Imperial College London

Response to “Cost of energy review: call for evidence”

Submitted on behalf of Energy Futures Lab and the Grantham Institute – Climate Change and the Environment at Imperial College London

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Grantham Institute is committed to driving research in climate change and the environment, and translating it into real world impact. Established in February 2007 with a £12.7 million donation over ten years from the Grantham Foundation for the Protection of the Environment, the Institute's researchers are developing both the fundamental scientific understanding of climate and environmental change, and the mitigation and adaptation responses to it. The research, policy and outreach work that the Institute carries out is based on, and backed up by, the world leading research by academic staff at Imperial.

This consultation response draws upon the expertise of academics and researchers at Imperial College London and has been prepared by Energy Futures Lab and the Grantham Institute.

Summary

The Helm Review has provided a focus for discussions in government about the cost of energy, in particular electricity prices. The Review was conducted on a wide scope and in a short time period, and we welcome the opportunity to widen the discussion through this Call for Evidence.

In the the longer term, the principal challenges for electricity generation, transmission and distribution, and supply are to:

- Continue to grow the share of low carbon generation and reduce the cost of low carbon power
- Ensure the system is flexible so it can incorporate low carbon power at minimum cost
- Increase the overall supply of electricity to meet new loads from electric cars and heat pumps
- Take advantage of new technologies, for example to enable flexible demand or storage
- Enable and respond to the development of new business models and services
- Upgrade parts of the network, in light of the changing context

It is vital that policy makers treat the generation system as a whole. Systems services needed to manage the increasing percentage of variable renewables in the electricity mix must be provided for, and incentivised at, the systems level. It is not economically efficient to require individual generators to provide for themselves in isolation. Requiring such self-balancing would be economically inefficient, could result in over-investment in flexibility and balancing services and ultimately risks increased bills.

When making decisions about the electricity generating system, policymakers must take care not to overestimate the costs of integrating variable renewables - at current penetrations of variable renewables in the UK (approx 17%), the additional system costs attributable to 'intermittency' is less than 0.2 pence per KWh of total electricity supplied.

Whilst we applaud the desire for a streamlined policy environment, we caution against oversimplification. We argue that the Review has not established a clear link between policy complexity and consumer price increases, demonstrated UK policy is overcomplex or provided an evidence based criteria for assessing policy complexity. There are a range of objectives that need to be achieved through energy policies, and conflating these may lead to poor outcomes. In addition, any reductions in complexity that may result from e.g. merging the CfDs and CMs, need to be weighed against the potential for new policies, such as a carbon-adjusted EFP, to create new complexities of their own. Indeed oversimplification, or trying to meet multiple policy goals with a single policy tool, may render policies ineffective and even increase costs

We include some suggestions here about policy changes that could reduce costs to the consumer, such as subsidy-free CfD contracts; or a different set of changes to system cost allocation that can minimise overall system cost of integrating more wind and solar. These issues require careful and empirical analysis to determine what changes would decrease bills. The government's own modelling expertise is a vital tool that enables government to test and improve its policy mix.

Importantly, the Helm Review recognises the 'valley of death' in innovation, but does not explain how to overcome it. Support for early markets for innovation helps to ensure that the UK can take advantage not just of the best technology today, or in the near future, but also in the longer term. Suppportive policies can continue both to reduce costs in the UK and help to provide UK companies with opportunities to benefit from the rapidly growing global market for low carbon energy. The international evidence suggests such policies are most likely to succeed if they take a form similar to existing CfDs/FiTs. We recommend such support for emerging options is retained.

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1 Electricity generation

1.1 What are the longer-term challenges for electricity generation?

1.1.1 Providing a low cost, flexible, low carbon system with ongoing innovation

The principal challenges for electricity generation are to continue to grow the share of power provided by low carbon sources, reduce the cost of low carbon power, and ensure that the wider energy system is flexible enough to incorporate low carbon power at minimum cost. Substantial reductions in emissions cannot be delivered merely by replacing coal with gas. Progress with low, or zero, carbon options is also essential. It is likely to be necessary to increase electricity supply to meet new loads from electric cars and heat pumps.

Recent progress with decarbonising electricity supply in the UK has been remarkable. Growth in renewables and reducing use of coal has reduced average emissions from 500g/kWh in 2013 to below 250g/kWh (Staffell, 2017). By the mid-2020s around 4 GW of older nuclear stations need to be replaced and the challenge will be to provide enough low carbon power[1] (Rhodes, Gazis, & Gross, 2017). The Levy Control Framework guidance announced in the Autumn Statement effectively freezes new finance until after 2025, but some low cost renewable options could be built without subsidy. This would likely require 'subsidy free CfDs' (see Section 1.2.5). Pursuing such low cost options is a policy priority.

1.1.2 Cost effective flexible, reliable supplies – a system level issue

A secure and reliable system requires both enough generation capacity to meet demand and a wide range of other system services– including more flexibility and ancillary services such as frequency response. Policy should not fixate on one aspect of reliability – the capacity margin (Rhodes et al., 2017). The Helm Review focuses on 'firm' capacity, neglecting other aspects.

As the share of variable renewables rises they begin to impose system costs, often referred to as the costs of intermittency. It is important not to overstate the magnitude of such costs. UKERC's review of such costs (Heptonstall, Steiner, & Gross, 2017) suggests that at current penetrations of around 17% GB energy from variable renewables, the additional system costs attributable to intermittency add less than 0.2p per kWh of total electricity supplied[2].

Security and reliability is provided most cost effectively at the system level, because system services have system-wide benefits. Because these services are shared across the system as a whole it is not economically efficient to require individual generators to provide them for themselves in isolation.

For example, provision of response and reserve services may be shared across a large number of renewable installations and also help to ensure that the system is reliable in the event of a fault in a large power station, loss of an interconnector, or unexpected spike in demand. Many services required to ensure that the system is reliable are tendered by the system operator and cannot be left to the wholesale market for operational reasons or because it would not be economic to do so.

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[1] Providing adequate capacity is unlikely to be problematic per se but in the absence of incentives for lower carbon options that new capacity is likely to be gas-fired plant (Rhodes et al., 2017).

