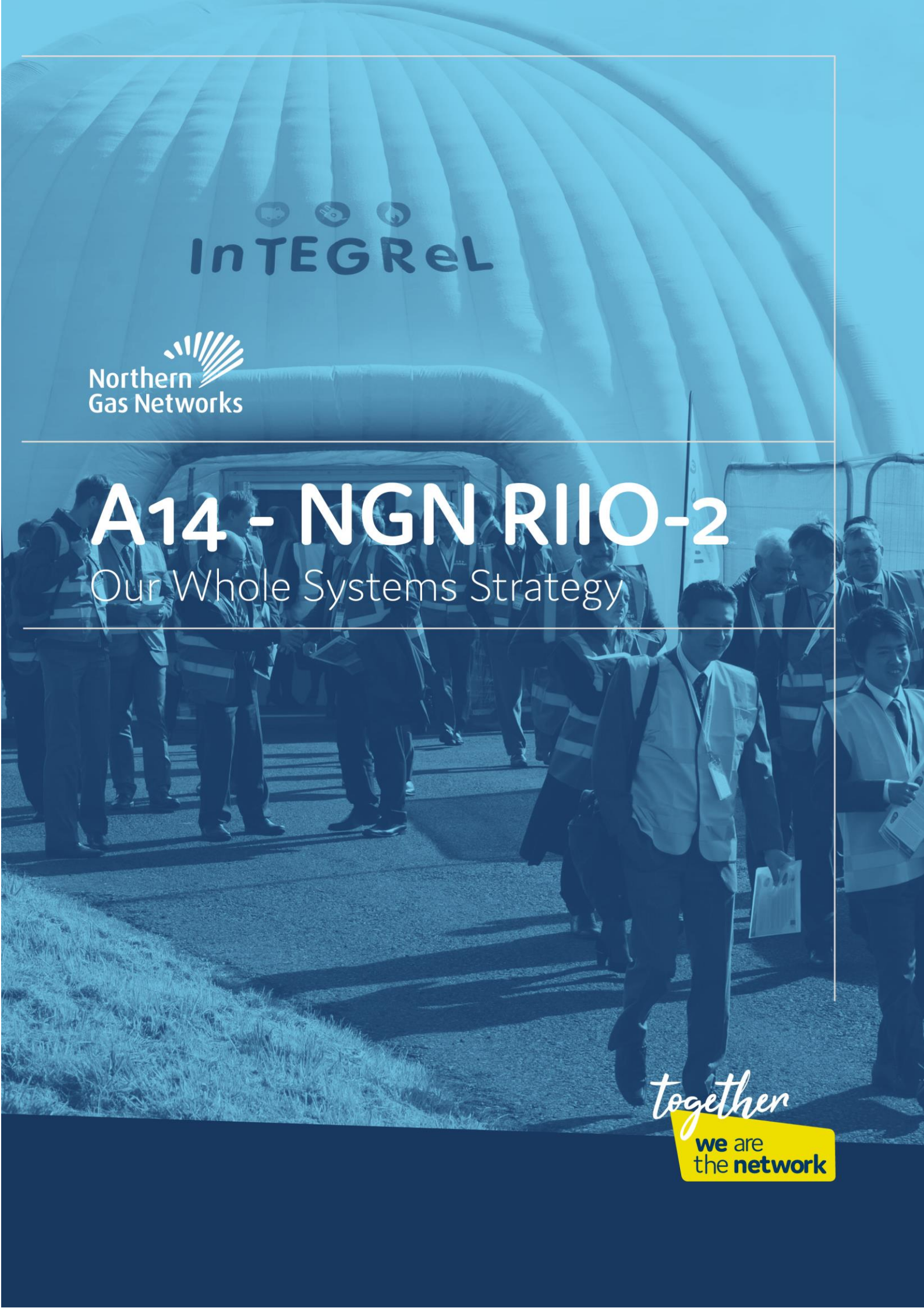


Northern Gas Networks

A14 - NGN RIIO-2

Our Whole Systems Strategy

together we are the network

Page left intentionally blank.

Foreword

This document outlines Northern Gas Networks' Whole Systems Strategy. This strategy addresses Ofgem's business plan guidance for us to provide information on our approach to enabling whole systems solutions in our RIIO-2 Business Plan. We have developed this strategy in conjunction with key whole systems stakeholders.

Importantly, NGN is committed to supporting the achievement of the UK's net zero emission targets and our Whole Systems Strategy sets out how we intend to contribute.

The purpose of this document has been to assist us with:

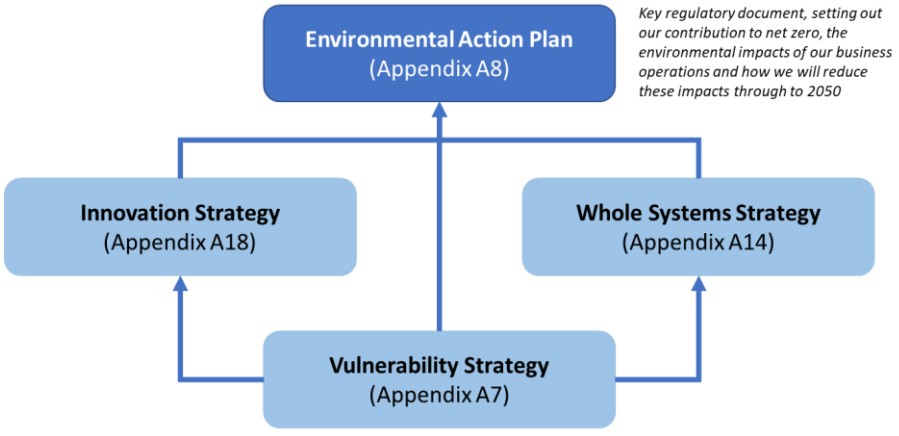
- determining our role in the whole systems landscape;
- determining how we will interact with other stakeholders in the creation of an integrated energy system; and
- defining the actions that we will need to take to deliver against our objectives.

We also note the interactions between this document, our Environmental Action Plan, Innovation Strategy and Customers in Vulnerable Situations Strategy:

- *Environmental Action Plan* – this is the primary regulatory document that sets out the environmental impacts of our business operations as well as short-term initiatives to reduce these impacts and our long-term strategy to contribute to the net zero emission targets by 2050, for the benefit of customers.
- *Innovation Strategy* – this sets out our approach to delivering innovation in RIIO-2 (particularly in relation to enabling the achievement of our net zero emission targets and supporting customers in vulnerable situations), with a focus on the benefits provided to customers.
- *Vulnerability Strategy* – this document sets out our approach to working with customers in vulnerable situations in RIIO-2 and includes consideration for ensuring a whole systems focus in our approach.

These four documents are complementary and together, set out our contribution to net zero.

Figure 1: Our Contribution to Net Zero



Further information on our Whole Systems Strategy has been provided in Section 5 of our Business Plan, with this document providing additional detail to supplement our main Business Plan document.

Document Structure

This document is structured as follows:

- **Chapter 1 "Introduction"**
- **Chapter 2 "Our Whole Systems Strategy"** – this chapter outlines our Whole Systems Strategy, taking account of the analysis and insights set out in the preceding chapters.
- **Chapter 3 "Whole Systems Enablers"** – this chapter focuses on the specific actions required in order to develop our Whole Systems Enablers.
- **Chapter 4 "Whole Systems Objectives"** – this chapter focuses on our approach to delivering each of our Whole Systems Objectives.
- **Chapter 5 "Summary"**
- **Annex A** – this annex has helped to inform and shape our Whole Systems Strategy. It describes:
    - Recent energy-related developments in the UK with a focus on the changing role of gas and the importance of a whole systems approach to ensure delivery of a sustainable, affordable and resilient future energy system; and
    - Different dimensions associated with whole systems thinking, identifying the key interactions and dependencies between stakeholders from the perspective of a GDN.
- **Annex B** – this annex summarises the stakeholder consultation that was undertaken and has informed the development of our Whole Systems Strategy.

Contents

1. Introduction 8
   1.1 Our Whole Systems Strategy 8
   1.2 Our progress so far 9
   1.3 RIIO-2 and beyond 11
   1.4 Initiatives for RIIO-2 12
2. Our Whole Systems Strategy 16
   2.1 Our Whole Systems Strategic Framework 16
   2.2 Why is a whole systems approach important? 19
   2.3 Acknowledging uncertainty 24
   2.4 Our approach 26
3. Our Whole Systems Enablers 29
   3.1 Information sharing 29
   3.2 Enacting Whole Systems 35
   3.3 Open innovation 38
   3.4 Stakeholder engagement 41
   3.5 Solutions and services 44
4. Whole Systems Objectives 47
   4.1 Sustainable Heat Solutions 47
   4.2 Sustainable Transport Solutions 56
   4.3 Sustainable Power Solutions 61
   4.4 Sustainable Business Solutions 64
5. Summary 69

Annex A | Stakeholder Consultation 70
   A.1 Electricity Distribution Stakeholder Comments 70
   A.2 Gas Distribution Stakeholder Comments 72
   A.3 Electricity Transmission Stakeholder Comments 73
   A.4 GB System Operator (Elec and Gas) stakeholder comments 73
   A.5 Academic stakeholder comments 73
   A.6 Letters of support 74

Annex B | Developing our Whole Systems Thinking 81
   B.1 Introduction 81
   B.2 The future role of gas 83

B.3 Key stakeholders for a whole systems approach 86
B.4 Key stakeholder interactions and dependencies 87
B.5 Stakeholder consultation and views 90
B.6 Whole systems from a technological, economical and societal perspective 90
B.7 Summary 94

Acronyms

Acronym	Name
CESI	Centre for Energy Systems Integration
CO_2e	Carbon dioxide equivalent (a common unit to measure emissions, including greenhouse gas emissions and air quality pollutants such as nitrous oxide (NOx)
CNG	Compressed Natural Gas (commonly used fuel in vehicles)
DNO	Distribution Network Operator
DSO	Distribution System Operator
EAP	Environmental Action Plan
ENA	Energy Networks Association
ENW	Electricity North West
GDN	Gas distribution network
InTEGReL	Integrated Transport, Electric, Gas Research Laboratory
LAEPs	Local Area Energy Plans
NELEP	North East Local Enterprise Partnership
NGN	Northern Gas Networks
NIA	Network Innovation Allowance
NIC	Network Innovation Competition
NPG	Northern Powergrid
NW	Northumbrian Water
R&D	Research and development
UK	United Kingdom
WPD	Western Power Distribution
YW	Yorkshire Water

Terms

Term	Definition
Green gas	We use the term “green gas” to describe gases that are low emission. In this document, we consider biomethane, green hydrogen and blue hydrogen (with CCUS) as forms of green gas.
Green hydrogen	We define green hydrogen as hydrogen produced through electrolysis, with renewable electricity.
Blue hydrogen	We define blue hydrogen as hydrogen produced from fossil fuels, coupled with carbon capture technologies.
Net zero	We use the term “net zero” as it relates to the UK legislation enacted in June.

