Royal Society of Edinburgh – 2017 Energy Study

Electric Vehicles - Energy Panacea or Problem?

Introduction

The Westminster Environment Secretary announced in the summer that the production of light vehicles with petrol or diesel engines will be phased out by 2040. The Scottish Government have since proposed a date of 2032. The 2040 timescale has also been adopted by France, but other countries plan faster progress. Norway has proposed a date of 2025. These pledges have been welcomed by environmental pressure groups, whilst some have demanded that the dates be brought forward. Immediately after the announcement, there were many discussions about the logic, but the issue has now been largely forgotten without any very substantial debate about the practicality of the proposal and the implications. Energy use in transport is a very significant sources of CO_2 emissions. This paper examines the implications of adopting electric vehicles on a large scale in Scotland.

Two Factors

There appear to be two principal factors motivating the replacement of the internal combustion engine. 1. To improve air quality in urban areas and 2. To reduce carbon dioxide emissions as the main greenhouse gas.

The first consideration is not too controversial, since battery –powered vehicles that consume no fossil-derived fuel will have negligible end-use emissions and must improve local air quality. However, the two largest cities in Scotland are small in international terms without serious pollution problems. Glasgow has a population of about 600,000 and air pollution not a desperate issue. Any benefits will be relatively small. The second consideration is less straight forward however and requires a rigorous scientific analysis before any conclusions can be drawn about the benefits. The assessment below looks at this proposal in the light of the current knowledge and the vehicle population.

Motor vehicle engine efficiency has improved considerably over recent decades and an average emission figure for vehicles on the road currently is about 140 g CO_2/km and it is reasonable to apply this value when looking ahead twenty years, as further improvements may be possible, but could be balanced by increases in vehicle size. This has recently been happening in Germany, where engine capacities and transport emissions are increasing, cancelling out efficiency gains.

The 140g/km figure is equivalent to 6.2 L/100 km. or ~27% fuel efficiency (45 miles per gallon). The full energy content of motor spirit is about 9.1 kWh/l and for diesel fuel, 9.7 kWh/l, so since the quantity of fuels sold are similar, an average of 9.4 is appropriate. So (at 27% efficiency), 2.54 kWh/L would be the energy delivered to the transmission. Average vehicle mileage is about 8,000 miles per annum, requiring 800 litres or 178 gallons of fuel.

Electrical Energy

To provide the equivalent electrical energy for the average vehicle would require 800 x 2.54 ie, 2030 kWhr. Generating the electricity for battery power charging involves a series of steps. Electricity is generated in the power station, transformed to 132 kV grid voltage, then down through the distribution system and into the rechargeable battery before finally reaching the vehicle transmission in use. An efficiency overall of 50% is taken for this series of steps. The battery car option will therefore require electricity generation amounting to 4060 kWhr for the year. For one million vehicles in 2032, 4.06 TWhr electrical energy would be needed – about 8% of Scottish annual consumption.

Carbon Emissions Comparison

Consider next the effect on carbon dioxide emissions. Average vehicle emissions are 140 g/km. Average mileage 12900 km producing 1.81 te/a of carbon dioxide. For 1 million vehicles, total emissions about 1.8 million te/a.

If the 4.06 TWhr is provided by power station generated electricity, then the replacement emissions would be about 1.15 million t/a., based on the split in UK electricity generation in 2016 (emissions were 0.283g/kWhr) . About 35% of Scottish electricity is generated by the two nuclear stations compared with 30% for the UK as a whole so Scottish emissions/kWhr may be slightly lower ca 0.27g/kWhr.

To a first approximation therefore, the carbon dioxide reduction is about 35%. Thirty-five percent is a very modest figure to justify such a scrappage and replacement scheme. This could very well be eroded completely if a number of relevant factors develop in an adverse direction.

Firstly, the life cycle emissions (manufacture/maintenance and waste disposal) of the electric vehicle vs the petrol equivalent may deteriorate over the next 25 years. The raw materials for batteries may become extremely scarce necessitating the use of less desirable source materials. I understand that the carbon dioxide emitted in the manufacture of a typical 500 kg car battery pack is already over 5 te. If correct, then it will take eight years before the lower emissions from the electric vehicle match that of the fossil-fuel equivalent.

Secondly, the life expectancy of batteries recharged several thousand times at different levels of residual charge may be measured in years rather than the decades of the internal combustion engine. Each replacement battery pack will produce several tonnes of carbon dioxide emissions. These will cancel out any reductions from regular use.

Thirdly, the carbon emissions of electricity generation may increase. UK nuclear plant generation and imports from France comprise almost 30% of demand in 2016. The Hunterston B and Torness AGRs will have been retired before 2032 and imports from France may be less reliable after the exit from the EU. These low-carbon sources would be replaced by intermittent renewable sources requiring some back up, with emissions/kWhr greater than nuclear stations. Emissions could increase towards 400g/kWhr. For example, at 9am on September 25, with very little wind (and being foggy little solar power) CO2 emissions were cited as 345g/kWhr by MyGrid. Such conditions occur frequently and must be used in any comparative analysis.

About 35% of Scottish electricity is generated by the two nuclear stations. As data from Germany shows, when nuclear plants are closed and replaced by renewables, carbon dioxide emissions increase. Data from Gridwatch from the end of August to the end of September confirm that wind power output can be very low for long periods, necessitating fossil fuel backup with high carbon emissions.

For only five days out of the twenty five, was there a high contribution (ca 20%) from wind turbines. For four days however, the contribution was less than 2%. On only five days was the wind power contribution higher than imports from France and Holland. For fifteen days, the thousands of wind turbines provided no more electricity than was being imported via the cross channel cables (6 – 10% of demand).

With a combination of all the factors in the supply chain, the thirty-five percent reduction in CO2 emissions computed above from the switch to electric vehicles would be nullified completely for a high proportion of the year.

If electric vehicles are bought in large numbers then the factors mentioned above need to be monitored continuously to compare the emissions from power generation with those from liquid fuel use. It cannot be assumed that the battery power option will reduce total CO2 emissions.

Charging Batteries implications

The great advantage of conventional cars is their refuelling flexibility that will be lost with the uptake of electric vehicles. Petrol or diesel supplies can be taken on at any time of the day enabling diversity. Batteries take much longer to recharge encouraging most drivers to replenish at home at the end of the day. Fast chargers for electric vehicles are rated at between 7 kW and 22kW.

If there are one million electric cars in 2032 and 50% are connected to charge together in the early evening using the 22 kW units, then power demand will be 11 GW which is a massive increase over the winter peak load. Significant strengthening of the grid and distribution networks will be required to cope with such loads. National Grid has examined this in its future energy scenarios. FES2017 Chapter 5 forecasts an increase of 30GW in peak demand by 2045.

"To manage the rapid changes in frequency and voltage caused
by the newer type of low carbon generators, a holistic approach, which
harnesses capabilities across energy and network resources, is required
to address this shortage. What technologies will be utilised has yet to be
established by the marketplace……or to translate the euphemism……*the problems managing electricity supply will become more serious and we don't know how they will be solved.* "

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