[2] Based on generation and supply data from BEIS November 2017 Energy Trends: Electricity https://www.gov.uk/government/statistics/electricity-section-5-energy-trends (Q1+Q2 2017 VRE generation=29TWh, total electricity supplied=167TWh).

The Helm Review's proposals require individual generators to 'self-balance' or to enter into contracts to provide 'firm' power. However there is no a priori need for all generators to provide identical capacity credits[3]. The plants that provide secure capacity market contracts do not all need to be the same as the plants that provide low carbon energy. It is also not obvious that renewable generators are in a better position than the System Operator to contract for ancillary services. The economic incentives already in place reward firm capacity, and renewables tend to trade at a discount in the wholesale market because of their intermittency (Staffell, 2017; Staffell, et al 2017). Simply put, requiring renewable generation projects to 'self-balance' through the EFPs is inefficient, would result in over-investment in balancing services, and risks *increasing* bills.

1.2 What matters should the Government take into account in considering the policy framework for electricity generation?

1.2.1 The need for distinct and complementary policies – the CM and CfDs

The Policy Framework that the UK created through EMR rests upon two important and well-established principles: First, that long run fixed price contracts can reduce risks for investors in capital intensive and zero marginal cost plant such as wind/solar and nuclear. This in turn can reduce bills compared to other forms of support for such technologies, since a lower cost of capital will lower their generation costs. Second, that the phenomenon of 'missing money' may lead to underinvestment in generation capacity, which may be exacerbated by the impact of intermittent, zero marginal cost plant on wholesale power prices (Newbery, 2016).

As a result, EMR created two complementary policies, each serving distinct policy objectives – CfDs serve to de-risk investment in low carbon generation and the CM to ensure that there is adequate capacity to meet peak demand. Each of these two policies also targets generation types with different physical and operational characteristics. There is no a priori reason why removing or simplifying policies will reduce costs. Indeed oversimplification, or trying to meet multiple policy goals with a single policy tool, may render policies ineffective and even increase costs.

1.2.2 The benefits of fixed price support and the problems with capital subsidy

The main goal of CfDs is to ensure that zero marginal cost generation such as wind farms and nuclear power stations are insulated[4] from price risk caused by movements in fossil fuel prices feeding through into electricity prices (Gross, Blyth, & Heptonstall, 2010). A key rationale is that in most power systems flexible plants (usually fossil fuel plants; gas plants in the UK) act as 'price makers'. Investments in new gas fired plant have an inherent hedge against fossil fuel price variability, but renewables and nuclear do not (Gross et al., 2010). The UK is far from alone in providing structures that offer renewable generators long-run fixed price contracts. Internationally, some 82 countries offer a feed-in-tariff (FiT) of some form and 34 countries run tenders, linked to a FiT or power purchase agreement (PPA) (REN21, 2017)

With CfDs/FiTs developers are rewarded for energy output, which creates strong incentives for them to choose the best sites and cheapest technologies. In contrast, international experience with capital subsidy has been rather mixed, because of perverse incentives leading to poorly sited and

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[3] The ratio between average energy output and expected availability at peak (see Heptonstall et al 2017 for definitions).

[4] The implicit judgement is that in transferring risk from investors to consumers/government the benefits of reduced cost of capital exceed any costs to consumers/government from providing this insurance to investors.

suboptimal developments (Moallemi, Aye, Webb, de Haan, & George, 2017). Now that the CfDs are allocated on an auction basis, the potential for this approach to realise cost reductions is being demonstrated through falling CfD auction prices. Annex 1 argues that this will also remove any excess returns. We return to opportunities to build upon success with CfD auctions below, but first consider the case to merge the CfDs and CM.

1.2.3 Are EFPs the way to tackle intermittency?

The principal criticisms offered by the Review of CfDs are that past prices were set too high, and that too much capacity was procured when technologies were immature and expensive. This is debatable but that is irrelevant to the future of CfDs and CM since prices for both are now set through auctions. The principal reason the Helm Review recommends merging CfDs and the CM is to tackle the costs of intermittency. As explained above though, intermittency costs are a modest share of total costs and best tackled on a system-wide basis. Requiring individual plants to self-balance will lead to overinvestment in balancing capacity or ancillary services.

In places, the Review reads as if policy should be based upon a justice principle, apportioning ‘blame’, whether for carbon emissions or particular categories of system cost. However, the ultimate objective is to reduce bills, not maximise market ‘justice’. System costs will be minimised if they are allocated to those best able to manage them irrespective of who ‘causes’ them. In many cases the System Operator continues to be better placed than individual generators to manage these costs.

If desirable then reallocation of system costs is feasible with existing policies. Renewable operators can be exposed to more of costs they impose on the wider system, for example through additional use of system charges, perhaps with an option to reduce such charges if they can provide system services themselves. It is also possible to expose renewable generators to a larger share of wholesale market balancing costs. For example, changes to how the CfD reference price is calculated could encourage operators to forecast output further in advance. Some countries are moving to premium FiTs, which expose renewable generators to wholesale price fluctuations. Premium FiTs do not offer protection from wholesale price risks. However they are widely used internationally and thus have the advantage of being familiar to developers and financiers. Government could assess the pros and cons of a range of changes to system cost allocation and options for minimising overall system costs of integrating wind and solar.

The EFP auctions may create new complexities of their own. For example, it is suggested that the System Operator should score EFP bids against carbon budget constraints, taking into consideration advice from the CCC on opportunities in other sectors. How system wide emissions would be calculated, the timeframe over which emissions will be assessed, or how opportunities/barriers for action across and within sectors would be taken into account aren’t specified. Prima facie this scoring appears to have the potential to be complex and fraught with difficulty. This approach also suggests that the EFP auction is the best forum to act as a clearing house for prioritising carbon budget decisions across the economy, which seems unlikely and is certainly beyond the scope of the Review.

1.2.4 Could CfDs be split into phases?

In the absence of a move to EFP auctions the Review also recommends dividing CfDs into construction and operational phases. Again, it is hard to understand how this could be made to work in practice since any support during construction would have to take the form of a capital subsidy, which CfDs do not provide. Annex 1 discusses construction risk and operational rewards in more detail from a finance theory perspective and explains why Helm's contentions appear to be misconceived. We are not aware of any examples of other countries running carbon adjusted equivalent firm capacity auctions[5]. The UK competes for investment in a global market for clean and conventional energy. Brexit has increased the uncertainty associated with all UK investments. It would not appear a particularly auspicious point in history for UK policymakers to engage in a new and experimental approach to encouraging investment in low carbon power.

