# Energy Technologies Institute Response to Energy and Climate Change Committee inquiry: Low carbon network infrastructure

## Executive Summary

1. The future of our electricity infrastructure cannot be considered effectively in isolation but needs to be viewed as part of a systems wide approach that examines heat, power, transport and the infrastructure that links them.
2. Adapting our electricity infrastructure will play a key role in enabling the UK to implement an affordable transition to a low carbon energy system by 2050.
3. This transition will involve the development, commercialisation and integration of a portfolio of technologies and solutions that are already known, but underdeveloped.
4. Critical, long-term decisions must be made about the design of the UK future energy system by 2025 to avoid wasting investment and ensure the 2050 targets remain achievable. Considered planning, technology evaluation and demonstration is required ahead of these decisions.

## Introduction

5. The Energy Technologies Institute (ETI) has developed an internationally peer-reviewed national energy system modelling and analysis capability (it's Energy System Modelling Environment or 'ESME'). ESME represents UK energy demands and systems in terms of both space and time, and is based on technical data drawn from ETI's technology and knowledge building projects as well as a wide range of industry and academic expertise. By using ESME, ETI is able to identify lowest-cost decarbonisation pathways, as well as strategies which are robust against a broad range of uncertainties.
6. ESME is capable of examining the future role of electricity infrastructure within a **whole energy system perspective** and ETI's analysis suggests that this whole system perspective is vitally important. In particular many future scenarios suggest very large changes in the role of electricity in meeting our future low carbon energy needs, so it is essential to consider electricity infrastructure as part of a systems wide approach encompassing heat, power, transport and the infrastructure that links them.
7. Earlier this year ETI published scenarios for low carbon energy system transitions for the UK which illustrate this whole system perspective in its report 'Options Choices Actions: UK scenarios for a low carbon energy system transition'. In particular these scenarios envisage:
    - Greater flexible interaction between electricity and a range of other energy vectors for power, heat and transport, in operating and balancing an integrated system of infrastructure

networks (e.g. interacting heat and power networks, transport fuelling from both electricity and liquid fuels).

- The creation of new energy network infrastructures at varying scales (e.g. new local and City-scale heat networks, hydrogen storage and distribution infrastructure, $CO_2$ transport and storage infrastructure).
- Substantial investment in new energy generation, conversion and storage facilities (e.g. new nuclear, Carbon Capture and Storage (CCS) and renewable electricity generation, gasification plants, biomass handling infrastructure, hydrogen storage etc.).
- Major shifts in the volume and patterns of usage of existing energy networks with substantial new demands on electricity transmission and distribution assets.

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

*Limitations of today's electricity infrastructure*

8. From the perspective of a move towards a future low carbon energy system, today's electricity infrastructure has a number of limitations:

   - It was designed largely to distribute power from centralised power stations through passive distribution networks to end users.
   - It will need substantial investment to enhance and upgrade the networks to accommodate new forms of power generation, in new locations and with significantly more complex flow patterns. (Note that to reduce the impact on consumer bills, capex deployed to provide infrastructure should be optimised across the vectors and also reflect the underlying location and security of supply in that vector; relative gold-plating should be avoided).
   - Electricity assets have largely been designed in isolation from other energy services and demands (e.g. gas for domestic heat, or petroleum based fuels for transport). Many analyses of the UK's low carbon transition suggest that there will be an increasing need for electrification or partial electrification of at least some heat and transport energy demands. In turn this will require electricity networks to operate in a way that is flexible and integrated with other energy infrastructures such as heat networks, or charging infrastructure for electric (or plug-in hybrid electric) vehicles.

*Addressing limitations: new engineering solutions*

9. Addressing the limitations of today's electricity infrastructure will require the development of new engineering solutions and enabling innovation in new technologies. ETI, for example, has invested in the development of 'fault current limiters' which enable the connection of more distributed generation to existing assets, and remove the need in many cases for other more costly network capacity enhancement. ETI has also invested in the development of promising new energy storage technologies which can be implemented at distribution network level.
10. New forms of renewable electricity generation raise challenges around intermittency and the need to store energy. Some of this may be in the form of electricity storage, but ETI analysis

suggests that there may be substantial advantages in enabling a large role for other forms of energy storage (e.g. heat or hydrogen storage) to balance the overall energy system.

