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Some key issues for reviews of the costs of low-carbon electricity generation in the UK

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Policy insight

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Executive summary

The energy policies of recent UK governments have aimed to balance the three main contributors to the 'trilemma' of energy security, affordability and sustainability. However, the current Government has placed a greater emphasis on affordability for consumers than on the other two dimensions.

Ongoing concerns about the best policies to achieve affordability have led to three reviews: of energy costs, of the Levy Control Framework, and of carbon pricing. This paper draws on research findings and empirical evidence to identify key principles and issues that should be taken into account by the Government in relation to these separate but related reviews.

A guiding principle for each of the three reviews should be that effective policies are likely to result from harnessing the power of markets. That requires understanding and addressing a number of factors that distort the power market by misaligning the link between prices and the real costs of different sources of generation (giving rise to 'market failures').

The price of power generated by fossil fuels does not currently reflect the environmental costs they generate in the form of climate change and local air pollution. This gives rise to arguably the biggest market failure, which can be addressed by implementing a price on emissions of greenhouse gases and other pollutants. Unpriced externalities caused by fossil fuels are, in effect, paid for by households and businesses through the harm they suffer from climate change and air pollution.

The UK power sector is currently subject to a combination of inconsistent and overlapping carbon pricing mechanisms. Carbon prices seem set to remain well below the level needed to meet both the UK government's emissions reductions targets and the goals of the Paris Agreement. A uniform, economy-wide carbon price should be the aim, as recommended by the *Cost of Energy Review*.

The Government needs to find a balance between carbon pricing and subsidies to meet emissions reduction targets at the lowest cost, remembering that these policies address different market failures. The Government should take account of the distribution of costs between all parts of the economy, including household and business consumers, power generators and government.

Subsidies are often used to address further market failures that create obstacles for new alternatives to fossil fuels in the power sector. The subsidies have led to a significant increase in the deployment of renewables, but they should be time-bound and removed once the relevant market failures have been overcome.

The application of a cap on overall subsidy payments, through the Levy Control Framework, may endanger the fulfilment of the UK's five-yearly carbon budgets if the cap prevents sufficient deployment of low-carbon power capacity. Contracts for Difference provide more certainty to generators, and competitive auctions reduce the costs for household and business consumers.

The system costs of renewables rise at higher penetrations. In future, it is possible that at least some of these costs could be reflected in the network charges faced by variable renewable generators. This would improve cost-effectiveness much more efficiently than requiring individual wind or solar farms to provide back-up generation.

Electricity prices faced by UK households and most UK businesses are not the highest in the EU. A large proportion of the differences in electricity prices between EU member states is due to network and wholesale costs rather than low-carbon policies.

It is important that electricity prices reflect the real costs of generation and supply. To limit electricity costs for consumers, the Government should focus on bills rather than prices – and thus should seek to cut consumption through greater energy efficiency and a reduction in energy waste.

Recommendations

- **Recommendation 1:** The Government should seek to optimise the balance between carbon pricing applied to fossil fuels and direct subsidies for low-carbon alternatives, to ensure that market failures and distortions are addressed while meeting emissions reduction targets as efficiently as possible. This should be an explicit goal of its Clean Growth Strategy, and reinforced by other policies, such as the Industrial Strategy and Budgets.
- **Recommendation 2:** The Government should reform the currently overlapping carbon pricing policies in order to create a consistent carbon price, not only across the power sector, but also across all firms and fuels in the economy. The Climate Change Levy or the Carbon Price Support Rate could be modified to become an effective economy-wide carbon tax.
- **Recommendation 3:** The Government should consider how the electricity market should develop in order to take into account the fact that renewables potentially have low, if any, marginal costs, and that fossil fuel plants enjoy a hedge against price risk. In the current electricity market marginal costs of the marginal plant are usually related to the operating costs of fossil fuels, i.e. the cost of fossil fuels for the marginal plants can be passed through into electricity prices.
- **Recommendation 4:** In order to realise its ambition of having the lowest energy costs in the EU for household and business consumers, the Government should focus on bills, not prices.
- **Recommendation 5:** The Government should focus on measures to improve energy efficiency for households and businesses, such as minimum energy-efficiency standards, increasing information available to consumers (for example, appliance labelling or household energy-use certificates), financial support for consumers seeking to undertake energy efficiency improvements, or direct financing.
- **Recommendation 6**: The Government should consider funding subsidies for new low-carbon power sources through measures that are less regressive than increases to consumers' electricity bills.
- **Recommendation 7:** The Government should allow competitive auctions to drive down prices rather than applying a cap on overall expenditure on subsidies through the Levy Control Framework, which risks undermining reductions in greenhouse gas emissions from the power sector.
- **Recommendation 8:** The Government should explore the possible introduction of 'subsidy-free' Contracts for Difference for mature renewables technologies, such as onshore wind, to reduce the risk for developers and thus lower the cost of financing.
- **Recommendation 9:** The Government should not accept the recommendation by the *Cost of Energy Review* to merge the Contracts for Difference and capacity auctions, as this would be less efficient and would create additional barriers to new renewable power generators attempting to enter the market.
- **Recommendation 10:** The Government should explore better ways of promoting energy efficiency for businesses, as recommended by its Clean Growth Strategy.
- **Recommendation 11:** The Government should assess the overall welfare cost to household consumers, taxpayers and businesses, and not just the direct cost to consumers, when assessing the cost-effectiveness of policies to reduce greenhouse gas emissions.

1. Introduction: Reviewing the costs of electricity generation

The energy policies of recent UK governments have aimed to balance the three main contributors to the 'trilemma' of energy security, affordability and sustainability (e.g. Rudd, 2015). However, the current Government has placed a greater emphasis on affordability for consumers than on the other two dimensions. Ongoing concerns about the best policies to achieve this objective have led to three reviews. This paper identifies the key principles and issues relating to the costs of electricity generation that should be taken into account by the Government in considering the independent review of energy costs published by Professor Dieter Helm in October 2017, and in completing its reviews of the Levy Control Framework and carbon pricing.

The Cost of Energy Review

On 6 August 2017, the Department for Business, Energy & Industrial Strategy (BEIS) announced an independent review of energy costs, led by Professor Dieter Helm, to make recommendations about how to achieve the Government's ambition for the UK to have 'the lowest energy costs in Europe, for both households and businesses' (Helm, 2017: iv), but at 'minimum cost and without imposing further costs on the exchequer' (ibid). The *Cost of Energy Review* was published on 25 October 2017. It suggested that the two main aims of energy policy should be first to ensure security of supply – including 'the level of capacity margin, the composition of that capacity, the flexibility options, and the extent to which resilience should be built into the electricity system' (ibid: 2) – and second to decarbonise, with the costs to consumers constituting a constraint.

The Levy Control Framework and carbon pricing reviews

Her Majesty's Treasury announced in the Spring Budget of 2017 that the Levy Control Framework, capping the total annual subsidy for renewable energy, would be 'replaced by a new set of controls', to be set out later in the year. The Treasury also indicated that, 'starting in 2021–22, the government will target a total carbon price and set the specific tax rate at a later date, giving business greater clarity on the total price they will pay', and that it would provide 'further details on carbon prices for the 2020s' in the Autumn Budget 2017 (HM Treasury, 2017).

2. Improving the cost-effectiveness of the power market

The price of any source of power should reflect its true costs, including any damage to the environment that imposes costs on current and future generations of citizens and consumers. A guiding principle for each of the three reviews – on energy costs, the Levy Control Framework, and carbon pricing – should be that effective policies are likely to result from harnessing the power of markets. That requires understanding and addressing a number of factors that distort the power market by misaligning the link between prices and the real costs of different sources of generation (giving rise to 'market failures'). More effective operation of markets can be promoted by the use of regulations, standards or pricing mechanisms.

