Enabling sustainable electrification of the UK economy

RESPONSE to Call for Evidence to UK Parliament Committees

Environmental Audit Committee – Call for Evidence

About the Institution of Engineering and Technology (IET)

About the Institution of Engineering and Technology (IET) The IET is one of the world's largest engineering institutions with over 158,000 members in 150 countries. We are a diverse home across engineering and technology and share knowledge to engineer solutions to global challenges like climate change. With our roots in electrical engineering, we have been championing engineering solutions and the people who deliver them for 150 years. The IET provides independent, impartial, and expert advice, spanning multiple sectors including Energy, the Built Environment, Transport, Manufacturing and Digital.

The following represents The IET's submission to the Committee's call for evidence and has been informed by drawing on the expertise of a wide range of industry professionals and academics within The IET's membership.

Key recommendations

We welcome the opportunity to respond to this consultation however we feel that the questions do not fully address some of the important provisions necessary to achieve decarbonisation of the electricity system by 2035. We would therefore like to also recommend the following:

1. **Whole system approach** - whilst published energy policy and strategy statements provide an outline of ambitions and targets, **a full strategic, whole-energy system, long-term, spatially and temporally defined development plan will be needed** to ensure progress. Further detail must also include interdependencies between critical infrastructures, potential risks, and contingencies.

2. **Power System Architecture -** incremental adaptation to emerging power system management, operability and security of supply challenges is not sustainable. **There needs to be a fundamental review of power system architecture, and a commitment to invest in a power system that has designed-in system management, operability, and security of supply capability** as part of a managed transition of the power system.

3. **New technology** - there are technologies which have not yet reached maturity or economy of scale but will need to be developed at scale if the 2035 and 2050 targets are to be met. **Financial support and/or some form of guarantee of return on investment might be needed to attract investors**, for example hydrogen production, transportation, and storage; CCUS infrastructure; local hydrogen distribution systems; long duration energy storage technologies, wave and tidal generation, and Advanced and Small Modular Reactors.

4. **Planning processes** - **the planning and consent process can be impacted by affected communities who will understandably be concerned to minimise disruption and/or loss of amenity (or aesthetic impact)**. Clearer forward visibility of proposals and their purpose, together with sympathetic environmental mitigation and, where appropriate, compensation might lead to more positive engagement and timely acceptance.

5. **Role of interconnectors** - strategic interconnections of energy infrastructure between countries can enhance both the economics and security of energy supply. However, **it is important to recognise that interconnector power flows are market-led and that weather conditions might simultaneously affect neighbouring North European countries** and hence limit interconnector imports at times of tight supply margins particularly when output from weather-dependent generation is low.

6. **Climate change** - whilst all future GB electricity scenarios assume a major increase in weather-dependent renewables **there is an urgent need for a full appraisal of the options to ensuring sufficient dispatchable supply side (as well as demand side) flexibility**. There are as yet unknown impacts on the Jet Stream and Gulf Stream which might lead to more frequent and prolonged weather-blocking events (including anti-cyclones) and more extreme ambient temperatures.

7. **Future governance** - the creation of the FSO as an independent system (operator) and planner (ISOP) is an important development, but **it will be essential that the FSO has a whole-energy system remit and is empowered through its authority extending across the whole of the energy sector to delivery of both the 2035 and 2050 targets.** The relationship between the FSO, DESNZ and Ofgem in terms of responsibility and accountability for strategic decision-making must be clear from the outset. In that regard, the ISOP role should be that of an energy systems architect, with 'architecture' extending beyond the technological design and physical connectivity of the energy system to embrace markets and other enabling aspects of energy transition such as codes and standards.

8. **Regional planning - coordination between the FSO and proposed Regional System Planner (RSPs) will be essential** to ensuring regional energy needs are addressed, and opportunities maximised, whilst also remaining aligned with national energy system strategic objectives. Key challenges in establishing RSPs are likely to include the recruitment and training of human resources and the allocation of sufficient dedicated budgetary provision. Consideration should be given as to whether distribution system operators (DSOs) might help establish regional whole-energy system planning capability.

9. **Investment in infrastructure** – **the regulatory framework must support prudent anticipatory investment, not only in relation to the power system but also to related infrastructure** such as hydrogen transportation and storage and CCUS. The framework must recognise lead times and supply chain constraints in building the necessary integrated infrastructure within the required timescales to meet decarbonisation and net zero objectives. This in turn requires a long-term (say 25-year) perspective with an agile system of governance that can respond quickly and objectively to emergent threats and opportunities along the transition pathway to 2035 and 2050.

10. **Home energy efficiency - an important aspect of energy decarbonisation, security and affordability is home energy efficiency**. Improvements targeted at poorly insulated homes would benefit not only the residents of such homes but all consumers through avoided marginal costs of energy production and infrastructure capacity, and at least in the interim, reduced need for dispatch of unabated fossil-fuelled generation. In terms of social obligations, such measures will be particularly beneficial to low income and vulnerable customers.

11. **Smart homes** - enabled by smart appliances, smart home EV charging (including V2G/V2H), home energy management systems and (increasingly) AI will enable consumers to engage seamlessly with the energy system. Time-of-use and dynamic tariffs will enable them to benefit by aligning demand with low-cost electricity production, and by avoiding system peak demand periods when networks might be constrained. **This will require a comprehensive communication and education strategy together with affordable financing options for smart home technologies** that enable those on low incomes to take advantage of the opportunities.

12. **Built-in adaptation -** whilst the focus of energy strategy is on decarbonisation to address global warming, the effects of climate change need to be accommodated through adaptation and improved physical resilience of both the energy system and energy system-dependent infrastructure such as telecommunications. As we become increasingly dependent on electricity, **the need for greater physical, operational, and cyber resilience are factors which should be designed-in** to future energy system architecture and infrastructure investment strategies.

What challenges does connecting more renewable electricity to the grid pose, both for those businesses and households who wish to connect to it, and for grid operators?

Impact of renewables on the grid

Both the national transmission system and local distribution systems have traditionally been constructed to transfer power from transmission-connected centralised power stations fuelled mainly by coal, gas and nuclear to homes and businesses across the country. The power flows have therefore been essentially ‘top-down’ from transmission to distribution systems, and from higher to lower network voltages across distribution systems, to serve industrial, commercial and domestic demand customers.

However, the drive for low carbon forms of renewable generation is resulting in both the transmission and distribution systems having to accommodate more decentralised and distributed sources of generation, including from homes and businesses, as well as from new locations such as offshore wind farms. This has led to a need for transmission and distribution network operators to reappraise network power flows and undertake reinforcements and enhancements where necessary to maintain required levels of security and quality of supply.

Power system management implications
It has also led to the national system operator (ESO) having to manage the system effects of self-dispatching generation and lower system strength and inertia levels. This in turn has created a need for the ESO to develop new markets for procured ancillary services such as frequency response and inertia, including from distributed energy resources. DNOs meanwhile have had to adopt more ‘active’ network management strategies to manage power flows within distribution equipment thermal ratings, and voltages at consumers’ terminals within statutory limits. In order to meet the demand for network connections in generator-dominated parts of their networks, DNOs have offered the alternative of non-firm connections for distributed generators. This allows a greater number of connections whilst minimising the need for protracted and costly programmes of network investment, and hence delayed and expensive connections. We expand on these measures in our commentary on decentralised energy distribution points and distributed energy generation.