1. Introduction

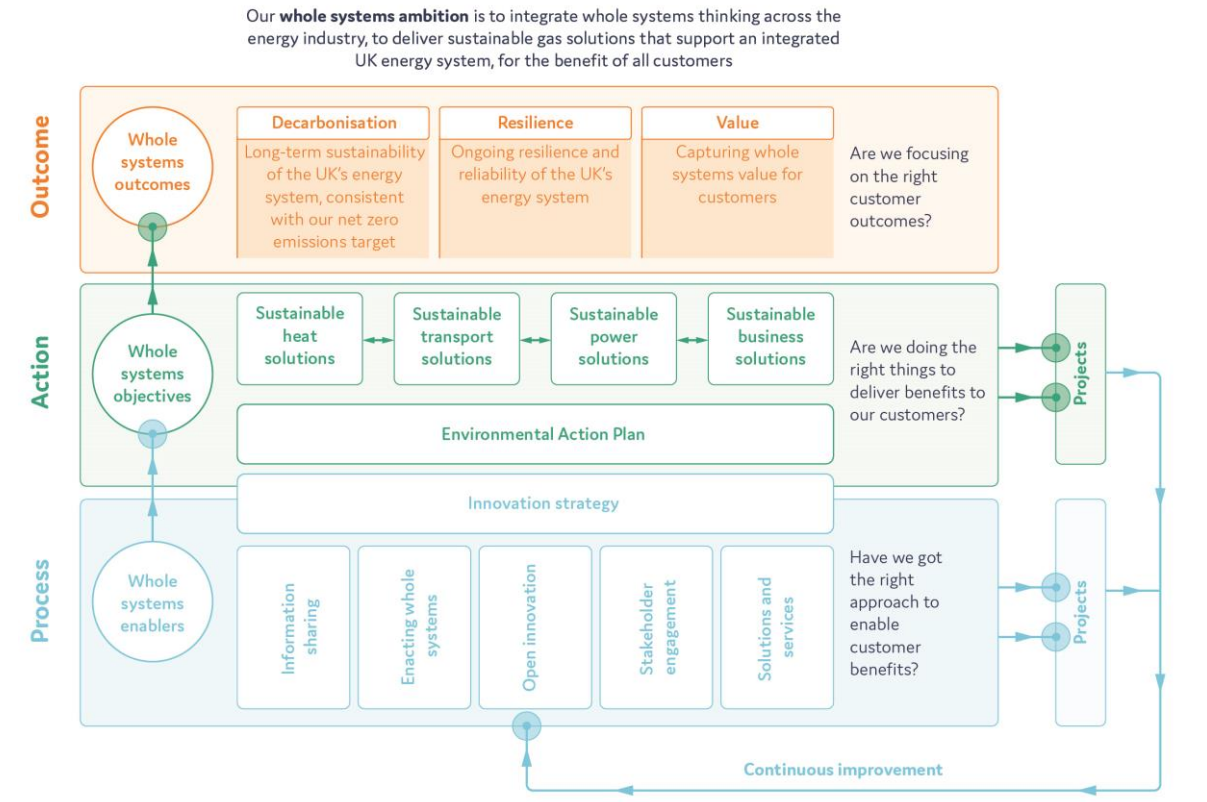
1.1 Our Whole Systems Strategy

Our Whole Systems Strategy and Business Plan for RIIO-2 demonstrates our ambition to achieve the integration of whole systems thinking throughout the UK's energy sector, to deliver sustainable gas solutions for the benefit of all customers.

Through our Whole Systems Strategy, we commit to facilitating the development of an efficient, coordinated, and cost-effective approach to meeting our net zero emission targets by 2050. We will also support local authorities in our region who are targeting net zero emissions much earlier (for example Leeds City Region by 2038) – we recognise that we have an important role to play in supporting these targets.

Figure 2 below sets out our Whole Systems Strategic Framework.

Figure 2: Our Whole Systems Strategic Framework



Our approach adopts a broad focus on whole systems thinking across our business, based on three key components:

- **Whole Systems Enablers** – these are process-driven and are focused on laying the right foundations to ensure that we have a whole systems approach within our operational and day to day activities.
- **Whole Systems Objectives** – these are action-driven and outline what we intend to deliver to ensure that we're undertaking the right activities at a programme level to facilitate whole system benefits for customers.
- **Whole Systems Outcomes** – these are customer-driven and set out what our enablers and objectives will be delivering for customers over the longer-term, taking account of the needs of both current and future stakeholders.

1.2 Our progress so far

Over RIIO-1, we have established ourselves as a thought leader in relation to whole systems thinking in the energy industry.

In 2016, we began working with the National Centre for Energy Systems Integration with Professor Phil Taylor and in 2017 we jointly launched the Integrated Transport Gas Electric Research Laboratory (InTEGReL) site in Low Thornley. This site has so far attracted £5 million in funding from third parties (with a further £14 million currently being sought). This is one of the UK's first integrated whole systems site, with active participants involved in the project spanning academia, electricity, water, telecommunications and gas.

Through this facility, we have already invested in a project with Newcastle and Durham Universities and Northern Powergrid (NPG) to identify key barriers and opportunities for the integration of electricity and gas network control systems and identify areas that require further in-depth research. We have so far completed Phase 1 of this project and are currently seeking third party funding to support delivery of Phase 2.

We have also been the driving force behind the increasing recognition of the potential of hydrogen as an alternative zero emission substitute for natural gas.

We consider hydrogen is an immensely versatile energy vector with broad applications in heat, transport, electricity and industry and a decarbonisation approach largely based around the increased utilisation of hydrogen would yield benefits well beyond combatting climate change. In this way does hydrogen have the potential to provide a truly whole systems solution in order to support the achievement of our net zero emissions target.

We have so far published two key feasibility reports (H21 Leeds City Gate and H21 North of England), which have been successful in generating significant interest in the UK and internationally. These reports have had the customer at the centre – with a focus on providing a low cost and sustainable heating option for our customers. We have also commenced work on hydrogen blending on our network, through HyDeploy.

Box 1: Integrated Transport Gas Electric Research Laboratory (InTEGReL)

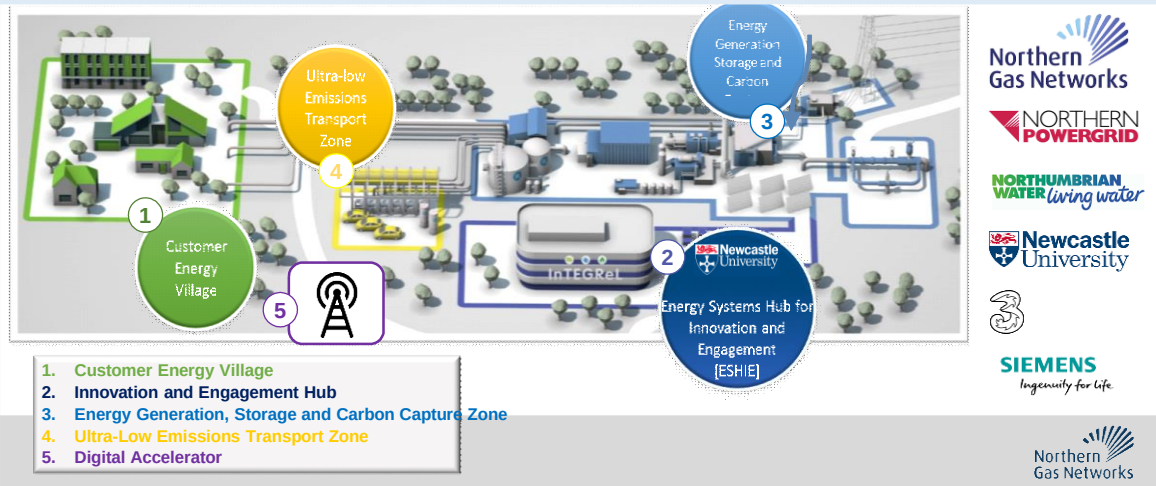
We recognised the importance and potential of a whole systems approach in 2016, engaging with researchers from Newcastle University, and subsequently supporting the development of the £20m EPSRC National Centre for Energy Systems Integration (CESI), primarily funded by the Engineering and Physical Sciences Research Council (EPSRC) and Siemens.

Our continued involvement with CESI, as a member of the Industrial Advisory Board, presenting at workshops and energy conferences has significantly increased our understanding of the approach and has subsequently led to the development of the Integrated Transport Gas Electric Research Laboratory (InTEGReL) based in Low Thornley, Gateshead. Led by ourselves, and in partnership with Northern Powergrid, Northumbrian Water, Newcastle University, Siemens and 3 Mobile, InTEGReL is the UK's first multi-vector integrated energy systems research and demonstration facility investigating utility scale infrastructure.

Subsequent to the vision launch we have continued to promote this vision across industry which focuses on:

- The value of taking a whole systems approach to the energy system, looking at lowering cost, decarbonization and resilience and adaptation;
- Investigating the interactions between energy vectors at a network utility scale; and
- How customers switching between gas and electricity affects the energy system.

InTEGReL allows us to leverage our NIA investments, by re-using various aspects of newly developed capabilities from a project in future areas of work, thus getting greater value from the use of customers' money in this innovation space. We have also so far attracted £5 million in third party funding to develop this site.



The proposed Newcastle University funded facility of 4000 m^2 two-story drive-through Energy Systems Hub for Innovation and Engagement (ESHIE facility) will incorporate a wide range of laboratories and supporting spaces and is ideally suited for whole systems innovation. In addition, three key facilities are planned:

- *Customer Energy Village* – Residential properties enabling the research, testing, de-risking and demonstration of energy technologies within the home environment.
- *Energy Generation, Storage and Carbon Capture Zone* – Zone for researching, testing, de-risking and demonstration of equipment.
- *Ultra-Low Emissions Transport Zone* – Future energy links, and associated available power and energy flexibility, between the transport sector and the electrical, gas and hydrogen energy vectors, amongst others.
- *Digital Accelerator* – A new NB-IoT industrial research lab funded by 3 Mobile, to explore how digital technologies can support the transition to net zero.

The first projects are now underway on the site and InTEGReL is expected to play a key role in our open innovation efforts.[1]

Importantly, we have already delivered most of our H21 Phase 1 work program (due for completion in mid-2020), which has established a baseline of information on the feasibility of converting gas networks over to 100% hydrogen. Delivery of Phases 2 and 3 of our H21 work program (i.e. delivery of hydrogen's safety case) is the foundation that will underpin other hydrogen-related projects in the UK – without it, gas distribution businesses cannot progress consideration of conversion to 100% hydrogen.

In its recommendations in relation to our recent H21 Phase 2 Network Innovation Competition (NIC) bid, the Gas NIC Expert Panel stated that:

> It has been encouraging to see how the vision of the potential role of the gas network in supporting a low carbon economy, at least cost to customers, has developed since the Gas NIC began in 2013. The initial concept of decarbonising heating by using hydrogen has been quickly developed from a few isolated pieces of work to a comprehensive and well co-ordinated programme of work with a real sense of momentum. The Panel is pleased to see a significant body knowledge being developed with Gas NIC funding that will support a cost-effective adaptation of the NL's to a low carbon agenda.
>
> Gas NIC Expert Panel, Gas Network Innovation Competition 2019 Report and Recommendations, October 2019, https://www.ofgem.gov.uk/publications-and-updates/network-innovation-competition-2019-funding-decisions, page 13.

We are proud of our significant contribution to this area so far and are committed to delivery of all phases of our H21 work program in order to provide the necessary evidence to support a policy decision on heat that will contribute to the achievement of our net zero emission targets by 2050.

1.3 RIIO-2 and beyond

We have a demonstrated track record of adopting whole systems thinking in RIIO-1. As such, in RIIO-2, our focus will shift to embedding whole systems thinking across our business. For this reason, we are not proposing any specific investment in whole systems initiatives, instead we are linking our approach to whole systems across other business functions such as Innovation.

To achieve this, our focus in RIIO-2 will be on improving coordination of investment planning and operational delivery between the electricity system operator (ESO), the gas system operator (GSO) and the four network sectors (gas transmission, electricity transmission, gas

distribution and electricity distribution). We intend to lead the way in encouraging stronger collaboration within our sector.

We will also continue our strong focus on ongoing investment in research and development (R&D) activities to support the long-term role of gas in the UK's energy system.

Specifically, we will:

- *Increase our collaboration capabilities* – Whole systems thinking requires strong links between organisations to ensure effective knowledge-sharing. We will improve our capabilities around data sharing through our focus on digitalisation and innovation in RIIO-2. We will explore technology and data capabilities to enable sensing, control and information transfer through cross connected network systems.
- *Embed a whole systems approach* – We are broadening our focus in RIIO-2 to include dedicated focus on Sustainable Transport Solutions, Sustainable Power Solutions and Sustainable Business Solutions, to ensure that we are embedding a truly whole systems approach across our business. We will continue to leverage third party funding to support development of our InTEGReL facility, in collaboration with our stakeholders.
- *Continue R&D investment* – We will continue to invest in delivering the safety case for hydrogen through our H21 work program. This is NGN's key contribution to demonstrating the technical feasibility of converting gas networks in the UK over to hydrogen and we note that it is a critical work program that needs to be delivered to support a government policy decision on heat.
- *Deliver a small 100% hydrogen conversion community trial* – We will deliver a small (around 300 customer) occupied community trial on our network, subject to funding. This trial will provide significant insights into both the technical challenges and customer impacts of converting our network to hydrogen, which will help to inform future, larger-scale roll-outs across the UK.
- *Improved service levels* – We are committed to improving the level of service we provide to biomethane producers and will be implementing a range of initiatives to support a better, faster and cheaper service offering in RIIO-2 (i.e. we will make it simpler for people to connect to our grid).

1.4 Initiatives for RIIO-2

Over the course of RIIO-2, we have identified initiatives that we intend to deliver to achieve our Whole Systems Strategy. As mentioned above, these aren't considered to be whole systems initiatives as such, as they are embedded across other areas of our business.