Principal market failures affecting the power sector

The biggest market failure affecting the power sector arises from the fact that the price of the production and consumption of power generated by fossil fuels does not reflect the costs they impose on others through climate change and local air pollution. One of the most effective options for correcting this failure is internalisation of the externalities by implementing a price on emissions of greenhouse gases, in line with the 'polluter pays' principle.

There are several further market failures that create obstacles for new alternatives to fossil fuels and other mature generation technologies in the power sector, such as access to networks (Stern, 2007, 2015). These are often addressed through subsidies, including government funding for research and development, Feed-in Tariffs, and quantitative requirements to support the deployment of new renewable and nuclear power capacity (e.g. Röttgers, 2017). For instance, more than 80 countries globally have introduced Feed-in Tariffs (REN21, 2016). In addition, Helm (2017) identified a failure arising from the current structure of the market, which does not create enough incentives to ensure security of supply, and specifically to invest in the construction of gas-fired power stations that provide an adequate power capacity margin.

What is the…?

Carbon price floor and Carbon Price Support Rate: UK government policy implemented to support the EU emissions trading system (EU ETS), which places a price on greenhouse gases by requiring heavy energy users to acquire emission allowance permits. The support rate is a tax payable on gas, Liquefied Petroleum Gas, coal and oils, set as the difference between the carbon price floor and the price of carbon permits in the EU ETS.

Climate Change Levy: An environmental tax on commercial energy use, paid at either the main rates or Carbon Price Support Rate.

Contracts for Difference: A contract between a low-carbon electricity generator and the Low Carbon Contracts Company (LCCC), a government-owned company. The generator is paid the difference between the 'strike price' – a price for electricity reflecting the cost of investing in a particular low-carbon technology – and the 'reference price'– a measure of the average market price for electricity in the UK market.

Feed-in Tariff: Payments for electricity generated by households who install small-scale renewables.

Levy Control Framework: Designed to 'control the costs of supporting low-carbon electricity, paid for through consumers' energy bills. It sets an annual budget for projected costs of all BEIS's low-carbon electricity levy-funded schemes until 2020/21, rising to £7.6 billion in 2020/21 (2011/12 prices)' (gov.uk, 2016).

Source/further information: www.gov.uk

Carbon pricing is a mechanism for removing distortions in the market

In order to remove distortions that stop the power market from operating effectively, mature sources of electricity generation should be confronted with their real costs through appropriate pricing mechanisms. For fossil fuels, carbon taxes and cap-and-trade systems have different strengths and weaknesses from carbon pricing mechanisms (Bowen, 2011). In theory, cap-and-trade can achieve a target reduction in emissions, but the price required is unknown in advance, and it can be more complicated to administer. A carbon tax may be easier to administer, and allows a price to be set in advance, but does not automatically result in an emissions reduction of a pre-determined amount.

It should be remembered that the primary aim of carbon pricing is to reduce emissions by cutting power from high-carbon generators, either by substituting low-carbon generation or by reducing overall electricity consumption. However, the UK power sector is currently subject to a combination of inconsistent and overlapping carbon pricing mechanisms through cap-and-trade, carbon taxes and regulations (Advani et al., 2013).

Carbon prices are too low to meet UK and Paris Agreement targets

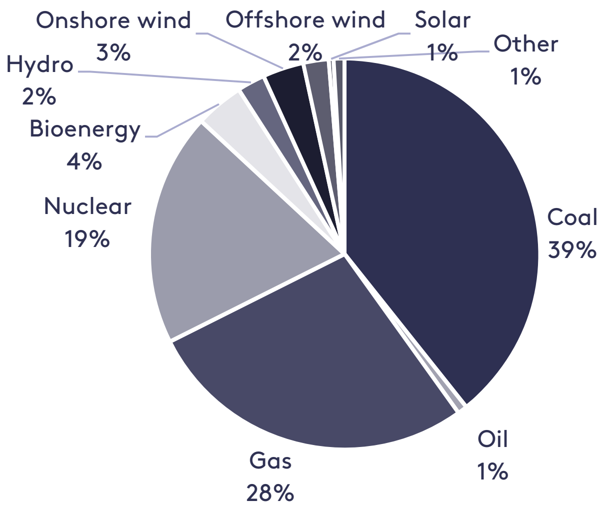
The UK's carbon price floor, created by the Coalition Government in 2010, envisioned a stable and increasing carbon price for electricity producers. However, the Government's decision in 2014 to freeze the Carbon Price Support Rate at £18 per tonne of carbon-dioxide-equivalent (tCO_2e) until 2021, together with the low trading price of allowances within the European Union emissions trading system (EU ETS), means that the carbon price has remained lower than expected.

At the end of 2016, emissions allowances within the EU ETS were about £5/tCO_2e, and the Carbon Price Support Rate added £18/tCO_2e. Hence, the trading price in the EU ETS and the Carbon Price Support Rate together meant that the carbon price for UK electricity generation was about £23/tCO_2e. Unless the EU ETS price increases significantly, this means that carbon prices will probably fall well below the trajectory envisioned by the Government (approximately £33/tCO_2e in 2020), as well as below the levels suggested by analysis of what is required to cut emissions in line with international targets for climate change. For example, Stiglitz et al. (2017) estimated that the appropriate carbon price across the world will need to be US$40–80/$tCO_2e$ (£31–62/tCO_2e) by 2020, and US$50–100/$tCO_2e$ (£39–77/tCO_2e) by 2030, to be consistent with meeting the goals of the Paris Agreement.

Less than 40 per cent of the UK's annual greenhouse gas emissions in 2016 were subject to an explicit carbon price through the EU ETS and Carbon Price Support Rate (Committee on Climate Change, 2017). Overall, because the damages caused by greenhouse gas emissions and local air pollution are not priced in fully, fossil fuels received an implicit subsidy in the UK estimated to be more than £25 billion in 2015 (Coady et al., 2015).

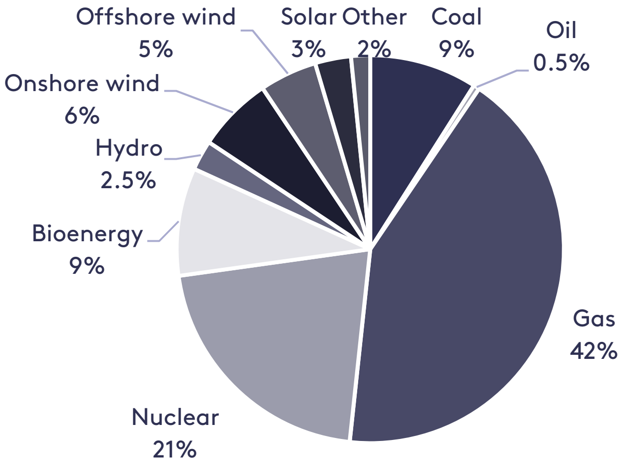
Nevertheless, the Government attributes the dramatic displacement between 2015 and 2016 of coal by natural gas and renewables for electricity generation to the increased Carbon Price Support Rate of £18/tCO_2e, which took effect in April 2015 (BEIS, 2017e). On an output basis, the percentage of total electricity generated by coal fell from 22.4 per cent in 2015 to 9.0 per cent in 2016. This compares with 39.2 per cent in 2012. Although the proportion of electricity generated by renewables rose from 8.1 per cent in 2012 to 25.7 per cent in 2016, the share from natural gas increased from 27.5 to 42.2 per cent over the same period (see Figures 1 and 2).