System operability considerations
From an operability perspective, the displacement of conventional coal and gas-fired generation by renewable alternatives such as wind and solar, is leading to increasing challenges for the ESO in managing system frequency even under normal operating conditions, and in terms of maintaining resilience of the system to shocks such as a sudden loss of infeed from a power station or interconnector, or a transmission system short-circuit fault. The former can result in a more rapid fall in system frequency whilst the latter can lead to more severe and widely propagated voltage depressions. In the event of a simultaneous loss of two or more infeeds these system frequency and voltage impacts can lead to an increased risk of distributed generation disconnecting from the system leading to an even more rapid fall of frequency and a risk of supply interruptions. An event of this nature occurred on 19 August 2019:
https://www.nationalgrideso.com/document/152346/download

The system voltage and frequency challenges described above arise due to reducing levels of system strength and inertia resulting from conventional ’synchronous’ generation associated with coal and gas-fired power stations being displaced by inverter-connected wind and solar PV generation. This is leading to the need for the ESO to procure new types of ancillary services such as frequency response and reactive support, as well as synthetic forms of inertia to improve system stability. NGESO’s Operability Strategy report 2023 describes a wide range of emerging operability challenges and the steps being taken to address them: https://www.nationalgrideso.com/news/operability-strategy-report-2023

Future security of supply challenges

Emerging challenges for the ESO (or in future the FSO) include ensuring sufficient dispatchable, flexible sources of power to maintain supply in the event of a sustained period (i.e. several consecutive days) of calm overcast weather conditions, and the ability under all circumstances to be able to meet the Electricity System Restoration Standard in the event of a partial or total system shutdown. The former requires sufficient long-duration forms of energy storage which can be used to generate electricity whilst the latter requires sufficient generation with 'grid-forming' capability to restart the system. Overall, there is a need for a more strategic approach whereby system security is a designed-in attribute of the overall electricity system architecture.

In addition to nuclear generation (potentially including AMRs and SMRs as well as conventional plant) potential options include gas or bioenergy generation with CCS and/or hydrogen fuelled generation. The latter would complement the concept of producing hydrogen through electrolysis using surplus wind generation (i.e. at times of low demand) which could be stored until required to generate electricity. Both would require sufficient complementary transportation infrastructure and storage capacity: the former for carbon dioxide, the latter for hydrogen. Under any future generation mix, it will be essential to ensure sufficient flexible (non-weather-dependent) capacity.

A new system architecture

Taking all the above into consideration, the current policy of incremental adaptation to emerging power system management, operability and security of supply challenges is not sustainable. Instead, there needs to be a fundamental review of power system architecture, and a commitment to invest in a power system that has designed-in system management, operability and security of supply capability as part of a managed transition to accommodate new zero carbon forms of generation with a near doubling of peak demand and at least a doubling of electricity consumption due to electrification of heating and transport by 2050.

Businesses and households

For businesses and households, provided there are no distribution system capacity constraints (or once they are resolved) the connection of 'behind-the-meter' generation simply requires their installations to adhere to an industry published standard (ENA Engineering Recommendation G99) - for example in respect of the type and settings of electrical protection (loss-of-mains, over/under frequency and over/under voltage protection). In terms of planning approval, such installations are classified as 'permitted development' with the exception of listed buildings, buildings in conservation areas, and buildings with flat roofs if the panels are mounted at an angle and hence increase the height of the roof by more than 0.2 metres.

To what extent do the following act as barriers to the UK's targets to decarbonise the power supply? How well is the Government addressing these barriers, and what else can be done to address them? What, if any, targets should be set in these areas?

1. **grid connection delays and bottlenecks, onshore and offshore**

   Whilst the approach described in our commentary above has enabled rapid growth in both transmission and distribution network-connected renewable generation, the continued and accelerating drive for further offshore and onshore renewable generation capacity, coupled with new 'low carbon' types of electricity demand such as heat pumps and EV chargers, is giving rise to increasing transmission and distribution network capacity constraints and hence delays in being able to accept new connections of generation at some locations. Initiatives to address this include an Accelerated Strategic Transmission Investment programme and the introduction by the Electricity System Operator (ESO) of a new Connection Management Methodology and a time-limited ‘two-step’ connection process introduced in March 2023. This will enable a more realistic assessment of projects in the current queue and hence earlier connections of projects at a more advanced stage of development.

Nevertheless, over the last five years, the volume of new connection offers has grown tenfold, with an increase in applications of 80% in the last year alone. This has led to significant growth in the amount of new generation capacity in the transmission queue, with 280GW now allegedly holding connection agreements. On distribution systems, volumes of generation connection applications have also increased, and some are delayed by transmission constraints even when there are no local distribution constraints. Many generation developers in the transmission queue have a connection offer date of over 5 years in the future with some having a connection offer date of 10 or more years in the future.

To put this in context, under NGESO’s 2022 Future Energy Scenarios there would be in the order of up to 80GW of connected wind generation capacity by 2030 and up to 160GW by 2050 (depending on scenario) - and for solar generation up to 40GW and 80GW respectively. Again, under NGESO’s 2022 Future Energy Scenarios, peak demand on the GB system would grow to between circa. 95 and 115GW (depending on scenario) by 2050. This suggests that a significant contributor to the transmission connection queue is the number of applications that are unlikely to proceed to construction.

This suggests the need for a holistic approach whereby the future national generation portfolio is the subject of a strategic spatial and temporal development plan which meets the 2035 and 2050 objectives whilst reconciling decarbonisation and security of supply objectives across the whole of the transition period. In the meantime, in recognition of the immediate connection queue challenges, Ofgem has issued an open letter proposing a future reform to the electricity connections process:
https://www.ofgem.gov.uk/sites/default/files/2023-05/Open%20Letter%20Connections%20%28Final%2016.5.23%29.pdf

2. lack of, or delays to developing, necessary infrastructure

Although the initiatives outlined above will help shorten connection queues, achieving the scale of network investment at both transmission and distribution system level necessary to facilitate the objective of decarbonising the electricity system by 2035 will remain challenging due to the processes that have to be undertaken to secure approval before work can commence. This typically includes consultation with affected stakeholders and communities; obtaining permissions and legal consents from landowners and tenants over whose land the power lines will be constructed (and where appropriate agreeing compensation); meeting requirements for environmental mitigation; and obtaining local authority planning consents. An Electricity Networks Commissioner has been appointed with the objective of streamlining elements of this process where practicable. We expand on this in our commentary on planning, local government and communities. However, this again points to a need for a fundamental review of the process for developing and connecting generation to the grid. Instead of the current piecemeal case-by-case basis, the need is for the future generation portfolio and associated grid development requirements to be considered holistically as part of a spatial / temporal development plan.

3. insufficient scale or capacity

Whilst the above initiatives will help address the current capacity shortfall, ensuring sufficient scale of investment and grid capacity going forward will depend critically on the regulator Ofgem continuing to approve transmission and distribution companies' network investment proposals, including proposals for prudent anticipatory (ahead of need) investment in transmission and distribution network capacity, balancing the risk of stranded investment with that of insufficient investment to achieve the 2035 objective of decarbonising the electricity system whilst ensuring security of supply. Uncertainty mechanisms can be part of the solution for managing this risk but there needs to be a commitment from the outset to the scale and pace of both transmission and distribution capacity upgrades required to meet the 2035 decarbonisation target.

Delivering for 2035

NGESO has recently published a briefing document - Delivering for 2035: upgrading the grid for a secure, clean and affordable energy future – which outlines five priority areas requiring urgent attention: planning system reform; a fit-for-purpose regulatory and governance framework; transforming the renewable energy connection process; prioritising communities and consumers; and developing the supply chain capacity and UK skills pipeline: https://www.nationalgrid.com/document/149496/download

4. supply chain and skills constraints

Notwithstanding practical constraints surrounding consents and planning approvals outlined above, a further risk is that the required scale and pace of network capacity upgrades becomes either impracticable, or cost-prohibitive to resource from a supply chain perspective (in terms both of human resources and materials) unless the programme begins ahead of need and hence enables a smoother resourcing profile.

The transformation of our energy system gives rise to skills and supply chain challenges, but it also provides opportunities for employment in 'green' technologies. It also creates economic growth opportunities from developing home-grown expertise and capability in manufacturing products which have export potential. It would be unfortunate if the UK did not capitalise on its leading position in decarbonising electricity supply (and energy generally) by failing to grasp the opportunity of becoming an international green technology hub. Achieving this will require a strategic approach to securing supply chain capacity, and an educational and training system focused on developing a pipeline of future talent. Given the strategic long-term objective of 'net zero by 2050' this should extend to a strategic review of the schools' curriculum, and courses offered at colleges and universities.