Table 1 below provides a high level summary of our Whole Systems Objectives initiatives that we will look to deliver through to the end of RIIO-2.

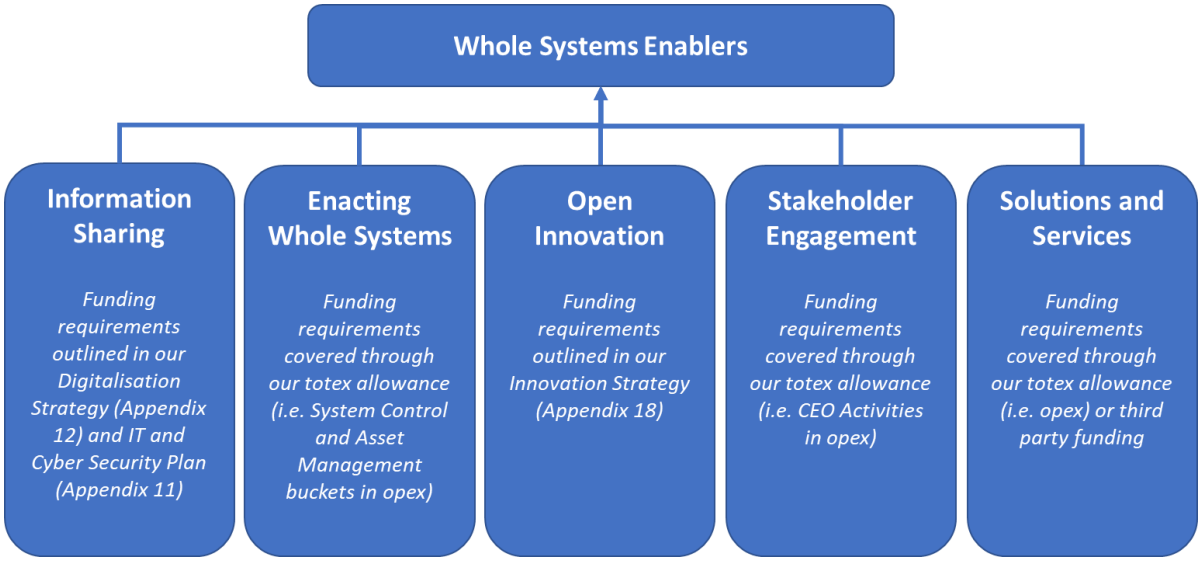
Table 1: Whole Systems Objectives initiatives

Objective	Initiatives
Sustainable Heat Solutions	• Improved customer service levels for biomethane producers • H21 Phase 1 • H21 Phase 2 • H21 Phase 3 • Biomethane injection hub facility • HyDeploy 1 • HyDeploy 2 • Remote pressure profiling • Large-scale network modifications required to support conversion to 100% hydrogen
Sustainable Transport Solutions	• Lamesley CNG development • Market development through facilitating cheaper connections • Tees Valley Hydrogen Transport Initiative • NGN fleet initiatives • Future role of gas in transport: a transition pathway for renewable gas alternatives • Develop and promote map of optimised low emission transport solutions • Flagship hydrogen refuelling station • Vehicle to Grid capability at InTEGReL
Sustainable Power Solutions	• Installation of solar panels at each of our sites • Control Rooms of the Future: Coordinating Supply and Demand in Integrated Energy Systems • Net Zero Customer Energy Village at InTEGReL • NPG's battery installation • Vehicle to grid capability
Sustainable Business Solutions	• Environmental Action Plan initiatives • Workforce resilience initiatives • Meeting the needs of future stakeholders

Where we can, we will look to deliver these initiatives in collaboration with other parties, and with a view to adopting whole systems thinking. Our direct contribution to the above initiatives is approximately £23 million however, given our focus on collaboration, we estimate that by supporting delivery of these initiatives, we are supporting total investment of around £50 million in our Whole Systems Objectives in RIIO-2.

In terms of our Whole Systems Enablers, costs associated with these initiatives have been accounted for in various aspects of our Business Plan, as Figure 3 shows below.

Figure 3: Whole Systems Enablers Funding



Importantly, we intend to continue leveraging funding from a range of different sources reflective of our embedded approach. For example, our Innovation Strategy contains justification for our proposed innovation spend over RIIO-2 which will be split between seeking third party funding and inclusion of costs in our Network Innovation Allowance, among other funding mechanisms. This is set out in Table 2 below.

Table 2: Energy systems transition innovation funding for RIIO-2

	NGN NIA	Third party funding	Total investment
Creating evidence-based solutions to support the transition towards a hydrogen future	£1.14m	£1.92m	£3.06m
Creating data driven networks to manage risk, enable transition and modernise delivery	£1.25m	£1.25m	£2.50m
Enabling decarbonisation through intelligent network solutions (e.g. overcoming capacity constraints)	£5.50m	£2.25m	£7.75m
Total energy systems transition funding	**£7.89m**	**£5.42m**	**£13.31m**

For further information on our Innovation Strategy, please see Appendix 18.

We have also identified initiatives where our efforts are best focused on providing technical expertise, rather than financial contributions.

We consider delivery of these initiatives will provide various customer benefits, focused on the three whole systems outcomes of:

- Decarbonisation;
- Resilience; and
- Value.

Should the government make a policy decision on heat, we will trigger a reopener to seek funding to enable us to commence preparations for a future conversion.

We consider these funding arrangements provide us with sufficient ability to "flex" our plans to the changing needs of the market, changes in government policy and changes in the priorities of our stakeholders.

2. Our Whole Systems Strategy

2.1 Our Whole Systems Strategic Framework

We define a "whole systems approach" as one that facilitates strong collaboration and integration across the energy sector in order to realise the value associated with whole systems solutions, for the benefit of both existing and future energy customers.

The key premise of a whole systems approach is that an integration of energy infrastructure, operation, markets and supporting processes can deliver low carbon, resilient energy systems in an affordable way to all customers.

The scope of our whole systems approach is broad covering Heat, Power, Transport and Business Solutions, and whilst we see a strong link with our role to facilitate decarbonisation of the energy system, we also consider that strengthening our whole systems approach will enable better communication and knowledge-sharing among infrastructure providers in our region and further afield. This will lead to greater awareness of leading practices amongst ourselves and our peers, resulting in improved outcomes for our customers.

Our approach is based on three key components:

- **Whole Systems Enablers** – these are process-driven and are focused on laying the right foundations to ensure that we have the right approach within our operational and day to day activities.

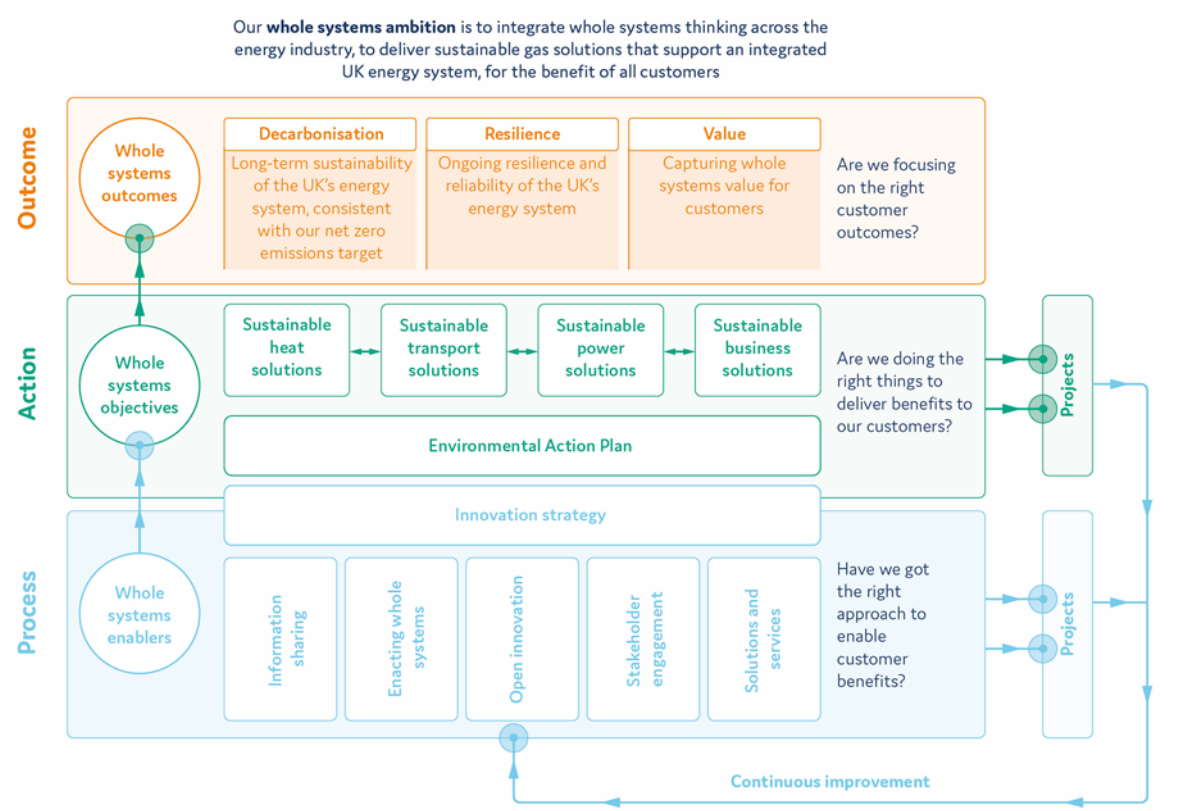
- **Whole Systems Objectives** – these are action-driven and outline what we intend to deliver to ensure that we're undertaking the right activities at a programme level to facilitate whole system benefits.

- **Whole Systems Outcomes** – these are customer-driven and set out what our enablers and strategies will be delivering for customers over the longer-term, taking account of the needs of both current and future stakeholders.

We consider our approach provides an appropriate balance between delivering the right outcomes for our customers, whilst also facilitating a flexible framework that can adapt and evolve over time.

Figure 4 below outlines our Whole Systems Strategic Framework.

Figure 4: Our Whole Systems Strategic Framework



The following sections explain our Whole Systems Enablers, Whole Systems Objectives and Whole Systems Outcomes in further detail.

2.1.1 Whole Systems Enablers

We have worked collaboratively with key stakeholders to identify what our whole systems focus areas should be going forward. In these conversations, our stakeholders told us:

- Gas distribution companies are leading innovation in relation to streetworks, customer service and safety.
- There have been whole systems demonstration projects and conversations between network companies, but RIIO-2 will be the time to implement the first steps.
- There should be a short-term focus on collaborating in the areas of network planning, connections, streetworks, operations, forecasting and customer service.
- Network companies could benefit from sharing data on assets and vulnerable customers, as well as collaborating on resources, major project planning and delivery, emergency response and customer service.

We used this feedback to develop our five Whole Systems Enablers, which are explained in further detail in Table 3 below.

Table 3: Whole Systems Enablers

Enabler	Description	What will this enable?
Information Sharing	We will work to share planning/operational data and models for strategic planning, real-time network operations and market facilitation.	This will ensure that investment decisions are made based on verifiable, consistent data across the energy system.
Enacting Whole Systems	We will implement whole systems thinking by enacting initiatives like secondments, job swaps, integrated planning and joint execution of excavation and road works.	This will ensure cross-sector cost efficiencies are realised from optimising control room and planning activities across the energy system.
Open Innovation	We will facilitate collaborative innovation on future cross-energy sector solutions (i.e. we will not focus solely on gas solutions), consistent with the approach outlined in our Innovation Strategy.	This will ensure innovation delivers optimised, cross-energy sector products, services and solutions for customers.
Stakeholder Engagement	We will continue to engage with stakeholders frequently to share insights, shape policy and support customer choice.	This will ensure we understand other stakeholders' objectives and how we can contribute to them.
Solutions & Services	We will work to develop and deploy innovative and sustainable whole systems solutions and services to customers.	This will ensure services and solutions deliver what is ultimately important to customers i.e. value, reliability, safety.

2.1.2 Whole Systems Objectives

Our Whole Systems Objectives have been developed to ensure that the benefits of our whole systems approach are captured and used to deliver our whole systems outcomes.

Our Whole Systems Objectives are focused on enabling and delivering in the following four areas:

- **Sustainable heat solutions** – we will investigate the potential and test the role of gas in delivering sustainable sources of heat through the facilitation of biomethane injection into the network and demonstration of the capabilities of hydrogen.