11. ETI's scenarios for a future low carbon energy system suggest that it is essential to consider electricity infrastructure as part of an integrated low carbon energy system, increasingly designed and operated in combination with other energy infrastructure (e.g. heat networks, other forms of energy storage such as hydrogen or heat storage, or systems to support plug-in hybrid vehicles), if consumer costs are to be minimised.

*Addressing limitations: reforms to regulation and governance*

12. ETI's energy system analysis suggests that an economically efficient transition to low carbon energy in the UK (i.e. one which contains overall costs to consumers and the wider economy) will require substantial reform of existing approaches to the governance, regulation and incentives for investment in network infrastructures. The underlying engineering and economics (as reflected in modelling and techno-economic analysis of future low carbon energy systems) strongly points to the potential for a broader mix of energy vectors, with optimisation across heat, power and gaseous fuels.
13. Enabling these kinds of future energy mixes would raise new and different issues for the governance and regulation of energy network infrastructure which both challenge and go beyond the current essentially 'vector-specific' statutory regimes (e.g. electricity and gas acts). This is because of the apparent potential to realise substantial efficiencies in the costs of low carbon energy by

- Enabling and incentivising investment to substantially adapt and enhance existing network infrastructures (e.g. efficient configuration of electricity networks to meet needs of decarbonised generation)
- Enabling and incentivising investment in the creation of efficiently configured new network infrastructures (e.g. new heat networks and/or heat-based energy storage)
- Configuring and operating network infrastructures so that they can interact and integrate to enable optimisation across vectors (e.g. enabling efficient interplay of power, heat and gaseous energy vectors).

14. In view of these challenges ETI has initiated a project ('Enabling efficient networks for low carbon energy futures') to build understanding of the market and regulatory options to enable efficient investment in low carbon energy network infrastructures.

## 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?

15. The ETI's work on energy system scenarios suggest that a low carbon energy system will be radically different to today's, with a very different role for electricity infrastructure within a more integrated energy system.
16. Major uncertainties remain, in particular around the extent of electrification of heat and transport energy demands which will be required in future to meet carbon targets. For

example, ETI analysis suggests that a lowest cost pathway to meeting carbon targets would involve the UK successfully developing CCS and bioenergy value chains. CCS when applied with bioenergy can deliver 'negative emissions' by sequestrating the carbon absorbed during the growth of bioenergy feedstocks, thus allowing more headroom for some continued use of fossil fuels to meet heat and transport demand. However, other potential pathways, where CCS is less fully developed, involve much greater reliance on renewable electricity to meet heat and transport energy demand (although modelling suggests that this would be more costly). More details are available in the ETI report Options, Choices, Actions. (http://www.eti.co.uk/options-choices-actions-uk-scenarios-for-a-low-carbon-energy-system/)

17. Regardless of the precise future energy mix the scale of transformation required raises a number of key challenges around the policy and regulatory framework for investment in electricity and the other energy network infrastructure assets which will underpin and enable the transition.

18. Currently network assets are subject to separate specific regulatory regimes but ETI's future scenarios envisage:

    - Greater flexible interaction (and potentially competition) between a range of energy vectors for power, heat and transport, entailing more complex trade-offs in investment choices and greater flexibility in the operation and balancing of different infrastructure networks (e.g. interacting heat and power networks, gaseous vectors, transport fuelling from both electricity and liquid fuels)
    - The efficient creation, location and establishment of new energy network infrastructures at varying scales (e.g. new local and City-scale heat networks, hydrogen storage and distribution infrastructure, $CO_2$ transport and storage infrastructure)
    - Substantial investment in new energy generation, conversion and storage facilities (e.g. new nuclear, CCS and renewable electricity generation, gasification plants, biomass handling infrastructure, hydrogen storage etc), with a need for economic signals to drive efficient choices and location decisions in relation to network capacity
    - The potential break up of some aspects of national energy network provision, with for example a patchwork of choices for heat provision reflecting local characteristics, as well as the development of new consumer propositions for home energy supplies
    - Major shifts in the volume and patterns of usage of existing energy distribution networks (e.g. a potential decline in usage of gas distribution infrastructure, alongside substantial new demands on electricity transmission and distribution assets)

