Electricity Transmission

Whole System Strategy

PRINCIPAL PARTNER
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DELIVERING THE GLASGOW CLIMATE PACT

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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 offshore 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 biofuels 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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Our Vision and strategic priorities

Our Vision

Our vision is to be at the heart of a clean, fair and affordable energy future. This vision describes 'what' we want to achieve in the long term.

Clean: Our goal is to achieve net zero by 2050. We have a key role to play in the transition to clean energy. We must show leadership, make positive changes and set an example for others to follow. One way that we have shown our commitment to global change is by being a Principal Partner of the COP26 climate summit. Initiatives and projects are taking place right across our business to deliver on our commitments to decarbonise the energy system and achieve net zero.

Fair: The benefits of achieving net zero should be shared across society. To us, a fair transition means is no matter who or where you are, your income or background, everyone should be able to benefit from the clean energy future. No one should be left behind in the transition to a net zero and climate-resilient future. This includes access to clean energy, health, job opportunities and economic development.

Affordable: Energy poverty is a barrier to participating in the energy transition. As a responsible business, we're committed to ensuring everyone can afford to pay for their essential energy needs. This has never been more important than in a world where we're experiencing the effects of a global pandemic, war in Europe, an energy price crisis and the rising cost of living in the US and UK. We recognise the growing challenge energy poverty brings to many households and are working to understand how we can best help, both in the short and long term.

Our strategic priorities

In a rapidly changing world, our purpose remains the same - to bring energy to life. We're doing this by putting National Grid at the heart of a clean, fair and affordable energy future, and we have transformed our business to make it possible. We've achieved many great things on our journey so far, but now it's time to focus on even bigger and bolder goals. We can't do it alone. We'll bring industry experts, governments and communities together to overcome the world's greatest energy challenges and deliver a greener future for all. It's what society demands and what we demand of ourselves. It's the right thing to do for our people and business, our customers, stakeholders and the future of the planet.

- **Enable the energy transition for all:** Climate change remains the defining issue of our generation and time is running out to take action and limit global warming to 1.5C – the world community needs to act now to avoid the worst effects.
- **Deliver for our customers:** We're here for our customers, delivering safe, reliable and affordable energy around the clock no matter what the weather.
- **Build tomorrow's workforce today:** we're creating the place to develop a career that positively impacts energy and the planet.
- **Build the networks of the future now:** We will improve network reliability and resilience to meet future needs and have better visibility and control of our networks as distributed sources of demand and supply increases.
- **Operate safely and efficiently:** We're committed to improving our efficiency to make sure we're not a burden on people's bills. Our ambition is to be a top performer for safety. We want every colleague to go home safely to their families every day and no one to experience a life-changing injury.

Network Strategy to 2035

In 2023, we published our Network Strategy indicating that will take a more strategic, programmatic approach to deliver the energy transition. Three strategic planning principles have been set up to guide the approach:

- **Enabling investments:** We will move away from the current focus on "no regret" investments. We will instead plan and build a network platform today that is ready for future requirements, making sure we are not the blocker to the energy transition
- **Do it once, do it right for the future:** We will plan the scope and timing of network investments to address multiple drivers at once, We will coordinate delivery to reduce system access requirements, increase efficiency and minimise disruption to communities.
- **Whole system network planning:** We will work with other utilities, across vectors, and with stakeholders at all levels to ensure planning and delivery of our future network is coordinated and optimised for UK plc.

Our network strategy also indicated that "*The future development of our transmission network is inherently linked to other energy system infrastructure, and the parties connecting into this infrastructure. We will achieve the fastest and most economic infrastructure solutions for UK plc by working closely with our stakeholders to consider*

interactions across the energy system. This could include offshore transmission, electricity distribution, non-wire alternatives, and gas/hydrogen networks, as well as indirectly connected sectors, such as transport, water and industry. We will consider macro consumer outcomes as well as local/regional factors and site-specific investment drivers, to ensure that at every level we deliver the optimal outcome."

Whole System vision

Our Whole System strategy will feed into the Network strategy to embed whole system solution in our network planning process. A Whole System approach allows industry infrastructure and developing technologies to be integrated with policy, market, stakeholder, other energy vectors, etc. Our network planning process in the future will take consideration of the developments of each element within the whole system to find the best solution which unlocks values from collaboration and coordination.

The Whole System vision is

To collaborate with our stakeholders to optimally plan, develop, and operate the transmission network, protect vulnerable customers, and deliver whole system benefits while ensuring the delivery of the energy transition by 2050.