- **Sustainable transport solutions** – we will work with stakeholders to facilitate sustainable transport solutions, with a focus on how we can support the roll-out of required infrastructure to enable CNG, hydrogen and electric vehicles.

- **Sustainable power solutions** – we will continue to investigate optimised energy solutions for customers and support the ongoing integration of electricity and gas networks through innovation at InTEGReL.

- **Sustainable business solutions** – we will ensure the sustainability of our business by continuing to adopt best practice, not just in relation to environmental management, but also workforce resilience and ensuring we understand and are adapting to the needs of future stakeholders.

We consider that our approach strikes the right balance between leveraging value from our achievements in RIIO-1, strengthening our activities in areas that we haven't focused on in the past, whilst taking a pragmatic view to any further investments required.

2.1.3 Whole Systems Outcomes

Our Whole Systems Outcomes are the deliverables of our Whole Systems Strategy as well as the customer benefits of adopting whole systems thinking. This also align to the UK's energy trilemma. These are outlined in Table 4 below.

Table 4: Whole Systems Outcomes

	**Decarbonisation** Long term sustainability of the UK's energy system, in a net zero emission economy.	Gas can play an important role in decarbonising the energy system, through the integration of biomethane and adoption of hydrogen. From a whole systems approach, joint planning of decarbonisation efforts with the electricity and transport sector is crucial to prevent adverse effects of electrification and ensure the optimal decarbonisation pathway is identified.
	**Resilience** Ongoing resilience and reliability of the UK's energy system.	Climate change results in changing weather patterns and more extreme weather events like storms and flooding. The complex interdependencies that result from a whole systems approach require cross-sector resiliency and adaptation actions that ensure a resilience model that is at least as strong as the current gas resilience model.
	**Value** Capturing whole systems value for customers.	Stronger integration between utilities, and, going forward, the buildings and transport sector, offers numerous cost savings opportunities ranging from better asset planning and utilization to leveraging synergies in maintenance and repair works. Whole systems thinking will result in a least cost pathway through to achievement of our net zero emissions target by 2050.

2.2 Why is a whole systems approach important?

Gas has previously been seen as a transition fuel, but it is now becoming increasingly clear that it is a destination fuel that has an important role to play in a net zero emission energy system due to the advent of green gases such as hydrogen and biomethane[1].

The gas industry's high energy density and robust and reliable infrastructure contribute to the unique capability of gas to transport and store large volumes of energy, in a safe, reliable and low-cost manner. There is also a strong role for gas to play in supporting the decarbonisation of the electricity sector, by providing significant storage to maximise energy generation from intermittent, renewable electricity production.

Our Whole Systems Strategy builds on from this view that there is a strong role for gas to play in supporting the achievement of the UK's net zero emissions target by 2050. This is also supported by views outlined in the following:

[1] In this document, "green gas" is defined as either or a combination of hydrogen and biomethane.

- *Future Energy Scenarios* – three of the four core FES scenarios indicate that gas will continue to provide more energy to the UK than electricity whilst the net zero sensitivity indicates that the role of natural gas fundamentally changes but remains crucial to the energy supply.[2]
- *Climate Change Committee* – this report explains that a shift to a net zero emissions target changes the potential of hydrogen from being an option to an integral part of the strategy.[3]

We have also worked collaboratively with other gas distribution networks (GDNs) and Navigant through the ENA to develop the "Pathways to Net Zero: Decarbonising the Gas Networks in Great Britain" report, which was released in October 2019.[4] This report finds that:

- A balanced scenario (in which low carbon and renewable gases are used in a balanced combination with low carbon electricity) is a lower cost pathway through to meeting our net zero emissions target by 2050, than an electrified scenario (in which low carbon and renewable gases are limited in use to applications where there is no viable alternative);
- Gas throughput will reduce by approximately 46% by 2050; and
- Gas networks will continue to be relied on to supply peak energy needs, particularly in relation to supplying peak electricity demand.

Specifically, this pathway is built around four core elements, which work together to reduce the overall cost and disruption of decarbonising the energy system:

1. *Low Carbon and Renewable Gases* – the report estimates that alternative low carbon and renewable gases will be fully integrated into Great Britain's energy system. By 2050, all gas end-users will be supplied with hydrogen and/or biomethane. Hydrogen will be produced by natural gas reforming, creating the basis for hydrogen clusters, and by electrolysis using renewable power (both dedicated and curtailed generation). Biomethane will be produced by anaerobic digestion and thermal gasification.

2. *Carbon Capture, Utilisation and Storage (CCUS)* – the report estimates that CCUS will be needed to reduce emissions from hydrogen production and industrial processes. It will also provide "negative emissions" when combined with certain bioenergy technologies.

3. *Electrification* – the report acknowledges that some current uses of gas will be electrified. Specifically, the report expects that most road transport will be

[2] This report is available online here: http://fes.nationalgrid.com/media/1409/fes-2019.pdf.
[3] Climate Change Committee, "Net Zero: The UK's contribution to stopping global warming", May 2019, page 181.
[4] This report is accessible online here: http://www.energynetworks.org/gas/futures/gas-decarbonisation-pathways/pathways-to-net-zero-report.html.

electrified, although there is still an ongoing role for gas transport solutions through to 2050. Electrification of some low-temperature industrial processes will occur and hybrid heat systems (an electric heat pump paired with a low carbon or renewable gas boiler), will be a key technology for decarbonising the buildings sector in a cost-optimal way.

4. *Energy Efficiency* – the report sets out the importance of ongoing energy efficiency improvements across Great Britain, particularly in the buildings sector. Renovation measures such as loft insulation and high performance glazing will be deployed to bring the majority of buildings up to a moderate level of energy efficiency.[5]

We have reviewed Navigant's findings and have used this information to inform our own view of how our network will be used in 2050:

- *Improved efficiency and reduced gas demand* – gas flows through our network may reduce by 46% (although our network will still be relied upon to deliver peak heating demand in winter), largely driven by increasing energy efficiency of homes, the uptake of alternative technologies such as heat pumps and identification of areas of our network that are better suited to full electrification.
- *Biomethane* – biomethane will either solely supply segmented areas of our network (accounting for up to approximately 45% of total gas flows to customers by 2050), or be displaced by hydrogen and instead used for other applications such as transport.
- *Hydrogen* – most (if not all) of our network will be converted over to hydrogen and it will be predominantly supplied by blue hydrogen (coupled with CCUS), with further transition to green hydrogen required beyond 2050.
- *Net zero emissions* – by 2050, our network supplies net zero emissions gas to customers, as CCUS technologies have either improved to ensure 100% carbon capture or ongoing emissions will be offset by "negative emissions" derived from biomethane or biomass. Green hydrogen production will be supported by renewable electricity sources.

Importantly, this view of 2050 will only be achievable through strong collaboration with other sectors. A key example of this is in relation to close collaboration with the building sector to improve insulation levels of the building stock, resulting in lower utility bills and increased customer comfort.

This view is depicted in Figure 5 below.

[5] Navigant, "Pathways to Net-Zero: Decarbonising the Gas Networks in Great Britain", October 2019, page vi (available online here: http://www.energynetworks.org/gas/futures/gas-decarbonisation-pathways/pathways-to-net-zero-report.html)

Figure 5: Our Pathway to Net Zero

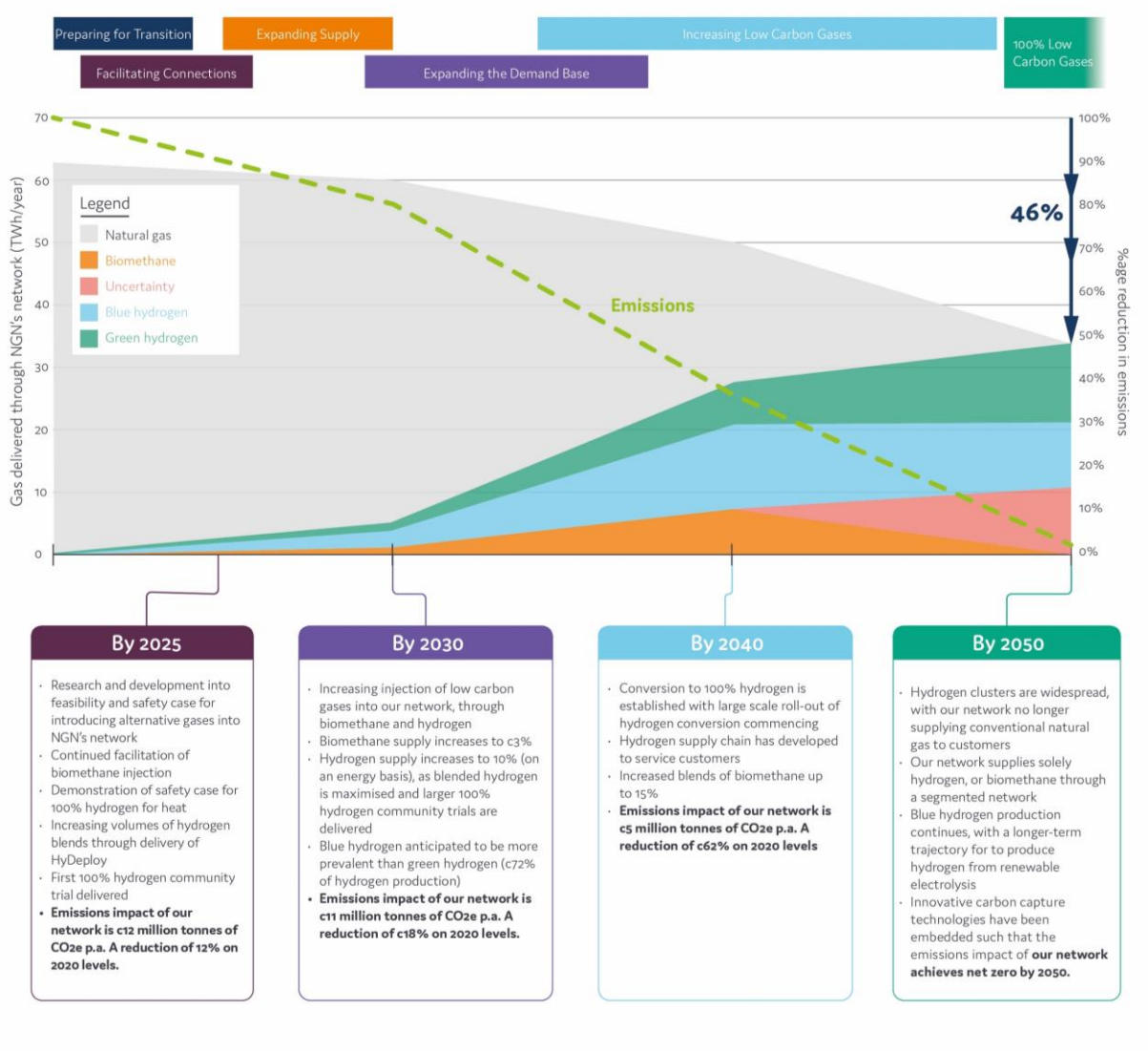


Table 5 below provides a very high level summary of how we consider these areas will contribute to the achievement of our net zero emissions target.

