UK Energy Research Centre

Technologies for meeting Clean Growth emissions reduction targets

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Introduction

1. This inquiry is both welcome and timely. Whilst the Clean Growth Strategy emphasises the significant progress that has been made in reducing emissions, the Committee on Climate Change has identified a number of areas where policy needs to go further (CCC, 2018). Innovation in a range of low carbon energy technologies and systems will be required to meet future carbon budgets and the 2050 target. Government policy has a vital role to play in supporting the development, demonstration and commercialisation of these technologies. Furthermore, policies to support innovation could also help to meet the wider economic objectives in the Industrial Strategy, by contributing to the development of new industries and jobs.
2. This submission draws on research and expertise from the UK Energy Research Centre (UKERC). UKERC is a publicly funded, interdisciplinary research centre that focuses on transitions to sustainable energy systems. The submission includes some introductory points in response to the committee's questions on the Clean Growth Strategy, followed by some more specific responses to subsequent questions on government support for low carbon innovation.

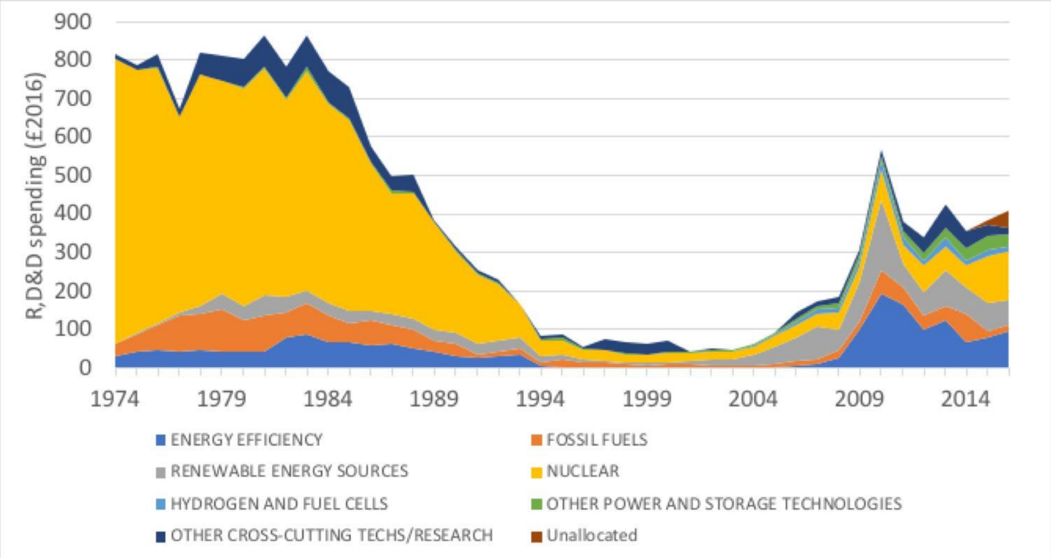
The Clean Growth Strategy

- The relative importance of the four main areas identified in the Strategy, and whether the Strategy places the right weight on each of those sectors to deliver emissions reductions;
- Progress on meeting carbon budget targets to date and areas where more progress is needed going forward;
- The extent to which current and future technologies can help to meet the carbon budgets; and
- The uncertainty in future technologies' contribution to emissions reductions, and how that uncertainty can best be incorporated into the Government's carbon budgets.

3. As the Committee on Climate Change has observed in its latest progress report (CCC, 2018), UK greenhouse gas emissions have fallen substantially – by over 40% from 1990 levels. However, emissions reductions have been uneven across sectors. The power sector is changing rapidly. The shift from coal to gas and the expansion of renewable energy have contributed to a steep drop in the carbon intensity of electricity. However, progress with reducing emissions in other sectors has either been slow or non-existent. Furthermore, the Committee concluded that the policies that have been implemented to reduce emissions further are either inadequate or may not deliver fully.
4. There a number of considerations which should inform future decisions on further government funding for low carbon innovation to meet the objectives in the Clean Growth Strategy. These include: the scale of funding for low carbon innovation; the timescales for low carbon innovation; the need to support low carbon energy systems as well as low carbon technologies; and the need to take uncertainty into account.

