Ecometrica

Technical Paper | Your new electric car emits 75 gCO2/km (at the power station)
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Overview
2011 is being hailed as the year of the electric car, or certainly the year that the electric car becomes available to the general public for everyday use. There are a host of new electric cars entering the market in 2011 and 2012 and every major car manufacturer now has plans to introduce an electric vehicle in the next three years. We all know that an electric vehicle has zero tailpipe emissions and the popular counter argument is usually "what about the emissions at the power station"? This Ecometrica paper answers that question by presenting a definitive figure of gCO_2/km for UK electric cars when CO_2 emissions at the power station are taken into account. Based on a range of electric cars that you can buy in the UK this year and next the average emissions are 75 gCO_2/km.

This figure is lower than any other car in production today, including the Toyota Prius (89 gCO_2/km) and VW Golf Bluemotion (99 gCO_2/km), two of the incumbent best performing low emission vehicles in the "small family" class of car. For reference the government figure for CO_2 emissions from an average UK car is 208 gCO_2/km. If emissions from the power station were included in official gCO_2/km figures electric cars would still qualify for exemption from the London Congestion Charge and UK road tax.

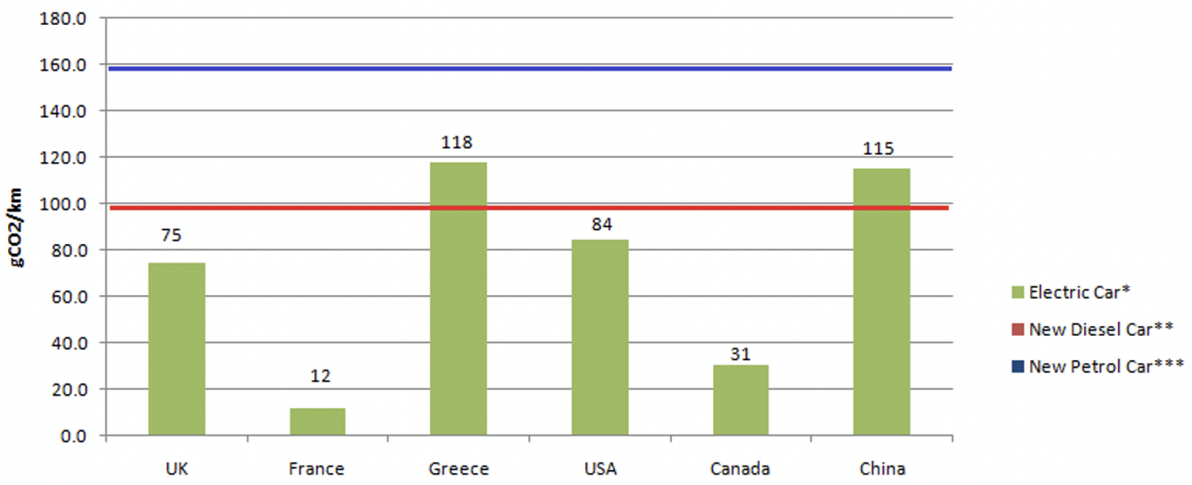
How did we calculate this?
Firstly we calculated electric car efficiency, which is a measure of how much electricity is required to power an electric car for every mile it drives. In essence this is equivalent to a car's miles per gallon figure (but in this case is kWh/km). This was done based on manufacturers' range and battery capacity data for three electric cars; the Nissan Leaf, the Mitsubishi i-Miev and the Renault Fluenz.

We then took government data on the UK grid carbon intensity which is a measure of the CO_2 emissions produced for every kWh of electricity consumed in the UK and applied this to our electric car efficiency. We ensured that in our grid carbon intensity calculations we included, not only the energy losses at the power station, but also the energy losses for transmission and distribution of the electricity across the UK electric grid. It's worth noting that we carried out this calculation on the basis of CO_2 only, deliberately omitting the other greenhouse gases (GHG) that are produced at the power station, so that the result could be compared to existing car manufacturers' data on a like for like basis, since these also omit other GHGs.

Is this figure the same in all countries?

No. Electric grid carbon intensities vary from country to country because the proportion of coal, oil, gas, nuclear and renewable generation is different in each country. This means our electric car in the UK will have a different gCO_2/km figure if charged and driven in another country. The chart below shows this effect for a number of countries and compares the electric vehicle results to modern diesel and petrol powered cars. You can see that diesel and petrol cars have the same emissions irrespective of which country they are in whereas the electric car emissions vary depending on the country in which it's used.