Figure 1. UK annual electricity generation by source, 2012 (output basis)



Note: Figures have been rounded.
Source: Department for Business, Industry & Industrial Strategy (2017e)

Figure 2. UK annual electricity generation by source, 2016 (output basis)



Note: Figures have been rounded.
Source: Department for Business, Industry & Industrial Strategy (2017e)

A dramatic reduction in carbon intensity is needed, requiring a higher carbon price

The Committee on Climate Change (2015) has calculated that the carbon intensity of the power sector (i.e. the amount of carbon dioxide emitted per unit of electricity generated) must fall to between 50 and 100 grammes of carbon-dioxide-equivalent per kilowatt-hour (gCO_2e/kWh) by 2030 to be consistent with the UK's fifth carbon budget for the five-year period between 2028 and 2032. Given that the annual carbon intensity of the power sector was 334 gCO_2e/kWh in 2015 and 254 gCO_2e/kWh in 2016, this implies a reduction of about 70 per cent and 60 per cent respectively by 2030. Such a reduction will not be possible just by displacing the remaining coal from power generation, which the Government has pledged to achieve by 2025, but will require a major substitution of low-carbon sources for natural gas. The current implicit carbon price applied to the power sector is unlikely to bring about such a change.

The carbon price for producers and consumers is inconsistent

The implicit carbon price is not only too low in the UK power sector: it is also inconsistent for producers and consumers. As noted by Advani et al. (2013), the combination of energy and climate policies in the UK has resulted in considerable variation in implicit carbon prices across users and fuel types, sending mixed signals. For instance, Advani et al. (ibid) calculated that the implicit carbon price paid by households for electricity in 2013 (through value added tax, the Energy Company Obligation, the Warm Home Discount, Feed-in Tariffs, the Renewables Obligation, the Carbon Price Support Rate and the EU ETS) was £5.92/tCO_2e, while the implicit carbon price for gas was -£18.92/tCO_2e. The overall effect of this disparity is to encourage households to move to gas from electricity for heating, for instance.

What is the...?

Energy Company Obligation: A UK government energy efficiency scheme to help reduce carbon emissions and tackle fuel poverty by obligating larger suppliers to deliver energy efficiency measures to domestic premises.

Warm Home Discount: A UK government scheme aimed at tackling fuel poverty. Larger energy suppliers support people who are in fuel poverty or are at risk of it.

Renewables Obligation: One of the main support mechanisms for large-scale renewable electricity projects in the UK, placing an obligation on electricity suppliers to source an increasing proportion from renewable sources.

Source/further information: www.ofgem.gov.uk

It should be acknowledged that many of the policies that contribute to the implicit carbon price are not designed to address the greenhouse gas market failure. For instance, the Renewables Obligation and Feed-in Tariffs are intended to provide direct subsidies for the production of power from renewable sources. The changes to the Climate Change Levy in 2015, which removed the exemption for renewables, means that it should be more correctly regarded now as a tax on energy consumption by businesses, rather than a carbon tax.

Inconsistent implicit and explicit carbon prices across the UK economy and between different types of user are an economically inefficient way of reducing emissions of greenhouse gases as they do not focus abatement on the most cost-effective options. A uniform, economy-wide carbon price would be more efficient and should be the aim of future UK government policy, as recommended by Helm (2017).

Membership of the EU emissions trading system

The shortcomings of the EU ETS also remain a significant problem. Without further reform to the ETS, it is unclear that those UK businesses subject to the system will have reason to expect a carbon price that is consistent with the long-term goal of the UK Climate Change Act (2008) of an economy-wide reduction in annual greenhouse gas emissions of at least 80 per cent by 2050 compared with 1990. Although the introduction of the Carbon Price Support Rate in 2013 initially helped to address expectations of a more credible carbon price, it was undermined by the Government's announcement a year later that it would freeze the level at £18/tCO_2e until at least 2020 (and it has since been extended to 2021).

If the UK withdraws from the EU ETS as a result of its departure from the European Union, it should replace it with a domestic carbon pricing mechanism, either through a UK cap-and-trade system or a carbon tax. This mechanism could be a modified version of the current Climate Change Levy or Carbon Price Support Rate, and should be applied to create a uniform carbon price across the economy. Even if the UK does not withdraw from the EU ETS, the Government should still seek to establish a uniform economy-wide carbon price by merging existing mechanisms (including the Climate Change Levy and the Carbon Price Support Rate) into a single instrument that is applied across all firms and fuels, promoting greater cost-effectiveness and fairness.

3. Addressing other market failures

Carbon pricing is a necessary policy for driving decarbonisation of the power sector in order to meet the UK's emission reduction targets, but is not sufficient on its own. In addition to the externalities associated with greenhouse gas emissions, there are other market failures related to electricity generation that privilege industry incumbents over new entrants, including those relating to research, development and deployment, imperfections in risk and capital markets, access to networks and information, and co-benefits that arise from cleaner air (Stern, 2007; 2015).

It has been the practice in many countries to try to create a level playing field and to help new entrants to the electricity market to overcome these market failures through policies to directly promote research, development, demonstration and deployment for low-carbon energy, for example through government funding for research in universities on renewable technologies and Feed-in Tariffs for deployment. In the UK, technology-specific subsidies have been used to promote the deployment of new sources of power, particularly renewables, through policies such as the Renewables Obligation, Feed-in Tariffs and Contracts for Difference. These subsidies have been paid for the amount of electricity generated over a period defined by a contract, and have generally related to the maturity of the technology. The subsidies have been funded through an additional charge on electricity bills for consumers, thereby increasing the implicit carbon price applied to electricity compared with natural gas, and the revenue is transferred directly to the power generators without being collected by the Government. The system of subsidies has led to a significant increase in the deployment of renewables.

In principle, subsidy schemes that are focused on increasing deployment should be time-bound and removed once market failures have been overcome and new and existing market participants are able to compete on a level playing field with incumbents. The termination of subsidy schemes should be predictable for existing and potential new market participants to avoid creating additional uncertainty, and hence policy risk, for generators.

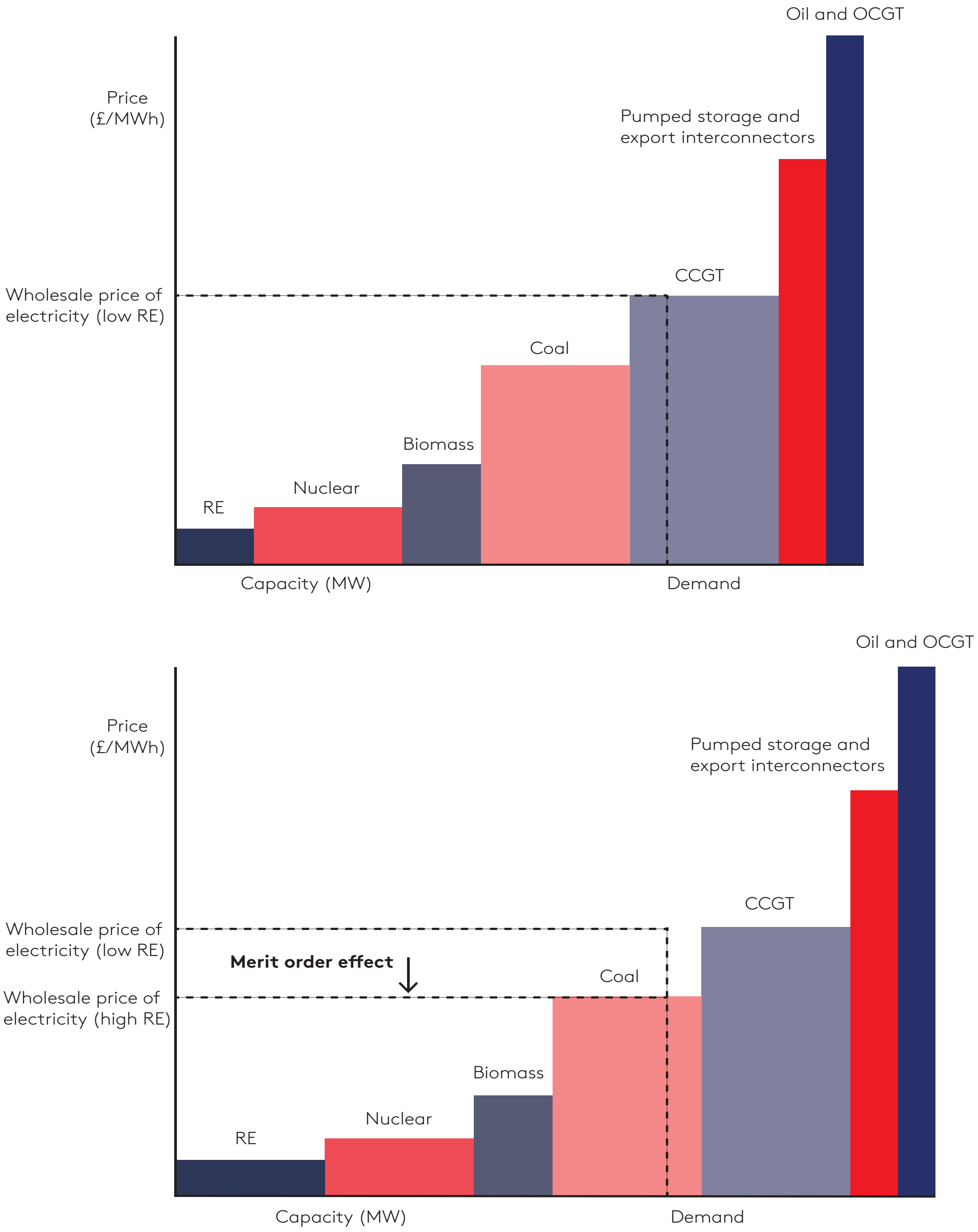
In practice, the administration of subsidies in the UK has not allowed all of the market failures to be overcome. Currently, the wholesale price of electricity is determined by the short-run marginal cost of supplying an additional unit of electricity (see 'The merit order effect' below). The marginal costs of power plants are larger if they have to pay for fossil fuels rather than renewable energy. That means at present fossil fuels are always the marginal supplier and have a built-in price risk hedge (i.e. the impact of any change in the marginal cost of fossil fuel generation on their profits is offset by a change in the wholesale price of electricity).