1.2.5 Subsidy free CfDs and an option to participate in the CM

There is a wealth of international evidence that support schemes such as CfDs and FiTs can attract new entrants and grow markets. Equipment prices in solar and wind have come down in large part because the huge market growth engendered by FiTs has created opportunities for so called 'learning by doing' (Gross et al., 2013). As the Review rightly points out, one means to ensure prices are as low as possible is through auctions. But lower prices do not in and of themselves obviate the importance of long run fixed-price contracts in securing investment at minimum cost. For this reason, the UK could offer 'subsidy free' CfD contracts, for example for onshore wind. These would provide investors with the low risk environment of the CfD, avoid further policy costs and help to meet carbon targets. Surprisingly, they are absent from Helm's discussion.

There's also no reason why the CM could not be extended to low carbon options able to offer firm power, such as nuclear and biomass. Indeed, in principle the CM could also be open to variable renewables who prefer to make provision for back-up. It would be possible to allow prospective generators to choose between entering CfD auctions and the CM, rather than closing the CfDs, though it is beyond the scope of this submission to discuss further. Retaining CfDs offers several advantages – a low risk, low complexity environment, familiarity to investors, and no need for regulatory change. A further advantage is that a small pot could be retained for early stage technologies, thus overcoming the 'valley of death' problem.

1.2.6 Empirical factors determine whether policies will decrease costs

Overall, our analysis suggests that the key question is whether whole system cost reductions *will* (not might) result from replacing CfDs with EFPs. Any potential system cost reductions from the EFP auctions need to be weighed against additional costs incurred by exposing renewable project developers to system costs/risks and complexities that they may not be best placed to manage. Any reductions in complexity that result from merging the CfDs and CM need to be weighed against the potential for a carbon adjusted EFPs to create new complexities of their own. The questions are complex, largely empirical, need a system wide perspective, and cannot be answered *a priori* or by recourse to economic theory.

Overall it is possible to imagine an approach to cost reduction using the tools created by EMR to better effect by using auctions to drive down prices, ensuring some CfDs are subsidy free, retain a small pot for emerging technologies, and to provide a cost-effective environment for minimising system costs.

[5] The Review notes lower returns on investment for wind developments in Germany, suggesting they result from something similar to the staged approach to CfDs that Helm recommends. But this is not the case. Germany does not offer capital subsidies during construction. Rates of return are lower for a range of reasons, including the perceived risk of the wider regulatory environment, what is 'bundled' with the FiT (for example environmental surveys/consents and grid connection), and role of state banks in financing.

1.3 What additional evidence should the Government consider to reduce the cost of electricity generation in the longer term?

See Annex 1 and Annex 2.

2 Electricity transmission and distribution

2.1 What are the longer-term challenges for electricity transmission and distribution?

2.1.1 Networks: From incremental change to radical innovation

Today's electricity networks are based on long-standing engineering design principles. This has led to a stable, secure electricity network system, characterised by small, incremental changes and technological advances. However, two major drivers are currently pushing a period of substantial innovation and change in the networks. The first of these is the need to incorporate increasing quantities of variable renewable generation at the distribution level, as well as to prepare for increasing and uncertain levels of electrification in heating and transport. The second comprises the new opportunities arising from the incorporation of ICT technology into the networks, including smart metering, smart appliances, demand-side participation and the development of new business models and services which facilitate active consumer engagement.

2.1.2 The changing role of network operators

Traditionally, DNOs have operated networks based on the principles of passive and predictable consumer demand and unidirectional flows of energy. In addition, a large quantity of distribution network assets are old and will require replacement in the near-term. The increasing penetration of generation, mostly solar PV, installed at the distribution level, and the variable and intermittent characteristics of much of this generation, provides a new challenge to the DNOs in managing and reinforcing their networks. In addition to this, the predictions of substantial levels of transportation electrification, as well as the electrification of heating through heat pumps or hybrid systems, lead to a scenario where the DNOs need to prepare for increased and uncertain levels of demand.

New technologies and developments in the ICT sector are also influencing the future development of electricity networks, allowing the possibility of greater and finer-grained control over electricity flows, and enabling new usage paradigms of distributed generation, control and consumer engagement. These developments will mostly affect the DNOs, due to the aforementioned penetration of renewable generation on their networks as well as their direct link to consumers. The installation of smart meters will open up new business models and opportunities for consumers to engage with the electricity market, and will inevitably lead to questions on how to optimise the energy system and maintain security and economic standards. It may well lead to system balancing on a local level and to DNOs to become distribution system operators, (DSOs) far more directly engaged with consumers and generators than at present. This transition will require a substantial shift in the mind-set, skill-set and innovation intensity of operating companies, and would be a significant institutional transformation.

2.2 What matters should the Government take in account in considering the framework for network regulation, and its associated institutional framework?

2.2.1 Encouraging innovation in network companies

Electricity networks have traditionally been seen as an area of mature technology and low innovation spend levels. Following privatisation, the R&D intensity of the network operating companies in 2005 was an average of less than 0.2%. This low intensity was a factor of the mature technological space occupied by electricity networks as well as the RPI-X price control method. This pricing mechanism incentivised the regulated-monopoly network companies to pursue efficiency programmes and extended utilisation of existing assets instead of capital spend and innovation measures. In 2008, Ofgem initiated the RPI-X@20 review to evaluate RPI-X for its effectiveness and appropriateness in tackling 21st century challenges. As a result of this review the price control mechanisms for the regulated monopolies of the transmission and distribution networks were overhauled, moving to a model, RIIO, which aims to incentivise efficient investments in innovation and assets.

The RIIO controls move from a five-year price control settlement under the RPI-X system to an eight-year period, which it is hoped will incentivise longer-term investments. A significant concern of the Helm Review is this eight-year price control period, which, it is asserted, is too lengthy in duration at this time of considerable technological change and has led to network companies significantly outperforming the assumptions made in the last price control review. The Helm Review therefore recommends that the periodic reviews be scrapped at the next period, 2021 for transmission and 2023 for distribution. We believe that there is a credible rationale for reviewing the eight-year period and changing to a shorter, rolling or redesigned price control approach as required, but that a complete move away from periodic price controls could lead to considerable uncertainty in this time of rapid change, and might counteract the recent increase in innovation investment spurred on by the RIIO structure.