This document sets out:

- The definition of whole system
- Whole system challenges
- The objectives
- Our resilient whole system approach
- Incorporating whole system thinking within our business plan

Introduction to the Whole System

Whole System is a term often used to describe a design approach 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, biogas) 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.

The roles of each energy type have largely been defined by use over the past century, with little consideration for 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 its subsequent adoption by the UK government, the UK is committed 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 provided additional detail to the Prime Minister's ten point plan for a green industrial revolution. As a result, it is necessary to adopt 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 suggesting that renewable generation can be increased to 65% of supply by 2030 at no adverse cost to consumers. This would enable 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 and can be used for both combustion and, 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, biodiesel and bio-kerosene. These products are generally used for combustion so can produce greenhouse gas biproducts 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 biproducts such as NOx and particulates in the air.

Whole System collaboration

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 operated in isolation, with limited interaction between different fuel types. Therefore, the electricity, gas and oil industries been working separately to meet energy needs driven by their respective markets and structures. Similarly, infrastructure for water, transport, electricity, gas, oil and communications has 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.

Whole Electricity System Licence Condition

Ofgem implemented the Whole Electricity System Licence Condition in April 2021 which outlined providing clarification on the definition of 'coordination' and 'cooperation' in the Whole Electricity System Licence Condition. We proactively engaged with the working group in developing the template and Form of Statement scope and we will continue to engage on this important new licence condition.

We update our Whole System Coordination register[1] annually and publish it on our website[2]. With the aim to continuously improve and better reflect the nature of whole system, we have collaborated with National Grid Electricity Distribution (NGED) to create and publish a single Whole System Coordination Register for 2024. The collaborative approach will facilitate more efficient and effective engagement and collaboration with other network licensees and users.

National Energy System Operator

In 2022, following industry consultation, Ofgem and the Government determined that the country required a new, independent organisation that would take a whole system approach to strengthen energy security, facilitate the achievement of net zero, and ensure long-term affordability of household bills. In October 2023, the Energy Act 2023 was passed, legislating for this National Energy System Operator (NESO) to be created.

The new NESO will function as an independent, expert, and impartial organization. NESO will be responsible for coordinating across the whole energy system and considering the connections between energy vectors and their relationship with the wider system.

[1] Find our latest publication here: https://www.nationalgrid.com/electricity-transmission/our-future-network/our-whole-system-approach

[2] https://www.nationalgrid.com/electricity-transmission/our-future-network/our-whole-system-approach

Part 1 – The Whole System Challenges

Current UK Energy Landscape

The energy landscape in the UK has experienced significant changes. In June 2020, the Office of National Statistics (ONS) released the historical actual energy use data in the UK between 1990 and 2018. The historical data for the 2018 energy landscape is depicted below, showing that 77% of our energy sources was come from greenhouse gas-producing fuels, mainly fossil fuels.

According to the latest government data from the Department for Energy Security and Net Zero (DESNZ), there has been a decrease in overall energy usage and a remarkable increase in renewable energy production in 2022. About 71% of energy sources are currently come from greenhouse gas-producing fuel. A total reduction of 6% can be seen compared to 2018.

The largest source of greenhouse gas emissions currently comes from the transport sector, with oil-derived fuels contributing to the largest impact for transport. Transport is producing 28% of the UK's total emission in 2022 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. In March 2024, the UK government has set out a plan committing to support the building of new gas power stations to maintain a safe and reliable energy source for days when the weather forecast doesn't power up renewables. This is a trade-off between Net-Zero and energy security.

Consumption by sector (TWh)

Year	2018[3]	2022[4]
Industry	264	256
Transport	662	592
Domestic	480	399
Services	254	235
Total	1,660	1,482

Energy by source (TWh)

Coal	5	71% (Fossil fuels to be phased out)
Natural gas	424	
Primary oil	481	
Primary electricity	220	29% (potentially green energy)
Bioenergy and waste	152	

[3] 2018 UK historic actual energy consumption by sector (June 2020 ONS data)

[4] 2022 Energy consumption by user (Energy Trends Table 1.3)

Another alternative energy supply for the future is long duration energy storage (LDES). LDES allows a larger amount of affordable renewable power to be integrated into the electricity system, lowering the overall cost of electricity for consumers. Additionally, it offers power capacity that can be readily activated or deactivated, enhancing the flexibility of the grid. However, LDES techniques are still in the early stages of development, and both financial and regulatory support are necessary for their advancement. A strategic approach is required to foster the development, integration, and regulation of LDES in the future.

