Electricity Transmission

Our resilient Whole System approach

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nationalgrid

We own, manage and maintain the 400,000 volt (400kV) and 275,000 volt (275kV) electricity transmission system in England and Wales.

The transmission network is like the motorways and dual carriageways of the electricity system, while the distribution system is like the smaller roads that deliver the electricity to homes and businesses. Transmission like the motorways for traffic, allows highly efficient bulk transfer of energy, with over 98% of the energy entering our network reaching its destination. This makes electricity transmission, allied with renewable generation sources, an incredibly green solution for transporting energy from locations off-shore and from the countryside to our towns and cities without losing energy along the way.

Our need as a nation to deliver Net Zero greenhouse gas emissions by 2050 is driving wider changes to the energy landscape. Fossil fuels such as oil, coal and gas are being phased out with a need to replace these fossil fuels with alternative forms of energy including electrification utilising renewable sources, battery technologies, hydrogen and bio-fuels all of which are likely to have a role to play in this transformation.

Smaller-scale sources of wind and solar generation are also connecting directly to the distribution network, creating a more complex system to manage. And consumers are using new technologies to manage their electricity demand – increasing energy efficiency in homes and businesses.

Therefore, there is an ever-growing need manage this transformation of energy and infrastructure on a Whole System basis to determine the best energy solutions for UK consumers and business. We have an important role to enable a resilient and reliable network securing a greener Net Zero future. That is why we are working to build a fairer and more affordable energy system, with Whole System at the heart of this approach.

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Introduction to the Whole System

Whole System is a term often used to describe design that considers a holistic approach to a topic, subject or the built environment. In the case of energy, a Whole System approach can be defined as follows:

The Energy Whole System comprises the interactions between electricity, gas (methane, hydrogen, bio-gas) and liquid fuels (oil and bio-fuel). Then, how those energy sources best contribute to delivering Net Zero greenhouse gas emission energy for technology, communications, transport, heat and water. The best mix of energy should provide economic, reliable and resilient green energy for UK society.

The roles of each energy type have largely been defined by use over the past century, with little regard to greenhouse gas emissions:

- oil has dominated the transport sector;
- gas has largely been used for heating homes, businesses and thermal industrial processes (including electricity generation);
- electricity has provided energy for technology, lighting and industry (largely generated from coal and gas fired power stations).

With the publication of the Committee on Climate Change (CCC) Net Zero report and subsequent adoption by the UK government, the UK is committing to moving away from fossil fuels providing energy to our homes and businesses. This has been further emphasised in December 2020 with the publication of the Energy white paper which added further detail to the Prime Minister's ten point plan for a green industrial revolution. Consequently, this means adopting alternative sources of energy to power our homes, transport and businesses.

Electricity is now moving to greenhouse gas-free methods of production including larger use of renewable sources, offshore and onshore wind, solar energy and a new generation of nuclear generation. The National Infrastructure Commission have recently published evidence that renewable generation can be increased to 65% of supply by 2030 at no adverse cost to consumers, enabling the decarbonisation in part of sectors such as transport and heating via electrification. With the long-term ambition to make the majority of our electricity supply year-round greenhouse gas free, electricity can play a significant role in decarbonising the UK economy.

Hydrogen is an abundant gas which can be produced in large quantities as a source of energy. hydrogen can be used for both combustion or via fuel cells to produce electricity. Combustion of hydrogen is cleaner than burning traditional methane gases and with control of Nitrous Oxides (NOx) production will minimise any emissions. Fuel cells can be used to produce electricity from hydrogen, for basic electricity storage, or to use fuel cells to power electric transportation including trains and road vehicles. Hydrogen can be produced from Steam Methane Reformation (SMR) with carbon capture use and storage (CCUS) techniques commonly called Blue hydrogen. Hydrogen can also be produced by electrolysis of water freeing the hydrogen and oxygen atoms with no greenhouse gas pollution, known as Green hydrogen. With the ability to produce hydrogen in significant quantities, it has a significant role to play in achieving Net Zero greenhouse gas emissions, both as an energy source and in energy storage.

Biofuels are sources of energy produced via natural processes including plant-based fuels and microorganism-generated fuels. These fuels are considered carbon neutral, as they consume carbon in their production via growing plants or anaerobic digestion of microorganisms. These fuels (either liquid or gas) can then be used to provide energy for transport, heating processes and other energy requirements. Examples of biofuels are alcohol, bio-methane, bio-diesel and bio-kerosene. These products are generally used for combustion so can produce greenhouse gas bi-products such as NOx and other particulates in the air. The CCC Net Zero report recommended using these fuels for the hardest-to-decarbonise sectors such as aviation, and production is limited by land use and by production facilities needed to create biofuels.