5. Scale of public innovation funding. Along with many other countries, the UK signed up to the Mission Innovation initiative at the Paris climate change conference. This included a pledge to double energy R&D spending between 2015 and 2020. UK energy R&D spending levels had already recovered from the lows seen in the 1990s, mainly due to the increasing emphasis on decarbonisation. The portfolio of energy technologies supported is now much more diverse than it was before the 1990s (see figure 1).

Figure 1: UK government energy research, development and demonstration (R,D&D) spending



Source: International Energy Agency.

6. Several analyses of public R&D spending on energy in the UK and in other countries have concluded that spending is much too low – particularly when compared to the scale of the challenge posed by climate change (e.g. Pless et al, 2018; Skea et al, 2013). Clearly, it also matters what increased budgets are spent on – including the portfolio of technologies and systems, what stages of development and demonstration are targeted and the extent to which R&D budgets are co-ordinated with other incentives for innovation (e.g. incentives that create new markets for low carbon technologies).
7. Timescales for low carbon innovation. A recent UKERC systematic review showed that innovation in the energy sector tends to take a long time. The timescales from early stage R&D to significant commercial deployment typically take 3 – 4 decades for energy sector technologies (Gross et al, 2018). The review provides some evidence that some consumer or demand-side products may have shorter timescales because they diffuse more rapidly. However, this analysis suggests that relying on technology breakthroughs to help meet carbon budgets and targets over the next few decades would not be wise. This does not mean fundamental R&D is unimportant, but it does mean that policies to demonstrate, scale-up and commercialise existing technologies are perhaps more important if the UK is to successfully comply with carbon budgets in the 2020s and 2030s (see below).
8. Low carbon energy systems. Much of the discussion on low carbon innovation tends to focus on individual technologies such as electric vehicles or wind turbines. Innovation in these individual technologies is important, but many of them could also have significant

energy system implications. It is therefore important that innovation programmes include space to develop, demonstrate and deploy new, low carbon energy systems – including for low carbon heat. There are already several energy systems innovation programmes in the UK, including the Energy Systems Catapult smart systems and heat programme and the Prospering from the Energy Revolution programme within the Industrial Strategy Challenge Fund[1].

9. Taking uncertainty into account. Uncertainty is inherent in the innovation process – and this is part of the rationale for public R&D funding. This means that some low carbon technologies supported by public programmes will be successful, whilst others will fail to realise their potential. It is therefore important that public R&D programmes for energy (and for other areas) are subjected to regular evaluations to learn lessons from both successes and failures. Such evaluations are not easy to perform (Pless et al, 2018). This is partly because innovation processes are not linear and partly because outcomes (e.g. commercial success) can take a long time before they are apparent. It is also because some of the indicators used to measure innovation focus on inputs (e.g. R&D spending) and outputs (e.g. patents) rather than outcomes (Watson, Kern and Wang, 2015).

How the development and deployment of technology can best be supported, and the extent to which the Government should support specific technologies or pursue a 'technology neutral' approach

10. Neoclassical economic approaches to low carbon innovation tend to emphasise technology neutrality (e.g. Helm, 2017). This is based on two well-known market failures that justify government intervention (e.g. Jaffe et al, 2005). The first is that the damage costs of greenhouse gas emissions are not internalised in market transactions – and hence, government policies to price carbon are required. The second is that private companies will tend to underinvest in R&D because they can't capture the returns from higher levels of investment. Therefore, governments should provide public funding for R&D, including for low carbon technologies.

11. Whilst correcting these market failures is important, this is unlikely to be sufficient to support the innovation required to meet carbon targets in the UK (and globally). Based on experience to date, a broader set of policy interventions is likely to be required using an innovation systems approach (Freeman, 1992). When applied to low carbon innovation, this systems approach combines R&D funding with more targeted, specific policy interventions to support technology demonstrations and market creation policies to support their deployment (e.g. Grubler et al, 2012; Mazzucato and Semieniuk, 2017).

12. Innovation systems approaches take into account the non-linear nature of innovation, which includes important feedbacks between the different stages of technology development (Rothwell, 1994). They also highlight the need to address the 'valley of death' that faces developers as they try to move technologies through demonstration and scaling up, into commercial deployment. This can provide a rationale for government

[1] UKERC has commissioned a mapping study of existing energy systems demonstrators, the results of which should be published in late 2018.

investment in demonstration projects to test and scale up technologies or systems (Gallagher, Holdren and Sagar, 2006). It also helps to explain why it is important to create early market opportunities, for example through targeted subsidies or support schemes.

