National Grid Electricity System Operator

Response to National Infrastructure Commission: Second National Infrastructure Assessment - Call for Evidence

Introduction

National Grid Electricity System Operator (ESO) is responsible for the real time balancing of electricity on the GB electricity network. We use our unique position, at the heart of the GB electricity network, to consider how energy use may change in the future, and the capability of the GB electricity network to meet these changes.

National Grid ESO's response to the Call for Evidence is focused on the NIC's Second Assessment priority area of *Reaching Net Zero*, based on our experience, expertise and our position within the energy sector.

Our Future Energy Scenarios

Each year we publish the Future Energy Scenarios[1] which represent a range of different, credible ways to decarbonise our energy system to deliver net-zero by 2050.

Our submission is therefore based upon the analysis published in our 2021 Future Energy Scenarios which can be found on our website[2].

Key points of our response

- The deployment of the infrastructure to accommodate flexibility from a diverse suite of technologies is crucial to operating a decarbonised electricity system, where the supply and demand of energy needs to be balanced over different timescales.
- The nature of peak demand on the electricity system will change - high renewable output will activate flexible sources of demand (e.g. electrolysis or Electric Vehicle (EV) charging) that operate in addition to typical consumer demand. These time periods present a challenge of very high flows on transmission and distribution infrastructure.
- The Government and relevant planning and approval bodies should prioritise improving the pace at which electricity transmission infrastructure can be approved for build, as it is currently outpaced by the rapid growth of renewable connections.
- New energy system infrastructure should be planned at a strategic level that encompasses the whole system. Where necessary, planning should consider anticipatory investment to avoid subsequent delays to connecting clean forms of generation.
- Coordination is required across system operation, policy, regulation and planning to consider the way we connect new generation and flexibility to the power system
- Domestic energy efficiency measures must be considered as part of the UK's infrastructure needs, as they can offset requirements for larger, low carbon infrastructure investments and improve the effectiveness of low carbon heating technologies for consumers.
- Without an EV infrastructure strategy for the UK, the correct signals for investment will not be sent to infrastructure providers. Longer lead times for EV infrastructure delivery could delay the opportunity to provide greater flexibility to the electricity system and risks excluding those who cannot charge directly from their homes.
- Both hydrogen storage and electricity storage are required to meet different energy system needs. Depending on how hydrogen is used to reach net zero 2050, infrastructure for its storage at large-scales may be required to deliver whole system flexibility and manage inter-seasonal swings in demand. As the UK does not currently have active hydrogen storage sites, preparation should begin now due to the lead times involved for community engagement, planning procedures, environmental impact assessments and engineering.
- A Virtual Energy System is required to improve resilience, planning, and operation of the whole energy system of the future.

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[1] Future Energy Scenarios report and supporting documents - https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

[2] Alongside the Future Energy Scenarios report we publish a FES in 5 summary covering the major topics of the larger report. FES in 5 is available here - https://www.nationalgrideso.com/document/174016/download

Response to Consultation Questions

What are the greatest risks to security of supply in a decarbonised power system that meets government ambition for 2035 and what solutions exist to mitigate these risks?

Managing resource adequacy in the transition

1. The electricity sector must decarbonise rapidly to meet net zero and facilitate the electrification of heat and transport. Resource adequacy will need to be carefully managed as the power system continues to decarbonise.
2. Peak electricity demands will increase[3] between now and 2050, meaning generation capacity could need to increase by up to three-fold. As power system decarbonisation progresses, we will see larger and more prolonged periods of excess demand and excess generation. In periods of excess demand, we are currently able to rely on unabated coal or gas to fill the gaps, but as the power system transitions away from these sources to 2035, sufficient supply and demand-side measures will need to be in place to maintain security of supply.

Changing needs and sources of energy flexibility

The decrease in traditional supply-side flexibility

3. We need flexibility to manage the electricity system safely and securely. Sources of flexibility enable us to match supply and demand quickly.
4. Flexibility has traditionally been managed from the supply-side of the electricity system e.g. by increasing or decreasing electricity generation from gas turbines. In 2020, 58% of our total power output from flexible electricity technologies came from natural gas[4]. As unabated fossil fuel generation reduces to 2035 and 2050, this source of flexibility will decrease.
5. The type of flexibility natural gas provides will continue to be important to the whole future energy system. As its use diminishes, alternative solutions are needed. Focus is required to optimise the energy system infrastructure changes needed to deliver zero-carbon energy to consumers[5].

Diversity of flexibility sources

6. Building and maintaining the infrastructure to accommodate a diverse suite of flexible supply and demand side technologies will be crucial to operating the future electricity system.
7. Interconnection capacity, vehicle-to-X, biomass generation, hydrogen production and generation, energy storage (of different scale, duration, and technology type) can all provide flexibility to the electricity system. The degree to which any one technology will contribute to managing renewable generation and peak demands on the electricity system will vary. To reach net zero by 2050, our modelling suggests plausible scenarios of 210GW-230GW[6] of demand and supply flexibility needed on the electricity system by 2050.