Synthetic fuels are chemically engineered fuels based upon hydrogen and carbon – the carbon can be extracted from the atmosphere making these fuels carbon neutral. These fuels are currently expensive to produce, but can be used to produce other fuels such as synthetic kerosene for the aviation industry and would be again deployed for hard-to-decarbonise sectors. However, like biofuels, these products are generally used for combustion, so can produce greenhouse gas bi-products such as NOx and particulates in the air.

Whole System working

To achieve the Net Zero greenhouse gas ambition, a combination of the energy sources described above needs to be used to replace our existing fossil fuel-based energy sources. Traditionally, each energy sector has worked in silos, with greater interaction within each fuel type but not between fuel vectors. Therefore, the electricity, gas and oil industries been working separately to meet energy needs driven by their markets and structures. Infrastructure for water, transport, electricity, gas, oil and communications have also been designed independently of each other in the past.

The concept of Whole System is to use the best balance of energy, delivering reliable, resilient and economic infrastructure services to the UK economy by considering the system as a whole and achieving the Government objective of a Net Zero economy by 2050. Ultimately this means that energy and infrastructure providers would consider alternatives and impacts upon each other to overall deliver the best solution for the UK economy in an integrated way. However, to reach this goal we need to take a structured approach. Starting with improving coordination across the electricity industry in a more strategic approach than traditionally undertaken.

Then to support integrated energy approaches across electricity, gas and hydrogen, for example. Then the build-up of learning can be applied across all energy and all infrastructure. Such an approach also needs to take into account the views of communities, businesses, local authorities and other stakeholders to develop a long-term whole system plan that delivers for the needs of all over the coming years.

The report is structured as follows:

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- **Part 2**
  Our approach to Whole System working
- **Part 3**
  Incorporating Whole System Working within our business plan
- **Part 4**
  Conclusions and next steps.

Part 1
The Whole System challenge

Current UK Energy Landscape

The Office of National Statistics (ONS) produces information regarding energy consumption by sector in the UK. In June 2020, the ONS released the historical actual energy use data in the UK between 1990 and 2018. The last historical data for the 2018 energy landscape is depicted below, showing that 77% of our energy sources currently come from greenhouse gas-producing fuels, mainly fossil fuels. Small changes will have occurred since 2018. However, overall the landscape today will look broadly like 2018 with some impact of Covid19 reducing outputs during the pandemic.

2018 UK historic actual energy consumption by sector (June 2020 ONS data)

Consumption by sector		Largest fuel source
Industry	**264 TWh**	Gas
Transport	**662 TWh**	Oil
Domestic	**480 TWh**	Gas
Services	**254 TWh**	Electricity and Gas
Total	**1,660 TWh**	665 TWh of total is for the production of heat

Energy by source		
Other fossil fuels	**22 TWh**	**77%** (Fossil fuels to be phased out)
Natural gas	**509* TWh**	
Oil	**740 TWh**	
By-product heat	**15 TWh**	**23%** (potentially green energy)
Electricity	**300 TWh**	
Biofuels	**75 TWh**	

* Natural gas total demand rises to 712 TWh when electricity generation included.

The largest source of greenhouse gas emissions currently comes from the transport sector, with oil-derived fuels contributing to the largest impact for transport. Natural gas (methane) is the next largest contributor, mainly used for domestic heating and industrial processes. To achieve Net Zero greenhouse gas emissions by 2050 there is a considerable challenge ahead for the UK.

Committee on Climate Change (CCC) central scenario 2050

As part of the work completed to produce the CCC Net Zero report, a central scenario of energy needs was produced. Given the uncertainty and economic detail required to deliver Net Zero, this scenario is just one of many that can reduce Net Zero greenhouse gas emissions by 2050 and is therefore used here to demonstrate the size of the challenge, rather than as a prediction of the future. The CCC energy landscape depicted below shows how 100% of energy is transitioned to low greenhouse gas emission fuels by 2050.

UK 2050 energy consumption from CCC 'Net Zero' report

Consumption by sector		Largest fuel source
Industry	**~235 TWh**	Hydrogen and electricity
Transport	**~300 TWh**	Electricity
Domestic	**~300 TWh**	Electricity
Services	**~235 TWh**	Electricity
Total	**1,070 TWh**	~400 TWh of total is for the production of heat

Energy by source		
Hydrogen	**270 TWh**	**100% Green energy**
Electricity	**600† TWh**	
Biofuels	**200† TWh**	

† CCC technical report some future process could increase electrical demand to 1200 TWh and bio-fuels to 300 TWh.