19. There is clearly a risk that misaligned economic signals could drive investment choices that ultimately increase costs for consumers. For example, choices may be influenced by how costs are socialised across users of networks. Heat network investments which may be 'optimal' from a system perspective could look expensive on a localised basis by comparison with alternatives primarily due to the absence of a large charge base across which the costs of new heat network infrastructure can be socialised but also due to different costs of capital given the difference in regulatory treatment. Similarly, the 'optimal' shape of electricity assets may look different when viewed from a whole energy system perspective, rather than within an electricity sector-specific framework.

20. A key challenge for Government will be in creating a governance and regulatory framework that enables coherent decision making across energy vectors. This is likely to require reforms to market frameworks to ensure that data is accessible to relevant market players and decision-making bodies.
21. The benefits to the UK of delivering an efficient low carbon energy system are likely to be large. ETI's analysis suggests that the extra costs of decarbonising the energy system could be contained at around 1-2% of GDP, with the lower end of that range achievable under a cost-effective strategy and policy framework. The efficiency with which the UK delivers reductions in its carbon emissions will have a major impact on its long term economic competitiveness and productivity.

- Energy is a key determinant of the cost of living – affecting real wages and living standards across the economy and all groups in society (particularly those on lower incomes)
- Energy is a key input to the UK's industrial cost base, particularly many manufacturing and process industries which have important broader economic linkages
- Direct spending on energy (solid and liquid fuels, gas & electricity) makes up around 7.5% of GDP. Total spending on meeting energy needs forms an even higher proportion of GDP, since it also includes complementary equipment and services (e.g. vehicles, buildings, appliances, heating systems etc).

22. The future cost to business and consumers of low carbon energy services will be significantly influenced by the UK's broad strategic approach to decarbonisation.

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

*Ensuring the UK can deliver a cost effective low carbon energy system*

23. A range of challenges need to be met to ensure that the UK can deliver low carbon energy networks that minimise consumer bills. The UK needs to invest over the next decade in developing, commercialising and integrating a portfolio of the most promising low carbon technology options that can enable it to deliver cost-effective low carbon energy. Many of the key technology options are currently largely known but under-developed. Investment is needed to prove, demonstrate and carry out early deployment and derisking of technologies, finance structures, consumer acceptance and appropriate regulatory structures.
24. The incremental (average annual) costs of carbon abatement across the national energy system (i.e. electricity networks, transport, heat, industry and infrastructure) could be contained at around 1% of GDP by 2050 within a coherent economy-wide market and policy framework. Failure to successfully develop and deploy key technologies could easily double this cost to the UK economy.
25. Action in the next decade will be critical in preparing for and beginning the large-scale deployment of key technologies. Resources should be focused specifically on bringing a basket of the most promising options to genuine deployment readiness in the UK. A portfolio approach will limit inevitable implementation risks (and cost) in the future and should include:

CCS, new nuclear, offshore wind, gaseous systems, bioenergy, efficient vehicles and low carbon heat for buildings.

26. By the early 2030s we will need to have largely decarbonised electricity production and be initiating large scale deployment of low carbon heat and transport solutions.

*Designing electricity networks to meet future needs*

27. The ETI is carrying out a number of projects which aim to provide practical answers and options for the design and operation of future electricity networks, particularly around the future role of electricity in meeting heat and transport energy demands.

- Our project 'Enabling efficient networks for low carbon energy futures' will explore and clarify the options for reform of governance and regulatory frameworks to enable investment in energy network infrastructure, including electricity infrastructure, that is efficient from a whole system perspective.
- The 'Consumers, Vehicles and Energy Integration' project is examining the challenges of transitioning to a secure and sustainable low carbon vehicle fleet and integrating low carbon vehicles, transport energy demand and electricity systems.
- Our Energy Path Networks modelling capability has developed software to support local area energy infrastructure and solution planning, integrating heat and power demands.