Table 5: NGN's net zero pathway to 2050

	2021	2026	2030	2040	2050	Carbon Saving Contribution[6]
Improved efficiency and reducing gas demand	• Actively engaging the market and considering findings from industry projects such as Project Freedom in relation to heat pumps. • Supporting customers to make the most efficient energy decisions (e.g. providing advice and delivering Fuel Poor Connection Scheme. • Ongoing R&D into efficient energy systems solutions through InTEGReL.	Gas throughput reduced by around 4% (on 2020 levels). Ongoing exploration of innovative energy efficiency technologies (such as improved materials to aid thermal insulation) through our Net Zero Customer Energy Village at InTEGReL.	Gas throughput reduced by around 6% (on 2020 levels). Ongoing collaboration with local, regional and national stakeholders to implement energy efficiency solutions that support customers in vulnerable situations.	Gas throughput reduced by around 21% (on 2020 levels). Ongoing support provided to local, regional and national stakeholders in implementing energy efficiency measures.	Gas throughput reduced by around 46% (on 2020 levels).	48% reduction in demand (compared to 2020), due to new efficient technologies and integration of gas and electricity. Carbon saving of around 50%, or 6 million tonnes of CO_2e on 2020 levels.
Biomethane	Continued facilitation of biomethane injection into our network, with volumes of around 1% of total throughput.	Biomethane volumes reach around 2% of total throughput. Growth in biomethane volumes attributable to improved customer service levels introduced in RIIO-2.	Biomethane volumes reach around 3% of total throughput as a result of innovative methods of minimising capacity constraints on our network and increased demand for biomethane for CNG vehicles.	Biomethane volumes reach around 15% of total throughput, as the market for biomethane continues to grow.	Biomethane volumes could reach up to 45% of total throughput (with some areas of our network segmented).	Carbon saving of up to circa 23%, or 3 million tonnes of CO_2e on 2020 levels.
Hydrogen	*Hydrogen blending:* Increased volume of blended hydrogen through delivery of HyDeploy 1 and HyDeploy 2.	Hydrogen reaches around 7% of total throughput on an energy basis (as a result of HyDeploy projects and commencement of community trials).	Hydrogen blending is now business as usual, reaching its maximum of 20% blending by volume, following delivery of first large-scale hydrogen production projects. Hydrogen accounts for around 10% of throughput on an energy basis.	Areas not converted to 100% hydrogen continue to have an increase in hydrogen blending, up to a maximum blend of 20% by volume.	100% conversion of our network using a combination of blue and green hydrogen. Some areas may be segmented to run on 100% biomethane.	Carbon saving of around 50% on 2020 levels, or 6 million tonnes of CO_2e on 2020 levels.
	100% hydrogen conversion: • Completion of H21 Phase 1. • Commencement of Phase 2. • Proactive sharing of findings among other GDNs and broader supply chain and industry.	• H21 Phase 2 complete. • H21 Phase 3 commenced. • Hydrogen safety case delivered and roll-out of 100% community trials commenced. • Government policy decision on future of heat in light of net zero emissions target.	Large-scale conversion to 100% hydrogen commences, as a gradual follow-on from community trials delivered in RIIO-2.	Hydrogen volumes reach around 40% of total throughput on an energy basis, with large areas of our network already converted to 100% hydrogen following further roll-out of community trials.		

[6] These numbers reflect the contribution of gas throughput delivered through our network and have been baselined against RIIO-1 throughput and an assumption that we deliver c. 99.5% of gas and lose/use c. 0.5%.

To summarise, this report demonstrates that gas can continue to contribute to the achievement of our net zero emissions target, through to 2050 and beyond.

Hydrogen specifically is an immensely versatile energy vector with broad applications in heat, transport and industry and a decarbonisation approach largely based around the increased utilisation of hydrogen would yield benefits well beyond combatting climate change. The skills, intellectual property and export value of being a first mover in hydrogen could lead to increased economic benefit in areas currently struggling from long term underinvestment. In this way do we see hydrogen as a truly whole systems solution that could contribute to the achievement of our net zero emission target.

Given this, we have sought to value the significant potential customer and social benefits of the effort we are investing in our hydrogen pathway. To do this, we've adopted a similar approach to how we have valued the benefits associated with our Business Plan's Customer Value Proposition.

Using this approach, we've identified various immediate and long-term potential benefits of our hydrogen pathway, as well as the substantial benefits to wider society. In many cases we haven't been able to value these benefits, however based on those that we can value we are estimating that our focus on demonstrating the potential of hydrogen could contribute circa $722 million in benefits to our customers over RIIO-2.[7]

We also consider that the north of England has strong potential to become a key hydrogen hub in Great Britain, with access to CCUS through Morecambe Bay and the North Sea as well as the presence of key industrial hubs such as the Humber and Tees Valley.

2.3 Acknowledging uncertainty

Any forecast through to 2050 will be subject to significant uncertainty and we acknowledge that our plans need to be able to flex in order to adapt to changing circumstances (whether driven by the market, changes in policy or changing customer preferences).

Key uncertainties associated with this pathway are outlined in Table 6 below.

[7] For further information, please refer to our Customer Value Proposition provided as Appendix 13 to our Business Plan.

Table 6: Key Uncertainties

Uncertainty	Description	Mitigation and NGN's Role
Effects of hydrogen blending beyond 20% volume	Beyond a blend of 20% volume hydrogen, burning properties of blended gas change to the point that end-use equipment requires adjustment, as does metering and billing (currently being addressed in the Future Billing Methodology project) and to some extent grid infrastructure.	**Active**. This is an ongoing field of research in which we and the wider industry are active and expect to provide solutions over the next couple of years. Specifically, we are currently involved in the delivery of HyDeploy 1 and 2.
Policy decision on heat	We expect the government to deliver its policy decision regarding the transition of heat to support our net zero emissions target by the early-mid 2020s.	**Active.** We will work to ensure the necessary evidence is delivered to support a decision relating to conversion of our networks to hydrogen and are ready to respond to this decision. Given the uncertainty associated with this decision, we have excluded costs associated with converting our networks over to 100% hydrogen from our Business Plan at this time, as we will propose a regulatory re-opener to seek funds for this work once the policy decision is confirmed.
Preferred deployment paths	Multiple deployment schemes for changing our grid from one dominated by natural gas to one based on hydrogen exist, ranging from multiple smaller interventions across the grid to gradually get to 100% hydrogen to a larger-scale approach where parts of the grid are segmented and converted.	**Active**. The preferred approach will be determined in part by the switch to biomethane and hydrogen at the national level. We will continue to progress our own plans to convert our network infrastructure over to green gases, in support of preferred deployment paths.
Viability of CCUS	CCUS has been identified as a key enabler of the UK's energy transition to 2050, but technically and commercially large-scale projects have yet to emerge.	**Participant.** We have identified some areas that GDNs can contribute to the development of CCUS in the UK, through the ENA's Gas Decarbonisation Pathways work program. We will work collaboratively through the Hydrogen Program Development Group to deliver this work program.
Viability of gasification of biomass to biomethane	Technical and cost challenges may negatively impact availability of biomethane from biomass.	**Observer**. We are actively involved in the ENA's Biomethane Technical Working Group to consider improvements in the consistency associated with biomethane connections to gas network infrastructure across the UK, however we have limited knowledge on technical challenges associated with biomethane production.

Collaboration across all sectors (spanning industry, academia and government) in order to deliver the evidence to support key decisions will be the primary mitigation of these uncertainties. This is where we consider our Whole Systems Strategy sets out an effective framework in which we can foster closer collaboration among key stakeholders, in order to ensure we are focused on delivering key customer benefits, through balancing of the energy trilemma.

2.4 Our approach

NGN is committed to supporting the achievement of the UK's net zero emission targets through our Whole Systems Strategic Framework, which is focused on delivery.

We also acknowledge that it is important we have a strong approach to delivering our strategy, focused on collaboration and knowledge-sharing and leveraging appropriate funding mechanisms.

2.4.1 Funding our Whole Systems Strategic Framework

Similar to our Innovation Strategy (provided as Appendix 18 to our Business Plan), we have identified different funding mechanisms that we will use to deliver whole systems initiatives over the course of RIIO-2. These are set out in Table 7 below.

Table 7: Funding Mechanisms

Funding mechanism	Relevance to Whole Systems
Totex allowance	Where we have identified specific projects that will deliver tangible customer benefits, we will fund delivery of these projects in RIIO-2 through our totex allowance.
Network Innovation Allowances (NGN and other GDNs)	Where tangible benefits for our customers are less clear (or are more long-term in nature), we will use NIA funding to deliver whole systems initiatives that support the energy systems transition in RIIO-2. Specifically, we are seeking £7.9 million in NIA funding to deliver initiatives summing to £13.3 million over RIIO-2. It is assumed that we will fund the £5.4 million gap with third party funding.[8]
Third party funding	Where projects are more prospective in nature (so customer benefits are unclear), funding will be sought through other means such as wider government funding mechanisms (e.g. Innovate UK) or in partnership with academia. Given the nature of these funding opportunities and the time taken to work through a competitive bid process, projects reliant on third party funding may not progress as quickly as others. That said, we still consider that leveraging third party funding is an appropriate way to fund these projects, and minimises costs borne by our customers. Of particular note is the Strategic Challenge Fund (SCF) which aims to address our net zero emission targets and decarbonisation challenge. We envisage using this funding to progress nationally important work on hydrogen.
Provision of technical expertise	In some instances, we've identified projects where there is benefit in NGN involvement in progressing whole systems thinking in our region but acknowledge that the most effective means of our involvement is not through a financial contribution, but rather through the provision of technical expertise and guidance. We consider these contributions are still an integral part of our approach to whole systems and demonstrate the value that we can add in support of our stakeholders.
Uncertainty mechanism	We will continue our R&D efforts to support a policy decision on heat. When the government make a policy decision on heat, we will trigger a reopener (i.e. an uncertainty mechanism) to seek funding to enable us to commence preparations for a future conversion.

[8] For further information on this, please refer to our Innovation Strategy provided as Appendix 18 to our Business Plan.

We consider that taking this approach will ensure that our customers only incur costs relating to projects with the greatest benefit to them, whilst also not excluding us from delivering projects that we think have merit, but where the direct customer benefit is less clear.

2.4.2 Working with Academia

In order to rapidly decarbonise energy systems to meet our net zero emission targets, we know that innovative technologies and approaches will be required to identify effective, reliable and least cost solutions. We consider that this will require industry to work outside its previous bounds and proactively establish close links with academia and thought leaders across the UK and internationally. This is consistent with our approach to innovation, which is set out in Appendix 18 to our Business Plan.

Most leading research establishments are focusing their efforts (at least to some degree) on the challenge of sustainability and balancing the energy trilemma outcomes. As such, there is a strong opportunity for partnerships between academia and industry to provide a significant contribution to reaching our net zero emission targets. Table 8 sets out what we consider to be the three key benefits to this approach.

Table 8: Key benefits to working closely with academia

Benefit	Explanation	Example
Access to funding	Academic institutions are eligible to apply for funding that organisations aren't. Partnerships with academia therefore provide businesses with an opportunity to leverage funding and resources toward research areas whilst also supporting the development of local expertise on industry issues relating to decarbonisation.	Through our partnership with Newcastle University, we have been able to access funding from the CESI, to deliver our Control Centre of the Future project with NPG and Newcastle and Durham Universities.[9]
Broadening the scope of the possible	Developing strong relationships with academic institutions ensures that industry is up-to-date with new technological developments and best practice. It also opens up opportunities to engage and work collaboratively with other industries on common problems, which organisations may otherwise not be aware of.	NGN was involved in the initial Fresh Partnership where gas, electricity and water utilities collaborated with academia, local authorities and the wider supply chain to share research and project ideas. This partnership led to closer ties with Newcastle University and development of whole systems thinking, which supported the establishment of CESI. CESI has now supported delivery of various projects in the North East, with demonstrable benefits to industry and energy customers.
Development of expertise	Industry and academia often have differing timescales for delivery and a divergence between priorities (i.e. theoretical vs practical). Establishing	So far, through InTEGReL and in partnership with Newcastle University, we have supported a PhD student to investigate efficient gas and

[9] Further information on this project is provided in Section X.

	closer links between academia and industry should assist with efforts being directed to areas of mutual benefit whilst also accelerating progress toward reaching our net zero emission targets.	electrical network management using pumped heat energy storage technology.

Going forward, NGN is committed to continuing its close working relationships with academic institutions such as Newcastle and Durham universities. We have found these relationships have contributed significantly to our whole systems thinking and demonstrate the world-class capabilities that our local stakeholders can bring to supporting the achievement of the UK's net zero emissions target.

3. Our Whole Systems Enablers

For each of our Whole Systems Enablers, a set of actions have been identified that contribute to achieving our Whole Systems Outcomes. These actions are a combination of our ongoing whole systems efforts, planned innovation projects, stakeholder input and identified gaps that need to be closed to fulfil our ambition of delivering a decarbonised, resilient and affordable multi-vector energy system.

Each of the Whole Systems Enablers is characterized by largely consecutive, but in some cases partly overlapping phases of complexity, and actions are allocated to each phase.

Key partners and stakeholders are linked to each action, and we have provided a status update against each action to clarify whether we have already commenced an action, we'll be focusing on the action in RIIO-2, or whether this is a longer-term action for RIIO-3 and beyond.

In the following section the Whole Systems Enablers are further explained, providing both a brief overview of current whole systems activities as well as future actions.

3.1 Information sharing

Signposts	• Appendix 12: Digitalisation Strategy • Appendix 11: IT and Cyber Security Plan • Appendix 7: Vulnerability Strategy • Appendix 18: Innovation Strategy

Creating an integrated, optimized multi-vector energy system requires a shared understanding between all stakeholders on what such a system entails and a shared sense of purpose in terms of what is to be achieved. Sharing information with other stakeholders is a low-regret step that we can take individually and, as our whole systems thinking progresses, collectively.

