THE FARADAY INSTITUTION

The Road to Electrification – from the Internal Combustion Engine to the Battery Electric Vehicle

The global automotive industry is transitioning from the internal combustion engine to electric vehicles. The UK is at the forefront of this dynamic change and the push towards the electrification of road transport. By 2030, the Faraday Institution expects that 64% of all new cars bought by the UK consumer will be electric vehicles, rising to 95% by 2040.

Electric Vehicles Enter the Mainstream

The global automotive market is going through a period of fundamental technological disruption. Business models, customers and suppliers are all in a state of flux as demand and supply move away from the petrol and diesel engines of the previous century towards a future dominated by electric vehicles (EVs). The global stock of EVs increased by 63% to reach 5.1 million in 2018 (Figure 1). China is currently by far the biggest market, accounting for 45% of the global fleet. Norway has the highest EV market penetration at 46% of total car sales.[1]

The number of EVs on UK roads is also increasing sharply. Sales for petrol and diesel vehicles still make up the vast majority of the UK market, but EV sales increased in 2018 by 29% per annum[2] whereas sales of petrol and diesel vehicles fell by 6.8%.[3] At the end of 2018, the stock of EVs reached around 590,000, or 2.5% of all licensed cars (Figure 2).

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The Faraday Institution expects battery EVs (BEVs) to outsell all other EV types combined from 2024. Currently, EVs on the road are skewed towards hybrid EVs rather than BEVs as follows:

- 70% of EVs on the road are hybrid EVs, defined as a vehicle with both an internal combustion engine and an electric motor;
- 20% of EVs are plug-in hybrid electric vehicles (PHEV), defined as a hybrid that can be charged from the electricity mains supply; and
- 10% of EVs are BEVs—powered entirely by a battery that can be plugged in to recharge.[4]

If the future EV industry replicates the current size of the automotive industry, it would remain one of the most important sectors of the UK economy. In 2018, the UK automotive industry directly contributed £15.4 billion[5] of Gross Value Added, supported 186,000 full-time-equivalent jobs and accounted for 8.1% of the UK's manufacturing base.

[1] Global EV Outlook 2019.
[2] Department for Transport Vehicle Licensing Statistics.
[3] Society of Motor Manufacturers and Traders (SMMT).
[4] The 10% share for BEVs includes range-extended electric models (1.6%) which have an auxiliary power unit that can be replenished before battery recharging is required.
[5] ONS, GDP Q1 2019 Low Level Aggregates Table.
Photo: Courtesy of Nissan

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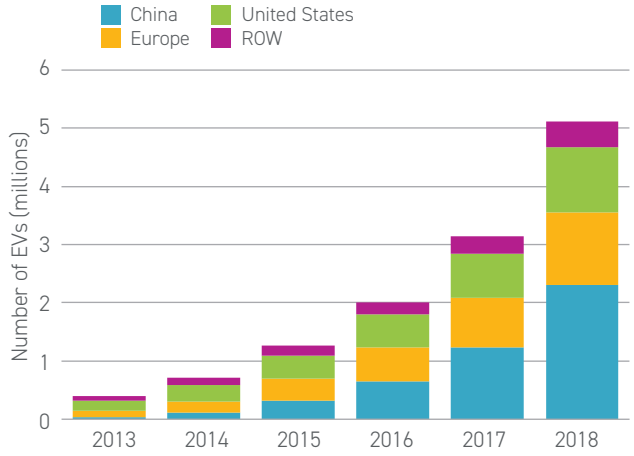
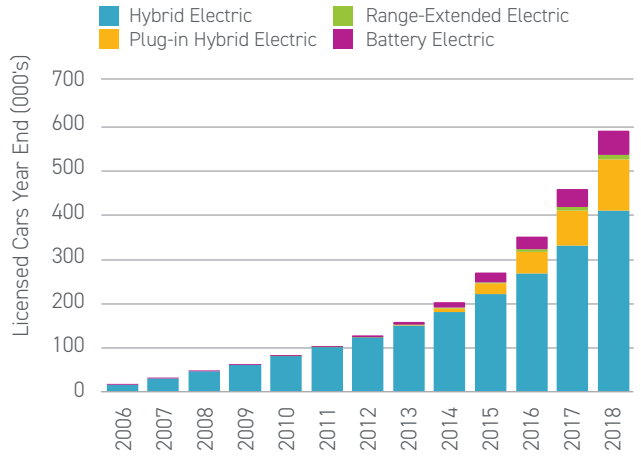
Figure 1: Global stock of electric vehicles