2.2.2 The potential benefits of independent system operators (NSO, RSO)

The Helm Review recommends the formation of a National System Operator (NSO) and a series of Regional System Operators (RSOs). These bodies would be publically owned and would be independent of the private network companies. They would auction and tender for system services, and would be supported by a new generic energy licence for network companies, generators, suppliers and storage operators.

In a recent Imperial College report: ReShaping Regulation (Sandys, Hardy, & Green, 2017), four high-level principles for a regulatory system are outlined:

- Regulate based on how consumers use energy, not on how businesses are organised;
- Regulate for system optimisation to deliver a productive, efficient and affordable system;
- Regulate to protect transparent, cost-reflective and open markets;
- Regulate for where the security of the system is truly at risk.

The formation of the NSO helps move towards several of these goals, providing independent oversight of the system and the market and allowing, in theory, a more efficiently optimised system owing to its ability to auction for services from many providers, including storage and demand-side providers which currently find it difficult to enter the market. Indeed, this structure contains many of the features of a traditional vertically-integrated system, with a single institution contracting for services, and breaks down many of the artificial barriers seen in the current system structure. This, in principle, seems a sensible recommendation.

The RSOs are described in vaguer terms, with important characteristics such as their number, geographical remit, powers and interactions with the NSO left either undefined or unclear. As described above, there is likely to be a great deal more activity at the local distribution level than has been seen previously, and an RSO structure could help break down artificial barriers between network owners and suppliers, which have caused issues around the ownership and use of smart meter data.

2.2.3 Potential problems with the NSO/RSO model

The NSO/RSO structure, or any equivalent, would also need to be carefully considered against a range of concerns to ensure the new structure would have clear, tangible benefits and lower costs over the current model. Concerns include:

Scale of disruption: The replacement of periodic controls with the NSO/RSO structure and a series of auctions for network operations and enhancements is an unproven model, and the transition would necessarily lead to a considerable amount of disruption. The scale and cost of this disruption would need to be assessed.

Timing: This change would create uncertainty in network institutional arrangements in the early 2020s. This is a period in which the smart meter rollout would be completed and new smart technologies and business models would be able to reach a far wider consumer base.

Ownership: The Review is also unclear how the RSO model would introduce effective competition, as the DNOs would still own the vast majority of regional network assets and would still effectively be a monopoly supplier for most functions. It may be that a DSO model, where the operator also owns assets, is more effective at this level.

Roles and Responsibilities: The Review is also unclear on the nature of the relationship between the NSO and the RSOs, the boundaries between their responsibilities, and how these bodies would work together to ensure the most optimised and efficient outcome for the system.

Innovation: The DNOs have traditionally low levels of innovation intensity, due to a paradigm of passive demand and traditional physical assets. In a time of rapid technological change in this sector, the RIIO price-control mechanism has increased innovation spend dramatically on the networks through the Network Innovation Allowance and Network Innovation Competition schemes, equivalent to about £100 million per annum. These schemes are designed for network companies to partner with other stakeholders to demonstrate new technologies, services and operating paradigms on the networks to evaluate them for a full rollout. While these schemes have been criticised for poor quality and rigour of project methodology and the dissemination of learning from projects to other network operators, they have seen to be successful as a method of stimulating innovation in the regulated monopolies of the networks and in incentivising a culture of innovation in the DNOs. There are concerns that this innovation culture would not withstand a withdrawal of public funds. (Rhodes, Van Diemen, & Skea, 2016) The Review makes no direct reference to the future of these schemes in the absence of price-controls, and it is unclear if they would be compatible with an RSO auctioning model, or if the RSOs mandate would extend to supporting development and demonstration projects.

2.3 What additional evidence should the Government consider to reduce the cost of electricity networks in the longer term?

See Annex 2.

3 Electricity Supply

3.1 What matters should the government take into account in relation to electricity supply?

As the UK's energy generation system changes, electricity wholesale and retail supply approach may also need to change. In electricity generation we are already experiencing a gradual change from few large generators, to more dispersed, numerous smaller generators. In parallel, the increase in renewable energy generation in the UK such as solar or wind, has made the electricity supply more intermittent, and we can expect this trend to continue, especially as the costs of these types of generating capacity continue to fall. These electricity generators may range from individual householders and businesses to small co-operatives or new electricity generating market entrants through to the larger, more established generators. The changing generation landscape raises questions about how generators reach their market, how prices are established, and how supporting infrastructure is paid for, and by whom.

In addition to these structural factors, consumer satisfaction with the current electricity suppliers is low, hovering around 70% satisfaction levels,(Ofcom, 2017; Ofgem, 2017; Ofwat, 2017) compared to much higher level of satisfaction in other regulated sectors with water at approximately 80% and telecoms at approximately 90% or higher. Some of the just cause for complaint was outlined in the Helm Review. This level of satisfaction could be interpreted as a need for change in the electricity supply sector.

In these changing circumstances, there are many opportunities for energy suppliers to develop new and innovative business models. Research carried out at Imperial, through interviews with a wide range of stakeholders, tested the potential of two extreme options – one where consumers hand over control to their energy suppliers completely to manage all of their heat and electricity needs, even engaging with selection and control of appliances. In the other model, communities own and operate the energy generation and local distribution fully themselves, cutting out the supplier middle man. In reality, it is likely that the future supplier network in the UK could include a combination of these approaches.

It is vital that any change in the electricity supply market enables diversity in supply models, allowing the potential for new entrants, as well as the operation across heat and electricity. We see the potential for new energy supply business models to arise, that are more consumer centric. We outlined three models in our report with Smart Energy GB (Hardy, 2017) We found that any new system must ensure that:

- Markets enable business model innovation
- Smart devices and data are accessible, interoperable and secure
- Solutions are required for consumers in all situations, particularly vulnerable consumers
- New and existing businesses must be incentivised or compelled to reduce carbon emissions (theirs and their customers)

3.2 What additional evidence should the Government consider to reduce the cost of electricity supply in the longer term?

See Annex 2.