13. A good illustration of the need for an innovation systems approach is the recent reductions in the costs of some renewable electricity technologies. Innovation has been a key component of these cost reductions, and has been mainly driven by technology specific policies that create early markets for emerging technologies, such as feed-in tariffs, which allow technologies to benefit from 'learning by doing.' (Gross et al, 2013). These technologies also benefitted from other forms of public funding and policy intervention (including funding for R&D) when they were at an earlier development stage. In future they may be incentivised by technology neutral capacity auctions or a carbon price. However it is unlikely that the remarkable cost reductions seen for example in wind and solar would have been achieved in the absence of technology-specific market creation policies.
14. A further important rationale for using a systems approach is 'lock in', and the difficulty of moving energy systems away from incumbent fossil fuels and the interests associated with them (Unruh, 2000). This is because many parts of energy systems consist of long-lived capital assets including electricity grids, gas pipelines, and buildings that were constructed to use fossil fuels. These assets are supported by interacting systems of rules, regulations, and institutions that coordinate energy flows, market relationships, and investment decisions (Hughes, 1983). Policies to support low carbon technologies therefore need to take this 'lock in' into account, and to ensure that markets, regulations and infrastructures do not act as fundamental barriers to their adoption.
15. The mission-oriented approach to innovation developed by Mariana Mazzucato (e.g. Mazzucato and Semieniuk, 2017) takes innovation systems ideas further – and is designed to put government support for innovation in the context of the societal challenges it is seeking to address. Climate change is a good example of such a mission. Mazzucato and Semieniuk show that countries that been particularly successful at low carbon innovation have implemented multiple interventions by state institutions and/or policies at different stages of the innovation process.

The relative priority that should be attached to developing new technologies compared to deploying existing technologies, including consideration of the costs and pollution involved in the decommissioning of technologies or infrastructure;

16. As we note above, a UKERC evidence review concluded that the timescales for innovations to move from the R&D stage to commercialisation can last several decades (Gross et al, 2018). This means that there should be more emphasis within public funding programmes on demonstrating and commercialising existing technologies to meet UK carbon budgets and targets. The 4^{th} and 5^{th} carbon budget periods are not far away (they cover the period from 2023 to 2032). At present, the UK is not on track to meet these carbon budgets unless further policies are implemented to reduce emissions further. It is unlikely that completely new technologies will make a major contribution to meeting these budgets.

17. This does not mean that basic R&D on new technologies should not be funded. New technologies have more potential to help meet longer term goals such as the current emissions reduction target for 2050. This potential may be greater still if UK targets are revised to make them more ambitious following the Committee on Climate Change's advice, which is expected in spring 2019.

18. Three related examples illustrate this point further. The first is low carbon heat. Several studies have explored potential UK-wide pathways to decarbonise heat (e.g. Strbac et al, 2018). The evidence from these studies is inconclusive about which pathway(s) could be the most technically and economically feasible. To reduce uncertainty and aid decision-making, there is a need for significant demonstrations of some of the potential options for low carbon heat – including low carbon heat systems based on hydrogen (through repurposing of the gas grid) and those based on electricity. Whilst there is a lot of international evidence on the electrification of heat through heat pumps, there is very little on the use of hydrogen.

19. The second example is CCS, which is likely to be required at scale for decarbonising heat via hydrogen, unless hydrogen production via electrolysis becomes significantly cheaper. It is also an important option for decarbonising some energy intensive industrial sectors. Whilst CCS has been demonstrated in a number of projects internationally (particularly in North America), there are insufficient incentives for deployment – and therefore to reduce costs through 'learning by doing' (Ekins et al, 2017). A number of reports have made proposals for a way forward (e.g. Oxburgh, 2016), particularly to finance the development of the required pipeline and storage infrastructure. However, at the time of writing, there is not a UK policy framework in place to enable this.

20. The third example is smarter electricity systems. Innovation is already having a significant impact on electricity systems at the national and local levels. A key challenge for electricity will be to ensure sufficient flexibility and other system services to ensure high levels of security and reliability in a rapidly changing context. There is likely to be an important relationship between the extent of flexibility in the electricity system and the costs of integrating increasing shares of intermittent renewable sources (Heptonstall et al, 2017). This flexibility can come from generation (e.g. flexible fossil plant), demand (e.g. via demand side response), networks (via increased interconnections) or via measures which do not fit neatly into any of these categories (e.g. electricity storage).