Demand-side flexibility

8. Flexibility can be provided by varying demand to match supply, through consumers increasing or reducing demand or shifting the time at which they consume energy. To varying degrees, this type of demand side flexibility can be provided from the residential, industrial, commercial or transport sectors.
9. Though the impact on the electricity system of an individual action is low, research[7] of 20,000 households from a consortium including National Grid ESO indicates that aggregating individual actions could have a significant impact in reducing or increasing demand, depending on what the electricity system requires. This indicated that consumers on dynamic time-of-use tariffs could reduce their peak demand by 7%-14%, with similar results across EV-owning and non-EV owning households.

Electric vehicles and vehicle-to-X

10. Smart EV charging and Vehicle-to-X[8] (V2X) behaviour will play an important role in the future energy system and presents an opportunity to increase electricity system flexibility[9]. The volume of flexibility that this can deliver depends on consumer engagement and V2X uptake. In high consumer engagement scenarios we could see up to

[3] FES 2021 – Key insights – Figure SV.22: Installed electricity generation capacity, storage and interconnection to 2050 pg.112.
[4] FES 2021 – Where are we now? Electricity system flexibility
[5] FES 2021 – Whole energy system flexibility
[6] FES 2021 – What we’ve found. Supply and demand flexibility in 2050 pg.145 Figure FL.3
[7] Energy Networks Association (2021) – Innovation portal: Crowdflex project
[8] Vehicle-to-x (V2X) technologies allow an electric vehicle to export the energy within its battery for another use, for example to a home or to the electricity grid. This offers additional flexibility to the energy system and a potential revenue source for businesses and consumers.
[9] FES 2021 – What we’ve found: Transport flexibility pg.148

32 GW of peak shaving capacity[10] from EVs by 2050. In a low consumer engagement scenario this could be 14GW[11].

11. The distribution of EV charging infrastructure needs to be fair[12] across the UK. This should include reducing disparities in pricing so that those who cannot charge at home are not excluded and are treated fairly, and the electricity system can harness the full flexibility potential of this technology.

12. The lack of a clear EV infrastructure strategy for the UK creates uncertainty, and risks not sending the correct signals for investment. This could delay an opportunity to reduce the costs of operating the electricity system, and costs for drivers themselves.

Energy storage

13. Both hydrogen storage and electricity storage are required to meet different energy system needs and maintain security of supply[13].

14. Hydrogen storage may be required to store electrolysed hydrogen, provide hydrogen for heating homes and buildings whilst managing inter-seasonal swings in demand, and for use in hydrogen turbines to create electricity.

15. Electricity storage will need to increase significantly[14] to support decarbonisation of our electricity system. Different durations of storage will provide different system benefits. Two to four-hour storage can help meet short periods of peak demand through dispatchable capacity, absorb excess supply or support grid stability. Longer duration storage can help to maintain the system over extended durations of high or low renewable generation output.

Hydrogen

16. As natural gas is phased out and its dispatchable peak generation capability diminishes, hydrogen generation will play a role filling this space during times of high demand and low renewable generation[15].

17. We do not view hydrogen as contributing significantly to meet demand outside of these periods. It could provide between 13GW – 21GW of capacity by 2050, depending on the extent of the hydrogen network rollout, the conversion of UK gas networks to support hydrogen transmission and overall demand.

Electrolysis

18. In a future with high levels of renewable generation, there will often be times of renewable output exceeding demand. Electrolysis could be incentivised to operate and respond to electricity prices and market conditions e.g. to produce green hydrogen at times of high renewable generation. Our modelling suggests 32-58GW of total electrolysis capacity is plausible by 2050[16].

19. The sub-optimal siting of electrolysers and their associated infrastructure could risk increasing network costs and constraints. Planning of electrolyser deployment must consider a range of factors to create maximum value for the energy system. For example, energy storage facilities should be available close by or on-site, or available hydrogen network infrastructure for hydrogen transportation.

20. Low carbon heating, electrolysis and hydrogen networks need to be planned and delivered in a coordinated manner. New infrastructure across these areas should aim to minimise assets, maximise consumer benefits and deliver against milestones to 2035 and to net zero by 2050.

Security of supply

Digital infrastructure

21. Data is important to operating a decarbonised electricity system that keeps costs low for consumers. For strategic planning and decision-making, we need to accurately model how the system might behave if changes across technology, regulation and policy are made. In collaboration with industry, the ESO is leading the development of a Virtual Energy System[17]- a real-time replica of our entire energy landscape which will work in parallel to our physical system, where we can share data and model and test scenarios to make our decision-making more robust. When planning new energy infrastructure, we recommend that when the Virtual Energy System is operational, asset owners should develop corresponding digital twins, based on a common standard, so they can connect to it directly.

