic and to rate them over time. Use both the cards below and the bullet points from page 2 to answer: what have been the most important events for electric car evolution?

<table>
<thead>
<tr>
<th>In 2020 Volvo announce a complete electrified carline of plug-in hybrids and pure electric cars (with the aim of 20% of car sales being plug-in hybrids)</th>
<th>Anne Hidalgo, the mayor of Paris announces plans in October 2017 to eliminate all non-electric cars from Paris streets by 2030</th>
<th>There are now many electric cars offering ranges in excess of 250-miles with the Tesla Model S Long Range claiming the longest range of 379-miles in 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>The rapid growth in EV demand internationally is largely credited to dramatic reductions in battery costs. Lithium-ion battery prices dropped from $1,000/kWh to below $100/kWh in the mid-2020s</td>
<td>In 2019 the UK government amend the Climate Change Act 2008 by introducing a target for at least a 100% reduction of greenhouse gas emissions (compared to 1990 levels) in the UK by 2050</td>
<td>In 2020 Norway become the first country in the world where the sale of electric cars (54%) overtook those powered by petrol, diesel, and hybrid engines (up from 42% in 2019)</td>
</tr>
</tbody>
</table>

5. Extension task. The 1997 Toyota Prius was the first electric hybrid manufactured for the mass market. It was released worldwide in 2000. Redraw a longer x axis with a timeframe from 2000 to 2026 and add in any additional milestones for the electric car.

6. Using your living graph (and the suggested further reading on pages 8 and 9) answer the following question: explain why electric car sales accelerated from 2000 to 2020?

7. How would you describe the pace of change in the automotive market?
California, the disrupter
The American state of California is colloquially known as “the disrupter” in the automobile industry with a specific few companies: Tesla, Faraday Future and Canoo, leading the charge towards battery power and EVs. Other American start-ups, such as Rivian, also have manufacturing plants in the Golden State (with their headquarters in Michigan).

California has been a progressive forward-thinking state for the automotive industry since the 1990s, largely due to the California Air Resources Board (CARB). The 1990 ZEV (Zero Emission Vehicle) mandate programme has been designed to encourage car manufacturers to sell specific numbers of the cleanest car technologies available, such as: battery electric, fuel cell, and plug-in hybrid EVs. The Californian ZEV mandate has been amended several times with key stipulations being that 2% of all vehicles produced by car manufacturers in California had to be ZEV by 1998, rising to 5% in 2001 and 10% in 2003.

In 2003 the programme suffered a setback following a litigation by ICE automakers. Subsequently General Motors and Toyota ceased EV production, citing slow battery development and limited demand. In 2021 the Advanced Clean Cars program was established which reinstalled the requirement that 10% of Californian car sales should be ZEV (by 2025).

Tesla has led the pack in producing both headline-grabbing designs and, recently, more affordable mass-market cars. The Silicon Valley-born company first released the Lotus Elise Roadster, with a lithium-ion battery in 2008. In 2009 funding from the US department of Energy allowed Tesla to acquire GM-Toyota’s closed Fremont Assembly plant. The factory now employs 10,000 people. The S Model, with an RRP of £73,990, was “the world’s first premium electric sedan” in 2012. Model 3, described as the world’s “bestselling electric car of all time”, came off the production line in 2017 announced by Elon Musk in this tweet. It is priced from £42,500.

Traditional obstacles to new start-ups have largely disappeared in the twenty-first century with a new wave of EV manufacturers coming into the industry hot on the heels of Tesla’s breakaway success. Modern EVs essentially have fewer moving parts and are therefore more straightforward to design and assemble than ICE vehicles. The challenge to the established “automotive dinosaurs” now stems from a number of small (yet rapidly growing) companies:

- **Byton**, is an all-electric automotive brand which, in 2020, announced would be selling right-hand drive Byton M-Byte SUV in the UK by the end of 2021. In January 2021 Foxconn (the world’s largest contract electronics manufacturer) chairman Young Liu announced a new deal to make electric vehicles with Byton (the decision is pending on factory location; either Wisconsin or Mexico)
- **Piëch**, is an electric Swiss sports car manufacturer. The Mark Zero is designed to recharge to 80% in less than 5-minutes and is an electric supercar. Crucially, the company is promising to bring recharging time on par with the time it takes to refill a conventional petrol or diesel car.
- With research facilities and headquarters in Detroit, **Rivian** aims to develop an electric SUV and pickup truck, made possible with substantial financing. In 2017 Amazon announced it was making a $700 million investment in the company. In 2019 Amazon CEO Jeff Bezos ordered 100,000 delivery vans from the start-up, to be on the road by 2024.
- Another start-up in California, **Canoo**, said it would offer electric vehicles by subscription by 2021, with drivers paying a monthly price similar to a lease but with no fixed time commitment. Canoo hopes this has overcome the main stumbling block consumers have with electric cars: the price.
Gridserve

Gridserve pioneers sustainable energy solutions such as developing and operating critical power infrastructure for the EV market. Gridserve are the UK’s first NetZero leasing service and run the UK’s first all-electric recharging forecourt in Braintree, Essex. Starting at just 24p per kWh (including VAT) it delivers the lowest ultra-fast charging rates in the UK with 36 rapid chargers all powered only by renewable energy.