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

28. A particular problem exists in funding large scale technology demonstrations which will reduce future risk and encourage investment. As Government wants to see open access to the technology, and benefits of competition accrue to consumers, there is a clear public benefit case (and market failure) in demonstrations. Failure to fund and develop timely demonstrations will result in consumers paying higher costs.

29. There are currently multiple schemes to fund and incentivise innovation, each with different rules and technology focus.

30. Ofgem could open the Low Carbon Network Fund (LCNF) so that it does not rely on network owners being the selectors or gatekeepers of new technology. A more open competition with network owners hosting innovation, but not driving it, could lead to more innovative technology being developed.

31. Technology Readiness Levels are often used to assess/explain the status of technology, with 1 being "blue sky" and 9 being commercial. In the energy space, universities and enterprising individuals occupy TRL 1-3. Universities have significant funding streams with energy being prominent as a study area. In TRL 4-7, there has been a gap. However, as TRL's increase, so do the costs of bringing a product closer to commercialisation. The UK therefore seems relatively heavy on investment at the front, low TRL level, but light on late TRL spend (pre-commercialisation).

## What impact will changes to the electricity system – including distributed energy generation/storage, demand response and interconnection – have on the role of National Grid and the Distribution Network Operators? (e.g. in terms of ownership structures, responsibility for system balancing and system security)

32. As set out above, ETI's work on future low carbon energy systems suggests that substantial changes in the role of electricity networks are likely to be required. The precise shape of these changes remains unclear, but it is important that the UK is open to governance and regulatory reforms (e.g. to the roles and responsibilities of regulated entities) to enable an efficient transition to a radically different future energy system. At this stage one or two key themes can be identified:

    - Electricity transmission: the challenges around system operation and balancing are likely to increase in complexity, as new renewable generation grows, other forms of energy storage emerge and as increased integration with systems to meet heat and transport energy demands develops.
    - Electricity distribution: the challenges of efficiently decarbonising heat energy demands (which are much higher that peak electricity demand) is likely to require increasing convergence of planning and governance between local electricity networks and heat solutions. Local spatial planning approaches involving DNOs may need to be developed to enable the efficient development of low carbon local energy assets.
    - Some innovations (eg demand side response) can solve transmission, distribution and security of supply issues; ensuring that the relevant data and access to products is available to all parties may be important in building the market volume and using the 'resource' efficiently.

## About the ETI

33. The Energy Technologies Institute (ETI) is a public-private partnership between global energy and engineering firms (BP, Caterpillar, EDF Energy, Rolls-Royce, Shell) and the UK Government.
34. Our mission is to accelerate the development, demonstration and eventual commercial deployment of a focused portfolio of energy technologies which will increase energy efficiency, reduce greenhouse gas emissions and help achieve energy and climate change goals.
35. We carry out three key activities:
    - modelling and strategic analysis of the UK energy system to identify the key challenges and potential solutions to meeting the UK's 2020 and 2050 targets at the lowest cost to the UK,
    - investing in major engineering and technology demonstration projects to de-risk and build capability both technology and supply-chain solutions for subsequent commercial investors
    - enabling effective third party commercialisation of project outcomes.
36. The ETI has developed an internationally peer-reviewed national energy system design tool (known as 'ESME' - Energy System Modelling Environment), to underpin our strategic techno-economic analysis of the UK energy system. ESME models choices across power, heat, transport and infrastructure sectors and is informed by evidence drawn from our private sector members,

our technical projects and a range of expert advisers. As such it enables the ETI to deliver evidence-based insights on how to deliver affordable, secure and low carbon energy for Britain in the decades ahead, including identifying credible, lowest-cost pathways to secure low-carbon energy in future.

37. The ETI also contributes insights and expertise to support a range of technology strategy and policy groups, including the cost reduction task forces on both offshore wind and CCS, the recently created CCS development forum, the low carbon innovation co-ordination group (LCICG) and a wide range of research advisory groups.

38. The ETI technology project portfolio to 2017 totals over £400m of investment with four key aims to reduce the costs of generating energy, demand reduction, increasing investor confidence and increasing public acceptance and engagement. We work with over 120 large corporates, SMEs and academic groups to deliver these projects.

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