Future scenario 2050

As part of the work completed to produce the Committee on Climate Change (CCC) Net Zero reports, a balanced Net Zero Pathway [5] was constructed as a central pathway. 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 noticeable reduction of energy consumption in transport from 662 TWh in 2018 to around 240TWh 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 425TWh 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 2023 (FES)[6] produced by NESO. The FES sets out four scenarios to achieve Net Zero, 'Falling Short', 'System Transformation', 'Consumer Transformation' and 'Leading the Way' (LW). 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.

Consumption by sector (TWh)

	CCC 2050	FES 2050 LW
Industry	269	329
Transport	240	314
Domestic	425	168
Services	334	347
Total	1268	1158

Energy by source (TWh)

	CCC 2050	FES 2050 LW
Electricity	722	751

[5] CCC Publications, https://www.theccc.org.uk/publications/?topic=&type=0-report

[6] FES, https://www.nationalgrideso.com/future-energy/future-energy-scenarios-fes

Hydrogen	223	105
Natural gas	217	64
Other fuels	105	88
Bioresource	-	160

There is no doubt that hydrogen will play a crucial role in the future energy system, but there are differing views on how hydrogen will be utilized to meet our energy needs. Electrolytic hydrogen production holds the potential to provide comprehensive system-wide benefits if strategically invested in the appropriate locations and at the right time. A cohesive strategy is necessary to guide the deployment of this technology, taking into account factors such as proximity to network constraints, end users, and the transportation and storage of hydrogen.

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 titled 'Anticipate, React, Recover – Resilient infrastructure systems'. This report highlights the importance of comprehending the interdependencies among segregated infrastructure systems, emphasizing the need for stress tests and long-term plans to address resilience gaps between systems. The report acknowledges the complexity and transformative changes associated with achieving Net Zero and advocates for a Whole System approach to enhance 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 in a

collaborative Whole System approach, improving all consumers' benefit.

Whole energy market

Markets are at the heart of the GB electricity system. They drive competition and innovation to benefit consumers. They provide price signals which guide decisions on electricity supply and demand, investment in new generating capacity and flexibility, and the efficient operation of the system.

The GB electricity market was designed at a time when bulk fossil fuel plants were dominated. Now, the generation mix has been going through great changes. Large growth of renewable generation such as wind and solar has taken place during the transition to net zero. We are also seeing rapid changes with the integration of low carbon technologies such as EVs, storage and heat pumps. These smart technologies created a rise in flexible demand across the entire energy system. And these assets need more accurate market signals if they are to locate, produce and consume electricity where and when needed. Otherwise, consumers may face the risk of high costs associated with balancing the electricity system in the years to come.

Reforming electricity markets through the Review of Electricity Market Arrangements (REMA) programme is vital to the delivery of the government's plan to deliver a fully decarbonised electricity system by 2035, subject to security of supply. The purpose of the REMA is to create the market arrangements to complete the move to low carbon technologies, managing a smooth and low-cost transition away from our remaining unabated fossil fuel generation capacity, while maintaining security of supply. With the introduction of new market mechanism, more opportunities are provided to the market participants, however, at the same time, more challenges could be posed to the future network planning for NGET.

New opportunities will be identified by NESO for improving market iterations across multiple energy vectors, including electricity, gas, hydrogen etc. The cross-vector market and their interactions will also pose challenges on future energy networks to ensure energy reliability and security. The future energy networks need to ensure infrastructure is ready for global, regional and local whole energy markets while considering net-zero targets.

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:

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 DESNZ, 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, biogas) 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

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.

infrastructure systems. Our proposed 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

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.

Renewable energy is an important factor in our way to Net-Zero. To allow more renewable generation to be connected to the transmission grid, we are aiming at delivering The Great Grid Upgrade[7]. The Great Grid Upgrade is the largest overhaul of the grid in generations – making sure that renewable energy can move from where it's generated to where it's needed, enabling us all to power the things we love with cleaner energy.

We have also been working on a list of innovation projects to explore whole system solutions to the challenges we are currently facing during the Net-Zero transition. We have also collaborated with other network operators and wider industry to develop business-as-usual (BAU) whole projects to facilitate energy transition.

Engagement and interactions with our stakeholders have also been a vital part in our whole system approach. Close and ongoing engagement with our stakeholders is helping us shape these plans. We've already begun to share and discuss them with network businesses, local authorities, and other stakeholders, which has helped to identify new opportunities for collaboration on network solutions. We're building on these valuable relationships and conversations to reach new stakeholder groups and further shape our blueprints. Collaborative, transparent discussion and decision-making is at the heart of our whole system collaboration. By thinking differently, and working closely with our stakeholders, we can transform our electricity transmission network to deliver net zero.