Source: International Energy Agency, Global EV Outlook 2019

Figure 2: UK stock of electric vehicles



Source: Department of Transport, Vehicle Licensing Statistics

Electric Vehicles Set to Dominate

The Faraday Institution has developed a model to forecast global and UK vehicle sales of EVs and vehicles powered by the conventional internal combustion engine (ICE).[6] The take-up of EVs is a key forecast variable and we assume it follows an innovation S-curve—the pattern and life cycle that typically follows the breakthrough of new technology.

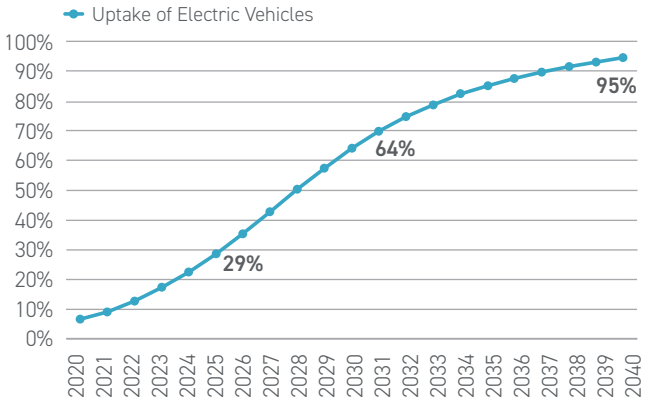
Under such an innovation model, the first group of buyers are often thought of as the innovators or early adopters. They have different socio-economic characteristics to the general population and different consumer preferences (for example, interest in technology or greater concern for the environment). As the typical buyer moves from the early adopters to the wider consumer, the product attains mass market appeal and experiences a growth spurt. Similar stages of growth were experienced for products as diverse as mobile phones, broadband and air travel, albeit that each had their own particular growth characteristics.

It is often difficult to predict exactly when the growth spurt will occur. The Faraday Institution expects that the market S-curve will start to slowly accelerate from 2025 (Figure 3) but will experience a more gradual surge in growth than other forms of technology.

EV take-up is combined with our forecasts of the UK and global automotive market. We expect global vehicle sales to grow by 1.3% per annum over the 2020-40 period as a result of strong demand in China and countries outside Europe and the US. Vehicle sales in the UK are also likely to increase but at the slightly slower pace of 1.1% per annum.[6]

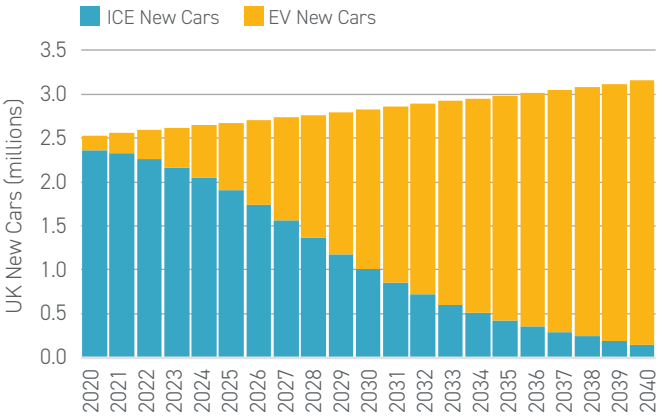
Figure 3 and Figure 4 summarise the Faraday Institution's forecasts, with EV purchases expected to reach 64% of total car sales by 2030 and 95% by 2040. We forecast 1.8 million EVs will be sold in 2030 and over 3.0 million in 2040 (of which around 80% will be BEVs).