5. access to finance

Generation

From a zero-carbon generation (wind, solar, BECCS nuclear) perspective, access to finance (and cost of capital) will depend on investor confidence which in turn will be dependent on certainty of continued Government commitment to net zero and the decarbonising of the electricity system. Future decisions arising from the current Review of Electricity Market Arrangements (REMA) in respect of wholesale (day-ahead / intra-day) market structure, the capacity market, CfD's, and nodal / zonal pricing will also affect investor confidence. For example, decisions on nodal / zonal pricing could affect the willingness of investors to develop generation capacity in places where 'natural capital' favours wind farm developments (e.g. high wind volumes / shallow sea beds) but where electricity demand is relatively low.

Emerging technologies

There are important, but emerging or relatively nascent, technologies which have not yet reached maturity or economy of scale but will need to be developed at scale if the 2035 and 2050 targets are to be met. For these to be investible, it is likely that financial support and/or some form of guarantee of return on investment will be needed to attract investors (and/or avoid the high costs of capital associated with what might be perceived as high risk investment) particularly where there is likely to be a long period of time before revenue streams begin and/or the profile of future revenue streams is uncertain. The decision to part-fund the construction of Sizewell C nuclear power station through a regulatory asset base (RAB) model is an example of such an approach. Technologies which might fall into this category include hydrogen production, transportation and storage; CCUS infrastructure; local hydrogen distribution systems; long duration energy storage technologies; wave and tidal generation, and possibly heat networks.

Key to achieving the Government's target of 24GW of nuclear generation by 2050 (as part of its energy security strategy) will be the development of Advanced and Small Modular Reactors (AMRs and SMRs) to a technology readiness level that makes them both economically viable and socially acceptable (from a safety perspective) for deployment at scale. In that regard Great British Nuclear has a strategically critical role in ensuring Britain will have a sufficient portfolio of dependable, dispatchable, and economic generation that is able to meet decarbonisation and security of supply requirements well before 2050.

Regulated networks

From a transmission and distribution network perspective, as regulated (by Ofgem) companies with low-risk profiles (investment grade ratings) transmission and distribution network operators (TOs and DNOs) are generally able to access finance at a relatively low cost of capital, typically though bond markets. However, their baseline allowances (effectively the expenditure that the regulator Ofgem believes from analysis and challenge of their business plan submissions they need to incur over the forthcoming five-year period) largely determine (notwithstanding various efficiency and performance incentives) the level of funding they can secure and expect to receive an acceptable return on. A potential limitation here is that as an economic regulator, Ofgem is generally inclined towards conservatism in determining investment requirements, relying on uncertainty mechanisms to enable in-period adjustments to companies' allowances (and hence revenues) as circumstances and investment needs become clearer.

Whilst helpful, these uncertainty mechanisms are not an adequate substitute for committing to a prudent level of anticipatory investment at the offset in order to ensure sufficient network capacity and capability ahead of need. The risk is that the 'need' might arise very quickly as levels of both onshore and offshore generation requiring grid connections accelerate (as they must if we are to meet the 2035 grid decarbonisation target), as electricity begins to substitute gas for domestic heating and some industrial processes, and as electric vehicles begin to displace petrol and diesel vehicles at scale. If the need for network extensions and capacity upgrades exceeds the capability of companies to serve that need due to lead-times and supply chain constraints, then connections of generation, heat pumps and EV charging infrastructure might be delayed and/or be more expensive due to a market supply/demand imbalance in terms of equipment and human resources. As we have commented in our response to earlier questions, this again points to the need for strategic whole-energy system planning as a basis for effective regulation, especially given Ofgem's future wider remit in respect of hydrogen and CCUS. At the time of writing, Ofgem is consulting on frameworks for future systems and network regulation: enabling an energy system for the future: https://www.ofgem.gov.uk/publications/consultation-frameworks-future-systems-and-network-regulation-enabling-energy-system-future

How resilient is the National Grid? How does it need to adapt to achieve the Government's targets of (a) decarbonising the UK power system by 2035 and (b) becoming a net zero economy by 2050? What changes are needed to promote resilience through diversity of supply?

Resilience and Reliability

In addressing this question, it is helpful to distinguish between resilience and reliability. An Electricity Engineering Standards Review - Independent Panel Report in December 2020 defined 'reliability' as the ability of the electricity system to withstand normal disruption (principally from everyday asset outage and single failures) and capacity as the capability of the system to fulfil customers' requirements – usually taking into account reliability. 'Resilience' encompasses the system's ability to resist much larger (however defined) events and its ability to then restore services to customers: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943685/Electricity_Engineering_Standards_Review.pdf

The nature of the question is essentially around reliability and security of supply, though we do comment elsewhere on resilience in the context of requirements for climate change adaptation, and also cyber resilience of telecommunications systems which have a strong mutual interdependency with the electricity system.

Design levels of security

Security is a measure of the ability of the electricity system to continue to provide the necessary capacity to maintain supplies, and/or how quickly supplies can be restored, following the loss or damage of some part of the electricity network. It follows that security encompasses reliability, capacity and resilience. The national grid (transmission and distribution systems) provides a high level of security and quality of supply. The Security and Quality of Supply Standard - SQSS - sets out the criteria and methodology for planning and operating the national electricity transmission system whilst a complementary document, Engineering Recommendation ENA EREC P2 (current issue 8) sets out the design security of supply requirements for electricity distribution systems. Adherence to these requirements has resulted in an electricity grid which, by design, is able to provide a high level of security of supply in respect of network faults and to losses of infeed (i.e. from generators or interconnectors).

Value of Loss Load and Lost Load Probability

The above security standards have been derived historically from consideration of value of lost load (VoLL) and loss of load probability (LoLP). LoLP is essentially the probability of an event and VoLL represents the impact or consequence of that event on customers. However, given our increasing dependency on electricity (including for information technology and communications which we are also increasingly dependent upon) and given the physical transformation in the physical architecture of the electricity system, it might be timely to revisit assumptions around VoLL and LoLP - noting that VoLL generally has a non-linear relationship with duration (of the loss of supply).

The value (or cost) of lost load will vary between different types of customers: for example, for an industrial customer the consequence might be loss of production (or loss of product in the case of a critical process); for a commercial customer it might mean loss of business; whilst for a domestic customer it could simply mean inconvenience or temporarily reduced comfort levels. However, for a prolonged interruption it could present a health or safety risk, particularly for vulnerable customers. The Electricity Engineering Standards Review suggested that a review of VoLL could consider the appropriateness of different formulations of VoLL that could be created to cater for the distinction between customers, customer groups, different appliance types and to cope with how these all vary with duration. We would add that consideration might also be given as to the extent to which mitigation against loss of supply might be more economically achieved, or at least supplemented, through demand-side measures, for example through standby generation for industrial customers, UPS systems for commercial businesses, and possibly home energy storage - including V2H for EV owners with home EV charging.

Security in respect of transmission faults and losses of generation

An important aspect of power system design is to limit the demand interrupted as a result of a loss of infeed, or a transmission system fault, and limiting the length of duration of any interruption of demand. In practice this is achieved largely through designed-in redundancy (giving rise to terms such as ‘N-1 security’) and through ensuring sufficient levels of system inertia and frequency response to maintain stability of the grid under specified ‘normal’ and ‘infrequent’ Infeed loss risk criteria.