Gridserve Braintree opened on 7 December 2020 as the first charging station of a wider EV infrastructure rollout. In total Gridserve and Hitachi Capital are planning to open 100 electric facilities across the country as part of a £1 billion programme by 2025.

Image 2 The UK’s first all-EV recharging facility at Braintree © Gridserve

Gridserve Braintree is powered by a “solar canopy” above the charging ports and has a power link to nearby Clay Hill solar farm. Clay Hill solar farm is significantly the first solar farm not to be supported by government grants or subsidies. The owners, Anesco, believe the farm is a first step on the journey to “grid parity” — this is when an alternative form of energy generates enough power at a levelized cost of electricity so that it is equal (or less) than the price of buying power from the grid. It is estimated that Clay Hill solar farm exports more than 9,000MWh per year. On site at Gridserve Braintree there is a 6MW battery designed to store power during low usage for times of peak demand. This allows the facility to mitigate against days with low solar intensity.

Dundee

Dundee is a really exciting city to study due to its huge investment in electric car infrastructure. Since 2011 Dundee city council has demonstrated consistent effort, since being one of the first UK councils to invest in EV, in pursuing an energy transition. The city now has 192 charging points, 2 electric bin lorries and is “at the vanguard of the switch to zero-carbon transport”.

The need for electrification is acute. Dundee has three of the most polluted streets in Scotland, because the city was built in the bowl of an eroded volcano and exhaust gases settle over its centre. Lochee Road is still ranked one of the most polluted streets in Scotland for NO₂.

The approach has been dubbed “build it and they will come” as the city council have decided to electrify the city first to then encourage public uptake, (rather than the other way round). This innovative approach included the UK’s first solar powered mass charging hub with 20 bays and battery storage to give users a cheaper rate of electricity, even at peak time. Located on Princes Street low-cost electricity is achieved by the charging hub storing electricity during periods of low usage — making it available to EV owners at a later time. Equally, if Dundee has had a day of low solar intensity, electricity will be taken from the grid between 1 and 2 a.m., when it is at its cheapest.

First wave uptake in Dundee was modelled by council employees and by taxis in the city. This was incentivised by the council bringing in the Electric Taxi Policy in 2016, meaning any new taxis had to be electric, which helped to increase the numbers of electric vehicles. There are now 87 electric taxis (15% of the taxi fleet) operating in the city. The main issue holding back greater uptake is lack of large electric taxis that have wheelchair access. The only suitable (and available) taxi is the e-NV200 by Nissan, but because of a failed height regulation test and the fact that there is a 60/40 split in wheelchair accessible/salon taxis in Dundee, rollout has stalled.

Whilst progress has slowed in the rollout of electric taxis in Dundee, a continued increased in EV popularity is still anticipated as the Scottish government aims to cut the country’s net carbon emissions to zero by 2045 and end sales of new diesel and petrol cars by 2032.

**Future trends**

There are numerous future trends in the EV market. Two much-anticipated developments are: Vehicle to Grid technology (V2G), and the EV circular economy.

V2G technology is a revolutionary way of using energy. Car users essentially charge the EV battery when there is surplus energy and, at other times of the day, return some of it when energy levels are low nationally. Most drivers only use a fraction of their battery power — V2G technology allows you to send a current in both directions. It is a solution to balance the requirements of supply and demand and is described “as potentially the biggest tech innovation in green energy since renewable became commercially viable”. It is hoped V2G could open up new income streams for drivers, fleet operators and vehicle manufacturers as the EV battery will increasingly been seen as an asset to make money from in the future. [This video gives you an excellent quick explainer on V2G.](#)

In order to halt the impacts of climate change energy providers also want V2G. In times of peak demand energy currently has to be bought from reserve power plants (which may not be renewable sourced) with increased energy prices. If V2G is made a reality, there will not be any need to rely on centrally produced power as the energy from millions of UK car batteries can be aggregated and utilised alongside the National Grid.

Batteries were the initial focus of critics when the first-generation EV cars were released, as they had short battery life spans. The issue was that batteries were quite simply wasteful, owing to the fact that they are “resource-heavy” when being manufactured (requiring lithium and cobalt).

In the past the main reason for battery degradation to a lithium-ion battery is time spent at full charge however manufacturers now say this will be solved by V2G as this new technology allows cars to move to a lower state of charge. New battery technologies promise strategies to reduce the reliance on cobalt, but some people worry this will simply shift demand towards nickel extraction and use.