Figure 3: UK EV take-up from 2020 to 2040



Source: Faraday Institution 'EV forecasting model'

Figure 4: UK vehicle sales from 2020 to 2040



Source: Faraday Institution 'EV forecasting model'

[6] UK Electric Vehicle and Battery Production Potential to 2040.

Legislation, Falling Battery Costs and Lower Costs of Ownership

The Faraday Institution's forecast of EV take-up is driven by our assessment of the direction of government policy and the gradual reduction over time of the cost of purchasing an EV and owning/running an EV.

Policy assumptions in the model are based on the UK government's 'Road to Zero' strategy, which sets out an ambition for between 50% and 70% of new car sales to be ultra-low emissions models by 2030 and full electrification of cars and light goods vehicles by 2040. Some of the substantive measures to drive the purchase of EVs include:[7]

- A Charging Infrastructure Investment Fund of £400 million to help ensure the UK has *"one of the best EV infrastructure networks in the world"*;
- Grants for plug-in cars, vans, taxis and motorcycles;
- A 'Go Ultra Low' campaign to provide consumers with facts and enable them to make an informed decision about buying, owning and running EVs; and
- Introduction of the 'Automated and Electric Vehicles Bill,' which, amongst other things, introduces legislation to help ensure public charge points are compatible and have common standards for payment and reliability.

There is some policy pressure to move faster. The UK government has recently agreed to implement the Committee on Climate Change's recommendation to have a target of net-zero emissions by 2050.[8] Options to ensure decarbonisation by 2050 that are relevant to the EV market include an earlier end to ICE sales than planned, particularly that all non-zero emission vehicles sold before 2035 should only be able to be used on UK roads up to 2050. Successful implementation of these options may mean EV take-up is much higher than our forecast and reach 100% by 2040 or before.

The upfront cost of EVs is a major barrier to purchasing, with EVs significantly more expensive than ICEs. Costs are, however, reducing quickly and the total cost of ownership (which includes running costs) of EVs is much closer or often even lower than ICEs.[9] As the market expands and volumes increase, economies of scale in all parts of the automotive industry and the supply chain will likely drive costs down substantially over the next decade.

But it is lower battery costs that are likely to have the biggest impact on the affordability of EVs. The cost of the battery represents up to 40% of the upfront cost of a BEV. Average battery costs have fallen by 85% since 2010 (Table 1) and are expected to continue to drop over the next few years. Falling costs on this scale will change the economics of EV ownership and lead to the acceleration of EV purchases from the mid-2020s. The other factor driving take-up of EVs in the long-term is the adoption of transport-as-a-service. These new forms of mobility, facilitated by autonomous EVs, are expected to have an impact from 2035 onwards.

Table 1: Average lithium-ion battery pack price

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Real 2018 US$ / kWh	1,160	899	707	650	577	373	288	214	176
% change p.a.		22%	21%	8%	11%	35%	23%	26%	18%

Source: Bloomberg NEF[10] Note: 'Real' prices are defined as prices adjusted to take into account the effects of inflation

[7] DfT (July 2018). Road to Zero. Next steps towards cleaner road transport and delivering our Industrial Strategy.
[8] Committee on Climate Change (May 2019). Net Zero Technical Report.
[9] Total cost of ownership & market share for hybrid and EVs in the UK, US and Japan (January 2018).
[10] Bloomberg New Energy Finance (March 2019). A Behind the Scenes Take on Lithium-ion Battery Prices.

About the Faraday Institution and Faraday Insights

The Faraday Institution is the UK's independent research institute for electrochemical energy storage research and skills development. We bring together academics and industry partners in a way that is fundamentally changing how basic research is carried out at scale to address industry-defined goals.

Our 'Faraday Insights' provide an evidence-based assessment of the market, economics, technology and capabilities for energy storage technologies and the transition to a fully electric UK. The insights are concise briefings that aim to help bridge knowledge gaps across industry, academia and government. If you would like to discuss any issues raised in this 'Faraday Insight', or our wider battery research programme, please contact Stephen Gifford.

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CONTACT
Stephen Gifford
Head of Economics & Market Insights
stephen.gifford@faraday.ac.uk
www.faraday.ac.uk
01235 425125
07741 853068

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