Diversity of supply - the changing generation portfolio

In order to decarbonise the UK (or GB) power system by 2035 and become a net zero economy by 2050, the national generation portfolio will not only need to expand in terms of capacity to serve electric heating and vehicles, but also to continue to transition away from generation fuelled largely by unabated gas (or other CO_2 emitting fuels) to a portfolio comprising renewables and generation fuelled by non-CO_2 emitting fuels (such as nuclear or hydrogen) or through (methane) gas or bioenergy energy with carbon capture and storage. Whilst these latter non-renewable but carbon-free or abated technologies will have relatively little impact on the operational characteristics of the grid, a major transition to renewables such as wind (offshore and onshore) and solar PV will significantly affect how the grid is planned and operated.

in terms of planning, the ongoing transition to renewables means that the geographic map of the GB generation portfolio will change with current centralised sources of generation being displaced (or complemented) by offshore wind farms served by offshore grids, and distributed onshore wind and solar PV farms connected mainly to distribution systems. The former has given rise to a 'holistic network design' (HND) philosophy: https://www.nationalgrideso.com/future-energy/pathway-2030-holistic-network-design which seeks to provide the necessary transmission capacity to connect offshore wind farms whilst both reducing the amount of offshore network required, and minimising the need to curtail wind farm output on occasions due to transmission constraints.

Future operability dependencies

From the perspective of how the transmission system is operated, there will be an increased dependency on energy storage and flexibility (which we expand on in response to a later question) and in terms of measures necessary to ensure continued security of supply and grid stability. At distribution system level, the focus is on maximising the capacity of the system to accommodate distributed generation through active management of power flows and voltage, and through exploiting flexibility opportunities to better balance generation output and demand. The objective behind this approach is to minimise the need for curtailment of generator output and/or network reinforcement driven by network component thermal ratings, and the requirement to maintain voltage at customers' terminals within statutory limits.

What contribution do, or should, localised mini-grids make to achieving the Government's targets of (a) decarbonising the UK power system by 2035 and (b) becoming a net zero economy by 2050? What role ought there to be for decentralised energy distribution points and distributed energy generation in the future of electricity supply?

Mini & micro-grids

Whilst not a substitute for wider grid investment, mini (or micro) grids, if managed as part of the wider electricity system, can make a useful contribution to decarbonisation by helping align the mini or micro-grids' demand profiles with the output profiles of both their own and national sources of renewable or carbon-free generation. The benefits will be lower (both to the energy communities they serve and to customers served by the wider electricity system) if operated as islanded networks rather than as an integrated part of the local public distribution system. Although this doesn't preclude their operation as an islanded network (for example if this enables supplies to be maintained during an interruption of the local distribution or wider network) the ability to do so safely will depend on the incorporation of control systems that can maintain frequency and voltage within acceptable limits, ensure the integrity of protection (i.e. against short-circuit faults), and enable resynchronisation with the local distribution system when required.

DER & CER

Distributed energy resources and consumer energy resources (such as rooftop solar PV and home energy storage) are already playing an important role in electricity system decarbonisation, both as sources of generation (for example onshore wind and solar PV farms) and demand flexibility. NGESO's Future Energy Scenarios envisage up to 30%

contribution from decentralised generation to overall national generation capacity by 2030, rising to over 40% under their 'Leading the Way' scenario by 2050.

Providing for distributed generation

At distribution system level, innovative new 'active network management' systems, have helped enable distribution networks to accommodate new types of decentralised generation (DG) and new low carbon sources of demand (such as heat pumps and EV chargers) with generally little increased risk to security of supply. Nevertheless, there are also generation connection queue issues at distribution system level for onshore wind and solar PV farms, and in some cases for distributed battery energy storage systems (BESS). These connection queue issues can occur due to the impact on power flows and voltages on distribution networks, particularly at times when output from DG is high and local demand is relatively low. In some cases, this can result in power flows crossing from distribution to transmission systems which can then trigger the need for modifications to protection and voltage management systems, or wider transmission system reinforcement.

Non-firm connections

One approach by DNOs to reduce connection delays for DG is to offer the alternative of non-firm connections either as a temporary expedient pending network reinforcement or as a permanent arrangement. The rationale for this approach is that it can enable faster and cheaper connections and hence allow the developer to begin trading sooner. The risk to the developer is that under certain (low) demand and network running arrangements the output from the DG installation might need to be temporarily curtailed. However, given the relatively (low) capacity factors for onshore wind farms (typically c. 26%) and solar PV farms (typically c. 11%) the curtailment risk is generally low.

Uncoordinated connection applications

A particular issue facing DNOs is the sheer quantum of applications for network connections for new wind and solar PV farms (and increasingly BESS). Many of these applications will be speculative (i.e. in advance of planning approvals or even before assessment of business case). This can result in DNOs having to consider multiple applications that would impact the same part of their network. When that happens, the DNOs then have to consider various scenarios (or permutations) each of which will have a different level of impact on the network. It also means that since the applications are interactive, DNOs can provide only conditional estimates of likely connection costs. Moreover, from a strategic network planning perspective, until there is a degree of certainty over which applications will proceed it compromises the DNO's ability to optimise the nature and extent of any required upstream network reinforcement.

What role will, or should, artificial intelligence play in decarbonising UK's power supply?

The role of AI in system planning and operation

AI has the potential to enhance the quality of decision making in both operational planning and investment timescales through modelling and simulation using digitalised twins of the energy system which will ultimately enable the creation of a 'virtual energy system' … https://www.nationalgrideso.com/future-energy/virtual-energy-system

However, operation of the power system, and associated markets (including markets for ancillary services to the ESO) is becoming increasingly complex and necessarily closer to real-time; for example, in responding to variations in output from intermittent generation (such as wind and solar PV) and to system events and perturbations (including transmission faults, and sudden changes in generation output or demand). The ability to assimilate real-time information and determine the optimum response is becoming increasingly dependent on computerised analysis and decision-making, taking full account of any associated risks and consequences. AI has the potential not only to inform (or perform) the optimum response to any given situation but also the ability to 'learn' (by comparing the anticipated and actual impact of a decision) and hence continually refining its decision-making criteria.

However, it is important to recognise there are risks in moving from using AI for decision support to using AI for real-time decision making. There will need to be transparency in terms of what, and how, data is being used, which in turn requires an open data (rather than a 'black box') approach. Application of systems engineering and assurance principles to AI solutions will be essential, which in turn means that the FSO must have the competencies of a Systems Architect.

AI beyond the meter

The role of AI will not be confined to transmission and distribution (or indeed to the electricity part of the energy sector), its role will also extend beyond the meter into homes and businesses, not least in optimising their energy management, including making decisions over timing of energy consumption over the day or week and, where appropriate, maximising energy arbitrage opportunities (for example in respect of home generation and energy storage). In summary, whilst there is currently limited use of AI across the power sector, we foresee it having an increasingly important role in enabling achievement of the 2035 and 2050 targets. However, as experts in the field of AI have recently commented, the risks of unintended consequences are real but not necessarily yet fully understood, and so will need to be carefully managed.

To what extent will the measures in the British Energy Security Strategy and the Powering Up Britain plan deliver the Government's high-level targets of (i) decarbonising the UK power system by 2035 and (ii) becoming a net zero economy by 2050?

These publications, along with others such as The UK Hydrogen Strategy and the CCUS Net Zero Investment Roadmap, provide a helpful compendium of initiatives, ambitions and targets (though they will need refreshing regularly in light of experience and progress) but the compendium does not meet the requirement for a strategic (joined-up) whole-energy system delivery plan. Achievement of the 2035 decarbonisation target is becoming increasingly challenging (and even unlikely) due to the lead times associated with bringing the required technologies to a level of maturity consistent with BAU implementation and in terms of building the associated infrastructure (Infrastructure including: hydrogen production, transportation and storage; CO_2 capture, transportation and storage; and transmission system infrastructure as per NGESO's 2023 Network Options Assessment and the Accelerated Strategic Transmission Investment programme).

How will the design of the future grid incorporate adaptation measures so as to minimise the potential impacts on the electricity system from extreme weather events, such as Storm Arwen in November 2021?