Examples of specific technologies whose development and deployment have been effectively supported so far, as well as those that show particular promise for meeting the Government's carbon emissions targets or supporting the UK's economy, or which would benefit from specific Government action, in the future; and

21. There is now significant evidence that a key driver for recent reductions in the costs of some energy technologies has been government intervention to create new markets. Policies such as feed-in tariffs, renewables portfolio standards, auctions and mandates have all helped to develop the market for technologies such as solar PV, onshore and offshore wind and electricity storage. These cost reductions are a product of 'learning by doing' due to cumulative deployment as well as scaling up of manufacturing. Research by UKERC and our partner universities has explored these drivers in detail. This includes an

evidence review of the evolution of the costs of six electricity technologies (Gross et al, 2013), and a recent report that reviewed the experience of wind and solar technologies to see what lessons could be learned for CCS (Hughes et al, 2017).

22. A key conclusion from the literature on successful low carbon innovation policy has been the importance of both national policies and international drivers of innovation. In some cases (such as solar PV), government support for innovation in a number of countries has provided benefits to UK consumers in terms of rapid cost reductions. In others (e.g. offshore wind), UK policy has played a leading role in supporting innovation across the 'valley of death' between R&D and commercial deployment – and in bringing down costs. The case of offshore wind in particular shows the value of patient government support, which may be needed for well over a decade in different forms, before significant cost reductions are achieved.

23. However, such cost reductions are not a universal outcome of support for innovation and for market creation. For example, significant questions remain about how to bring down costs of large-scale nuclear power technologies. Nuclear power has been consistently characterised by rising costs over time. Carbon capture and storage (CCS) technologies have also failed so far to deliver on industry promises of lower costs – though that may be a product of impatient and inconsistent policy rather than a lack of potential for cost reductions in the medium term.

The role of the Industrial Strategy 'Clean Growth Grand Challenge', and what the Government should do to ensure it contributes effectively to meeting emissions targets.

24. The Clean Growth Grand Challenge is important since it helps to ensure that the transition to a low carbon energy system is closely linked to the Industrial Strategy. This helps to broaden the political salience of energy system decarbonisation by focusing on the potential for economic as well as environmental benefits. It reflects the approach to economic policy advocated by Mariana Mazzucato, which she argues should be driven by 'missions' designed to meet societal goals (such as tackling climate change - Mazzucato, 2018). She also advocates breaking down these broad missions into more specific and tangible goals that can then be targeted.

25. The Clean Growth Grand Challenge already includes two more specific missions: halving energy use in new buildings by 2030 and phasing out petrol and diesel vehicles by 2040. To meet each of these, significant innovation is required – particularly to commercialise and deploy new, low carbon and energy efficiency technologies. New innovation programmes have been announced to help deliver those missions via the Industrial Strategy Challenge Fund: the Faraday Battery Challenge, Transforming Construction and Prospering from the Energy Revolution.

26. Whilst these missions and innovation funding programmes are welcome, it will be important to ensure that there is sufficient attention to market creation as well as technology development and demonstration. As noted earlier in this submission, market creation policies are an essential component of successful innovation systems. In their absence, there is a risk that low carbon technologies will be developed and demonstrated – but they will not be deployed sufficiently quickly because the incentives

are too weak. When compared to other countries and the pace of change required, the UK target for phasing out conventional vehicles is not ambitious enough. The mission for energy use in buildings only applies to new buildings, whereas the main challenge is to reduce emissions from existing buildings.

27. The process for identifying specific missions and innovation programmes has involved a significant amount of consultation by Innovate UK. However, more could be done by government to ensure that the rationale for the priorities chosen is clear, and based on evidence. Significant analysis has already been carried out by government and others to establish an evidence base to help prioritise spending on energy innovation. This includes assessments by the Low Carbon Innovation Coordinating Group of research funders (LCICG, 2014) and the prospectus published by the Research Councils Energy Strategy Fellowship (Skea et al, 2013). Assessment of specific proposals for funding against this evidence base will help to guard against the dominance of funded programmes by incumbents – and will also help to fulfil the Secretary of State's ambition that the Industrial Strategy 'must be about creating the right conditions for new and growing enterprise to thrive, not protecting the position of incumbents' (HM government, 2017).

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