The primary purposes of information sharing are to ensure that strategic, tactical and operational decisions are made based on verifiable, consistent data and that the build-out of whole systems is tracked and monitored.

Four stages of information sharing have been identified for a whole systems approach that progressively address a wider range of stakeholders and provide increasingly more specific data for realizing whole systems benefits. It should be noted that these stages are additive: at each stage activities are added to the activities from the previous stage(s), which continue to take place.

Figure 6: Four stages of information sharing

Current information sharing initiatives that we are undertaking and will build on for RIIO-2 are:

- **Network Data**: We are sharing network data with third parties performing digging works, but there are opportunities for us to share data on street works information, asset condition and asset proximity with other stakeholders as well as emergency services. Sharing this data will improve data reliability and quality for all participating utilities. Data quality is a challenge across all vectors, but a whole systems approach could improve consistency. There are also opportunities to share non-vector specific costs; network encroachment survey data; rail, river and road crossing information; and approaches to manage major projects (like HS2).

- **Operational Data**: There are currently data links and communication processes between us and the Gas Transmission Network operator, however we are planning to implement links to the electricity DNOs within the RIIO-2 period to facilitate more efficient cross-vector network operation.

- **Health and Safety Data**: We are already sharing information on health and safety, but there are still opportunities to share more learning across industries on: How to reduce incidents; street works, lane techniques, timelines; contingency plans; staff workloads; and whole system impacts of incidents on other vectors. (Note that data on these activities is currently shared for pipelines only using a data input forum)

- **Customer Services**: There are opportunities to identify additional vulnerable customers and share information about them between utilities. Sharing this information could help identify out-of-date information and make data access more efficient. Customers would also benefit from only needing to notify one utility. We are currently working with water utilities to share vulnerable customer data. We are also developing a customer needs list to help it better support vulnerable customer needs. We'll continue to build on the work carried out in RIIO-1 by the cross-GDN DNO Customer Safeguarding Working Group that has been looking at broad improvements to the existing Priority Services Register including security of customer data and improved services to customers.

- **Market Facilitation**: Gas distribution networks can be used to balance energy flows between electricity and gas vectors as well as provide energy storage services. We are working with partners to investigate how future DSO technology can be extended to include gas and hydrogen solutions under various future energy

scenarios. Our establishment of the InTEGReL facility and membership of CESI support this.

Box 2: The link to innovation

One of our key innovation focus areas for RIIO-2 is on creating data driven networks to manage risk, enable transition and modernise delivery. We have allowed £5.5 million in NIA funding to support this focus area, supported by an additional £2 million funding accessed from third parties.

We consider that although distribution assets will remain predominantly mechanical with manual intervention required to undertake a vast array of tasks, the advancement of digital technology creates an opportunity for transformational change that is essential to enable a network with sufficient flexibility to operate across energy vectors.

Our innovation program will explore technology and data capabilities to enable sensing, control and information transfer through cross connected network systems. The solutions will use real time data to enable automated optimisation of decision making and create an active network that enables cross vector connectivity. Data driven systems will create opportunity for proactive intervention, either remotely or physically on-site to reduce energy system activities and associated societal impacts.

For further information, please refer to our Innovation Strategy provided as Appendix 18 to our Business Plan.

Box 3: Our Digital Dream Statement

Our Digital Dream Statement is to give people an agile and intuitive NGN experience. By doing this, we empower them to know more, care more and do more.

There is an absolute understanding in NGN that we can deliver the excellent levels of performance that exist, but in a different way; a smarter NGN.

Our customers expect increasingly higher standards of service, our colleagues expect technology at work to be as good if not better than at home and we continually strive to be as safe, reliable and efficient as possible with our technology and its use in our organisation.

We have a fantastic opportunity to fulfil this by putting technology and information at the heart of our business processes, thereby transforming the way we work today. A smarter NGN will enable fundamentally new ways of working, with improved decision making and ever developing customer and colleague experiences.

For further information, please refer to NGN's Digitalisation Strategy provided as Appendix 12 to our Business Plan.

Box 4: A whole systems approach to customers in vulnerable situations

As a responsible organisation we recognise and have a responsibility to support communities and individuals facing difficulties and also more broadly within the communities we serve in our network, ensuring that we look to identify and support those that need a little extra help.

Through the Fuel Poor Network Extension Scheme, we already adopt a whole systems approach to assessing the needs of people in vulnerable situations in order to deliver an energy solution that is in their best interest. We are a strong performer in this area, with a commitment to ensuring a whole systems approach. This has in some cases meant we've installed heat pumps at customers' premises to help manage their energy bills.

Looking forward, we are committed to investing our resources wisely in order to ensure our efforts continue to derive the greatest possible social benefit. In relation to the Fuel Poor Network Extension Scheme, in RIIO-2 we will only claim the full Fuel Poor voucher for situations where we can demonstrate that the desired customer benefit was achieved. We are consistently ensuring we take a whole systems view of the needs of customers in vulnerable situations and will continue to do so in RIIO-2.

For further information, please see our Vulnerability Strategy, provided as Appendix 7.

Box 5: Smart Gas Grids

NGN recognise the significant changes which will be brought about as a result of climate change. There is a growing need to consider the impacts of climate change and develop solutions that provide climate adaptation strategies for the industry. This means we need new innovative solutions to support advanced management and control over our systems performance and behaviours.

To this end, NGN is supporting the development of new low cost technologies that will evolve our existing and future infrastructure and realise a Smart Gas Grid. The deployment and embedding of smart technologies into our networks will transition the gas industry into the new industrial age, enabling a new approach to gas system management, through advanced grid edge computing and application of AI systems.

Box 6: Open Data Institute

As an indication of our commitment to information sharing, we have recently become a sponsor of the Open Data Institute. The mission of this organisation is twofold:

- Create a place where people from all sectors/backgrounds can come together to be creative, innovative, and collaborative. We want to be inclusive, vibrant, and most importantly, fun for all.
- Encourage the people of Leeds (and beyond) to engage and innovate with open data. Ask questions, find answers. Look at problems from new perspectives then build solutions.

Other sponsors of this initiative include Local Authorities such as Leeds City Council, industry members such as KPMG, and other utility organisations such as Yorkshire Water, Northern Powergrid and Highways England.

For more information on this initiative, please visit https://odileeds.org/.

Table 9: Identified actions on Information Sharing

	Goal	Action	Key Partners	Key Stakeholders	Status
Sharing across network sectors	Provide insight into planning methodologies, operational challenges and identify potential for synergies across gas and electricity sector.	Share scenarios and operational forecasts.	• National Grid • NPG, Electricity North West (ENW)	• GDNs, DNOs • National Grid	Commenced. We already share our forecasts with other GDNs and stakeholders through the Future Energy Scenarios.
		Share street work plans.	• Local authorities • NPG, ENW	• Water utility • Telecommunications companies	Commenced. We work collaboratively with local authorities on this issue, however will increase our efforts in this space with other stakeholders in RIIO-2.
		Share data about flexible connections, assets and usage rules.	• N/A	• NPG, ENW • National Grid	Focus area for RIIO-2.
Open data	Facilitate discussions and decisions among wide range of stakeholders on whole systems opportunities.	Publish grid capacity usage data.	• NPG, ENW	• Suppliers • Developers • Energy service companies (ESCOs), aggregators	Focus area for RIIO-2.
		Publish location data of grid assets.	• GDNs, DNOs • Water utilities • Telecommunications companies	• Local Authorities • Developers • Customers	Focus area for RIIO-2. We will need to consider ongoing security of our assets.
Whole Systems messaging	Get support and buy-in from all stakeholders for whole systems transformation.	Public campaign on heating with hydrogen.	• Energy Suppliers • Local Authorities • Vendors/Manufactures	• Customers • Building owners • ESCOs, aggregators	Focus area for RIIO-2.
		Pubic campaign on hydrogen for transport.	• Energy Suppliers • Local Authorities • Vendors/Manufacturers	• Customers • ESCOs, aggregators	Focus area for RIIO-2.
		Promoting Energy-as-a-Service.	• Energy Suppliers • Local Authorities • Energy Systems Catapult	• Local Authorities • Vulnerable customers	Focus area for RIIO-3 and beyond.
Market facilitation	Enable whole systems services for multi-commodity services.	Online shared connection register.	• Electricity and gas DNOs	• ESCOs, Aggregators • Suppliers	Commenced. We are in early discussions with NPG on how we can provide a streamlined connections process to energy customers.
		Network Data and energy needs heat maps.	• Electricity and gas DNOs • Suppliers	• ESCOs, Aggregators • Suppliers • Manufacturers, Vendors	Focus area for RIIO-2.

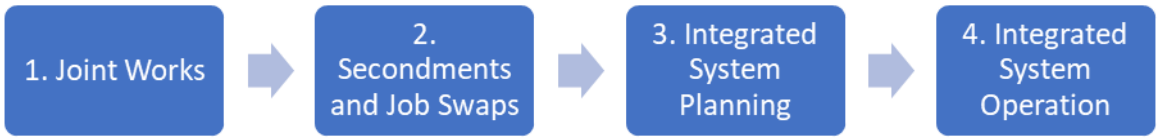
3.2 Enacting Whole Systems

Signposts	• Appendix 4: Stakeholder Engagement Insights

Significant benefits can be achieved for customers through applying whole systems thinking to operational activities. A prime example of this is in relation to improved coordination of street works, to minimise excavation costs and disruption to customers and communities.

We have already increased communications with our colleagues from the electricity distribution network operators, gas transmission system operator and water utilities throughout RIIO-1. In RIIO-2 we will expand this into a series of collaborative operational activities that will benefit our customers in the short term and enable the decarbonisation of the energy system in the longer term. These activities are summarised below.

Figure 7: Four stages of Enacting Whole Systems



- **Joint Works:**
  - *Street Works* – We are working to improve liaison with local authorities to minimise disruption of street works and outages to customers. We are looking at cross-vector solutions that leverage synergies and collaborative opportunities for street works planning and for back office functions relating to street works.
  - *Major Projects* – We are investigating opportunities to minimise disruption from diversions and enabling works associated with major projects (like HS2) using a single contractor formed of trained staff from each vector. This will provide a single point of contact, a holistic planning approach, and generate efficiencies. There are also potential synergies in undertaking further cross vector work, for example combining standby and depot facilities (e.g. cross vector depots to move people closer to the work). We will work with local anchor institutions as part of our ongoing engagement to assess the practicalities and opportunities of this approach.

- **Secondments and Job Swaps**: In RIIO-2, we will explore expanding training to include skills relating to other utility areas (e.g. basic electrical inspection).

- **Integrated System Planning**: Collaboration with Gas Transmission is effective, but more collaboration between electricity and gas distribution network planners will make our energy system more efficient. Longer term, we will need to ensure stronger collaboration with transport stakeholders too. Information will be shared on the level of generation planned on electricity distribution companies to enable

whole systems decision making on how generation will be managed to support networks across all vectors most efficiently.

Gas planners also need a better understanding of future housing demand and household energy trends. More collaboration with electricity distribution companies, developers and local authorities will lead to better decisions about how to meet future energy needs.

We have already adopted an integrated approach to assessing the needs of Fuel Poor customers, which is explained further in Section 3.5.

- **Integrated System Operation:** We and the gas transmission system operator undertake separate operational forecasts, but they are broadly consistent. We will work with the electricity distribution network operator to share further forecasts and operational data in RIIO-2.

  We have already undertaken a joint project with NPG, Newcastle and Durham Universities to investigate the practicalities associated with establishing a joint control room and will continue to focus on this in RIIO-2.

Box 7: Coordination of Works

In our engagement program to support development of our Business Plan, one of the key issues raised by MPs and Local Authorities/Councils focused on public inconvenience related to pipe replacement work. MPs specifically mentioned that they receive regular complaints from their constituents on this matter. A consistent message we heard is that there needs to be better alignment between plans to deliver works with other utility companies to ensure roads are not being dug up multiple times for works in a short period of time.

Currently, we hold coordination meetings with Local Authorities to understand the potential to coordinate works in their areas, however we will look to increase our efforts in this space going forward. Specifically, a couple of initiatives we are looking to deliver include the following:

- Provide a three-year rolling programme of works to help Local Authorities/Councils understand what we're planning in their area and giving them a better chance of supporting coordination; and
- Hold annual strategic planning meetings, where Local Authorities/Councils can brief us on their major schemes and we can work together on longer term strategic planning of works.