Resilience by design

We have commented above on the reliability of the grid in terms of its ability to adapt to accommodate decarbonisation of generation and demand (through electrification). The inbuilt 'redundancy by design' we referred to earlier is also an important factor in the ability of the grid to sustain network fault outages on transmission and distribution high-voltage networks, generally without widespread interruptions to customers (or in the event of an interruption, the avoidance of a severely delayed supply restoration in most cases). On distribution networks, which are generally most susceptible to storm damage due mainly to unavoidable proximity of trees to overhead-lines, network operators (DNOs) have invested heavily to improve quality of supply (i.e. to reduce the number and duration of customer interruptions) partly in response to Ofgem's Interruption Incentive Scheme. Measures taken include increased levels of network automation to reroute power flows following a fault and restore supplies within a target time of three minutes (and often in less than one minute); undertaking flood mitigation measures at vulnerable substations; reducing susceptibility of lines to lightning-induced surges; and increasing the physical resilience of overhead lines to enable them to better withstand the impact of falling tree boughs or windborne material.

LV networks

On LV overhead-line networks, which are particularly susceptible to being struck by falling trees or branches (due to their proximity to private gardens and hence restrictions on achievable clearances), DNOs have selectively invested in an insulated type of conductor known as 'aerial bundled conductor' to replace the conventional open-wire non-insulated conductors. This type of construction is far more resilient to tree-related faults since conductor clashing (when a tree branch falls onto the line) is no longer an issue. Moreover, the conductor attachment to the wooden supports incorporates a weak-link provision so that in the event of a tree falling onto the line, the bundled insulated conductors will break away from the support rather than cause the wooden poles to break. This eliminates the risk of uninsulated conductors remaining live while on the ground and enables a much quicker repair and restoration of supplies.

Factors of Safety

The components of transmission and distribution overhead lines are designed to a factor of safety of between 2.5 and 3.5 based on the stresses they would experience under severe weather conditions – i.e. high wind speeds and conductor ice-loading. However, due to the apparent effects of climate change, the expectation is that the power system will in future be exposed to increasingly frequent and severe windstorms and blizzards requiring further mitigation measures. Both transmission and distribution network operators (TOs and DNOs) are taking steps to learn from the findings of Ofgem's report into Storm Arwen in respect both of network performance and customer experience. For example, DNOs will give greater attention to assessing the residual strength of wood pole supports using non-invasive diagnostic techniques such as ultrasound rot detection; maintain adequate tree clearances; increased use of insulated conductor designs for LV networks (damage to which accounts for the majority of protracted supply restorations due to their particular vulnerability to tree related damage); and undergrounding in exceptional circumstances. Attention will also be given to increased monitoring of LV networks so that localised supply interruptions can be more easily identified, and to systems to improve call-centre intelligence so that interrupted customers can be given more realistic restoration time estimates, and vulnerable customers enrolled on DNOs' Priority Services Register can be more easily identified and contacted.

Communications systems
Whilst the physical resilience of electricity networks and the capability of DNOs' network monitoring and call-centre systems are important areas for attention, so too is the resilience of public telecommunications systems which support the public telephone system and the internet. A report by The Royal Academy of Engineering, The IET, and Lancaster University – 'Living without Electricity' describes the impact on the City of Lancaster following Storm Desmond which brought unprecedented flooding to North Lancashire and Cumbria in December 2015. A key finding from the report was that whilst the wired telephone system powered from batteries in the telephone exchange continued to operate over most of Lancaster, the mobile phone systems did not hold up due to limited battery back-up at the base stations which resulted in an inability to send or receive text messages or to use 3G and 4G internet services: http://wp.lancs.ac.uk/floodarchive/files/2019/09/Accessible-LU-2016-Living-without-electricity.pdf Given the interdependences between an increasingly digitalised national electricity grid and the national telecommunications systems, it will be important to ensure the adequacy of the telecommunications system in terms both of its data handling capacity, and its capability to withstand a prolonged supply interruption. It will also be apparent from the above that ensuring the cyber resilience of the telecommunications systems will also be essential and remain under continuous review in light of emerging threats.

Overall network design implications
Taken together, the need for greater physical and operational resilience, as well as increased power handling capacity as we become increasingly dependent on electricity, are factors which should be designed-in to future network investment strategies, whatever the primary investment driver in the case of any given network asset.

Storage and flexibility

- **What developments, including technological developments, and incentives are required in the areas of:**

1. **storage**

   As we described earlier in our response, the adaptation of the electricity and wider energy system to accommodate new sources of renewable and other non-carbon emitting generation will include the provision of sufficient storage facilities as per the following examples:

   - Short-duration energy storage, usually in the form of battery energy storage systems (BESS) to provide ESO ancillary services such as quick and slow reserve, and various frequency response services. Fully charged lithium-Ion batteries can typically export energy for a duration of up to 2 hours.

- BESS can also help relieve distribution network constraints and limit the need for curtailment of wind and solar PV export at times of low demand – especially when co-located with onshore wind and solar PV farms. For example, when demand is low and hence the local network might be unable to absorb the full export capacity of a wind or solar PV farm, part or all of the generation output can be used to charge the co-located BESS. When demand increases the BESS can then supplement the output from the generation and export power to the network, possibly helping release upstream network capacity.
- In addition to short-duration energy storage, it is important to recognise an increasing need for long-duration energy storage, as dispatchable forms of flexible generation such as gas-fired generation (CCGTs and OCGTs) are gradually displaced. On cloudy calm days, the combined export from wind and solar PV generation might on occasions be unable to make insufficient contribution to overall national generation export (and interconnector import) to meet national daily peak demand. Such anticyclonic weather conditions can sometimes persist for several consecutive days. It follows that forms of energy storage that can be used to produce electricity will need to be sufficient in terms of power rating and duration to reduce the risk of supply deficits to an acceptable level.

  One possible option might be to build (or convert) CCGTs and/or OCGTs to use hydrogen instead of methane, hence providing a carbon-free form of dispatchable flexible generation which would be able to export continuously subject to the amount of hydrogen available. One conceptually attractive option is to produce hydrogen through electrolysis (green hydrogen) using surplus wind power - i.e. when aggregate wind farm export would otherwise exceed national demand and interconnector export requirements, and hence have to be curtailed. Although conceptually attractive, such a strategy would be dependent on the availability of hydrogen storage and transportation infrastructure, and the overall economics of this energy arbitrage solution to the need for dispatchable forms of electricity flexibility. That in turn might be dependent on UK's overall hydrogen strategy, including in respect of both production and end-usage, the scope for blue hydrogen production, and the scope for hydrogen as an alternative fuel for transport (HGVs, rail and marine) and for industrial processes and (possibly) domestic space and water heating.
- Other longer-duration energy storage technologies which have the potential to make a contribution to the electricity system in terms of system balancing and mitigating tight supply margins include pumped hydro, flow batteries. liquid air energy storage, compressed air energy storage and gravity energy storage.

The above example illustrates the need from a whole energy system perspective for not only electricity storage but other forms of energy system-related storage, including hydrogen and, in respect of blue hydrogen production and CCGTs with CCUS, the need for (and economic feasibility of) both hydrogen and CO_2 storage facilities – for example salt caverns and depleted North Sea gas fields.

Overall, there is an urgent need for a techno-economic appraisal of the options for ensuring sufficient dispatchable flexibility under all future credible weather system scenarios, taking account of potential changes in weather systems as a consequence of global warming, for example as yet unknown impacts on the Jet Stream and Gulf Stream, which might lead to more frequent and prolonged weather-blocking events, and more extreme ambient temperatures.

2. **transmission and distribution**

   We have described above how TOs and DNOs are adapting their networks, both to accommodate new forms of low-carbon electricity generation and demand, and to make their networks more resilient to the effects of climate change. We have also outlined the incentives put in place by Ofgem with regard to quality of supply performance. In respect of the transmission system operability, we would refer again to NGESO's Operability Strategy report which refers to various developments, in particular under its 'Pathfinder' series of projects. Along with ESO and TOs, DNOs continue to explore innovative solutions to emerging operability challenges in many cases funded through Ofgem's Strategic Innovation Fund (SIF) and their Network Innovation Allowances (NIA).