4 Cross-cutting

4.1 What matters should the Government take into account in considering the wider recommendations of the Review?

4.2 Are there any other matters that the Government should consider to reduce the cost of energy in the longer term?

As noted in the Call for Evidence, the Review makes a range of other recommendations on issues including **policy simplification, innovation, wider approaches to decarbonisation, and use of modelling**. In what follows we address each of these issues in turn, taking the two questions together. In each case we raise fundamental concerns about several of the contentions and premises set out in the Review.

4.2.1 Policy simplification: Is energy policy too complex?

The Review describes a 'mass' of interventions and includes a section which purports to explain why complexity is expensive. It asserts that "energy policy is so complicated it is unlikely that few market participants, few regulators, ministers or civil servants can have grasped them all. The inability of the market participants to grasp all these interventions is in itself likely to increase the cost of energy."

There is no evidence offered to support these contentions. The Review does not establish either that energy policy is excessively complicated or that complexity increases costs. No attempt is made to quantify the impact of complexity on consumer bills. The argument that there are too many policies rests upon nothing more substantive than listing out all the various policies and provisions, then pointing out that this list runs to around three pages of text and describing this as a 'mass'. However, no criteria or framework for evaluating or measuring policy complexity is provided. Large amounts of policy can be found for just about any product or sector of the economy[6]. The case for electricity being in any way exceptional in terms of regulatory intervention has simply not been established.

The energy industry is complicated, with wide ranging social and environmental impacts and multiple policies serve many goals. Indeed the energy sector (or even electricity) is not a single industry – some policies affect appliance manufacturers, others the building industry, some affect fuel suppliers, some power generators, some network operators and so on. In many cases it is perfectly sensible to have different policies for different sectors and it is well established that the energy sector is affected by multiple market failures. For example there is a large body of literature on 'non price' market failures in the domestic demand sectors. Because consumers tend to have limited response to price signals exposing them to price based policies will have limited impacts. Other policies complement prices, such as labelling or appliance standards. Overall there is no a priori reason why removing or simplifying policies will reduce costs. Indeed oversimplification, or trying to meet multiple policy goals with a single policy tool, may render policies ineffective and even increase costs.

4.2.2 Policy complexity needs to be evaluated using evidence based criteria

[6] To illustrate this point we googled 'how many regulations on a loaf of bread'. The search revealed ten pages of guidance from the Food Standards Agency and a 27 page BEIS document on packaging requirements alone https://www.food.gov.uk/sites/default/files/multimedia/pdfs/breadflourguide.pdf https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/487018/Guidance_-_The_Weights_and_Measures__Packaged_Goods__Regulations_2006_v.4_December_2015.pdf

It is of course perfectly possible that policies have accumulated, that some are overlapping, some may not be well designed and others not necessary. However a thorough, evidence based approach would develop criteria for policy effectiveness and investigate individual and combined policies against these criteria. The National Audit Office carry out frequent 'value for money' investigations of UK policies for exactly these reasons[7]. Another approach would be to compare the UK policy mix with international comparators to establish whether UK energy policy is more complicated than competitors or peers.

Given the ambition and time constraints imposed on the Helm Review it would have been impossible for it to have carried out a detailed investigation of policy complexity. However instead of simply asserting with no substantive arguments that policy is overcomplicated the Review could have recommended a review of policy overlap or conflict. A guiding principle for such a review being to ensure that a least cost outcome is delivered – viewed from a system wide perspective, based upon empirical evidence.

4.2.3 The scale and significance of regulatory capture needs to be demonstrated

The argumentation in the Review related to policy complexity makes a further assertion: complexity increases costs because it begets lobbying and capture. Previous analysis by the authors has investigated one instance that appears to be relevant – increasing offshore wind costs (Greenacre, Gross, & Heptonstall, 2010). The analysis found that market power appeared to be significant (only two manufacturers provided offshore turbines at that time), but a number of other factors were also relevant, including supply chain constraints, commodity prices and the move to deeper waters. Far from being a product of 'capture' of policy, the cost escalations mainly resulted from real-world factors associated with trying to build a new industry in an aggressive natural environment in a short time, combined with the fact that the global market for wind was also experiencing very rapid growth, restricting dedicated turbine supply.

It is possible to argue that UK policymakers tried to drive offshore wind too far and too fast, leading to cost escalations, but this does not constitute capture by lobbyists. In any case lessons have already been learned. With the widespread global move to use auctions rather than administering prices for FiTs, as the UK has done with the CfDs, it is now unclear which policies continue to be captured by which lobbyists. The Review does not specify. It also does not explain how material regulatory capture might be in terms of impact on consumer bills. Given the centrality of policy simplification to the Review recommendations this is a surprising omission. Few would question the *potential* for regulatory capture, but it is important to understand the materiality and centrality of this concern, and what remains to be done now that many prices are set through auctions.

4.2.4 Policy and innovation: the role of market creation

The Review discusses innovation in a number of sections. It suggests that the electricity industry is on the cusp of profound technological change. This may be so. However the Review also makes observations that are very inaccurate and show a lack of appreciation of past technological change. For example, far from being '19th century technology' modern coal fired power stations went through immense technological improvements during the post-war period, and civil nuclear power represented huge scientific achievement at around the same time. It is similarly inaccurate to refer to CCGT as not much more than a WW2 jet engine. These misstatements matter because

[7] https://www.nao.org.uk/successful-commissioning/general-principles/value-for-money/assessing-value-for-money/

if past innovation is not properly understood the potential for future innovation can be mischaracterised.

Just as a combination of market and policy factors drove innovation in nuclear or CCGT so early markets created by policy drove cost reductions in new renewables. There can be no doubt that if the UK and other countries had not provided policies (mainly feed in tariffs) that grew markets for wind and solar in the 1990s and 2000s then the cost reductions seen recently could not possibly have happened.

4.2.5 Innovation, legacy costs and free riding on other countries

The Review notes the dramatic cost reductions achieved in wind and solar technologies but the cause and effect relationship between 'legacy' policies such as the RO and cost reductions is almost entirely ignored. The UK could of course have taken a free ride provided by others such as the Germans, Danes, Americans, Chinese, Indians, Brazilians and Spanish, and allowed them to invest in renewables on our behalf. However the UK chose not to free ride, and instead sought to take a role in commercialising low carbon technologies. As the leading global market for offshore wind in the early part of this decade the UK played a very significant role in reducing the costs of that technology. Rather obviously, if other leading economies (and many developing nations) had chosen to free ride the cost of other renewables would not have come down.