Table 10: Enacting Whole Systems

	Goal	Action	Key Partners	Key Stakeholders	Status
Joint Works	Lower cost through smartly combining operational work across energy vectors.	Integrate synergies in excavation, roadworks and major projects.	• NW, Yorkshire Water (YW), NPG, ENW, telecommunications companies	• Existing contractors	Commenced. We work collaboratively with local authorities on this issue, however will increase our efforts in this space in RIIO-2.
		Integrate standby and depot facilities.	• NW, YW, NPG, ENW, telecommunications companies	• N/A	Not yet commenced. This will be a longer-term project, beyond RIIO-2.
Secondments and Job Swaps	Broaden the skill set and improve quality of work through hands-on knowledge exchange between electricity and gas grid operators.	Enable knowledge exchange and secondments between electricity and gas planners and control room staff.	• NPG, ENW	• N/A	Not yet commenced. We have had initial conversations with NPG and will continue these discussions in RIIO-2.
		Enable knowledge exchange and secondments between teams responsible for civil and street works.	• NW, YW, NPG, ENW • Telecommunications companies	• Existing contractors	Not yet commenced. We have had initial conversations with NPG and will continue these discussions in RIIO-2.
		Update training programme for staff visiting customer premises to include cross-vector inspection and advice.	• NEA	• Third Party Training providers	Commenced. Have held initial discussions with NPG and will continue these discussions in RIIO-2.
Integrated System Planning	Further resilience and decarbonization through integrated planning of energy infrastructure extensions, upgrades and conversions.	Integrate generation planning between electricity and gas DSOs.	• NPG, ENW	• N/A	Commenced. Already share forecast information through the Common Energy Scenario work (e.g. gas-fired generation). Will continue to do so in RIIO-2.
		Develop Future Gas System Architecture.	• Energy Systems Catapult • Newcastle University	• GDNs, DNOs • BEIS	Commenced. We will continue to develop our InTEGReL site in collaboration with academia, over RIIO-2.
		Include generation and DER usage patterns rather than capacity in planning.	• NPG, ENW	• N/A	Not yet commenced, will form part of ongoing collaboration with NPG.
		Include building stock and transport growth in planning to meet customer needs.	• NPG, ENW	• Local authorities, • Developers	Not yet commenced, will form part of ongoing collaboration with NPG.
		Create common fleet conversion strategy (to optimise charging/refuelling infrastructure).	• NPG, ENW, YW, Northumbrian Water (NW)	• Local authorities, • Suppliers • Customers	Commenced. We have so far coordinated discussions with anchor organisations in our region on how to manage our respective fleet conversions, this will continue to be a focus for us in RIIO-2.
		Share network capacity heatmaps with third parties.	• N/A	• Local authorities, • Developers	Commenced. We will look at how we can provide better information to third parties in RIIO-2.
Integrated System Operation	Realtime operation and optimization of multi-vector energy system.	Share operational forecasting information.	• NPG, ENW	• N/A	Commenced. We already share our forecasts with other GDNs and stakeholders through the Future Energy Scenarios.
		Move energy across vectors to optimise the energy system.	• NPG, ENW	• N/A	Commenced. Investing in R&D at InTEGReL site. This will continue to be a focus area for us in RIIO-2.
		Cross energy-vector allocation and reconciliation.	• NPG, ENW	• N/A	Commenced. Investing in R&D at InTEGReL site. This will continue to be a focus area for us in RIIO-2.

3.3 Open innovation

Signposts	• Appendix 18: Innovation Strategy • Appendix 12: Digitalisation Strategy • Appendix 7: Vulnerability Strategy

Our vision for innovation at NGN is as follows:

NGN Innovation delivers improvements for our customers and networks, actively seeking ideas to help us modernise today and prepare for tomorrow. Through collaboration with colleagues and suppliers, we're developing new and novel solutions to deliver valuable benefits and make lives easier.

At NGN, innovation is crucial to the way we approach all aspects of our business. For us, the purpose of innovation is a dual one of delivering improved outcomes to our customers, while helping to facilitate the government's energy policy and transition to a zero-carbon economy.

A culture of innovation permeates our whole business and is not restricted to a siloed function or purely driven from our leadership. From enabling our engineers to work with a reduced impact on the environment to our close working partnership where direct service providers are an extended part of our organisation, all our employees are empowered to behave in an innovative manner.[10]

As an enabler of our Whole Systems Strategy, Open Innovation will ensure that we facilitate a collaborative approach to innovation with our stakeholders. Through this collaboration, we will ensure we are considering future cross-energy sector solutions and are not just focused solely on our own gas sector.

In RIIO-2, our innovation program will use research, development and demonstration challenge areas to ensure that a future decarbonised system is flexible, affordable and appropriate to enable essential solutions to make the choice to heat the home one that delivers benefit beyond immediate warmth.

The opportunities in this area will further support and enable flexible, whole system integration to achieve our net zero emission target and wider decarbonisation. This will be explored through collaboration with academia, third parties and cross sector organisations.

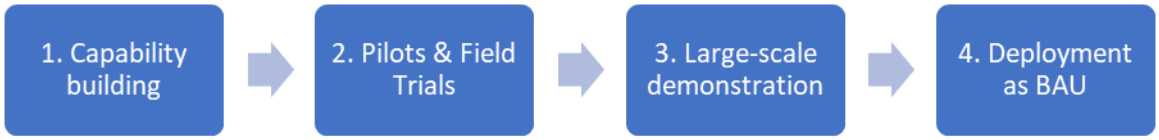
As whole systems matures throughout RIIO-2 and RIIO-3, a more diverse group of actors will be part of it and an open innovation environment is needed where utilities, companies, authorities and social institutions can collectively design and test whole systems products, services and solutions.

[10] Please see Appendix 18 for further information on our Innovation Strategy.

Throughout RIIO-2 we will, as we have done in RIIO-1 leverage existing and ongoing innovations in the sector from our peers.

Our innovation process has several stages, however for the purposes of whole systems applications, we have identified the following four successive stages as depicted in Figure 8 below.

Figure 8: The innovation process broken down into four stages



For each stage key actions are described in Table 9. These actions reflect the existing and planned facilities and projects at InTEGReL and other key multi-partner innovation projects.

Table 11: Open Innovation

	Goal	Action	Key Partners	Key Stakeholders	Status
Capability Building	Develop key system components required for the transition to a sustainable energy system where heat is primarily delivered through green sources.	Hydrogen gas meters in Hy4Heat	• BEIS • Arup	GDNs, customers, suppliers	Commenced. NGN is actively engaged in this project, but are not a project partner.
		Hydrogen-fired appliances	• Hy4Heat • Academia • Manufacturers	• National and local authorities, customers • GDNs, DNOs, National Grid • Building sector	Commenced. NGN is actively engaged in this project, but are not a project partner.
		Control Centre of the future	• NPG • Newcastle University • Durham University	• National Grid • GDNs, DNOs	Commenced. Phase 1 is almost complete and we are in discussions with CESI to develop the concept for the next phase.
		Whole Energy Systems Modelling Engine	• National Centre for Energy Systems Integration (Newcastle and Durham universities) • NPG	• National Grid • GDNs, DNOs • Transport, buildings sector	Commenced. NGN has provided data and analysis to support delivery of a maths model that can pull together electricity, heat and other energy vectors.
		Develop NB-IoT (narrow band IoT)	• HP1 • Radius Systems	• GDNs, DNOs • Water utilities	Commenced. Funded through NIA and will deliver low cost NB-IoT pressure sensor to allow us to improve visibility on our network and potential cost savings in relation to asset monitoring.
		Development of industrial IoT lab	• NW • 3 Mobile, Hutchison	• GDNs, DNOs	Commenced. Construction started on site at InTEGReL in August 2019. Have also identified other projects for delivery in RIIO-2.
		Cyber Security & Energy Cloud	• Academia • Telecommunications companies, manufacturers & Vendors	• GDNs, DNOs • Customers	Focus area for RIIO-2.
Pilots & Field Trials	Evaluate performance, usability and robustness of prototypes in a controlled, realistic environment that mimics integration of new solutions with existing systems and methods.	Futurewave- A shared energy platform	• Energy Innovation Centre • Electricity and gas networks	• Customers	Focus area for RIIO-2.
		NGN Solar Array	• NGN	• GDNs, DNOs • Transport, buildings sector	Commenced. NGN is leading this project at InTEGReL which will complement NPG's battery installation at the site.
		NPG Battery Storage House	• Newcastle University • NPG, ENW	• GDNs, DNOs • Transport, buildings sector	Commenced. NPG is ready to start construction on site at InTEGReL.
		Hydrogen refuelling	• Newcastle University • Transport sector	• DNOs, GDNs • Customers • Local authorities	Focus area for RIIO-2.
Large-scale demonstration	Controlled deployment at scale of pre-commercial release solutions to validate market-readiness and business case.	Flexibility services from dual fuel heating systems	• NPG, ENW • Newcastle University • National Grid	• DNOs, GDNs • ESCOs, Aggregators • Customers	Focus area for RIIO-2.
		City Centre EV filling stations and vehicle to grid capabilities	• NPG, ENW • Fastned UK • Local authorities, LEPs • Zero Carbon Futures	• DNOs, GDNs • Aggregators • Customers	Focus area for RIIO-2.
Deployment as BAU	Integration with existing commercial, operational and administrative processes and general availability of products, services and solutions.	50MW Power-to-gas	• NPG • Newcastle University • BEIS • ITM Power	• Building sector • Transport sector • Local authorities	Focus area for RIIO-2.

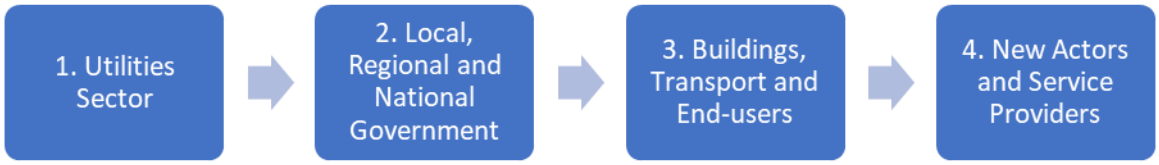
3.4 Stakeholder engagement

Signposts	• Appendix 4: Stakeholder Engagement Insights

Developing and realizing a whole systems approach is by its very definition an undertaking that requires all stakeholders to work closely together, and for that to be successful, to understand each other's objectives and how those can contribute to and be incorporated into an effective whole systems strategy.[11]

In line with Ofgem's respective focus areas for RIIO-2 and RIIO-3, our approach to whole systems engagement features four steps, where each step engages additional stakeholder groups. This is illustrated schematically in Figure 9.

Figure 9: Progressive levels of Stakeholder Engagement



We recognise the importance of continuity and building on from our existing relationships. The table below provides a summary of our current status and key focus areas for RIIO-2.

- **Utilities sector**: We are actively participating in the ENA's Open Networks project, which is currently focusing on developing whole energy system collaboration opportunities with the other gas and electricity networks. We have good working relationships with both YW and NW, which we will look to strengthen in RIIO-2. We will also look to establish stronger relationships with telecommunications businesses in RIIO-2. We are also planning to increase collaboration with utilities by working together on small projects like improving road resurfacing to help make collaboration a business-as-usual activity.

- **Local, regional and national government**: We are working with local authorities and other stakeholders to improve the way street works are managed. There is currently an overlap between the teams who notify local authorities for different utilities and we will work to find efficiencies and improvements with processes such that customer disruption from street works is minimised.

- **Buildings, transport and end users**: We are supporting clean transportation through the deployment of CNG filling stations, uptake of electric vehicles in our fleet and ongoing promotion of the benefits of hydrogen fuel cell electric vehicles. We are also

[11] For further information relating to our forward-looking approach to stakeholder engagement, please see Section 3 of our Business Plan.

facilitating cleaner transport by helping third parties, raising awareness and pulling logistics together.

- **New actors and service providers**: We are working with Digital Catapult to find efficient yet reliable ways to digitize the gas networks using Internet of Things technologies, and with Energy Systems Catapult and IGEM, Newcastle University on the Future Gas Systems Architecture Project.