   Technological development priorities for DNOs include enhancements to monitoring to provide increased visibility of power flows and voltages (and hence emerging constraints); various advanced distribution system management techniques to maximise available network capacity headroom for accommodation of low carbon generation and demand; further improvements to network efficiency and reliability, including thorough better modelling and diagnostic techniques; and improving customer service. DNO's innovation strategies can generally be found on their websites. The Energy Networks Association has also published an Innovation Strategy on behalf of its member companies.
   https://www.enwl.co.uk/globalassets/innovation/innovation-strategy/innovation-strategy-downloads/ena-national-innovation-strategy-2022.pdf

3. **demand management and flexibility**

   The need for flexible supply-side capacity
   NGESOs Future Energy Scenarios https://www.nationalgrideso.com/future-energy/future-energy-scenarios illustrate an increasing need for flexible capacity as conventional dispatchable generation is displaced by inflexible (or self-dispatching) generation such as weather-dependent renewables. Available sources of flexible capacity (other than retained thermal generation including nuclear) are assumed to include interconnectors, electricity storage, demand-side response, and electric vehicles – including vehicle-to-grid (V2G) capability. Given a future high dependency on non-flexible weather-dependent generation it will be important from both an economic and greenhouse gas emissions perspective to be able to call on these sources of flexible capacity for real-time electricity system balancing, including by real-time alignment of demand with zero carbon / zero-marginal cost generation as far as is practicable.

   The role of smart meters and time-of-use and dynamic tariffs
   An important driver of demand flexibility will be the promotion of time-of-use and (ideally) dynamic tariffs for domestic and small commercial customers. Such tariffs are already offered by some energy suppliers, but their application is currently limited by progress in the electricity smart meter installation programme. Completion of the programme will enable half-hourly settlement to be based on actual, rather than

profiled, consumption for these classes of customer and hence enable cost-reflective electricity pricing, including through incorporation of time-of-day distribution use of system charges (red, amber and green band charges) thereby also better reflecting the marginal cost of network capacity.

The role of demand-side flexibility in ancillary services

In addition to system balancing applications, flexibility markets also have a role in enabling ancillary services to NGESO and DNOs. For example, ESO will use BESS as a source of operating reserve and frequency response, and demand management as a means of mitigating anticipated tight supply margins - as has been demonstrated by their Demand Flexibility Service (DFS). DNOs also look to flexibility markets to provide network constraint management services which in the right circumstances can enable economic deferral of network reinforcement (for example where temporary deferral might lead to greater clarity as to the scale of reinforcement required and hence reduce the risk of stranded investment due either to under or over investment). Ofgem has recently consulted on 'The Future of Distributed Flexibility' through a call for input with the objective of a creating a common vision for distributed flexibility: https://www.ofgem.gov.uk/publications/call-input-future-distributed-flexibility

A single co-ordinated market for distributed flexibility

Under a separate consultation on the future of local energy institutions and governance, Ofgem proposes assigning a market facilitation function to a single entity with sufficient expertise and capability to deliver more accessible, transparent and coordinated flexibility markets: https://www.ofgem.gov.uk/publications/consultation-future-local-energy-institutions-and-governance

At the time of writing Ofgem is considering responses to this consultation. In principle we can see benefits of a single market facilitator (possibly the FSO) arising from improved coordination, including maximising synergies and minimising (or eliminating) conflicts in procurement and dispatch of flexibility services. However, it will be important not to lose the sometimes-localised value of flexibility (for example for network constraint management). Overall, the objective must be to ensure flexibility can be applied wherever it adds value, but at the same time ensuring that procurement and dispatch of flexibility resources is co-ordinated so as to confer the greatest value to the system - prioritising value stacking for the electricity system (and hence ultimately its customers) over revenue-stacking for flexibility service providers.

In summary, the use of flexible capacity needs to be managed through a coordinated market mechanism to ensure it delivers the maximum whole energy system benefit to customers in terms of providing secure and affordable low (ultimately net zero) carbon electricity.

4. interconnection with neighbouring grids

Interconnectors have the benefit of being able to provide two-way flexibility, i.e. a means of exporting surplus energy (for example when wind and solar PV output exceeds national demand) as well as a potential source of imported energy when supply margins are tight (or negative). Extending Britain's current interconnector capacity (including potentially beyond Northern Europe) has the potential to further increase flexible capacity with the caveat that interconnector flows are determined by wholesale market price differences. In that regard, it is important to recognise that weather conditions might simultaneously affect neighbouring North European countries and hence limit interconnector imports.

A potential future opportunity is that of multi-purpose interconnectors which will allow clusters of wind farms to connect directly with an interconnector. Subject to technical feasibility, this raises the possibility of a true offshore grid which would be preferable to the current 'point-to-point' approach to interconnectors and the 'one-by-one' connection of offshore wind farms to the shore. NGESO's holistic network design (HND) embraces this approach insofar as it envisages the selective application of integrated AC/DC mesh arrangements for connecting clusters of offshore wind farms: https://www.nationalgrideso.com/future-energy/pathway-2030-holistic-network-design/holistic-network-design-offshore-wind

- **How will the expected growth of demand for electricity to power low-carbon technologies such as electric vehicles and heat pumps affect how supply and demand is balanced across the electricity system?**

  Low-carbon technologies such as electric vehicles and heat pumps will present both challenges and opportunities for system balancing. On the one hand they represent significant increases in both annual and peak electricity demand which might on occasions coincide with periods of low output from weather-dependent renewable generation (for example on a cold and calm winter weekday evening). On the other hand, they have the potential to provide flexibility in terms of time-shifting to avoid peak demand periods or at least reduce peak demand. EV smart home charging in particular provides an opportunity for time-shifting EV charging demand to low price off-peak periods. V2G has the potential to go further by exporting to the grid at times of peak demand.

  Heat pumps are less flexible in that customers as a whole will generally want to heat their homes at times of peak demand when they return home from work (typically between 4pm and 7pm). However, opportunities do exist for well-insulated homes by way of pre-heating to avoid the peak demand period and by use of home energy management systems and smart thermostats that can control and/or schedule the heating load on a room-by-room basis according to required comfort levels and times when the room is occupied.

  Given that there will be times, especially during summer months, when renewable generation output exceeds system demand, EV charging will provide an opportunity to reduce the need for curtailment of generation output, with the prospect of either negative tariff prices or credits for providing demand flexibility services.

Governance and institutional arrangements

- **Are the current governance arrangements for the grid fit for purpose? To what extent do the proposals in the Energy Bill address any issues in governance?**

  An important provision of the Energy Security Bill is the creation of a Future System Operator (FSO) who will act as an Independent Strategic Operator and Planner (ISOP).

  A further provision in respect of governance is the creation of Regional System Planners who will exercise governance over local area energy planning. Effective overall energy system governance will depend on the successful and timely establishment of RSPs and ongoing co-ordination between the FSO and the RSPs.

Coordination between the FSO and RSPs will be essential to ensuring regional energy needs are addressed, and opportunities maximised, whilst also remaining aligned with national energy system strategic objectives. The overall objective must be the continuous development of a national spatial and temporal whole-energy system architecture.

- **Does the current Electricity System Operator—or will the proposed Future System Operator—have sufficient powers? If not, what further powers will they need?**

  The creation of an ISOP is an important provision, but it will be essential that the FSO has a whole-energy system remit and is empowered through its authority extending across the energy sector to delivery of both the 2035 and 2050 targets. In that respect some have commented that the establishment of an FSO under licence to Ofgem might compromise the FSO's authority to enforce strategically important decisions, including decisions that might in some circumstances challenge the remit of Ofgem as an economic regulator.

