
RESPONSE TO THE ENERGY AND CLIMATE CHANGE COMMITTEE'S INQUIRY INTO THE FUTURE OF THE UK ELECTRICITY INFRASTRUCTURE

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This submission is prepared by members of the Sussex Energy Group and draws on a large body of research from several projects, funded by the ESRC and EPSRC. Researchers at the Sussex Energy Group in SPRU, University of Sussex, are driven by an interest in prospects for a more sustainable energy future. Our primary focus is on the processes of innovation, technological and social, that will contribute to this objective, using a range of multi-disciplinary social science approaches. Over many years our researchers have developed expertise on infrastructure transitions, renewable energy, community energy and energy services. The authors do not have any conflicts of interest to declare.

Executive summary

- The challenges of upgrading current UK transmission and distribution networks to enable a transition to a low carbon electricity system, while at the same time maintaining system security and stability, and the affordability of energy for business and domestic consumers, are related to technical, institutional and governance features of the overall energy system.
- In this submission, we focus on institutional and governance challenges, rather than technical features.
- We highlight the importance of flexibility and support for non-traditional business models for energy, especially in the context of municipal energy management, the allocation of risk and cross-sector innovations for developing a low carbon network.

¹ The contribution to this response is accredited to work funded through the [Infrastructure Transitions Research Consortium](#) (ITRC) and the [International Centre for Infrastructure Futures](#) (ICIF) on the governance for smart grid innovations and business models transformations in UK infrastructure sectors.

What are the limitations of today's electricity infrastructure and how can these limitations be addressed?

1. The current electricity infrastructure in the UK, like most infrastructure, is subject to a wide range of market and governance failures. Key market failures relate to natural monopoly problems, significant externalities, (most obviously in relation to climate change), and public good features which can lead to under-investment. Governance problems relate to the inherent difficulties of managing highly uncertain technical change in an inter-dependent system with fragmented ownership, uncertainties about future costs, lock-in problems and ambiguity about risks and opportunities. The interconnected systemic nature of energy systems means solutions to any of these problems, may create unexpected implications for other problems, necessitating institutional learning by firms, regulators and the State.
2. From an innovation perspective, the current infrastructure is partially locked-into a configuration of technologies, markets and governance regimes that focus on the production of electricity, and then, after privatisation the “sweating” of existing assets. As a result, a large amount of infrastructure needs upgrading and replacing, requiring the Government to make strategic choices that balance a complex set of demands related to affordability, security and climate change.

What will a low carbon network look like, what are the challenges for Government and other bodies in achieving it, and what benefits (environmental, financial or otherwise) will it bring to the UK?

3. Electricity networks will need to incorporate much higher levels of both large-scale centralised low carbon generation (including offshore wind, nuclear and gas generation with carbon capture and storage) and small-scale distributed generation (including solar photovoltaics, biomass generation and combined heat and power generation)². The incorporation of high levels of distributed generation is particularly challenging for Distribution Network Operators (DNOs), which have historically tended to adopt low risk business strategies with a conservative culture towards risk taking³.

² Foxon (2013), 'Transition pathways for a UK low carbon electricity future', Energy Policy 52, 10-24

³ Bolton and Foxon (2015), 'Infrastructure transformation as a socio-technical process – Implications for the governance of energy distribution networks in the UK', Technological Forecasting & Social Change 90, 538-550

4. It is now widely accepted that incorporating higher levels of distributed generation requires a move to 'smart' grids to incorporate two-way power flows, which can also bring other benefits, but there is little agreement on the meaning of 'smart grids' or how they will develop⁴. Recent research has identified a mismatch between where the benefits of smart grid investment accrue and where costs are incurred, leading to problems in how the value of innovation is captured by innovating firms⁵. The benefits that smart grids could enable include managing embedded generation, communicating between the producers and users of electricity, and utilising ICT to respond to and manage demand. However, DNOs have had little incentive to take a strategic view of grid investment in order to realise these benefits, as in many cases it is unclear how they will benefit.