The noticeable reduction of energy consumption in transport from 662 terawatt hours (TWh) in 2018 to around 300TWh in 2050 is driven by the move away from internal combustion engines (ICE). ICE vehicles have a whole energy chain efficiency of roughly 20%, with the majority of energy in a car being turned to heat along with motion. Both hydrogen fuel cells and battery electric vehicles have much better energy efficiency and will therefore reduce energy consumption by half without vastly reducing the number of vehicles.

The other noticeable reduction is in domestic energy usage, down from 480TWh in 2018 to around 300TWh in 2050. This is driven by an increase in energy efficiency in our homes, largely through better insulation to reduce heating requirements and new heating technologies being deployed with increased thermal efficiency, including a greater use of electric heat pumps.

Alternative forecasts, to the CCC Net Zero report, can be found in the Future Energy Scenarios 2020 (FES) produced by National Grid ESO. The FES sets out four scenarios to achieve Net Zero, 'Consumer Transformation', 'System Transformation', 'Leading the Way' and 'Steady Progression'. These FES scenarios equally deliver the transition to Net Zero by different approaches. Both the FES and CCC scenarios are updated regularly through the CCC carbon budgets and annual FES updates.

The scale of change, regardless of the energy mix, is going to be significant and if approached in a siloed way will lead to delays, unnecessary cost and bespoke solutions across different areas of the UK. Therefore, if the UK is going to achieve the Net Zero ambition we are going to have to approach this challenge in a focused Whole System way, which delivers for the people of the UK.

Whole System resilience

In May 2020, the National Infrastructure Commission published its report 'Anticipate, React, Recover – Resilient infrastructure systems'. This report proposes greater understanding of the interdependencies between siloed infrastructure systems, with stress tests and long-term plans to address shortfalls in resilience between systems. The report recognises the complexity and changes that will be driven by achieving Net Zero and advocates a Whole System approach to resilience.

Whole System and Smart technology integration

The ability to maximise the capacity and interactions of our energy systems using smart technology, enabling supply and demand to more flexibly interact with the system, is an enabler to the changes needed to meet the Net Zero challenge. This digital technology will provide greater choice for consumers, who will be insulated from the complex interactions required to make the systems work, and will deliver great benefits for consumers. This smart flexibility supporting our energy networks will be able to support more efficient integration of electrification and other greenhouse gas-neutral energy technologies. This will give the consumer further choice in how they charge their vehicle, heat their home or when they use technology to improve convenience of their lives and must be made accessible to all to deliver full benefits to society. As such these smart technologies need to incorporate resilience responses to the technology, ensuring the systems cope with rare energy interruptions and restorations.

Further enabling the market are the future energy charging and access review and the Energy Code Review, which seek to set a level playing field across networks and energy markets to create more access for participants. These changes should allow greater comparison across different networks and energy types to evaluate Whole System solutions on an equal footing between stakeholders. This should allow transparency required to evaluate solutions against common cost benefit analysis (CBA) models. This should give stakeholders and consumers' confidence the most economic and efficient solutions are being taken forward n a collaborative Whole System approach, improving all consumers' benefit.

Part 2
Our approach to Whole System working

Our Whole System objectives

As the owner of the electricity transmission network in England and Wales, we have many interactions with other networks and with the majority of infrastructure in the UK. As a vital connection between electricity producers and consumers, we also impact road, rail, water, gas and communication infrastructure indirectly. As the complexity of these networks and deployment of smart technology grows, it is ever more vital that energy from greenhouse gas-free sources is resilient and reliable. Electricity transmission is used to transport electrical energy from these bulk sources of energy because it is highly efficient and low loss. Increasing the voltage means that high levels of power can be transported long distance, with over 98% of the energy being delivered to its destination. This makes electricity transmission a highly environmentally-friendly way to transport greenhouse gas-free energy from offshore and onshore sources across the UK, with much lower losses that could not be achieved by transportation at lower voltages.

However, it is vital that given the growth of embedded generation and an increase of energy flowing onto the electricity transmission network from distribution level, we accommodate these changes and use a Whole System approach to derive the best solutions. With the increasing need for an energy mix including hydrogen, where economic, electrolysis production of hydrogen may prove a viable solution. This hydrogen production will also provide Whole System solutions and interactions that need consideration. This could include where best to locate electrolysis hydrogen production, how to use hydrogen as storage, whether chosen locations can create competitive markets and can utilise spare off-peak capacity on electricity and gas networks to provide further benefits to consumers.