The merit order effect

Increased deployment of renewable power can help lower the market price for electricity through the merit order effect. A merit order curve ranks power plants by the short-run marginal cost of producing an additional unit (megawatt-hour) of electricity (Figure 3 below). In a perfectly competitive market, one would expect the merit order curve at any point in time to represent the short-run supply curve for electricity, with the short-run marginal cost of the marginal plant setting the market clearing price. In general, renewable sources of electricity have a very low marginal cost, as they do not have to pay for fuel. Hence, renewables enter the merit order curves at lower prices than conventional fossil fuel plants. This shifts the merit order curve to the right in Figure 3, resulting in the market clearing at a lower cost to satisfy the same amount of demand. The impact of higher deployment of renewable power on the merit order curve, and the resulting decrease in the market price of electricity, is illustrated in Figure 3. It should be noted that the merit order curve is not static and will change throughout a day as both demand and supply vary.

The impact of the introduction of renewable power into the wholesale electricity market has been estimated by British renewable energy supplier Good Energy (2016) using a dispatch model of national demand data and renewable energy generation, based on the 2013 and 2014 day-ahead markets for electricity (these are markets where contracts are signed between buyers and sellers for delivery of power the following day). The study concluded that the wholesale price of electricity in 2014 was reduced by £5.24/MWh because of the introduction of solar and wind into the market. The Committee on Climate Change (2017) estimates that the merit order effect of renewable power reduced wholesale costs by £1.50 per megawatt hour in 2016 for extra-large industrial users. While the estimates of the impact of the merit order effect differ, it is widely agreed that renewable power is decreasing one component of electricity prices – the wholesale costs.

Figure 3. Stylised merit order curve for UK illustrating the merit order effect



Key: RE = renewable energy; CCGT = combined cycle gas turbine; OCGT = open cycle gas turbine; MWh = megawatt-hour

Source: Authors, adapted from Figure 2 in Competition and Markets Authority (2015)

In addition, the UK Government has undermined the confidence of some investors and renewable energy providers by increasing pre-contract risk through sudden or unpredictable changes in the terms for potential new entrants to subsidy schemes (for instance, by changing the subsidy size or excluding specific technologies [House of Commons Energy and Climate Change Committee, 2016]). This has created additional risk at the project development stage, increasing the cost of capital, which is usually passed on to producers and consumers.

Contracts for Difference – concerns and proposed reforms

It is worth noting that the current system of subsidies for new renewables through Contracts for Difference, setting a floor and a ceiling to the price paid via a 'strike price', transfers wholesale price risk to consumers, who pay a price that reflects the difference between the strike price and the market wholesale price. As the market price cannot be predicted in advance with precision, and the strike price is, to a large extent, determined by competition between renewable generators, the size of the subsidy to renewables is uncertain during the period of a contract, leading to concerns about affordability for household and business consumers.

It has been proposed that Contracts for Difference could be reformed for more mature renewables technologies, such as onshore wind, by ensuring that the strike price does not exceed the levelised cost of the least-cost new entrant – in other words, the costs of building new marginal fossil fuel plant capacity for future generation, taking into account the additional costs of integrating the renewable generators. This would create, in effect, a subsidy-free Contract for Difference (e.g. Arup, 2017). An alternative way of creating a subsidy-free Contract for Difference is to levelise the potential revenues for the generator with a forecast of wholesale prices that is adjusted to address the costs of integrating renewables (ibid).

It should be noted that the latest projections published by the Department for Business, Energy & Industrial Strategy (2016) suggest that the levelised costs for onshore wind projects commissioned in 2020 could be lower than those for combined cycle gas turbine plants.

As the current wholesale electricity market price is wholly or largely determined by the cost of electricity generation from fossil fuels, the level of the carbon price applied to these fuels directly affects the gap with the strike price, and hence the size of subsidies offered through Contracts for Difference. If the wholesale price is lower than the strike price, consumers will ultimately pay the strike price, regardless of the size of the difference between the strike price and the wholesale price, even though the Government determines the relative contributions of the subsidies and the carbon price. Any increase in the Carbon Price Support Rate would probably reduce both the implicit subsidies for fossil fuels and, by increasing the wholesale price, the direct subsidies for renewables.

Subsidies affect the price of low-carbon electricity only, but carbon pricing affects the price of both low-carbon and high-carbon electricity if fossil fuels are the marginal supplier. While the UK continues to generate a significant amount of electricity from fossil fuels, their costs will determine the overall market price through the merit order effect. However, as the low-carbon share of electricity generation increases, more expensive marginal generation will be displaced, reducing the overall market price. Although carbon pricing currently affects the price of electricity for all consumers while fossil fuels determine the market price, it will not affect the cost of low-carbon electricity once high-carbon sources no longer determine the market price.

In theory, the Government could attempt to address all of the market failures, including the greenhouse gas externality, through one main mechanism: either a strong carbon price, or through large subsidies – but such an approach is unlikely to be the most efficient and cost-effective option. Carbon pricing is likely to be the most effective mechanism for addressing the greenhouse gas externality while subsidies can be more effective at correcting some of the market failures that hold back new sources of electricity generation.

Evaluating Helm's recommendations for addressing market failures

In the *Cost of Energy Review,* Dieter Helm criticised the size of the expenditure to date on subsidies for the deployment of immature renewable technologies (Helm, 2017). However, he did not offer any alternative mechanisms that would have been potentially more cost-effective. His argument that decarbonisation of the power sector should have focused on phasing out coal for natural gas does not address the issue of how deployment of renewables should have been managed. Indeed a focus on the transition from coal to gas might have meant that a much lower proportion of electricity would be generated by renewables today. The observation that the cost of renewables has dropped is, puzzlingly, presented by Helm as a criticism of earlier investments, which he labels 'legacy costs' (ibid). He does not explain how the costs would have dropped without the initial investments.