5. Currently in the UK, network connections are offered to generation developers on a first come first served basis. If there is capacity on that part of the network to connect the generation, a connection is paid for by the developer. If there is no capacity on the network, the developer must also pay for network reinforcement for the scheme to progress. In parts of the South-East of England, little new distributed generation capacity could currently be added without substantial upgrades of the network. The research identified three economic values that could be realised by a more strategic approach to smart-grid investment on a city-region basis: (1) Renewable energy connection co-ordination; (2) Inward investment stimulus; and (3) Municipal supplier load control.

6. This raises the question of appropriate incentives and/or organisational structures that would enable these values to be realised. The move to the RIIO (Revenue = Incentives + Innovation + Output) framework for the price control review for the period 2015-2023 has been broadly welcomed by the DNOs, as it represents a significant shift towards an allowable revenues structure that better incentivises smart grid solutions. However, there is still deep uncertainty as to the ability of this new framework to incentivise sufficient network investment to accommodate the levels of distributed renewable generation needed to meet the UK's carbon emissions reductions targets. The need to shift from a distribution network operator (DNO)

⁴ Balta-Ozkan et al. (2014), Scenarios for the development of the smart grid in the UK, Synthesis Report, UK Energy Research Centre

⁵ Hall and Foxon (2014), 'Values in the smart grid: The co-evolving political economy of smart distribution', Energy Policy 74, 600-609

model to a distribution system operator (DSO) model has been proposed^{6,7}. A DSO model would incorporate flexible demand response, system balancing, storage, and virtual power plant services, in addition to network maintenance and operation. The additional economic benefits identified above principally accrue at the city-region level, and hence greater involvement of municipalities (local authorities) in the management of energy systems has been proposed, and many UK local authorities are currently exploring municipal energy supply company business models. Other institutional innovations to enable these economic values to be realised could include the opportunity for local authorities to capture business rate uplifts from renewable generators, in the same way as proposals for fracking sites have been. This would ensure municipalities could capture value from, as well bear the impacts of, renewable energy developments. To capture the values of inward investment stimulus, the economic development funds being assembled by LEPs, and their associated value capture models of Tax Increment Finance and 'Earnback', could be extended in scope to incorporate smart grid investments⁸.

7. A low carbon network in the UK will introduce more flexibility in the governance of demand and supply, and will involve a higher number of mechanisms, and actors, some of which are non-traditional for the electricity sector (such as prosumers). A low carbon network will also imply a more advanced level of integration between several sectors (mainly ICT, electricity and vehicles), alongside more symbiotic interactions and spill-overs between them. This will also require creating a space for the utilisation of what Ofgem terms 'non-traditional business models' (NTBMs) for energy: a solution-neutral term describing business models that differ from conventional forms of generation, distribution and supply.
8. Business models describe how firms:
 - (a) create value,
 - (b) capture value and then
 - (c) monetize a proportion of that value (internally and externally).
9. Examples of NTBMs could include municipal energy management and Energy Service Companies (ESCOs). A low carbon network could facilitate the development of NTBMs

⁶ Realising Transition Pathways Engine Room (2015), Distributing Power: A transition to a civic energy system, Realising Transition Pathways Consortium, <http://www.realisingtransitionpathways.org.uk/>

⁷ Openshaw (2014), The Disrupted Energy Landscape: The evolution from DNO to DSO www.greencorporateenergy.com/assets/DaveOpenshaw.pdf

⁸ Sandford (2013), Business Rates. House of Commons Library. Standard Note SN/ PC/06247.

and their co-existence with other more traditional solutions. NTBMs are discussed in more detail below.