The electricity system is experiencing an unprecedented growth in connection requests due to the change from large fossil fuel generators (relatively smaller in number) to a diverse range of supplies, including renewable generation and storage. To tackle this challenge, NESO has established a Connection Reform project and we have taken a whole system approach in working with NESO, ENA and DNOs to revise the connection process and review the technical limits. With the revised connection process and technical limits, customers will understand more about the transmission and distribution network constraints and will experience a more efficient connection process compared to existing arrangements.

We are developing our infrastructures to allow more low carbon resources to be connected to the grid. For example, the Hinkley Connection Project. It is a new high-voltage electricity connection between Bridgwater and Seabank near Avonmouth. This project has achieved a key milestone with the completion of all 116 T-pylons which will connect six million homes and business to low-carbon energy. More details about our

[7] The Great Grid Upgrade, https://www.nationalgrid.com/the-great-grid-upgrade

whole system projects can be found in the next section.

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 jointly how we evaluate Whole System projects across different energy networks.
- 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.

NGET has committed to have carbon neutral construction by 2025/6 with the potential of leveraging carbon offsetting to reach this. To achieve these targets, we have investigated and did pilot trials of low carbon construction materials and techniques. Working groups have also been established working collaboratively with the supply chain to deliver the targets by focusing on low carbon technologies to minimise our carbon footprint.

Network infrastructure must be developed in the right place, at the right time, while also considering its impact on communities and the environment. We will also seek opportunities for infrastructure reinforcement considering whole system benefits. The opportunities shall focus on two main categories:

- ❖ Reinforcing the existing network to allow more connection of low carbon technologies.
- ❖ Upgrading the physical and non-physical assets to maximise the benefits from utilization.

NESO has published a Beyond 2030 report[8] which provides network development recommendations to allow 21GW of low carbon generation to be connected across Britain. It indicates a development plan including significant offshore network build and reinforcements from North-East

[8] Beyond 2030 Report, https://www.nationalgrideso.com/future-energy/beyond-2030

Scotland to Northwest England, to provide north-south transfer of power.

Innovation projects have approved the concept that communities can benefits from the wasted heat from substation. Taking advantage of the heat from substation not only brings financial benefits to communities, but also contributes to the Net-Zero transition by using the energy more effectively using a whole system approach. We shall collaboratively work with DNOs and local authorities to identify the needs for the repurposed heat and the actions required for directing the heat.

In the Infrastructure Transition phase, we would look to establish large scale pilots of increasing complexity. In addition to the points set out in the "Starting point" section, 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.
- Driving further development of whole system solutions based on previous projects and collaborative activities.

Delivering the future together

Ofgem set out its decision that the NESO will be responsible for creating a new Centralised Strategic Network Plan[9] (CSNP). CSNP aims "***to provide an independent, coordinated, and longer-term approach to wider network planning in GB to help meet the government's net zero ambitions***". The focus of CSNP will extend from the electricity transmission network - onshore, offshore and interconnectors, to gas transmission and hydrogen network at the national level.

We will adopt CSNP in planning our future and work closely with NESO and other networks to deliver whole system benefits.

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 the previous sections, 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.
- Engagement of all stakeholders effectively to ensure a fair, affordable system for all.

[9] Centralised Strategic Network Plan, https://www.ofgem.gov.uk/publications/decision-framework-future-system-operators-centralised-strategic-network-plan

Part 4 – Whole system projects

We are in the middle our RIIO-T2 regulatory period. However, by definition a whole system approach to delivering Net Zero by 2050 will expand across multiple regulatory periods. Therefore, we need to take a long-term view for all the projects we identify with others to ensure we deliver for UK society and business.

The projects set out below align with our approach of developing a strong whole system approach across the electricity industry, whilst making our first steps in incorporating other energy vectors into our approach. This has been reflected by engagement we have undertaken across the electricity network owners, who have proactively engaged with us. Our ambition to achieve maturity by 2030 in our whole system approach. We shall learn from every whole system project we undertake and improve to ensure we deliver the most economic, sustainable and efficient approach to delivering Net Zero through all our regulatory frameworks.