However, Helm is correct in saying that there is a mismatch between the market failures and the implementation of the subsidies. Most renewable technologies are capital-intensive: most of the costs are incurred during the construction of the wind turbines or solar panels, while the ongoing operating and maintenance costs are relatively low. The subsidies are not paid upfront, but are promised as a revenue stream in return for electricity generation over an extended period. Helm suggested that a more efficacious approach would be to offer capital grants and special tax regimes for capital expenditure (ibid).

Helm also recommends in the *Review* that renewable electricity generators should be responsible for managing the costs of intermittent output, an idea that he has proposed many times before (e.g. Helm, 2015). This would be the result of combining the auctions for low-carbon deployment with those for capacity, to create a single 'equivalent firm power capacity auction' (Helm, 2017). To do so would require, for instance, the owners of offshore wind farms to enter into arrangements to provide power to the network from alternative sources when wind speeds are too low to do so. However, this would likely create unnecessary additional costs, as balancing costs arise at a system level rather than for individual wind farms.

Nonetheless, renewables with variable electricity generation output, such as wind and solar, do create further system costs. The size of such costs is context-specific, depending on climatic factors, demand profiles and the wider mix of generation. A systematic review undertaken by the UK Energy Research Centre (Heponstall et al., 2017) found that, in UK conditions, these costs would be of the order of £10 per megawatt-hour of intermittent renewable output if 30 per cent of electricity was supplied by variable renewables. About 14 per cent of electricity in the UK was generated by variable renewables in 2016. Costs rise at higher penetrations and are significantly larger if the system is inflexible (ibid). At present these costs are socialised and not directly borne by renewables generators. In future, it is possible that at least some of these costs could be reflected in the network charges faced by variable renewable generators. This would improve cost-effectiveness much more efficiently than requiring individual wind or solar farms to balance their output.

4. Managing affordability

The current Government set out in the terms of reference for the *Cost of Energy Review* that ‘the government has the ambition for the UK to have the lowest energy costs in Europe, for both households and businesses’ (BEIS, 2017a: 1). This is a very challenging ambition and there may be concern that it will be hampered by efforts to ensure both that fossil fuels are faced with their real costs through carbon pricing, and that new forms of power are provided with sufficient support through subsidies, with the consequent impact on the price of electricity for households and businesses.

UK prices compared with EU prices

While this concern is valid in principle, the latest evidence shows that the electricity prices faced by UK households and most UK businesses are not the highest in the EU. Figures published by the Department for Business, Energy & Industrial Strategy showed that, in 2016, small, medium and large domestic consumers (in terms of annual consumption in kilowatt-hours) paid electricity prices, including tax, that were, respectively, 16, 16, and 12 per cent above the EU28 median (or the 10th highest among the EU28 for each consumer group [BEIS, 2017b]). Small, medium, large and extra-large business consumers paid electricity prices, including tax, that were, respectively, 25, 49, 63, and 74 per cent above the EU28 median (or the eighth, fourth, second and fourth highest among the EU28 [BEIS, 2017c]). However, when taxes are excluded, the corresponding figures for business consumers are 12, 35, 45, and 56 per cent above the EU28 median, respectively (or 10th, fifth, second, and second highest among the EU28). Hence taxes are not the only factor in determining the ranking of UK electricity prices for businesses.

The most recent analysis by the Committee on Climate Change (2017) concluded that a large proportion of the differences in electricity prices between EU member states is due to network and wholesale costs rather than low-carbon policies.

Redistribution – and regressive policies

It should also be appreciated that the huge implicit subsidy currently provided to fossil fuels through unpriced externalities is, in effect, paid by households and businesses through the harm they suffer from climate change and local air pollution. Therefore, carbon pricing should be regarded as redistributing, rather than increasing, the costs, and enables markets to incentivise the reduction of these costs. By confronting fossil fuels with their real costs, other forms of power can compete more effectively in markets. Increases in the price for consumers of power generated by fossil fuels should lead to lower electricity consumption and/or switching to cheaper low-carbon sources.

In addition, recent UK governments have made the decision to fund subsidies for immature renewable power sources through a charge that increases electricity prices for household and business consumers. This is a relatively regressive policy as poorer households typically spend a larger proportion of their income on energy, including electricity, than better-off households, as noted by the Department of Energy and Climate Change (2014), Gough (2013), and Advani et al. (2013). The Government should consider the merits of funding the subsidies for new forms of power from other sources, such as income tax and environmental taxes.

The Levy Control Framework: present and future

Since 2010, UK governments have attempted to limit the total amount of subsidies paid by consumers for low-carbon electricity through the Levy Control Framework, which sets an annual cap on expenditure. This cap has been under pressure due to an unexpectedly high amount of electricity generated by renewables and a drop in the market price (National Audit Office, 2016). The Government has responded by excluding onshore wind from Contracts for Difference, reducing Feed-in Tariffs for small-scale solar, and other measures. However, it has also indicated its intention to introduce a replacement for the Levy Control Framework beyond 2020–21 (HM Treasury, 2017).

The application of a cap through the Levy Control Framework creates a number of risks for current and potential energy generators due to uncertainties about future strike prices and market prices. In theory, the Government may endanger the fulfilment of the UK's five-yearly carbon budgets if it prevents the deployment of low-carbon power capacity. As the auction of Contracts for Difference tends to drive down strike prices through competition, and the costs of new technologies have been declining as they mature, it is not clear that the Government needs to apply a cap on overall expenditure on subsidies to minimise costs to consumers. For instance, the publication in September 2017 of the results of the second auction of Contracts for Difference (BEIS, 2017d) revealed a strike price for offshore wind of £57.50/MWh (in 2012 prices) for delivery in 2022–23, compared with £119.89/MWh hour (in 2012 prices) for delivery in 2017–18 through the first auction (DECC, 2015).

The need for greater energy efficiency and a reduction in waste

Nevertheless, confronting fossil fuels with their real costs and providing temporary subsidies for new alternatives have tended to increase electricity prices in the UK. Average domestic electricity prices rose by about 75 per cent in real terms between 2004 and 2014 (Competition and Markets Authority, 2016), partly due to low-carbon policies. The Government has responded by reducing the amount added to electricity bills to support the Energy Company Obligation, which promotes energy efficiency. However, it is important that electricity prices reflect the real costs of generation and supply in order for the market to work effectively. If the Government wants to limit electricity costs for consumers, it should focus on bills rather than prices. Therefore, the most significant way in which the Government can help business and household consumers to control their electricity bills is by helping them to cut their consumption through greater energy efficiency and a reduction in energy waste.

Energy efficiency improvements have already saved the typical UK household around £290 a year since 2008, according to the Committee on Climate Change (2017), more than offsetting the cost of supporting low-carbon energy sources (DECC, 2014). Rosenow et al. (2017) estimate that total household electricity use in the UK fell by 13 per cent between 2004 and 2015, largely due to energy efficiency improvements, despite a 12 per cent increase in the number of households. It should be noted that space and water heating account for about 80 per cent of final energy consumption by UK households, and most of this is provided by gas.

However, energy efficiency improvements for households also suffer from market failures: consumers may lack the upfront capital or necessary information to undertake these improvements themselves, or they might face a principal-agent problem, such as opposition from non-resident landlords who doubt their ability to recoup the cost through increased rental fees (Advani et al., 2013). Government policy can address these market failures through command-and-control regulation (such as minimum energy-efficiency standards), increased information for consumers (for example, appliance labelling or household energy-use certificates), financial support for consumers seeking to undertake energy efficiency improvements, or direct financing (International Energy Agency, 2011).