It is impossible to say whether the amount of subsidy provided to renewables in the UK or other countries was too large relative to the cost reductions that have resulted. However, irrespective of what the 'right' level of support for emerging technologies might be it is important to avoid the misapprehension that innovation is exogenous to policy and arrives as if it were manna from heaven. It is also important to avoid the misperception that innovation is only about laboratory R&D and some demonstration projects. The Review notes the risk of a 'valley of death' between research and deployment. The market opportunities provided by FiTs allowed the valley of death to be overcome, they provide market opportunities, which is exactly why wind and solar were able to commercialise so successfully. It is odd that the Review recognises the innovation achieved in wind and solar but appears blind to the fact that market creating policies were the principal source of this innovation.

Looking to the longer term it will be important to continue to promote innovation, both to reduce costs in the UK and to help to provide UK companies with opportunities to benefit from the rapidly growing global market for low carbon energy. New technologies include (but are not confined to) floating wind turbines, tidal stream, next generation solar, new nuclear and CCS, as well as storage and demand side response. If any of these technologies are to flourish then policy needs to continue to provide a pipeline that will allow them to enter the market. Despite observations about the 'valley of death', the Review does not explain how early markets for innovation would continue to be fostered in the UK if the CfD and CM were merged (as discussed above).

4.2.6 Wider approaches to decarbonisation and the use of modelling

These two topics are closely linked and for that reason we discuss them together. Much flows from the Helm Review's observation that scenario modelling undertaken in the UK did not anticipate the oil price collapse of 2014. This observation is correct, even the low gas price scenarios used by government prior to 2014 now appear high. The expectation that prices would remain high was widely shared internationally and price collapse was not anticipated by the International Energy Agency or large oil companies (International Energy Agency, 2012; Shell Scenarios Team, 2013).

History teaches us that fossil fuel prices are inherently volatile. Paradoxically there is now a risk that the opposite assumption prevails in future – that fossil fuel prices will be forever low.

We support the recommendation that a wider range of sensitivities and uncertainties are explored in future modelling. However the use of scenarios by the CCC and government is mischaracterised in the Review. Modelling using least-cost optimisation models seeks only to show what mix of technologies could meet a policy goal such as carbon budget, based upon assumptions and judgements about future technology costs that are likely to be wrong (Gross et al., 2013). Those undertaking such modelling efforts are fully aware that there is plenty of potential for error and that technologies can surprise us – whether the example is solar costs coming down or nuclear costs turning out higher than expected. For these reasons the CCC and others test numerous sensitivities. Scenarios are not used as planning tools and do not directly shape policy. It is inaccurate and misleading to suggest that they are used by governments to ‘pick winners’.

However, scenarios yield important insights that can help inform policy. They can show for example what appears to be least cost under a wide range of assumptions – energy efficiency might be an example. They also show that electricity can be decarbonised through a range of options. They show that costs would generally tend to rise if particularly important sources of low carbon energy are excluded. Efforts by the CCC or UK government also need to be set in an international context. Agencies such as the IEA, OECD, IPCC and other national governments also use cost-optimisation models – not to predict the future but to help understand how we might rise to the challenge of carbon abatement (Intergovernmental Panel on Climate Change, 2014; International Energy Agency, 2012).

Models can also be constrained to reflect particular real-world constraints. One such is the time new technologies take to emerge from the lab and make a meaningful contribution to energy markets. The authors have undertaken empirical research in this area that suggests it typically takes two to four decades for new technologies to reach widespread commercialisation (Hanna, Gross, Speirs, Heptonstall, & Gambhir, 2015). Hence, even the most rapidly developing technology that emerged in the next few years would be unlikely to be able to make a material impact on energy or emissions before around 2040, and more likely 2050 to 2060.

For these reasons we find very little merit in the recommendation that modelling capabilities within government should be scaled back. The cost of retaining such capacity represents a tiny fraction of consumer bills, or individual taxation. It allows government to be an ‘informed consumer’, which is useful even if policies are less technologically prescriptive and more is done through auctions. These considerations also lead us to strongly question the contention that the CCC is wrong to model a fairly linear path to 2050. Furthermore, the CCC scenarios are particularly focussed on keeping cumulative emissions within our carbon budgets, not just hitting a target in a given year. The cumulative volume of greenhouse gases emitted is the essential metric that determines our impact on the climate.

5 Concluding remarks

Overall, we hope that this submission has provided useful discussion of some of the wide range of topics presented in the Helm Review. We very much welcome the Review and believe that it provides a very useful contribution to ongoing policy development in the UK as government seeks to reduce energy bills, create industrial benefits for the UK and to drive forward with the goals of the Climate Change Act. However we also believe it is important that government takes an evidence-based approach to any prospective policy changes. Any moves to simplify the mix of policies needs to be grounded in an evaluation of the impact of policy complexity on bills. It is important to ensure that key policy goals continue to be met if policies are removed or combined.

We are not convinced that the proposal to replace long run contracts for low carbon generation with capacity based payments is the best way to minimise the system costs associated with variable renewables. It could also introduce new complexities of its own. We agree with the sentiment expressed throughout the Review that auctions can deliver cost reductions. Properly used such auctions can help eliminate many of the concerns about excess profits and regulatory capture laid out in the Review. However it is also important to ensure that a system level view of costs is maintained and that government is able to inform itself about the scale and nature of such costs, using appropriate modelling tools.

Finally, if ongoing innovation is to be secured then it is also important that policy continues to provide opportunities for emerging technologies to enter into the market. Encouraging innovation, bringing technologies to market in a timely fashion and minimising cumulative emissions all require progress with decarbonisation is sustained and not delayed in the hope or expectation that cheaper technologies will emerge in future. Innovation is essential to cost effective decarbonisation but is not exogenous or automatic, policy needs to continue to create the market opportunities needed to drive it.

Annex 1: Split auctions for power generation

The Helm Review suggests that energy consumers are funding excess returns to construction phase investors in power generation projects under mechanisms such as the CfD. The suggested solution is splitting the award of support by the use of separate auctions for the construction and operating phases of a project. The problem is real, but misunderstood, and the proposed solution will not be effective.

