The contribution of taxes, subsidies and regulations to British electricity decarbonisation

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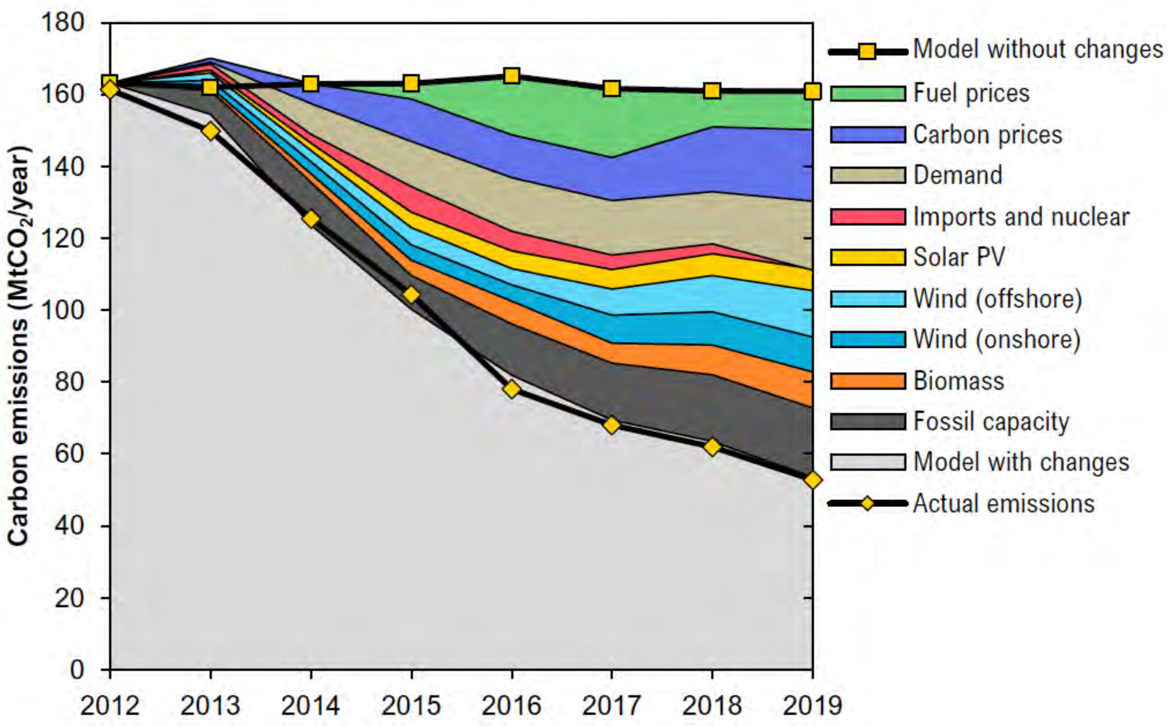
Carbon dioxide emissions from electricity generation in Great Britain have fallen by 66% between 2012 and 2019 – a faster decline than in any other country. The UK government adopted all the standard policy responses to a negative externality: taxes, subsidies and regulations. Polluters pay a price for carbon emissions, through the EU Emissions Trading System (EU ETS) and the UK's Carbon Price Support. Substitutes for fossil-fuelled electricity are subsidised via several schemes supporting renewable generation and energy efficiency. Regulations to reduce acid rain had the effect of closing 40% of high-carbon power stations (11 GW). The relative contribution of these policies towards decarbonisation is unknown as they happened simultaneously, interacted with one another, and were muddied by exogenous effects such as changing fuel prices and the weather.

In this study, we estimate the emissions reductions that can be attributed to the above changes that took place, along with their impact on wholesale electricity prices and consumption of fossil fuels. We calculate Shapley Values from repeated runs of an electricity dispatch simulation with different combinations of changes activated. The Shapley Value is a concept from cooperative game theory that allocates the benefits created by individual players when they come together in a coalition. We replace "players" by changes to the electricity system and define "outcomes" as changes in carbon emissions, prices and fossil fuel consumption.

This incorporates all the interactions between drivers, as for example the effect of closing coal plants added to that of (separately) raising carbon prices will differ from the impact of doing both together. In doing so, our method avoids the under- or over-allocation which can happen with current methodologies. We show the relative importance of the changes we document, over the entire period and in each year.



This diagram (Figure 6a of the main paper) shows actual emissions (the yellow diamonds) falling over time, closely matched by our simulation model (light grey area). The yellow squares show simulations in which only the weather varied – these counter-factual emissions are highest in 2016, a year when wind load factors were unusually low. The coloured bands show the emissions savings attributed to each of the changes we modelled, compared to 2012. Note that gas became more expensive relative to coal in 2013, which offset about half of the savings from the other changes in that year.

The reduction in coal capacity (some of it converted to burn biomass) and the growth of wind and solar output both saved 29 Mt of CO_2 emissions in 2019, compared to 2012. The British carbon tax and the (relatively recent) increase in the EU ETS price saved 20 Mt, while falling demand saved 19 Mt. Increasing imports (measured as a pure saving on a UK territorial basis, and still a net saving when comparing British and continental emissions rates) almost exactly offset falling nuclear output in 2019. The lower price of gas relative to coal saved 11 Mt.

We believe that this technique offers a robust way to estimate the ‘value’ of individual technologies or actions to decarbonisation, accounting for the complex interactions they have upon one another.

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