Project – Harker Substation

Harker substation is located near Carlisle in the Northwest of England and has seen a large number of customers seeking connections with the Electricity Northwest Ltd (ENWL) distribution network and Scottish Power Transmission (SPT). These connections impact significantly with Harker substation and changes that need to be made on ENWL and SPT networks depending upon the solution which is chosen. As a set of network owners, we are working closely to identify the right whole system solution to maximise the benefit to customers in the most economic and efficient way. This involves working jointly on options and evaluating the right outcome. This has involved working differently from the past by assessing options across multiple organisations and agreeing compromises between NGET, ENWL and SPT to ensure the outcome best meets future need. We are using this approach in the future where multiple solutions across different networks and companies can deliver solutions that meet the needs of customers, consumers and our broader stakeholder population. Being able to evaluate the best approach between us on a neutral basis and identifying the right solution for all will bring significant benefits to consumers.

Project – Mid Wales whole system

Wales effectively has two electricity systems, one in the south of the country consisting of transmission and distribution, the second in the north of the country also consisting of transmission and distribution. The transmission systems in the north and south of Wales are owned by us and are interconnected through circuits in England, with no transmission connection between the two in Wales itself. The distribution system in North Wales is owned by Scottish Power Energy Networks (SPEN) and the southern distribution system is owned by NGED, with limited interconnection between the two systems through mid-Wales. A significant number of renewable generators are seeking connection in

mid-Wales, well in excess of the capacity available. Also, to meet the Net Zero challenge in mid-Wales by 2050, with the majority of properties being off gas grid, significant changes in demand can be expected in the future, along with storage opportunities presented by new generation, including potential hydrogen production. We are working with the Welsh Government, SPEN and NGED to identify whole system options and the right solution to deliver the energy system required for Net Zero 2050. This demonstrates our commitment to work with Government and Local Authorities, considering a multi-energy whole system solution which delivers for the communities impacted, enabling their transition to Net Zero.

Project – Zero2050 South Wales

The Zero2050 South Wales project is an initiative led by us to speed up the rate of progress towards achieving Government targets of Net Zero by 2050 in South Wales. As part of the project, we are working with National Grid Gas Transmission, Wales and West Utilities and NGED network companies. It also involves suppliers Arup, BMT, Digital Engineering, Cardiff University, Burns McDonnell, CR Plus and Progressive Energy. The project is being reviewed by Welsh Government, South Wales Industrial Cluster and the Department for Business, Energy and Industrial Strategy among others. The project looks at providing a whole system deliverable solution for the major industrialised part of South Wales and the local communities in that area. This project shows how we are engaging in significant projects across wide geographic areas involving multiple energy vectors and industries. Working together to identify viable solutions to deliver Net Zero, this project is being run by our innovation teams and involves multiple suppliers to identify innovative ways Net Zero can be delivered. The project will publish its initial findings in 2021 and we will take learning into our future whole system projects.

Project – East Coast

The UK Government has set a target for 40 gigawatts of offshore wind to connect to the electricity system by 2030. With the majority of those wind farms expected to connect to the east coast of England, we are exploring with DESNZ, Ofgem, local government, NESO, windfarm developers and distribution companies a whole system approach to these connections. If each windfarm is treated individually the system development will take longer and is likely to not deliver the most economic and efficient whole system design. By considering all the connections together and considering how they can be integrated with other infrastructure to deliver Net Zero, it will benefit electricity consumers. This project demonstrates how by working with generators we can help achieve the Government ambition to connect greenhouse gas-free energy sources as quickly and efficiently as possible. There is potential to deliver innovative solutions and start incorporating other energy vectors to deliver a truly transformative project for energy consumers across Great Britain. This project follows the principles that transmission offers the most efficient and low-loss way to deliver energy from the coast to demand centres where communities and businesses consume the energy. Done in the right way, this should also improve the speed of connection, getting more greenhouse gas-free energy to consumers quickly.

Project – NGET Resilience Framework

Following the release of the National Infrastructure Commission report “Anticipate, React, Recover – Resilient infrastructure systems”, National Grid are working with Arup and the University of Manchester to help develop our resilience Framework and

model. This Framework is designed to help identify how National Grid Electricity Transmission and it its interdependencies are measured against a set of definitions. This is so we can establish how better we can serve our customers, stakeholders and communities by improving our resilience approach over and above our current high standards. We will also be able to quantify our decisions and simulate stress tests on the network via the model. As we deliver Net Zero with a greater dependency being placed upon energy to drive our world environment, from smart homes, devices to automation of vehicles and communications. It is more important than ever we ensure that resilience is at the heart of Whole Systems infrastructure designed to deliver net zero.