Even with energy efficiency partially offsetting higher costs through reduced electricity consumption, there may be distributional effects. Additional government support may be necessary for some vulnerable households, such as those facing 'fuel poverty'. In England, fuel poverty is measured using the Low Income High Costs indicator, which considers a household to be fuel-poor if it has required fuel costs that are above average (the national median level), and if, were they to spend that amount, they would be left with a residual income below the official poverty line (BEIS, 2017f). Those made worse-off by carbon pricing could be compensated by the revenue generated from it (Advani et al., 2013), while still encouraging reduced energy consumption. The Government could also consider financing energy efficiency improvements directly through general taxation, or supporting a more progressive energy pricing framework (e.g. the first x number of kilowatt hours are priced lower but the marginal cost of successive units rises sharply [Gough, 2013]).

Electricity costs and international competitiveness

As for industry, another concern is that increases in electricity prices could reduce international competitiveness. Domestic firms paying higher prices might face higher production costs than their international competitors. A recent analysis of the available academic research found that, while environmental regulation may have short-run effects for some pollution- and energy-intensive sectors, these costs are relatively insignificant compared with other production factors, and environmental regulation may also encourage innovation (Dechezleprêtre and Sato, 2017). If necessary, targeted measures could be selectively applied to shield emissions-intensive industries from the full overall consequences of carbon pricing, for example through support for investment in new processes or technologies. Any targeted support should, however, be consistent with the carbon budgets and the low-carbon transition: the intention should be to support these companies to transition effectively, rather than to maintain the status quo.

Looking forward, as climate change policy is the focus of action across the world, other countries are likely to implement policies, such as carbon pricing, to reduce emissions. As a result, UK businesses should not be uniquely disadvantaged. As with households, the most effective strategy for helping businesses with rises in electricity prices is likely to be the promotion of greater energy efficiency. Across the UK industrial sector as a whole, energy intensity (energy consumed per unit of output) decreased by 39 per cent between 1990 and 2016, with 33 per cent of overall consumption now provided by electricity (BEIS, 2017b). Energy intensity in the services sector fell 67 per cent between 1970 and 2016. However, it seems unlikely that the Climate Change Levy, which is effectively a tax on businesses' energy consumption, is, on its own, the most effective way of driving sustainable reductions in energy waste by UK businesses. Instead, the Government should explore more direct methods of incentivising further improvements in energy efficiency.

5. Finding the right policy mix

The Government needs to find a balance between carbon pricing and subsidies to meet emissions reduction targets at the lowest cost, remembering that these policies address different market failures. When considering costs, the Government should take account of the distribution between all parts of the economy, including household and business consumers, power generators and government. As described above, the Government has set an ambition, articulated in the terms of reference for the *Cost of Energy Review*, for the UK to have 'the lowest energy costs in Europe, for both households and businesses', but has also specified that any changes to policies for the power sector should be 'at minimum cost and without imposing further costs on the exchequer' (BEIS, 2017g). However, it would be more sensible for the Government to seek to minimise the costs to the economy as a whole (including businesses, taxpayers and consumers), rather than just the burden on consumers.

Helm (2017) concluded that the implementation of a universal carbon price across the UK economy and the merging of Contracts for Difference with the capacity auctions would go a long way to addressing the two main objectives of decarbonising the power sector and creating security of supply. While the simplicity of this model is attractive, it is unlikely to adequately address the market failures that distort the current market.

The Government should also take into account how the generation mix in the UK power sector will change in the future. In particular, as deployment of low-carbon generation increases, scale and learning effects will help decrease fixed costs, and energy generated from renewables has a very low marginal cost. This means that the deployment of renewables will drive down wholesale energy prices over time, as Helm (2017) acknowledges. The subsidies required to initially support immature low-carbon power generation should be withdrawn when they are able to compete on a level playing field with high-carbon generators. However, electricity markets currently provide fossil fuel plants with a price risk hedge, so it would be premature to assume that renewables no longer need measures to help them overcome market failures.

Modelling the policy mix

The fundamental observations outlined in the previous subsection are confirmed by the results of a simple economic model for the power sector, developed originally to assess the relative cost-effectiveness of policies to reduce emissions of greenhouse gases in Spain[1] (Doda and Fankhauser, 2017). For this study, the model was calibrated for the UK to assess the relative cost-effectiveness of policies to achieve a reduction in annual emissions of greenhouse gases from the power sector of 70 per cent between 2015 and 2030. This emissions reduction target was calculated by noting the carbon intensity of 334 gCO_2e/kWh of the UK power sector in 2015 (BEIS, 2017e) and assuming that it declines to the upper end of the range of between 50 and 100 gCO_2e/kWh that the UK Committee on Climate Change (2015) has identified as being broadly consistent with meeting the fifth carbon budget for 2028–2032.

The model takes all current UK energy policies and power generators' input prices as given, using the UK power sector in 2015 as a baseline (see Appendix 1 below for full details). The model assumes that all policies enacted by 2015 had achieved their maximum impact on annual emissions by the end of that year. It also assumes that low-carbon electricity generation capacity is available to substitute for high-carbon generation: in other words, it assumes that all of the additional market failures that are barriers to alternatives to fossil fuels have already been removed.

The model evaluates the welfare impact of several different scenarios for additional policy interventions after 2015 to achieve another 70 per cent reduction in greenhouse gas emissions from the power sector by 2030. The welfare measure comprises the changes in generators' profitability, consumer surplus and the government's fiscal position due to policy intervention. The policy instruments and scenarios considered here are listed in Table 1 below, alongside an indication of the approximate UK policy equivalent. It is important to note that, in each of these scenarios, the effectiveness of all of the instruments is assessed solely in terms of reducing emissions, and not, for instance, in terms of tackling market failures other than the greenhouse gas externality.

[1] Full details of the model's methodology and the results for Spain are presented in a recent working paper published jointly by the Grantham Research institute on Climate Change and the Environment and the ESRC Centre for Climate Change Economics and Policy (Doda and Fankhauser, 2017).