- **Is there enough resource available—across the Electricity System Operator, regulatory bodies, Government, and network companies—to deliver policy, regulatory and industry workstreams at the pace necessary to achieve Government targets? If not, what additional resource is required?**

  ESO, TO and DNO resourcing

  The ESO, TOs and DNOs have generally been adequately resourced in terms of their overall organisational structure and level of expertise. However, there is a risk that the required scale and pace of network capacity upgrades becomes either impracticable, or cost-prohibitive to resource from a supply chain perspective (in terms both of human resources and materials). To scale-up delivery of transmission and distribution system investment to the extent required, will require a review of the current supply chain and further options for outsourcing without losing the benefits of co-ordination and quality assurance. We comment on the role of competition later.

  FSO

  It will be important to ensure that the FSO is sufficiently resourced to deliver its Independent Strategic Operations and Planning function from a whole energy system perspective. Although difficult to quantify, this represents an additional resource (and expertise) requirement beyond that currently available to the ESO.

  Regional System Planners

  A further key plank of resourcing a whole energy system integrated planning capability is the establishment of Regional System Planners (RSPs) which Ofgem proposes the FSO should be responsible for. Although the RSP framework has yet to be finalised (including how many RSP hubs there should be) this represents a very significant ramp-up of resources with the requisite energy planning skill sets at subnational level. It is envisaged that in determining the number of RSP hubs a balance will need to be struck between ensuring sufficient subnational specificity and resource capability. RSP hubs will need to act as a point of consolidation for more regionally disaggregated local area energy plans, combining these into a single coherent multi-vector regional energy plan. It will be a function of the FSO to then reconcile these regional plans with national energy objectives in the formation of a national strategic spatial energy plan.

Overall governance

Whilst adequate attention to the resourcing of both the FSO and RSPs will be essential. there are also resource implications for delivering effective whole energy system governance. High-level options for energy code governance reforms have been subject to a recently closed call for input:
https://www.ofgem.gov.uk/publications/energy-code-governance-reform
Whilst these should deliver improvements in code governance in respect of the electricity (and to some extent gas) system, there is a need to also consider the governance resourcing implications arising from an integrated multi-vector and national / regional energy system perspective.

Is Ofgem fit for purpose as a regulator to deliver the increase in electricity supply and grid connection needed? Should Ofgem have a net zero remit?

A broad coalition of charities, environmental and anti-poverty groups, as well as trade associations representing the breadth of the UK energy industry, have called on the Government to empower Ofgem with a net zero mandate, claiming that progress towards meeting the UK's net zero goals could otherwise stall. Having a specific net zero mandate might be helpful to Ofgem by way of achieving a balance between having regard to (relatively short-term) economic considerations in the interests of customers whilst also having regard to the importance of ensuring delivery of net zero from an energy system perspective. However, that is not to say that Ofgem should be the Energy Systems Architect: that should be the role of the FSO acting as an independent system (operator) and planner (ISOP).

- **Could the introduction of competition in parts of the network be used to reduce the cost to consumers in delivering a net zero power system?**

Potential risks

Whilst competition is often cited as a means of reducing costs, the perceived benefit of introducing further elements of competition in networks would need to be considered against possible risks of compromise to strategic network development. For example, whilst the creation of independent distribution network operators (IDNOs) and independent connection providers (ICPs) may have provided some competitive pressure in terms of service delivery, care needs to be taken that it doesn't compromise the host DNO's ability to fulfil its licence obligation to develop an efficient, coordinated, and economical whole electricity system.

In that regard, treating network extensions to serve newbuild development on a piecemeal basis risks missing opportunities to incorporate longer-term network development needs – either in respect of adjacent developments or in respect of anticipated future load growth in surrounding networks. For example, whilst it might be possible to serve a discrete newbuild development by connecting to an existing DNO LV network, consideration of other factors such as anticipated load growth might justify the establishment of a substation with interconnecting LV cables to the existing DNO network. We do however acknowledge that ICPs whose role is limited to competing for the installation of 'sole-use' assets (e.g. network extensions installed solely to serve a new development such as an onshore wind farm, a solar PV farm, a battery energy storage system, or an EV charging hub) but where the host DNO has approved the point of connection and determined any requirement for upstream network reinforcement could be helpful in supplementing the supply chain, as well as creating market pressure on prices and service levels.

Market-testing
It should in any case be recognised that the great majority of TO and DNO investment is market-tested in terms both of plant and equipment, and installation and maintenance services, through a range of contractual instruments managed through framework agreements and ITTs. Typically, these would include call-off contracts for high-volume plant and equipment, schedule rate contracts for tree management, cable laying and civil works maintenance, and project-specific ITTs (including turnkey contracts where appropriate).

- **Is the five-year business plan cycle appropriate to achieve the overarching objectives of delivering a net zero grid by 2035 and a net zero economy by 2050? How does the pricing review process need to evolve to achieve the UK's strategic objectives on decarbonisation?**

Limitations of a five-year review period
A limitation with the current RIIO framework is that as an economic regulator, Ofgem is generally inclined towards conservatism in determining investment requirements for Britain's transmission and distribution companies, relying on uncertainty mechanisms to enable in-period adjustments to companies' allowances (and hence revenues) as circumstances and investment needs become clearer.

Whilst helpful, these uncertainty mechanisms are not an adequate substitute for committing to a prudent level of anticipatory investment at the offset in order to ensure sufficient network capacity and capability ahead of need. The risk is that the 'need' might arise very quickly as levels of both onshore and offshore generation requiring grid connections accelerate (as they must if we are to meet the 2035 grid decarbonisation target), as electricity begins to substitute gas for domestic heating and some industrial processes, and as electric vehicles begin to displace petrol and diesel vehicles at scale. If the need for network extensions and capacity upgrades then exceeds the capability of companies to serve that need due to lead-times and supply chain constraints, then connections of generation, heat pumps and EV charging infrastructure might be delayed and/or be more expensive due to a market supply/demand imbalance in terms of equipment and human resources.

In summary, a rigid five-year review period is not ideally suited to the needs of a longer-term (to 2035 and ultimately 2050) strategic plan for electricity (and gas) networks. A number of suggestions have been aired publicly, ranging from abolishing the periodic review process completely, to extending the review period beyond five-years (for example based on a 25-year horizon). In the latter regard a possible refinement that has been suggested is to replace the rigid five-year review period with a rolling five-year review such that allowances and incentives could be continuously adjusted to remain aligned with the 2035 decarbonisation and 2050 net zero objectives. A further benefit would be the adoption of an 'open book' approach whereby Ofgem had full visibility network companies' continuously updated asset management plans. Overall governance would be based on project change control principles. Implemented effectively, this should significantly reduce the regulatory burden on both Ofgem and the companies associated with the current regulatory business planning process.

A whole energy system strategic plan
From the perspectives of 'a decarbonised electricity system by 2035' and 'net zero by 2050' the strategic plan needs to extend beyond electricity and (methane) gas. The need is for a whole-energy system / cross-vector long-term, spatially defined development plan (i.e. a plan that sets out not just what and how much needs to be built, but where and by when) taking full account of interdependencies, cross-vector interactions, lead-times, critical paths, potential risks and contingencies, and enabling requirements such as skills, supply chain capability, targeted research and trials, complementary markets, regulation, codes, standards, and overall governance.

At the time of writing, Ofgem is consulting on frameworks for future systems and network regulation:
https://www.ofgem.gov.uk/publications/consultation-frameworks-future-systems-and-network-regulation-enabling-energy-system-future

Planning, local government and communities

- **What barriers are there in the planning process? Do the proposed changes to the National Policy Statements on energy infrastructure address these adequately? Can the grid development required be undertaken wholly under the nationally significant infrastructure project planning arrangements in the Planning Act 2008?**

Background
The Electricity Act 1989 sets out that, with certain exceptions, consent must be obtained for installing and maintaining any electric lines above ground (overhead lines). With certain exceptions, applications for new overhead lines that fall within section 37 of the Electricity Act 1989 are made to the Secretary of State for Energy and Climate Change. The section 37 regime enables views to be gathered on any particular overhead line proposal before the Secretary of State makes a decision to grant consent. All applications for consent are considered by the Secretary of State carefully on a case-by-case basis and a decision is taken on the merits of each proposal.