Nothing in basic finance theory suggests that an operating cash flow in the future should be discounted at a different rate before and after construction, other things being equal. Excessive returns may appear to come from investors applying a higher hurdle rate to all cash flows pre-construction, and indeed that is what they do in practice, however they are solely a function of perceived risk and supply of capital in the construction phase. The Review is right that refinancing gains post-construction have been large. It is likely that some combination of the lack of a competitive process for awarding support, the use of out-of-date information by governments to set support levels, and gaming by industry are key reasons for this. The impact of such factors has been amplified by the falling costs of renewable energy technologies, meaning that administrative prices have lagged the actual projects costs.

For technologies such as wind and solar which are now well-established and where there is a sufficient and competitive supply of capital for the construction phase, the introduction of competitive auctions has meant that excess pre-construction returns have been competed away. It is clear that developers are bidding auction prices based on their estimates of future technology costs (15MW offshore wind turbines for instance), rather than responding to administrative prices set based on old technology. For such technologies, excessive returns is a problem of the past which the existing arrangements for competitive award have solved, and hence there is no case for change.

For technologies such as nuclear and CCS there is a clear shortage of construction capital, whatever the solution for allocating support. Better solutions to deal with this issue exist, including the government increasing the supply of capital by investing itself in the construction phase, or by contracting to assume specific risks which have the potential to be mispriced by construction phase investors. Such solutions would be consistent with how the government finances other large infrastructure such as high-speed rail; Crossrail; Thames Tideway; and would be consistent with the recommendations of the NAO in respect of the Hinckley Point C project[8] and the Oxburgh report on CCS[9].

It is important to recognise the role of states in financing the construction of complex, large-scale energy infrastructure, due to the persistent scarcity of private sector capital. Hinckley Point C is financed entirely by majority state-owned enterprises; offshore wind, while highly competitive now, is a market dominated by majority state-owned enterprises as well has having benefited from an injection of EU and UK state capital in the form of the EIB and Green Investment Bank financing.

In short, the theoretical basis for the move to split auctions is weak; for some technologies it is a solution to a problem of the past; and for other more complex technologies it fails to address the core problem of scarcity of private capital and associated excessive pricing of risk for the construction phase.

[8] https://www.nao.org.uk/report/hinkley-point-c/
[9] https://publications.parliament.uk/pa/cm201617/cmselect/cmenergy/497/497.pdf

Annex 2: Additional sources

Our response references a wide range of sources throughout (see References). To complement the response we have also collated a series of relevant publications that we believe should be considered to meet the aims of the Review and Call for Evidence.

5.1 Electricity Generation

- **Impact of deployment subsidies on photovoltaic costs**
  Gambhir, A., Green, R.J., Gross, R.J.K., 2014. The impact of policy on technology innovation and cost reduction: a case study on crystalline silicon solar PV modules (Imperial College London Working Paper). Imperial College London, London, UK. https://www.imperial.ac.uk/grantham/publications/working-papers/the-impact-of-policy-on-technology-innovation-and-cost-reduction-a-case-study-on-crystalline-silicon-solar-pv-modules.php

- **Impact of deployment subsidies on various aspects of UK offshore wind costs including project finance, competition, learning, economies of scale**
  ORE Catapult, 2017. Cost Reduction Monitoring Framework 2016. Offshore Renewable Energy Catapult, UK. https://ore.catapult.org.uk/our-knowledge-areas/knowledge-standards/knowledge-standards-projects/cost-reduction-monitoring-framework/

- **Impact of multiple factors, including niche markets and deployment support, in driving technology penetration and commercialisation**
  Nemet, G.F., 2013. Solar photovoltaics: multiple drivers of technological improvement, in: Energy Technology Innovation: Learning from Historical Successes and Failures [Grubler, A., & Wilson, C. (Eds.)]. . Cambridge, pp. 206–217. https://www.cambridge.org/core/books/energy-technology-innovation/solar-photovoltaics-multiple-drivers-of-technological-improvement/B689AC4923CD771432D8F6A597B7ADA8/core-reader

- **How energy systems models and energy scenario methods incorporate disruption in their design and use**
  Hanna, R., Gross, R.J.K., 2017. Representing disruption and continuity in energy models. UK Energy Research Centre (UKERC). http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/disruption-continuity-energy-models.html

- **How investment decisions are impacted by electricity generation costs and the issues posed by uncertainty and risks**
  Anderson, D., 2007. Electricity generation costs and investment decisions: A review. UK Energy Research Centre (UKERC). http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/investment-in-electricity-generation-report.html

- **How investment decisions are impacted by electricity generation costs and the issues posed by uncertainty and risks**
  Gross, R.J.K., Heptonstall, P., Blyth, W., 2007. Investment in Electricity Generation: The Role of Costs, Incentives and Risks. UK Energy Research Centre (UKERC).

http://www.ukerc.ac.uk/publications/investment-in-electricity-generation-the-role-of-costs-incentives-and-risks.html

- **Investigating the electricity sector's ability to deliver low-carbon forms of generation and whether there is a sufficient flow of money into the sector to finance it**
  Blyth, W., McCarthy, R., Gross, R.J.K., 2014. Financing the Power Sector - Is the Money Available. UK Energy Research Centre (UKERC).
  http://www.ukerc.ac.uk/publications/ukerc-energy-strategy-under-uncertainties-financing-the-power-sector-is-the-money-available-.html

- **The costs and impacts of intermittent electricity generation technologies**
  Heptonstall, P., Gross, R.J.K., Steiner, F., 2017. The costs and impacts of intermittency – 2016 update. UK Energy Research Centre (UKERC).
  http://www.ukerc.ac.uk/publications/the-costs-and-impacts-of-intermittency-2016-update.html

- **A review of the evidence surrounding electricity supply security in the UK**
  Rhodes, A., Gross, R.J.K., 2017. Is the UK facing an electricity security crisis? Energy Futures Lab, Imperial College London.
  http://www.imperial.ac.uk/energy-futures-lab/paper-1/