10. Some of the challenges in achieving these characteristics of a low carbon network in the UK involve the lack of regulatory incentives and support for NTBMs in contributing to its development; and balancing trade-offs between strategic (ahead of need) investment in the electricity distribution networks and smart grids solutions (targeting demand reduction and efficiency gains through innovations).
11. Distributed Generation (DG) developers often encounter limited residual capacity in distribution networks where they need to connect, leading to significant reinforcement costs. Strategic investment in electricity networks is possible within price control periods as part of the regulated asset base (RAB). However, it requires DNOs to make a strong commercial case for these, e.g. by demonstrating projections of firm demand, acting as a regulatory barrier to strategic investment. As the cost of investments is socialised through consumer bills, Ofgem does not generally allow DNOs to invest 'speculatively' to prevent the risk of funding stranded assets. However, lack of strategic investment ahead of firm demand increases direct costs for developers through requiring significant upgrade work and forcing longer connections to where capacity is available, also known as 'smearing'. The latter could lead to higher costs for consumers in the long run, creating a more complex and less resilient network.
12. As part of the distribution price controls that ran until 31 March 2015, Ofgem established the Low Carbon Networks Fund (LCNF) to support pilot projects by the DNOs to try out new technology, operating and commercial arrangements. Some of the projects funded by the LCNF aimed to enable UK distribution networks to accommodate new demand through innovations such as demand side response (DSR), rather than through new investment in additional capacity. The development of a low carbon network would accommodate both investment approaches, without one precluding the viability of the other. More clarity should exist within the operation of Ofgem and DNOs about the circumstances in which one DNO can develop both within its licence area. Smart grid pilot projects undertaken within the LCNF framework are thought of as providing more flexibility in connecting electricity demand and generation; contributing to higher levels of certainty in infrastructure planning and management; and reducing cost to consumers by helping avoid redundant assets, among other things. For example, requiring significant investment in the cost of connection in advance could make small-scale DG projects financially unviable.

13. Traditional 'asset heavy' reinforcement techniques and smart grid solutions are particularly competitive with respect to low load, where ICT systems offer solutions to customer that are 25-35% cheaper than the traditional network solutions. However, there are trade-offs between different types of connection schemes, such as those offered under the Flexible Plug and Play project (funded by the LCNF). While non-firm connections offer cheaper connection costs, cheaper system charges, faster connections and the avoidance of reinforcement costs, firm connections guarantee future capacity requirements and the maximum export capacity. The ability of DNOs to offer both connection schemes will introduce more flexibility. However, the efficient application of this dual approach requires a level of synchronisation of demand and supply activities which goes beyond traditional types of stakeholders and stakeholder relationships within the UK distribution system, but which could be a feature of a DSO model. For example, the FALCON project reduces the need for traditional network reinforcement and provides opportunities for faster and cheaper connections to high voltage networks by offering interruptible connections for industrial and commercial demand customers and distributed generation customers. Smart grid innovations such as DSR can introduce more flexibility in the distribution system by providing more choices for DNOs and the introduction of 'flexibility platforms' to solve grid constraints.
14. As part of the RIIO price controls, Ofgem introduced the Electricity Network Innovation Competition (NIC) from 2015, an annual competition to allow electricity network companies to compete for funding of the development and demonstration of new technology, operating and commercial arrangements, replacing the LCNF. These projects, which typically run for 3 to 5 years, should help network operators to explore flexible solutions for low carbon networks, whilst reducing costs and maintaining security of supply. However, there remains a challenge of how the resulting best practice will be shared with other transmission or distribution network operators.

How can we ensure that a low carbon network is designed and operated fairly and in a way that helps to minimise consumer bills?

15. Because infrastructure systems deliver services that are typically considered essential for modern living, a key feature of their development has involved regulations that

support cost sharing, the socialisation of any risks and universal access. A number of issues will influence future consumer bills and how costs are generated, managed and distributed.

16. The need to replace and upgrade existing infrastructure is going to generate significant costs. Given that infrastructure technologies are often subject to very significant cost over-runs, it is important that project costs are controlled. It is encouraging that HMT and the Cabinet Office are paying attention to these risks, and it is important that their management is subjected to oversight. Key issues relate to: the choices of technologies, with some technologies such as nuclear having been subject to considerable cost increases in the past; uncertainties about how costs are calculated and what is included and what is excluded; management of projects, particularly how risks in construction are managed and allocated; supporting technical change and a portfolio approach to deal with uncertainty.

17. A key issue will be ensuring that the risks of construction and operation are properly identified and placed with the institutional actors best able to manage them. For example, construction risks are typically equity risks that are best managed by firms and should not be taken on by tax-payers. Firms should be strongly incentivised to keep project costs under control and 'pain and gain' contracts have proved effective at ensuring these incentives are in place in the private sector. Governments can further reduce construction risks by influencing project features. For example, projects are more at risk of substantial cost over-runs if they attempt significant innovation (particularly related to software), are overly complex, have poor communications between regulators, contractors, systems integrators etc, or are subject to repeated design changes. Project costs are also likely to reduce on subsequent projects if learning is captured and fixed costs can be spread. To reduce risks it is important that the UK Government builds up the capability to manage its portfolio of new projects as an 'intelligent client'.