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[10] FES 2021 – *Consumer Transformation Scenario* – Transport flexibility. Figure FL.11: Difference in 2050 between unmanaged EV demand and net EV demand after smart charging and V2G

[11] FES 2021 – *System Transformation Scenario* – Transport flexibility. Figure FL.11: Electric vehicle charging behaviour at Average Cold Spell winter peak system demand pg.149

[12] FES 2021 – Where are we now? pg. 59

[13] FES 2021 – What we've found. Whole energy system flexibility pg.141

[14] FES 2021- What we've found. Electricity storage pg. 152

[15] FES 2021 – What we've found: Hydrogen generation pg.126

[16] FES 2021 – What we've found: Electrolysis pg.150

[17] National Grid ESO (2021) – Virtual Energy System: Powered by National Grid ESO

22. With increasing levels of data from the energy system available as we move towards 2035, consideration should be given to the digital infrastructure required for decarbonisation, as relying on current internet protocols may not be the optimum approach to ensure security of supply.
23. Energy is relied upon for the economy and society to function, and discussions need to start now to plan the Critical National Infrastructure required to deliver a highly digitised energy system of the future.

Whole energy system resilience

24. Climate change presents an increasing risk to the whole energy sector. Extreme weather events or shifts in climate patterns could damage infrastructure and assets that are vital to delivering power, which could disrupt the economy. There is a need to consider energy resilience and emergency management in detail. This should include a single point of coordination for the strategic management of emergencies, resilience assessments and standards across different networks. As part of this, the interactions, and vulnerabilities between current or planned parts of the whole energy system should be identified and mitigations developed to address them.

Future system planning

25. As more renewable energy generation is connected to the electricity network, there is a requirement for building additional transmission infrastructure to allow electricity to flow where it is needed. Consumers pay for further investment in the transmission system and the costs of balancing flows through the transmission system. To achieve the lowest overall sum of these costs for consumers, we use a Network Options Assessment.
26. Increasing renewable generation means that the transmission system will get bigger, increasing the costs of balancing the system in the short term and the cost of investing in the system in the longer term. Though the deployment of high quantities of offshore wind needs to occur quickly for government targets to be achieved, the timescales for building the required transmission to relieve network congestion is longer. The result of this, combined with a rapidly changing generation mix, is that constraint costs will increase up to the 2030s.
27. As we move to a more renewable dominated electricity system, it will be important to ensure that the benefits of more anticipatory investment are realised as far as possible through a clear articulation of the opportunities they present for connection to, and use of, the system.
28. A holistic approach to future network planning and design is required to deliver the infrastructure to achieve net zero. To deliver optimum energy engineering solutions that consider economic, environmental and community impacts and address the pace of transmission build, future system planning should follow the approach of the Holistic Network Design[18] (HND). Following this approach allows a long-term, coordinated view of the energy system rather than an annual or shorter-term, iterative approach to building new infrastructure.

Market Reform

29. There is growing industry sentiment that the existing designs for electricity markets require reform to: support a carbon-free electricity system by 2035; address the mismatches between where energy is generated and where it is consumed and send the correct investment signals to asset owners.

30. Electricity markets, regulation and policy must be designed to provide clear, consistent signals to investors and market participants, and deliver a fair and just transition for current and future consumers.

31. The ESO's Net Zero Market Reform[19] programme is developing new market design options that will support the development of our power system and ensure we have the resource adequacy and flexibility we need to keep the lights on and reduce costs.

What evidence do you have on the barriers to converting the existing gas grid to hydrogen, installing heat pumps in different types of properties, or rolling out low carbon heat networks? What are the potential solutions to these barriers?

32. Our 2021 Future Energy Scenarios[20] indicate that the decarbonisation of heat is likely to require a mixture of heat pumps, hydrogen and heat networks, with different low carbon solutions across geographies. Regional factors such as building stock, housing density, proximity to hydrogen production and renewable electricity installations will affect how homes and buildings are heated.

Delivering energy efficiency for the low carbon heating rollout

33. Previous analysis indicates that future low carbon technology choices do not vary the cost of the energy system significantly towards 2050[21] but that costs are kept lower when energy efficiency is pursued.