- **The International Energy Agency's cost of energy report**
  Wittenstein, M., Rothwel, G., (2015). Projected Costs of Generating Electricity. International Energy Agency, Nuclear Energy Agency and the Organisation for Economic Co-operation and Development.
  https://www.iea.org/publications/freepublications/publication/projected-costs-of-generating-electricity-2015-edition.html

- **The International Energy Agency's System Costs Report**
  IEA. (2016). System Integration of Renewables: Implications for Electricity Security.
  https://www.iea.org/media/topics/engagementworldwide/g7/IEAIRENAReporttotheG7onSystemIntegrationofRenewables.pdf

- **On Picking Winners: The need for targeted support for renewable energy.**
  Gross, R., Stern, J., & et al. (2012). On picking winners: The need for targeted support for renewable energy. http://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/icept/On-Picking-Winners-low-res.pdf

5.2 Electricity Transmission and Distribution

- **The impact of the Low Carbon Network Fund on innovation in electricity transmission and distribution**
  Rhodes, A., Van Diemen, R., Skea, J., 2016. Has the Low Carbon Network Fund been successful at stimulating innovation in the electricity networks? British Institute of Energy Economics.
  http://hdl.handle.net/10044/1/40838

- **How regulation can provide consumers with improved options for managing their electricity**
  Sandys, L., Hardy, J., Green, R., 2017. ReShaping Regulation: Powering From The Future. Challenging Ideas and Imperial College London.
  http://www.challenging-ideas.com/pubs/reshaping-regulation-power-from-the-future/

5.3 Electricity Supply

- **What the changes a smarter energy system might bring to the way we buy and use energy**
  Hardy, J., 2017. How could we buy energy in the smart future? Smart Energy GB.
  https://www.smartenergygb.org/en/resources/press-centre/press-releases-folder/future-energy-white-paper

- **Potential future energy business models that put people or communities in control of energy**
  Hardy, J., 2017. Society-led low carbon transformation. Grantham Institute – Climate Change and the Environment.
  https://www.imperial.ac.uk/grantham/publications/society-led-low-carbon-transformation.php

References

Greenacre, P., Gross, R., & Heptonstall, P. (2010). *Great Expectations: The cost of offshore wind in UK waters – understanding the past and projecting the future*. Retrieved from www.ukerc.ac.uk/asset/967F73E3-E952-4CF7-B6C04BC2E978B016/

Gross, R., Blyth, W., & Heptonstall, P. (2010). Risks, revenues and investment in electricity generation: Why policy needs to look beyond costs. *Energy Economics*, *32*(4), 796–804. https://doi.org/10.1016/j.eneco.2009.09.017

Gross, R., Heptonstall, P., Greenacre, P., Candelise, C., Jones, F., Castillo Castillo, R. G., … Jones, F. (2013). *Presenting the Future: Electricity Generation Cost Estimation Methodologies*. Retrieved from http://www.ukerc.ac.uk/publications/presenting-the-future-electricity-generation-cost-estimation-methodologies.html

Hanna, R., Gross, R., Speirs, J., Heptonstall, P., & Gambhir, A. (2015). *Assessment Innovation timelines from invention to maturity*. *UKERC Technology and Policy Assessment*.

Hardy, J. (2017). *How could we buy energy in the smart future?* Retrieved from file://icnas3.cc.ic.ac.uk/arhodes/downloads/How could we buy energy in the future by Dr Jeffery Hardy.pdf

Heptonstall, P., Steiner, F., & Gross, R. (2017). *The costs and impacts of intermittency – 2016 update - A UKERC TPA report*.

Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014: Mitigation of Climate Change - Summary for Policymakers*.

International Energy Agency. (2012). *Energy Technology Perspectives 2012 Pathways to a Clean Energy System*. *Energy Technology Perspectives 2012 Pathways to a Clean Energy System*. https://doi.org/10.1787/energy_tech-2012-en

Moallemi, E. A., Aye, L., Webb, J. M., de Haan, F. J., & George, B. A. (2017). India's on-grid solar power development: Historical transitions, present status and future driving forces. *Renewable and Sustainable Energy Reviews*, *69*, 239–247. https://doi.org/10.1016/j.rser.2016.11.032

Newbery, D. (2016). Missing money and missing markets: Reliability, capacity auctions and interconnectors. *Energy Policy*, *94*, 401–410. https://doi.org/10.1016/j.enpol.2015.10.028

Ofcom. (2017). Service quality of telecoms providers. Retrieved January 4, 2018, from https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2017/service-quality-telecoms-providers

Ofgem. (2017). Comparing supplier performance on customer service. Retrieved January 4, 2018, from https://www.ofgem.gov.uk/consumers/energy-supplier-comparison-data/compare-supplier-performance-customer-service

Ofwat. (2017). Customer service. Retrieved January 4, 2018, from https://www.ofwat.gov.uk/regulated-companies/company-obligations/customer-service/

REN21. (2017). *Renewables 2017: global status report*. *Renewable and Sustainable Energy Reviews* (Vol. 72). https://doi.org/10.1016/j.rser.2016.09.082

Rhodes, A., Gazis, E., & Gross, R. (2017). *Is the UK facing an electricity security crisis?* Retrieved from http://imperial.ac.uk/energy-futures-lab

Rhodes, A., Van Diemen, R., & Skea, J. (2016). Has the Low Carbon Network Fund been successful at stimulating innovation in the electricity networks? *British Instutite of Energy Economics 2016: Innovation and Disruption: The Energy Sector in Transition*. Retrieved from http://hdl.handle.net/10044/1/40838

Sandys, L., Hardy, J., & Green, R. (2017). *ReSHAPING REGULATION: POWERING FROM THE FUTURE*. Retrieved from https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/collaborative-publications/Reshaping-Regulation-Powering-from-the-future.pdf

Shell Scenarios Team. (2013). *Shell New Lens Scenarios*. Retrieved from www.shell.com

Staffell, I. (2017). Measuring the progress and impacts of decarbonising British electricity. *Energy Policy*, *102*, 463–475. https://doi.org/10.1016/j.enpol.2016.12.037

Staffell, I., Green, R., Gross, R., & Green, T. (2017). *Electric Insights Quarterly*. Retrieved from https://s3-eu-west-1.amazonaws.com/16058-drax-cms-production/documents/Drax_Electric_Insights_Report_2017_Q1.pdf