Given all of these options and alternatives, we believe a Whole System approach best achieves this by us:

"Maximising the utilisation of our existing network through operation, maintenance and innovation to provide greater Whole System opportunities, whilst also enhancing our network, working with communities and stakeholders across energy vectors and other infrastructure networks, to deliver the right Whole System solutions that benefit UK society and economy."

Our approach to Whole System working

By its very nature Whole System working is not something we can do alone and will require collaboration with stakeholders who are directly and indirectly impacted by our network. This has to start with improving our Whole System approach to electricity across the whole sector, whilst starting to reach out to other energy providers. This will require us to take a proactive approach to working with others to derive the best solutions to deliver the energy transition for the UK to achieve its Net Zero ambition. In our approach, we shall aim to be targeted, tailored and proportionate, seeking to strike the right balance to achieving Net Zero.

To do this we shall employ a model approach set out below:

Engage with others	Identify the right solutions	Deliver value to the UK Economy
Agree our approach with our stakeholders and communities	Develop collaborative approach to network and infrastructure solutions	Innovate, improve and promote Whole System solutions

Agree our approach with our stakeholders and communities

It is very important that we work jointly with others to agree our approach with wider stakeholders and communities. This will include consulting with organisations such as The Department for Business, Energy and Industrial Strategy (BEIS), Ofgem, Energy System Catapult, National Infrastructure Commission (NIC), Committee on Climate Change (CCC) and consumer groups among others. Working with organisations such as the Energy Networks Association (ENA) and other network owners and system operators, we can define common frameworks for assessing Whole System solutions.

Develop a collaborative approach to network and infrastructure solutions

Whole System solutions cannot be delivered by one organisation in isolation. They require a collaborative approach with a common set of principles that network and infrastructure owners can agree to work with on any Whole System project. Aligned with this plan, in developing this document we have reached out to other electricity infrastructure providers. We already have strong approaches with the electricity industry with common engagement on planning, however through discussion it is clear that we all want to take a more strategic approach to delivering Net Zero. We are committed to taking this strategic approach and working across energy and infrastructure with others to deliver a coordinated whole system approach.

The ability to work together to design and consider alternatives, to assess the ability of options to meet the need and at what economic cost to consumers is important. Together we need to agree and approve the right investment solutions across our businesses, with a fierce focus on what UK society and economy needs to thrive in the Net Zero future.

Innovate, improve and promote Whole System solutions

We are committed to innovation and our innovation strategy states:

"Our ambition is to make a difference, and we can't make a bigger difference in today's or tomorrow's world than to create a road to Net Zero"

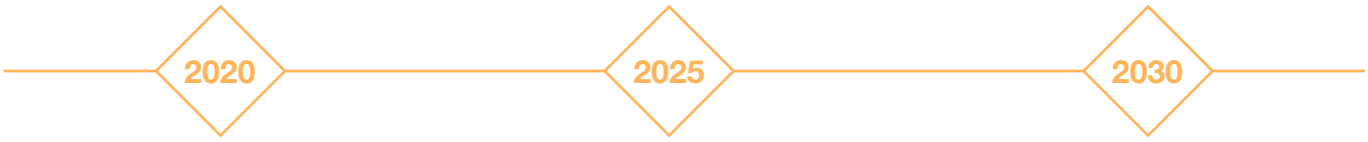
Therefore, being innovative in our approach to deliver Whole System solutions that deliver Net Zero is important to us. We are also continually seeking to improve the way we develop solutions collaboratively with our stakeholders, and how we maximise the utilisation of our network to deliver Whole System solutions. We will also promote Whole System solutions and demonstrate how collaboratively these deliver value to UK society and business, keeping us on track to deliver Net Zero greenhouse gas emissions by 2050.

Part 3
Whole System business plan

As set out in our introduction to this document, we define the energy Whole System as follows:

The Energy Whole System comprises the interactions between; electricity, gas (methane, hydrogen, bio-gas) and liquid fuels (oil and biofuel). Then, how those energy sources best contribute to delivering Net Zero greenhouse gas emission energy for technology, communications, transport, heat and water. The best mix of energy should provide economic, reliable and resilient green energy for UK society.

This is a very broad definition and therefore requires a structured approach to achieve the long-term aim of providing a strong collaborative role across Whole System integration, delivering the Net Zero ambition by 2050. We aim to collaboratively broaden our Whole System approach, from the base of the electricity industry, with whom we have consulted in producing document about expanding our existing joint planning more strategically. Then reaching further across energy vectors and finally across all infrastructure systems. Our proposed ten-year timeline for full integration of a Whole System approach is set out below. This timeline represents the point at which we would expect to achieve maturity in each area.



Starting point

- Establish NGET Whole System Forum and Governance
- Establish pilots to improve electricity industry Whole System working/projects.