Table 1: Modelled policy scenarios

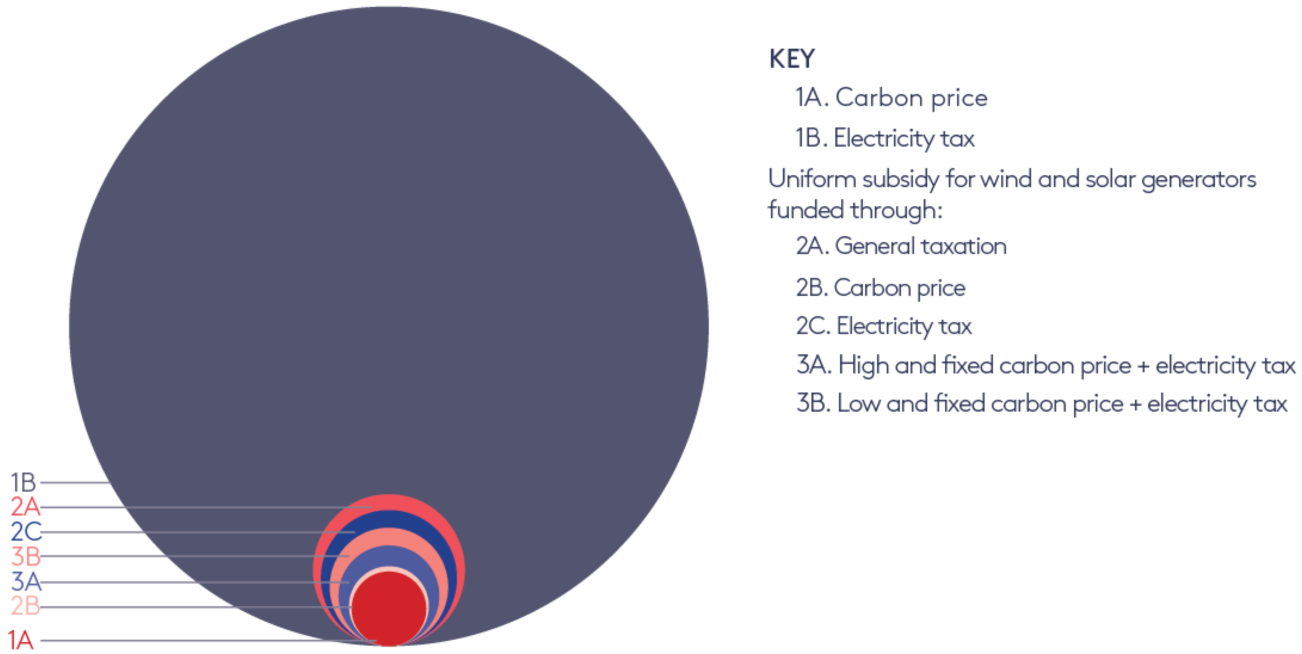
Scenario	Instruments			Notes	Broad UK policy equivalent
	I	II	III		
1A	Carbon price			Carbon price raises the cost of fossil fuel inputs in proportion to their carbon content	Increase in the Carbon Price Support Rate and/or market price in the EU Emissions Trading System
1B	Electricity tax			Tax on consumption of electricity by households and industry	Increase in the Climate Change Levy and other green levies electricity users face
2A	Uniform subsidy to wind and solar generators	General taxation		Subsidies are exactly financed by revenues from general taxation	Increase in support to new capacity or generation, for example the UK's Contracts for Difference paid from general government revenues
2B	Uniform subsidy to wind and solar generators	Carbon price		Subsidies are exactly financed by proceeds from an appropriately selected carbon price	As in 2A except financed by revenues from 1A
2C	Uniform subsidy to wind and solar generators	Electricity tax		Subsidies are exactly financed by proceeds from an appropriately selected electricity price	As in 2A except financed by revenues from 1B
3A	Uniform subsidy to wind and solar generators	High and fixed carbon price	Electricity tax	Subsidies are financed in part by the proceeds from a high and fixed carbon price with any remaining deficit paid for by electricity consumption tax	As in 2A except financed by revenues from 1A and 1B, assuming a high carbon price
3B	Uniform subsidy to wind and solar generators	Low and fixed carbon price	Electricity tax	Subsidies are financed in part by the proceeds from a low and fixed carbon price with any remaining deficit paid for by electricity consumption tax	As in 2A except financed by revenues from 1A and 1B, assuming a low carbon price

Policy scenarios – results

For all policy scenarios, there is a welfare loss. This is by construction because the model does not include the benefits from emissions reductions or from the reduction of several market failures that may be alleviated by the policy intervention, including network, innovation, and scale effects for renewable energy. In this case, the best policy scenario is the one with smallest welfare cost, i.e. the most cost-effective policy.

The results show that a carbon price (scenario 1A) is the most cost-effective policy (see Figure 4), and is broadly equivalent to an increase in the Carbon Price Support Rate and/or carbon market price in the EU ETS. The next most cost-effective option uses the proceeds from a carbon price to finance the uniform subsidies to wind and solar generation (2B); the welfare cost is much smaller than in the scenario in which the subsidies are financed by an electricity consumption tax (2C).

Figure 4: Impact of select policy combinations on social welfare



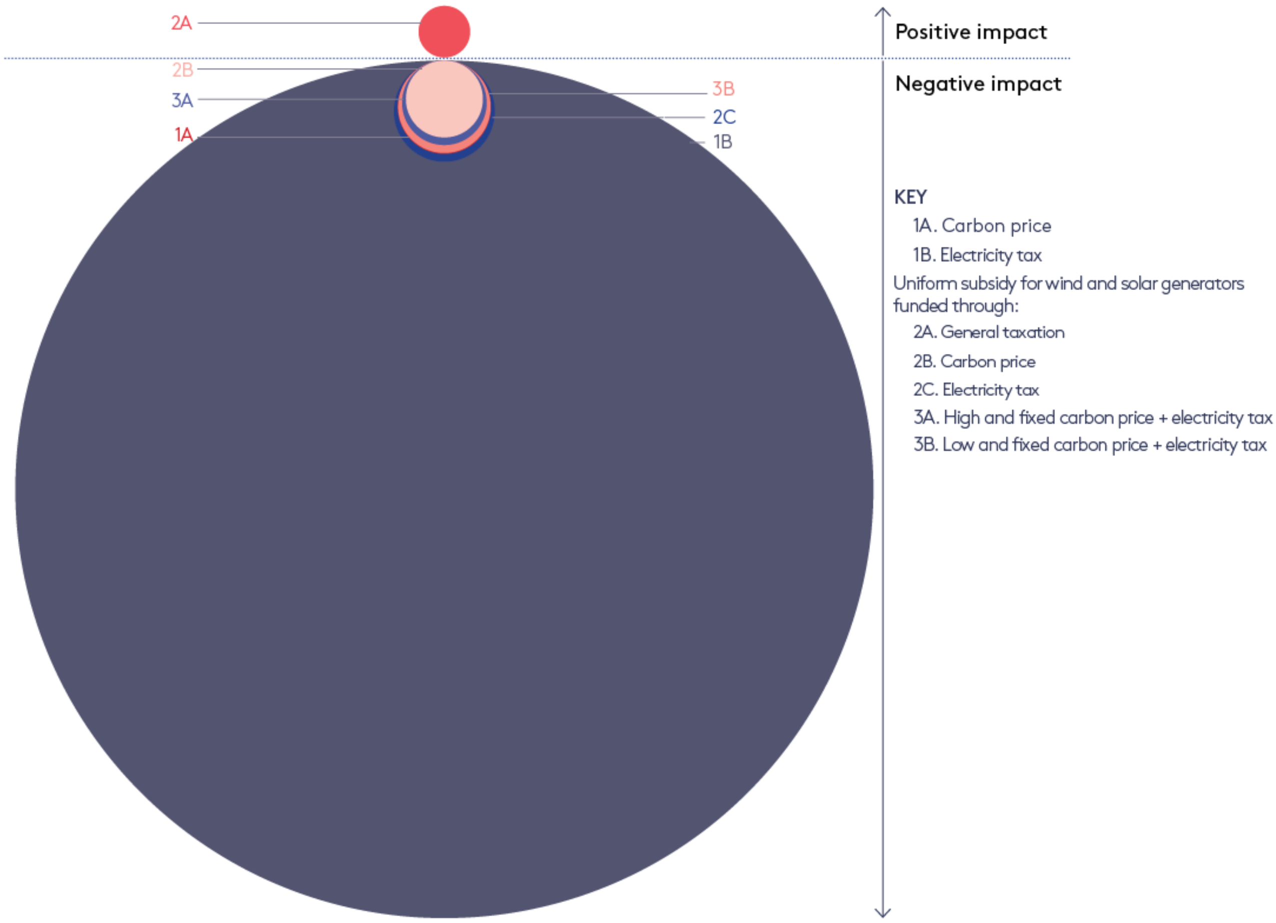
Note: The area of the circles shows the relative size of the cost to social welfare (government revenues, consumer surplus, and firm profitability) of the different policy options, such that the smallest circle has the smallest negative impact. Source: Authors.

If a combination of carbon price and electricity consumption tax is used to finance the subsidy, the model suggests that a high carbon price scenario (3A) has a smaller welfare impact than the low carbon price scenario (3B), while achieving the same emissions reductions, and leaving consumers, in particular, better-off. The costliest option by far is to use an electricity consumption tax (1B) on its own, with large costs to consumer surplus. The impact is especially large because the model does not allow for energy efficiency improvements that households might undertake in response to higher electricity prices.

Focusing only on the impact on consumers (Figure 5), there is an increase in consumer surplus generated by scenario 2A, which finances the subsidies for wind and solar generation using revenues from general taxation. However, the increase in consumer surplus is more than offset by the large negative impact on government revenues, as shown by the large overall welfare cost of scenario 2A. The next best option for consumers is subsidies financed by a carbon price (2B), followed by subsidies financed by a combination of a high carbon price and an electricity consumption tax (3A).