18. Once projects are completed, construction risks disappear and the key risks are often political and regulatory risks for investors. The use of RAB models and effective arms-length regulators has been shown to be an effective way of managing these investor risks and substantially reducing the costs of capital. Firms that are involved in construction of major projects will not have much ability to influence political risks that drive up investors' risks. Consequently, allocating risks they cannot manage is likely to add substantially to the costs of capital, as investors risks are substantially increased.

19. Given the very significant levels of investment, managing and placing these risks effectively is likely to have a major impact on consumer costs. Costs that arise from the operation of local monopolies will continue to require effective regulation in the absence of competition.
20. Given how these costs will rise in in the future, whether they are covered by general taxation or by consumer bills will influence their social distribution. Increasing the proportion of the costs that are covered by consumer bills will shift costs from richer to poor members of society. As highlighted by the NAO in 2013⁹, if these costs are high, they may well become politically charged, which can create additional regulatory and political risks.

What are the key technologies available today and how effectively do Government and Ofgem incentivise innovation and development of the grid and grid technologies?

21. Funding for innovation activities and policy for smart grid development in the UK is led by the electricity sector through programmes such as Ofgem’s Low Carbon Network Fund (LCNF) and Electricity Network Innovation Competition (NIC), and introduced into the business strategies of Distribution Network Operators (DNOs). Placing the electricity sector in the centre of smart grid policy has introduced barriers to the rate of diffusion of innovative solutions, because SMEs emerging from the ICT sectors, working on smart grid systems, struggle to break through DNOs procurement systems and compete with incumbent actors (large international ICT companies) whose accounting and order systems are aligned with Ofgem’s requirements for DNOs investments. In the context of smart grids, spillovers and innovation diffusion tends to take place from the ICT sector to the electricity sector. Software systems, apps, and operational systems developed within ICT are translated and applied to various aspects of DNOs operations. So, high transaction costs for SMEs in working with DNOs and the regulatory system create conditions for path-dependency and lock-ins, which in turn affect levels, types and sources of innovations for the grid¹⁰.

⁹ National Audit Office (2013) Public funding for innovation in low carbon technologies in the UK, <http://goo.gl/RcPx4n>

¹⁰ Hiteva and Watson (forthcoming), Governance of multi-regime interactions in the case of smart grids in the UK, SPRU Working Paper.

22. The UK Regulators Network (UKRN) has started considering a range of issues on opportunities and barriers to cross-sector innovation and co-deployment. However, cross-sector innovations are still considered a relatively small portion of overall activities in individual sectors and improvements of existing conditions were left to self-regulation and the introduction of 5 general good practice principles for managing infrastructure interactions. This approach may not be adequate in addressing some of the key barriers to both cross-sector innovation and interactions. Differences in the types and extent of regulation between the sectors, and their underlying logics, especially in terms of innovation as a core focus of activities, have created competing priorities between sectors. These differences can be particularly disabling in cases where support for innovation is focused on one sector and regulatory decisions are siloed by sectors, as in the case of smart grids in the UK¹¹. A cross-sector regulatory organisation like UKRN could play a more proactive role in creating opportunities for cross-sector innovation by working with specialised agencies like Innovate UK and becoming a member of the Low Carbon Innovation Coordination Group in its own right. The Government could take a lead in introducing a cross-regulatory regime, which alleviates regulatory measures and levels differences between regimes and sectors in cases of cross-sector innovations and interactions.
23. The Government and Ofgem can further incentivise innovation and development of smart grid technologies by proactively supporting the development of NTBMs in low carbon energy networks, along with more traditional models. NTBMs could include process innovations enabling new ways of distributing value in the supply chain and introducing innovations that create social benefits. New business models have the potential to allow new value to be captured from new technology in new ways. This could enable the successful diffusion of technology that would not pay off under existing business models (e.g. localised production of renewable energy). Business model changes can also accompany a change in focus, for example fulfilling new customer needs or defining the customer differently (e.g. vulnerable consumers). Although Ofgem conducted an inquiry into NTBMs earlier this year, it can take a more active role in supporting the emergence and diffusion of new business models, through coordination, training and learning diffusion activities, while the Government can introduce funding and operational support for NTBMs, as well as seek to improve the entry of NTBMs grid solutions in the regulated segment of the network. One way of achieving the latter could be by linking up with UKRN's activities on removing barriers to cross-sector business model innovation (e.g. smart meters). A transparent

¹¹ Hiteva and Watson (forthcoming), Governance of multi-regime interactions in the case of smart grids in the UK, SPRU Working Paper.

and consistent process for assessing and, potentially, making adjustments for NTBMs is one way to both study and assist their entry into the market.