Infrastructure transition

- Establish a suite of Whole System projects and promote successes
- Work with other energy vectors (gas and bio-energy) and wider infrastructure (networks, heat, transport, water and comms) to establish resilient Whole System approach.

Delivering the future together

- Consistently working collaboratively across energy vectors and infrastructure to deliver resilient Whole System solutions jointly
- Working with local authorities and government jointly to deliver the UK Net Zero future by 2050.

Starting point

Collaborative Whole System working is a very different from the siloed approach of all networks in the past and will require time for all of us in the industries to establish new ways of working. As part of this, we have set up a Whole System Forum within our business to ensure we maximise the impact of our approach by making Whole System part of our mindset.

Reaching out to our stakeholders, including other networks and Local Authorities, requires undertaking pilot projects to establish our Whole System working processes and procedures. Critical to gaining a collaborative working approach with our stakeholders is establishing the following:

- agreeing which projects to establish as Whole System pilots with stakeholders
- agreeing jointly how we evaluate Whole System projects across different energy networks
- develop data sharing practices between different entities to jointly evaluate solutions
- establish governance approaches to agree Whole System solutions across different businesses
- ensure any changes to codes, standards and regulations are being identified to remove blockers and deliver Whole System solutions for UK society and business.

Infrastructure transition

As we establish a good working set of pilot projects we should be able to define our processes which will have been developed in co-ordination with stakeholders. This refined set of processes, procedures and governance approaches should enable a wider agreement across network and infrastructure providers. The ability to apply a common approach, developed by many infrastructure providers, that allows the assessment of Net Zero Whole System solutions is ambitious. However, working in this coordinated way across all energy and infrastructure networks will help deliver Net Zero as quickly and cost-effectively as possible.

Such examples could be hydrogen electrolysis integration across electricity, gas and water infrastructure networks; or transport provision for new electrified transport solutions in road and rail; or industrial cluster and domestic heat hybrid electric and hydrogen solutions. In the Infrastructure Transition phase we would look to establish large scale pilots of increasing complexity. In addition to the points set out in 3.1, this expansion in complexity will require:

- alignment of codes, standards and regulation across energy vectors and infrastructure
- establishing a common approach to Whole System resilience to ensure interfaces and dependencies are robust to system failure and responsive to co-ordinated system recovery as complexity increases

Delivering the future together

The delivering the future stage would be achieved when networks across energy vectors and infrastructure are fully collaborative and co-ordinated ensuring the Net Zero future is delivered for the UK. There will be common approaches, forums and data sharing to enable the best Whole System solutions to be selected and delivered at pace. Local authorities and government will be fully involved with networks and infrastructure providers to deliver a fully co-ordinated plan that will transform the UK economy. To achieve this along with the points set out in 3.1 and 3.2 above, this final solution will require:

- co-ordinated legislation from Government and development of strategic cross-sector plans for delivering Net Zero
- alignment of resilience expectations across Government, regulators and network infrastructure to ensure an acceptable level of risk is maintained for infrastructure.

Part 4
Conclusions and next steps

Conclusions

To achieve Net Zero by 2050 it is clear a different approach is needed to deliver our energy and wider infrastructure solutions. If we want to deliver an energy system and infrastructure fit for our future needs, whilst minimising the impact on the planet, we need a Whole System approach.

In this document we provided our definition of Whole System as:

The Energy Whole System comprises the interactions between; electricity, gas (methane, hydrogen, bio-gas) and liquid fuels (oil and biofuel). Then, how those energy sources best contribute to delivering Net Zero greenhouse gas emission energy for technology, communications, transport, heat and water. The best mix of energy should provide economic, reliable and resilient green energy for UK society.

We also set out our overall approach to implementing Whole System approach and thinking into our into our way of working going forward including:

- **Engaging with others**
  Agree our approach with our stakeholders and communities
- **Identify the right solutions**
  Develop collaborative approach to network and infrastructure solutions
- **Deliver value to the UK economy**
  Innovate, improve and promote Whole System solutions.

We are committed to taking a proactive approach with our customers and stakeholders to deliver Net Zero. A Whole System approach will provide a more strategic view to deliver for domestic and business consumers. Whilst also ensuring greater coordination, delivering value and resilience to the solutions adopted as part of the energy transition.

Next steps

This document sets out how we propose to establish a Whole System approach to deliver the UK Net Zero ambitions and will be reviewed on an annual basis. We shall look to develop more projects and engage widely across energy and wider infrastructure, to further develop our resilient Whole System approach. This shall include more development of the interactions and benefits associated with green hydrogen production and improved utilisation of our network.

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