Using an electricity consumption tax only (1B) to reduce emissions would be the costliest option by far, both to consumers and for society as a whole.

Figure 5: Impact of select policy combinations on consumer surplus



Note: The area of the circles shows the relative size of the cost to consumer surplus of the different policy options. Option 2A has a positive impact on consumer surplus, though this is outweighed by the negative impact on government revenues (see Figure 4). Source: Authors

To summarise, the results show that a carbon price is the most cost-effective policy to reduce emissions. Renewable energy subsidies – the use of which is primarily justified by the need to overcome additional market failures in low-carbon power generation – would be best financed by a carbon price rather than by an electricity consumption tax or revenues from general taxation.

6. Conclusions and policy recommendations

Carbon pricing, taxes and subsidies

The UK needs to ensure affordability of energy without threatening security and sustainability. This can be achieved through a set of policies that harness the power of markets by correcting the many market failures affecting the power sector.

- **Recommendation 1:** The Government should seek to optimise the balance between carbon pricing applied to fossil fuels and direct subsidies for low-carbon alternatives, to ensure that market failures and distortions are addressed while meeting emissions reduction targets as efficiently as possible. This should be an explicit goal of its Clean Growth Strategy, and reinforced by other policies, such as the Industrial Strategy and Budgets.
- **Recommendation 2:** The Government should reform the currently overlapping carbon pricing policies in order to create a consistent carbon price, not only across the power sector, but also across all firms and fuels in the economy. The Climate Change Levy or the Carbon Price Support Rate could be modified to become an effective economy-wide carbon tax.

Renewables

Renewables tend to drive down the market price of electricity through the merit order effect, which means they enter the market at a lower short-run marginal cost of production and thereby reduce the wholesale price of electricity.

- **Recommendation 3:** The Government should consider how the electricity market should develop in order to take into account the fact that renewables potentially have low, if any, marginal costs, and that fossil fuel plants enjoy a hedge against price risk. In the current electricity market, the marginal costs of the marginal plant are usually related to the operating costs of fossil fuels, i.e. the cost of fossil fuels for the marginal plants can be passed through into electricity prices.

Prices for households and businesses

In general, electricity prices for households and most businesses in the UK are not the highest in the EU.

- **Recommendation 4:** In order to realise its ambition of having the lowest energy costs in the EU for household and business consumers, the Government should focus on bills, not prices.

Energy efficiency

Energy bills are reduced most sustainably through tackling energy waste (thus also reducing the amount of energy consumed), rather than through pricing measures.

- **Recommendation 5:** The Government should focus on measures to improve energy efficiency for households and businesses, such as minimum energy-efficiency standards, increasing information available to consumers (for example, appliance labelling or household energy-use certificates), financial support for consumers seeking to undertake energy efficiency improvements, or direct financing.

Cost distribution

The distribution of the costs of electricity generation between consumers is important and can lead to fuel poverty for poor households.

- **Recommendation 6**: The Government should consider funding subsidies for new low-carbon power sources through measures that are less regressive than increases to consumers' electricity bills.

Contracts for Difference

The auctions of Contracts for Difference provide a basis for affordable prices for clean power because they drive down strike prices for immature renewable sources through competition.

- **Recommendation 7:** The Government should allow competitive auctions to drive down prices rather than applying a cap on overall expenditure on subsidies through the Levy Control Framework, which risks undermining reductions in greenhouse gas emissions from the power sector.
- **Recommendation 8:** The Government should explore the possible introduction of 'subsidy-free' Contracts for Difference for mature renewables technologies, such as onshore wind, to reduce the risk for developers and thus lower the cost of financing.
- **Recommendation 9:** The Government should not accept the recommendation by the *Cost of Energy Review* to merge the Contracts for Difference and capacity auctions, as this would be less efficient and would create additional barriers to new renewable power generators attempting to enter the market.

Climate Change Levy

The Climate Change Levy, which is effectively a tax on energy consumption by businesses, appears unlikely on its own to be the best way to drive sustainable reductions in energy waste or emissions of greenhouse gases.

- **Recommendation 10:** The Government should explore better ways of promoting energy efficiency for businesses, as recommended by its Clean Growth Strategy.

Welfare costs of competing measures

A simple model of the cost-effectiveness of instruments reveals that carbon pricing reduces emissions with the least overall welfare costs for the UK, while an electricity consumption tax is the most costly.

- **Recommendation 11:** The Government should assess the overall welfare cost to household consumers, taxpayers and businesses, and not just the direct cost to consumers, when assessing the cost-effectiveness of policies to reduce greenhouse gas emissions.

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Appendix 1: Overview of the model methodology

The results reported here are based on the stylised model of the power sector described and modelled for Spain in a recent working paper (Doda and Fankhauser, 2017). The model can be calibrated to apply to the power sectors in other countries, including the UK. We explain the methodology here briefly but advise readers to consult the working paper for a full description of the model, its assumptions and the calibration strategy that was adopted.

The model is a simple deterministic partial equilibrium model of the power sector with multiple generation technologies. It is partial equilibrium because key variables, including the prices for fossil fuels and capital inputs, as well as consumers' income and the level of GDP, are determined outside the model. Put differently, taking these variables as given, the price of electricity adjusts to bring the demand for and supply of power by individual generation technologies in line.

The model is designed to evaluate the impacts on welfare and its components for alternative policy scenarios. Each scenario achieves a fixed reduction in emissions relative to a benchmark equilibrium that subsumes all existing policies. The policy instruments examined include carbon pricing, a uniform capital input subsidy to wind and solar only, and electricity consumption taxes. These instruments are implemented individually or in policy packages, as described in Table 1.

A novel feature of the model is that electricity production takes place at technology-specific sites, which can differ in productivity. A representative firm decides whether or not to develop these sites and, if developed, also decides the quantity of inputs to use at each site to maximise the net present value of its profits. Production can be subject to physical-geography constraints, system-level technological constraints and political-economy constraints. Given exogenous government policies, input prices and a demand function, the model can be used to characterise the equilibrium price and quantity as well as generation and profit mix in the power market in the long run.

Here, long run means the time horizon that is long enough to be able to abstract from hourly, daily, seasonal and annual fluctuations in supply and demand. At the same time, this horizon is short enough for the electricity production technology to be assumed approximately constant. For simplicity, the model excludes: local and global benefits of emissions reductions; all market imperfections and externalities that arise in the climate change context; and energy efficiency investments that can limit the impact of higher energy prices on consumers. Against the backdrop of these important theoretical exclusions it must be emphasised that the model results can be, at best, interpreted as a ranking of policy scenarios by their welfare impact, rather than a forecast of the precise magnitude of their effects on prices, consumers, generators or governments.

In order to perform a quantitative analysis, the model is specialised to six electricity generation technologies: wind, hydro, solar, coal, gas and nuclear. Doda and Fankhauser (2017) provide a detailed discussion of how these technologies are parametrised, and how the model is calibrated to Spain under the assumption that the country's power sector is in equilibrium over the 2010–15 period. For the purposes of the current analysis the model was recalibrated to the UK under the assumption that the UK power sector is in equilibrium in 2015, and using data from a number of official sources (BEIS, 2017e; European Commission, 2017; International Energy Agency, 2017). In light of the substantial coal-to-gas switch and the rapid growth of wind generation in the UK over the last few years, this assumption is much less justifiable for the UK than for Spain. As a consequence, relaxing this assumption is sure to alter the impact magnitudes quantitatively. Indeed, a robustness analysis where the model is alternatively calibrated to 2010–15 and 2013–15 averages confirms this conjecture. However, the ranking of alternative policy packages discussed here remains the same under the alternative calibrations.