The Resilience Framework has been successfully developed and tested within NGET in 2023, and we are developing it to be more widely applicable to the energy sector and Critical Network Infrastructure (CNI). We shall use this framework to inform our own business about our resilience measure but also to support others with whom we have interdependencies. We can also take the learning we gain from having a framework to inform our whole system projects to ensure resilience is considered in our whole system evaluation.

Project – Neptune Project

Neptune is considering multiple decarbonisation pathways to Net Zero 2050 on a national basis. This project is designed to help us identify the likely needs for England and Wales from a transmission basis, considering transport, domestic and industrial space heating, industrial low grade and process heat. The project considers the types of technologies required to deliver a whole system solution to 2050 and is looking to see how we can support the NESO pathfinder projects. This project looks at interactions with other energy vectors, including hydrogen, and considers the different requirements based upon blue and green hydrogen production. The project is also considering how improved load smoothing, with integrated storage (including hydrogen), can release additional electricity system capacity currently unused due to the load profile of electricity demand.

Project – Role and value of electrolysers in low-carbon GB energy system

This project aims to analyse the benefits of linking electricity and hydrogen vectors from a whole-system perspective to determine the optimum capacity, location, technologies, and system benefits of electrolysers under different future development scenarios. The impact of power-to-gas on the whole energy system, particularly, integration of renewable generation (provision of system balancing and ancillary services), electricity transmission network operation and development, will be investigated. The project will develop an integrated whole system model to optimise the portfolio and locations of electrolysers considering several factors such as system constraints, end-use application of hydrogen, hydrogen transportation costs to end-use, and water availability to provide cost effective investments to achieve decarbonization of energy networks. The net benefits for consumers from this project are expected to be delivered collectively from lower cost for the decarbonization of electricity power system, transport, and heat sector.

Project - Future Network Blueprints

Our Future Network Blueprints bring our stakeholders right into the heart of our network planning process. We're examining, sharing and debating our plans with industry, and using digital visualisations to shape our future network based on that engagement. With this new lens on network development, we're building a live and accessible picture of how our infrastructure plans need to

change, and where we can capture whole system opportunities. It's helping us to make more coordinated decisions about when and how to upgrade the grid. Future Network Blueprints encompass everything from regional-level network plans and their nuances to more granular insight around specific substation sites.

At a regional level, the focus in one area of the country might be on bulk electricity transmission from local renewable generation to where it's consumed. Elsewhere it might be working with distribution networks on the complexities of increased electric vehicle charging. Site-level priorities might focus on making best use of land and space around existing infrastructure to help accelerate connections, or where there are opportunities for us to implement environmental commitments such as our biodiversity net gain targets. Our Future Network Blueprints' digital visualisations are capturing this insight into a live picture of the network and how it will evolve over time. We've already identified that by 2035 we'll need to upgrade around half of our existing transmission lines, and that in the same period over 90 of our more complex sites will benefit from further investment.

Project – Local Area Energy Planning (LAEP)

Local Area Energy Plans (LAEP) are recognised as the leading method for translating national Net Zero targets into local energy system action with plans that are collaborative, data-driven and cost-effective. LAEPs are led by local government and developed collaboratively with defined stakeholders. The results are a fully costed, spatial plan that identifies the change needed to the local energy system and built environment, detailing 'what, where and when and by whom'. LAEP sets out the total costs, changes in energy use and emissions, and sets these out over incremental time periods to meet the 2030 target of a 68% reduction in emissions, and the 2035 target of a 78% reduction in emissions, and net zero by 2050. The LAEP scope addresses electricity, heat, and gas networks, future potential for hydrogen, the built environment (industrial, domestic and commercial) its fabric and systems, flexibility, energy generation and storage, and providing energy to decarbonised transport e.g., electricity to electric vehicles and charging infrastructure.

Project - Innovative Materials and Construction Techniques

NGET has committed to reduce carbon emissions as much as is feasibly possible, to deliver net zero construction by 2026. As part of this, we are looking at novel construction materials to reduce the carbon footprint of concrete used in construction projects.

This project aims to examine the use of low carbon construction materials in detail both at feasibility and trial stage for the reduction in carbon emissions associated with construction activities. This project will present a feasibility study and an implementation for the civil elements, mainly foundations and bunds, and then an implementation stage for structures, where these could be mounted on the foundations from the previous stage. Further, this project looks to leverage the latest advances in structures and civil elements technology to ensure that the right asset investment decisions are made for future generations.

Part 5 – 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, biogas) 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 way of working going forward including:

- **Engage 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 strategy 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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