24. Since NTBMs can cross sector boundaries and include areas that are not regulated by Ofgem, NTBMs may not be immediately visible to or fully contained within the remit of the electricity regulator. Environment scanning processes and/or transparent processes developed to work with any entrants proposing new business models for the electricity network could be implemented, calling for the involvement of specialised innovation institutions such as Innovate UK to support NTBMs through the provision of demonstration projects, to clarify cost structures and support effective forms of operation for such firms. This could be especially useful for the growing number of municipal energy supply and management companies.

25. The regulatory framework for offshore transmission (commonly referred to as the OFTO regime) introduced an innovative business model consisting of a fixed 20 year revenue stream indexed to UK inflation to third parties for the construction and maintenance of transmission assets from the offshore wind farms to the shore. However, the planning of the first 2 Rounds of licencing for offshore wind farm construction by the Crown Estate favoured the development of bilateral transmission connections between offshore arrays and the shore. Difficulties in transitioning from the Transitional to the Enduring OFTO regime, and the terms of the regime itself, produced circumstances that can hamper competition and innovation in terms of price and service quality (e.g. the construction of duplicate infrastructure in key points like substations to facilitate access by both generators and OFTOs; generators offering zero-cost maintenance contracts to OFTOs to mitigate risks of transmission failure). Although the Crown Estate has started to think strategically about bundling of connections¹² for Round 3, the regulation of the OFTO regime needs to change to remove these barriers to innovation and to create conditions for the construction of excess capacity within substations, a necessary step in the construction of interconnectors and interoperability of the grid¹³. The current regulatory regime precludes the possibility of anticipatory investment ahead of generation, which may hinder opportunities to create NTBMs that could deliver that.

¹² Connections to several bordering arrays could be brought up to the shore with a single cable rather than through the use of separate transmission assets.

¹³ Hiteva (2013) Geographies of energy governance – negotiating low-carbon infrastructure in the European Union, PhD thesis submitted to the University of Manchester, available on request.

What lessons can be learnt from low carbon electricity grids from other countries?

The role of ICT and electricity sectors in smart grids development

26. In comparison to the UK, South Korea has placed the ICT sector - represented by the SK Telecom chaebol - at the centre of its national operational programmes for smart grids development. SK Telecom is coordinating the Test Bed smart grid programme, as well as the development of a Network Operation Centre Building Energy Management System, a smart grid system for commercial use. To a significant extent, South Korea's approach is facilitated by the traditionally close relationship between industry conglomerates (or chaebols) like SK Telecoms and the government, and the less extensive regulatory framework imposed on the ICT sector, in comparison to the UK electricity sector. However, a more active role of the ICT sector in shaping smart grids policy, and direct participation in available funding for smart grid innovations can facilitate the spill over of more knowledge and innovative solutions from ICT to electricity.

Connecting more intermittent renewables to the distribution and transmission networks

27. In Ireland, a "gate" process is used to coordinate batch planning of distributed generation connection applications to TSOs and DNOs. Since 2004, DG is planned in "groups" based on their network location and capacity and processed in batches known as "gates". The queue for connection comprises both applicants to DNOs and TSOs. Applications are processed by the system operator most suited to their group connection irrespective of which system operator they originally applied to. The DSO generates a range of options for connecting all the applications, and determines the "least cost, technically acceptable" method for the group as a whole from the candidate options. A similar approach is used for those developments large enough to justify a connection directly into the transmission system. The regulator (with input from both system operators and the wind industry) determines criteria for eligibility for inclusion in the "gate". This method facilitates large quantities of renewables being processed in a structured manner and rationalises allocation of scarce capacity.