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[18] National Grid ESO (2021) – Holistic Network Design
[19] National Grid ESO (2021) – Net Zero Market Reform
[20] FES 2021 – What we've found: Different regions, different heating types pg.53
[21] FES 2020 – Analysing the cost of each scenario

34. Our new spatial heat model[22] has given us a more granular view of residential heat and opportunities for moving heat demand within the home.
35. In England and Wales, the median Energy Performance Certificate rating is a Band D[23]. For a rollout of hydrogen and heat pumps to be successful in reducing demand, keep costs low and efficiency high, energy efficiency improvements to properties are required.
36. The Government must act boldly and identify how it can deliver energy efficiency improvements to buildings of all types in a fair way for all. This is a no-regret policy priority because reducing demand reduces the costs of energy security and improves benefits for consumers.
37. In our most ambitious scenarios that reach net zero, we assume that new homes built from 2025 meet the Future Homes Standard, which will make them optimal for heat pumps and could aid heat demand savings of up to 85TWh annually by 2050[24].
38. The discussion on the rollout of heat pumps needs to be more granular. There are a variety of heat pumps available including high and low temperature, water based, air based, ground sourced. Each heat pump variant will be best applied in a slightly different setting.
39. Though available infrastructure will be a factor[25] in the low carbon heating choices available in different regions, it will be critical that the transition to low carbon heating is delivered in a way that puts the needs of consumers at its heart. Different heating solutions will require different changes within the home when installed. Consumers will need unbiased information that they can trust on the changes that would best suit their properties. Financial incentives may be required to overcome cost hurdles, and protections would need to be in place to deliver this transition fairly.

Heat networks

40. We model credible pathways to reaching net zero by 2050 that include low carbon heat networks (LCHNs). LCHNs are suitable for decarbonising heat but are unlikely to be deployed in areas of low housing density. This could limit their potential to around 4 million homes by 2050[26].

What barriers exist to the long-term growth of the hydrogen sector beyond 2030 and how can they be overcome? Are any parts of the value chain (production, storage, transportation) more challenging than others and if so why?

Long-term growth of the hydrogen sector

41. Hydrogen is essential to achieve net zero as it will support decarbonisation in different parts of the economy – particularly some of the hardest to abate sectors such as industry, heat or non-passenger transport. The role of hydrogen in the future of heat is uncertain, as a final decision is yet to be taken by the Government. Until this is resolved, it remains a barrier to the long-term growth of the sector. The areas of the economy in which hydrogen is used will determine the production levels required, the way in which hydrogen is stored and the way it is transported. The right incentives and signals will need to be in place to deliver the required supporting hydrogen infrastructure in a timely manner as government decision-making progresses.

Hydrogen storage

42. Hydrogen storage is necessary to support whole energy system security of supply, as well as to accommodate electrolysed hydrogen at times of excess wind or solar. This storage capacity could act as a sink for renewable energy generated when demand is low and make it available for later use. Despite low round-trip efficiency, H2 storage has the potential to manage seasonal differences in demand for heating, provided that sufficient hydrogen storage capacity is available.
43. We assume[27] that hydrogen will be stored in salt caverns, as is currently the case with natural gas storage. By 2050, the electricity system may require 50TWh of hydrogen storage to manage winter demand.
44. Clarity on suitable hydrogen storage sites is required. A recent[28] study indicated that the UK has a theoretical hydrogen storage capacity of 3000 TWh. However, when small sites are discounted, this drops to 200TWh.
45. Hydrogen storage infrastructure delivery is likely to take time. Environmental impact assessments, planning procedures and geological engineering work will all be required, meaning that discussions on the necessary

[22] FES 2021 - Regionalisation
[23] Energy efficiency of housing in England and Wales: 2021
[24] FES 2021 – Thermal efficiency measures and consumer behaviour change. Figure CB.12 Annual savings in underlying heat demand from both improvements to building fabric and consumer behaviour changes.
[25] FES 2021 – Key insights pg.46
[26] FES 2021 – Figure CV.17: District heat networks in 2050 (page 52).
[27] FES 2021 – Hydrogen Supply: Overview of hydrogen storage
[28] British Geological Survey 2020 - Theoretical capacity for underground hydrogen storage in UK salt caverns

infrastructure should begin as soon as possible. Any discussion should consider the importance of public sentiment and engaging communities on the matter.

Hydrogen transportation

46. Until a decision is made on the way that homes and buildings are heated in the future, the role of the existing gas national transmission system (NTS) infrastructure in hydrogen transportation is unclear[29]. If homes and buildings have mostly hydrogen boilers for heat, the NTS could be repurposed to carry hydrogen. If hydrogen is more limited to industrial clusters, a part of the NTS could be converted to transport hydrogen between them.

What are the main barriers to delivering the carbon capture and storage networks required to support the transition to a net zero economy? What are the solutions to overcoming these barriers?

47. CCUS will need a network build-out for transportation and storage (T&S) of carbon dioxide. For it to function, a system operator is likely to be required to oversee the day-to-day operation, manage and administer charges for the use of the T&S system and take decisions on enhanced T&S network planning.

[29] FES 2021 – the natural gas network in a net zero world pg.95