Figure 1. Electric car emission by country charted against modern diesel and petrol cars



* based on average of Nissan Leaf, Mitsubishi i-Miev and Renault Fluenz EV
**based on new Ford Focus 1.6 diesel
***based on new Ford Focus 1.6 petrol

The chart shows that in Greece and China an average electric car would emit more CO_2, at the power station, than modern diesel vehicles. This is because most of the power stations in China and Greece are coal fired which is the most carbon intensive form of electricity generation. The electric grids in the UK and USA are made up of a range of coal, oil, gas, nuclear and renewable power stations and produce a similar carbon intensity to each other, and in turn a similar gCO_2/km figure for electric cars.

In France the electric grid is mainly fed by nuclear power stations, resulting in a very low carbon intensity and in Canada the reason for low carbon intensity is a very high proportion of renewable power generation from hydro-electric power stations[1].

This also demonstrates that as governments move to clean up their grids by replacing carbon intensive power stations with lower carbon intensity sources of generation then electric cars will see their equivalent gCO_2/km figure drop too. UK Government projections are for the grid average carbon intensity to drop to 22.6 gCO_2/kWh by 2050, which would mean that the emissions associated with electric cars (based on current efficiencies) would be as low as 3 gCO_2/km.

What happens if we include the emissions associated with manufacturing the fuels that go into the power station?

The effect of adding in these so called "upstream" emissions sources is that our 75 gCO_2/km figure increases to 85 gCO_2/km. If we do the same thing for diesel and petrol cars, so that we can continue comparing on a like for like basis, we see that the figures increase from 99 to 118 and 159 to 187 gCO_2/km respectively. Assessing the CO_2 impacts in this way is known as a "well-to-wheels analysis". A well-to-wheels analysis can be taken further still by asking about the relative emissions associated with manufacturing a traditional combustion engine car versus an electric car and its batteries. We won't answer that very complex and detailed question with figures here but suffice to say that based on our experience the embodied emissions of the materials used in manufacture of a vehicle tend to be 15% to 20% of a vehicle's "lifetime" emissions, when all the emissions associated with fuelling the car throughout its life are taken into consideration. The key point is that, at least on a CO_2 basis, the main impact a vehicle has in its lifetime is in the consumption of energy when it's being driven.

Is an electric car more efficient than a petrol or diesel car?

This is actually a more complicated question to answer than it first appears. If we looked at the efficiency[2] of the vehicle itself we can see that an electric vehicle is seven times more efficient than a petrol car and four times more efficient than a diesel car. This is because in an electric car there are far fewer energy losses, principally because there are fewer moving parts; an electric car has about four main moving parts compared to an internal combustion engine car with over 300.

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[1] Some analysts have suggested using the carbon intensity of the marginal generating capacity, which often differs from the average grid intensity. However, given the gradual introduction of electric vehicles and the fact that charging is quite likely to be done at night rather than peak time, we considered the average intensity to be a reasonable basis for estimation.

[2] Efficiency is the amount of energy used per unit of distance travelled. Energy per unit of distance is different from emissions per unit of distance as different energy sources create different amounts of CO2

However this is a simplistic view as, in essence, an electric car does have a combustion engine – at the power station. So if we include the thermal efficiency of the power station, which varies greatly from power station to power station, and the transmission and distribution losses associated with getting the electricity to the car we can see that, in the UK, an electric car is slightly less efficient than the best diesel cars but more efficient than the best petrol cars. It must be noted that these results are very sensitive the assumptions made about the efficiencies of the power stations and the assumed efficiency of the comparative petrol and diesel car. One could easily obtain quite different results using different assumptions. What we've presented here is effectively the worst case scenario for electric cars as we have pitched them against some of the most efficient petrol and diesel models currently available, and we have assumed that the manufacturers' claimed MPG figures would be achieved in the real world (see calculations in Appendix I).

So will electric vehicles reduce emissions in the UK?

Yes. Even including the emissions at the power station electric cars have lower emissions than an average petrol or diesel car. To give you an idea of the scale of the potential emissions reduction we've estimated what the total reductions would be if the UK government's plug in car grant was fully subscribed by 2012. This could be used to subsidise 8,600 electric vehicles in the UK, and assuming that these electric cars displace a mix of the most efficient diesel and petrol cars on sale this would reduce CO_2 emissions by 7,483 tonnes of CO_2 each year, equivalent to taking over 3,600 cars off the road.