Additionally, there has been a concerted effort to move towards a circular economy in battery production. The circular economy describes reuse and recycling, [this National Geographic article](#)
explains the concept for children. Many other EV car parts are already recycled such as aluminium and steel, or sustainably sourced such as leather and wood. Battery life currently ranges from 10-years for early EV models to 20-years for newer models, largely dictated by the number of charge cycles. There are 3 possible destinations for an end-of-life battery:

- It is simply thrown away. An example of the linear economy
- It is recycled by a specialized company, possibly a subsidiary, to recover the valuable elements of nickel, cobalt, manganese, and lithium
- It is immediately repurposed, reusing the battery cells with new software and power electronics

Whilst only 50% of EV batteries are currently recycled there is widespread hope that the EV battery industry, which is in its infancy, will learn from the long-established lead-acid battery industry (largely found in ICE vehicles).

8. Read the Wired article The Race To Crack Battery Recycling—Before It’s Too Late and create a mini case study on Redwood Materials, the battery recycling company in Carlson City, Nevada.

9. Different manufacturers have moved at different speeds in battery recycling. Read the Driving Electric article How recyclable are batteries from electric cars? and make notes on the different approaches of:

   a. Mercedes
   b. Nissan’s xStorage
   c. Honda
   d. BMW

Further reading
- Global sales of electric cars accelerate Global sales of electric cars accelerate fast in 2020 despite pandemic | Environment | The Guardian
- Gridserve electric forecourt Gridserve Electric Forecourt: we try the UK’s first bespoke EV charging location | Auto Express
- Tech Radar visits Gridserve Future of fuelling: we visit the UK’s first all-electric forecourt for electric cars | TechRadar
- Dundee is aiming to be the cleanest city in the UK Dundee’s green revolution: council-run charging hubs and electric cabs | Dundee | The Guardian
- Can the UK be rid of petrol and diesel cars by 2030? Can the UK be rid of petrol and diesel cars by 2030? | Euronews
- The Apple Car Apple Car expected to shake up auto industry worldwide | Financial Times (ft.com)
- Leaded petrol Throwback Thursday 1989: the switchover to unleaded petrol | Autocar
- What did the NRDC do? Global Phase-out of Lead in Gasoline Succeeds: Major Victory for Kids’ Health | NRDC

- The Death of Diesel [The death of diesel: has the one-time wonder fuel become the new asbestos? | Cities | The Guardian](The death of diesel: has the one-time wonder fuel become the new asbestos? | Cities | The Guardian)

- Diesel fumes [Diesel exhaust fumes cause lung cancer, WHO says | Reuters](Diesel exhaust fumes cause lung cancer, WHO says | Reuters)


- Percentage breakdown for petrol, diesel and electric [UK: fuel new car market share 2016-2020 | Statista](UK: fuel new car market share 2016-2020 | Statista)

- The electric car future is finally taking off [www.ft.com/content/f6e9ea18-acf6-46d9-ba2b-2920495db8f3](www.ft.com/content/f6e9ea18-acf6-46d9-ba2b-2920495db8f3)


- FT Hydrogen — Fantasy or fuel of the future? [www.ft.com/content/839f9cf4-a4b6-4c4c-83f8-6141d77404a0](www.ft.com/content/839f9cf4-a4b6-4c4c-83f8-6141d77404a0)

- FT Bolsonaro and climate change [www.ft.com/content/67f547f3-fb8e-4a27-88da-78adea07d51c](www.ft.com/content/67f547f3-fb8e-4a27-88da-78adea07d51c)


- Foxconn announces Byton deal and weights up making EVs in Wisconsin [www.ft.com/content/2920cf0b-9a7c-40ed-a2cc-50b8d13d3bb2](www.ft.com/content/2920cf0b-9a7c-40ed-a2cc-50b8d13d3bb2)


- Inside Clay Hill [www.solarpowerportal.co.uk/blogs/inside_clay_hill_the_uk's_first_subsidy_free_solar_farm](www.solarpowerportal.co.uk/blogs/inside_clay_hill_the_uk's_first_subsidy_free_solar_farm)

- Watch Maddie Goes Electric episodes 1 to 6 [www.youtube.com/watch?v=9A4ytljB-jo](www.youtube.com/watch?v=9A4ytljB-jo)

- Dundee charging infrastructure [www.dundeecity.gov.uk/news/article?article_ref=3555#;~:text=Charging%20infrastructure%20in%20the%20city,battery%20storage%20was%20opened](www.dundeecity.gov.uk/news/article?article_ref=3555#;~:text=Charging%20infrastructure%20in%20the%20city,battery%20storage%20was%20opened)

- Scotland’s most polluted streets [www.bbc.co.uk/news/uk-scotland-51163098](www.bbc.co.uk/news/uk-scotland-51163098)

- Solar, Storage & Electric Taxis; Dundee demonstrates what’s doable [www.youtube.com/watch?v=uDpblnu9xUE](www.youtube.com/watch?v=uDpblnu9xUE)