Nationally Significant Infrastructure Projects (NSIPs)
The Planning Act 2008 introduced a threshold for development consent for overhead lines of 132kV or greater to be considered as Nationally Significant Infrastructure Projects (NSIPs) and prescribed that consent for these projects would be determined under the Planning Act regime, not under the Electricity Act 1989.

The National Policy Statement for Electricity Networks Infrastructure (EN-5) covers overhead electricity lines whose nominal voltage is expected to be 132kV or above. Hence this covers all transmission lines which have nominal voltages of 275kV or 400kV as well as 132kV distribution lines in England and Wales and 132kV transmission lines in Scotland.

Distribution System lines
Whilst it is hoped the above changes will facilitate the process in respect of applications for new transmission lines, they will have no effect on the process in respect of the majority of distribution lines – i.e. lines operating at 11kV and 33kV.

Hence, unless through underground cables, new, or extensions to existing, 11kV or 33kV lines required to connect small-medium capacity onshore wind farms and solar PV farms will still require applications through the section 37 process.

The Electricity Networks Commissioner has been appointed to further explore how the overall lead times for constructing new transmission lines might be further streamlined, in particular so that the ASTI and wider NOA transmission system projects are able to proceed to time.

- **Is land availability a constraint? If so, how can the constraint best be addressed?**

Wayleaves, 'necessary wayleaves' and permanent easements

Notwithstanding improvements in the process for gaining Secretary of State consent for new transmission lines there remains the challenge of obtaining legal consents from landowners, and where applicable tenants, for new transmission or distribution routes over privately owned and/or rented land. Consents may be in the form of wayleaves which are a legal consent by the landowner (and where relevant also the tenant) for the licence holder to erect and maintain a line, but which do not transfer legal ownership or right of way to the licence holder.

Wayleaves may be time-limited and have an expiry date but can in any case be subject to termination following (typically) either 6 or 12-months' notice by the grantor. If no agreement has been reached during the interim period, the grantor must then serve a subsequent notice to remove the line whereupon the licence holder must either take steps to remove (or divert) the line or, if no practicable alternative route exists or can be agreed, apply to the Secretary of State for a 'necessary wayleave'. Such an application will invariably involve a public enquiry. A similar process will apply if a wayleave for a new line is sought but no wayleave or other form of consent is forthcoming.

An option that is sometimes considered is for the landowner to agree to a permanent easement granting rights in perpetuity to the licence holder. In such cases, a significant financial consideration will generally be required based broadly on the capitalised cost of wayleave payments and compensation that would otherwise be payable over the lifetime of the line.

How can communities be encouraged to accept the infrastructure required to increase capacity? What compensation, if any, might be required?

Encouraging communities

One difficulty in gaining the acceptance of communities over which transmission lines are planned to be installed is that the transmission lines will generally confer no direct benefits to those communities in terms reliability or quality of supply. From their perspective the installation works are likely to cause some disruption to their daily activities, and once erected the lines are likely to be regarded as a visual intrusion. Acceptance therefore depends on communities understanding the indirect benefits – for example in terms of decarbonisation of electricity production and national security of supply.

Practical steps towards acceptance might include environmental mitigation measures to either (or both) reduce the visual intrusion and/or undertaking some form of amenity improvement unconnected to the transmission line installation. However, a transmission line will typically cross many communities over its route and so the overall cost of such amenity works will need to be managed.

Compensation

There is a nationally agreed (and regularly reviewed) schedule of rates for wayleave payments in respect of lines erected over agricultural land. In addition to annual wayleave payments, compensation is also payable to cover aspects such as land loss and yield loss, and to compensate for constraints on irrigation and harvesting activities as a result of the line.

Shared national and regional objectives

Whilst individual communities affected by national strategic infrastructure proposals (whether energy or transport system related) will understandably be concerned to minimise disruption and/or loss of amenity (or aesthetic impact) clearer forward visibility of proposals and their purpose might lead to more positive engagement and timely acceptance. In the case of electricity infrastructure, there is limited understanding by communities of the interdependencies between renewable or carbon-free generation, electrification of heat and transport, and the need for power system extensions or upgrades. A shared whole-energy system development strategy identifying not only the infrastructure implications but also the economic and environment benefits to the nation (and hence ultimately individual communities) might at least enable a more constructive conversation.

Overall considerations

Notwithstanding all the above, the scale of transmission infrastructure newbuild and upgrading required under the current Network Options Assessment (NOA) creates a risk of cost escalation, not only in terms of costs associated with compensation payments and consideration (for permanent easements) and the possibility of landowners obstructing progress by creating 'ransom strips', but the potential also for precedents to be set in respect of existing wayleave grantors' expectations. This risk extends to distribution system lines, the GB population of which at approaching 300,000km aggregate route length exceeds the current aggregate onshore transmission system route length by a factor of around 12.

This is an issue which we feel requires specific attention by government and the Electricity Networks Commissioner to ensure that the costs of securing consents for new overhead (or indeed underground) lines doesn't lead to an unacceptable long-term legacy for energy consumers. In respect of transmission lines designated as nationally strategic infrastructure projects, the 'necessary wayleave' process referred to above would ideally be streamlined such that only in exceptional cases would a public enquiry be initiated (for example in the case of lines crossing AONB's or conservation areas, or if there was substantial evidence of harm to wildlife habitats). Moreover, there should be inbuilt protection against termination such that only in exceptional circumstances (decided by The Secretary of State) could a notice of termination in respect of a necessary wayleave be issued by the landowner and/or tenant.

- **What potential is there for community energy schemes to contribute to sustainable electrification? How can they be encouraged to develop?**

Energy communities can be physical or virtual. A physical energy community offers the potential to socialise, within a specified community, the benefits of optimising distributed energy resources (DER) such as local generation, or consumer energy resources (CER) such as micro-generation, home energy storage and home EV charging (including V2Hor V2G) to maximise market opportunities for export whilst minimising their import costs. This might include local (peer-to-peer) trading within the community.

Experience of energy communities to date shows that they engender enhanced energy awareness among their members, which contributes to a willingness to participate, for example, in flexibility programmes and smart systems. These aspects are likely to be valuable in achieving net zero goals using the most economic solutions.

A virtual energy community could constitute a virtual power plant (VPP) where the aggregated community consumption or generation profile is able to support wider system balancing or provide ancillary serves such as reserve. It is possible, for example, to envisage communities of EV owners with smart chargers participating in such a scheme managed by an energy retailer or possibly a charge-point provider.

An important consideration in respect of local energy community schemes is that benefits to customers who have the option to be served by a mini-grid, or participate in an energy community, are not at the expense of customers who reside in locations where such opportunities are not available, or who for other reasons are unable to take advantage of such opportunities. In particular, it will be important to ensure consumers served by an energy community continue to make appropriate contributions to transmission and distribution use of system charges.

What role are local authorities playing in delivering the Government's targets to decarbonise the grid by 2035? Should net zero energy plans be mandated at a local level?

At the time of writing, Ofgem is undertaking a consultation exercise on the future of local energy institutions and governance which envisages the creation of Regional System Planners (RSPs):
https://www.ofgem.gov.uk/publications/consultation-future-local-energy-institutions-and-governance

RSPs will work with existing electricity and gas network operators, heat network operators, onshore wind and solar PV generation developers, newbuild developers, public EV charge-point installers and other relevant local stakeholders to create holistic regional energy plans. Co-ordination between local area energy planning undertaken by RSPs and strategic national energy planning undertaken in future by the Future System Operator (FSO) will be essential. If done well, this should help achieve net zero by identifying place-specific energy challenges and opportunities that would be opaque from a centralised energy planning perspective, and at the same time ensure that local area energy plans are aligned with the national net zero objective.

Key challenges in establishing RSPs are likely to include the recruitment and training of human resources and the allocation of sufficient dedicated budgetary provision. Consideration should be given as to how distribution system operators (DSOs) which all DNOs are currently developing might help establish regional whole-energy system planning capability.