Table 12: Stakeholder Engagement

	Goal	Action	Key Partners	Key Stakeholders	Status
Utilities Sector	Develop coherent, scenario-based and data driven roadmaps for decarbonizing the energy system in a resilient, cost-effective way, supported by all stakeholders in the gas and power sector.	Participate in ENA's Open Networks work stream.	• Network companies	• DER and generators	Commenced. This will be an ongoing work stream in RIIO-2.
		Participate in ENA's Gas Decarbonisation Pathways Project.	• ENA	• Government • GDNs, DNOs, Nat. Grid • Suppliers	Commenced. Development of Pathways complete, next steps are focused on delivering work programs. This will be a focus in RIIO-2.
		Work with academia and policy makers to support energy transition.	• Academia	• Government, Local authorities	Commenced. This will be an ongoing work stream in RIIO-2.
Local, Regional and National Government	Drive and coordinate hydrogen research, demonstration, evidence gathering.	Member of the Hydrogen Transformation Group (now the Hydrogen Programme Development Group).	• BEIS • Ofgem	• GDNs, DNOs • Suppliers	Commenced. NGN led the establishment of this group and continues to play a key role in its strategic direction. Focus for RIIO-2 will be on ensuring ongoing collaboration between GDNs, government and broader energy industry.
	Collaborative approach to development of Local Area Energy Plans.	Contribute to the development of regional energy strategies in our network area.	• NPG, ENW	• Local Authorities	Commenced. We will look to increase our efforts in this area in RIIO-2.
	Work with national and local authorities to develop necessary policy and incentives required for the transition to hydrogen-based future-proof energy system.	Actively identify collaboration opportunities with other utilities to accelerate whole systems thinking as business-as-usual.	• GDNs, DNOs • Water and telecommunications utilities	• Contractors	Commenced. We will look to increase our efforts in this area in RIIO-2.
		Optimise street work activities between utilities.	• GDNs, DNOs • Water utilities • Telecommunications companies	• Local Authorities	Commenced. We work collaboratively with local authorities on this issue, however will increase our efforts in this space in RIIO-2.
Buildings, Transport and End-Users	Co-develop specific action plans with building and transport sectors and end-users, including industry, on how to deliver whole systems outcomes.	Increase deployment of CNG, H_2, EV refuelling/charging stations for transport in our region.	• Filling stations for HGVs	• N/A	Commenced. We are working collaboratively with stakeholders in this space, however will increase our focus on delivering infrastructure in RIIO-2.
		Increase support for customers to find economical cross-vector heating solutions.	• NPG, ENW	• NEA	Focus area for RIIO-2.
		Support developers to find the optimal cross-vector energy connections to new build sites.	• NPG, ENW	• Developers	Focus area for RIIO-2.
		Work with electricity distribution network operators to provide support to the electricity networks as heat and transport are electrified.	• NPG, ENW	• DER, generators and hydrogen plants	Focus area for RIIO-2, anticipate this will continue into RIIO-3 and beyond.
New Actors, Future Customers and Service Providers	Engage new actors and service providers to accelerate development of offerings to end-users that contribute to meeting our whole systems ambition.	Accelerate the digitisation of the gas distribution network and ensure investment is optimal.	• Digital Catapult	• IoT equipment providers • Telecommunications companies	Focus area for RIIO-2, anticipate this will continue into RIIO-3 and beyond.

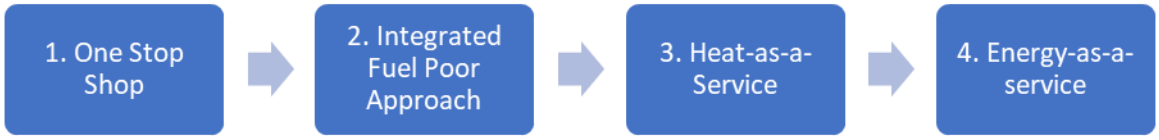
3.5 Solutions and services

Signposts	• Appendix 7: Vulnerability Strategy • Appendix 18: Innovation Strategy

The key premise of whole systems is that an integration of energy infrastructures, operations, markets and supporting processes can deliver low-carbon, resilient energy system in an affordable way to all customers.

In such a multi-vector system, services and solutions that deliver what is ultimately important to customers (e.g. comfort, or lowest cost) will become increasingly important relative to offerings that focus on an individual commodity. This approach is reflected in Figure 4.6 which illustrates the Solutions & Services component of our whole systems strategy. Note that as gas grid operator in the regulated domain, we are not likely to provide all of these services ourselves but have a key role to play in facilitating the development and deployment of these services.

Figure 10: Four consecutive stages of Solutions & Services development for Whole Systems



- **One Stop Shop**: Our Infrastructure North programme involves a partnership with NPG, YW, Northumbria Water and housing associations to support vulnerable customers with advice about reducing bills, safety and customer support. In RIIO-2, our employees visiting customer premises will also offer energy saving advice, identify new vulnerable customers, offer water saving advice etc. This will be expanded to include additional key service providers like telecommunication companies.

- **Integrated Fuel poor Approach**: We are currently delivering the Green Doctor programme, in collaboration with NPG, which helps customer better manage their energy (energy efficiency, grants and switching advice). This will be extended to include collaboration with water companies in RIIO-2. In addition, we, in collaboration with local councils, will help fuel poor with free gas connections and heating systems to help them save money on heating. The valued benefits derived from the initiatives we're looking to deliver in RIIO-2, is approximately £22 million over the RIIO-2 period.

- **Heat as a Service**: We are working with heat pump suppliers to find ways to offer customers the cheapest multi-vector connection. Our innovation project with NEA "Making Every Connection Count" helps customers by identify ways they can get economical or subsidised heating system replacements after their heating fail. We

will extend this initiative to include economical heating advice to more customers in RIIO-2.

- **Energy as a Service**: We are working with third-party energy connection providers to develop customer centric connections solutions. We will roll this out in RIIO-2.

Table 13: Solutions & Services

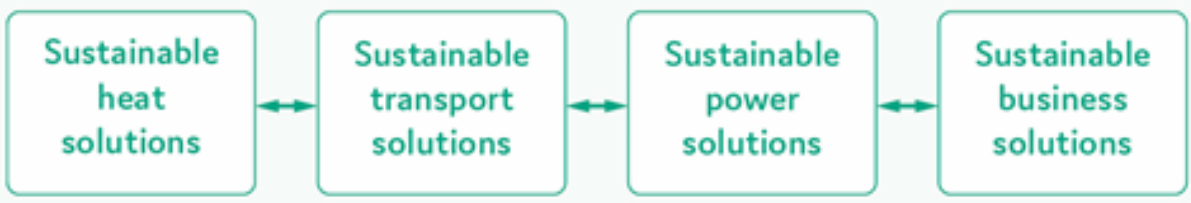
	Goal	Action	Key Partners	Key Stakeholders	Status
One-Stop Shop	Create a multi-vector one-stop shop for customers (in the broadest sense) to manage all their basic needs centrally at reduced cost	Joint Customer Service Centre	• NPG, ENW	• Customers	Commenced. Started discussions with local anchor institutions and will be a focus area in RIIO-2 and beyond.
		Shared New Connections Process	• National Grid • NPG, ENW • NW	• Customers • Industry • Developers • Local Authorities	Commenced. We've had early discussions with NPG and will continue to progress this project in RIIO-2.
		Joint Procurement Process	• GDNs • DNOs	• Customers • Shareholders	Not yet commenced. This will be a focus area for RIIO-2.
		Joint Major Projects office for holistic planning and execution of major projects like HS2, minimizing disruption, maximizing efficiency	• GDNs and DNOs • Water utilities • Developers	• Local Authorities • End-users	Not yet commenced. Will consider in RIIO-2.
Integrate vulnerable customers approach	Integrate all efforts, operationally and strategically for vulnerable customers across energy vectors	Identification of potentially vulnerable customers by visiting multi-skilled employees	• GDNs and DNOs • Water utilities • Academia • Healthcare	• Customers • Local Authorities	Commenced. Working in RIIO-2 to implement customer and social competency framework.
		Joint energy efficiency and energy savings program across energy vectors	• GDNs and DNOs • Energy Suppliers • ESCOs	• Customers • Local Authorities	Commenced. We work collaboratively with NPG to deploy our Community Fund and we will undertake further efforts to implement a joined up approach in RIIO-2 (as outlined in our Vulnerability Strategy).
		Flexibility proposition for fuel poor to leverage dual fuel systems	• GDNs and DNOs • Energy Suppliers	• Customers • National Grid • DNOs	Commenced. We will look to add assessment of benefit delivered from fuel poor voucher before we claim full value. Only claim full value of fuel poor voucher if we can demonstrate customer benefit.
Heat-as-a-Service	Enable the offering of low-carbon heating solutions to customers in such a way that it lowers the barriers for decarbonising heat demand	Co-develop detailed per-area plans for transitioning to hydrogen/biomethane and associated asset migration (including finance models)	• Energy Suppliers • ESCOs • Vendors • Financial sector	• Customers • Building owners	Commenced. We will continue to work through the Hydrogen Program Development Group to progress a coordinated approach to decarbonisation of heat.
Energy-as-a-Service	Enable the use of cross-vector energy solutions to customers that maximise comfort at lowest possible cost by utilizing cross-vector flexibility	Co-design and implement operational and market processes and interfaces to enable energy-as-service	• Energy Suppliers • ESCOs/Aggregators • Ofgem • DNOs • National Grid	• Customers • Building owners • Transport sector	Focus area for RIIO-2. In RIIO-2, we will provide information on the most efficient energy solution for customers when they request a connection.

4. Whole Systems Objectives

Our Whole Systems Objectives have been developed to ensure that the benefits of our whole systems approach are captured and used to deliver our whole systems outcomes, on a pathway to net zero emissions by 2050.

As outlined earlier, we have four Whole Systems Objectives (supported by our Environmental Action Plan) as outlined in Figure 11 below.

Figure 11: Our Whole Systems Objectives



Our approach and specific initiatives we are looking to deliver is outlined in the subsequent sections.

4.1 Sustainable Heat Solutions

Signposts	• Appendix 18: Innovation Strategy • Appendix 8: Environmental Action Plan

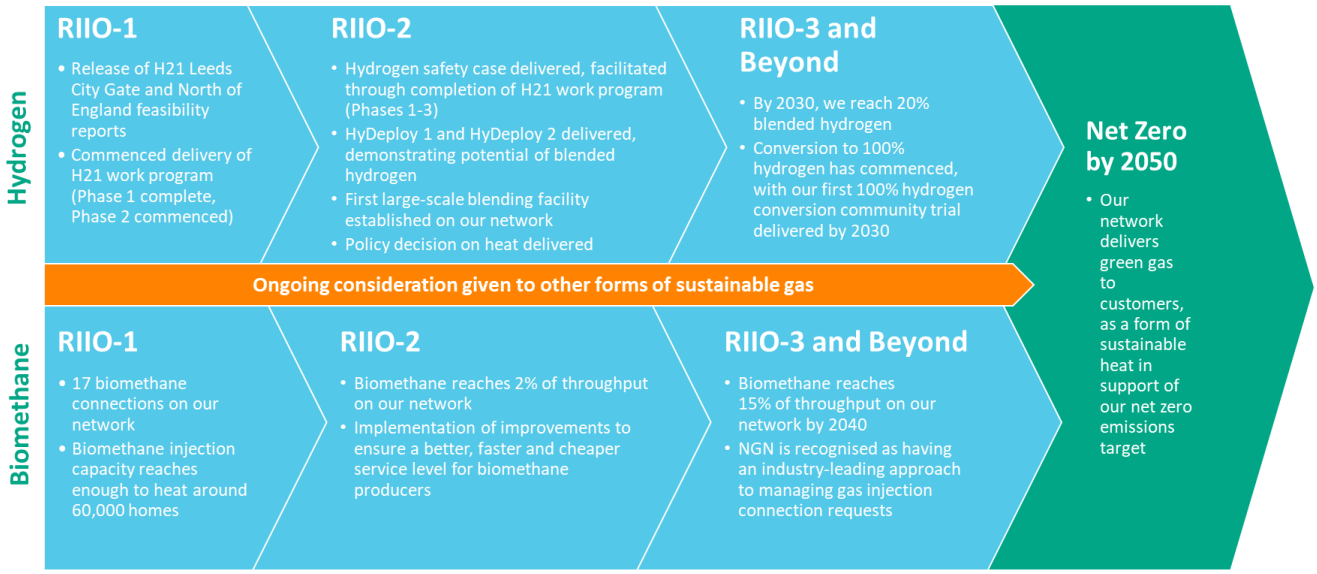
4.1.1 Background

Our long-term objective is to deliver green gas to customers through our network, as a form of sustainable heat.

To support this objective, we are committed to investigating and testing the role of gas in delivering sustainable sources of heat through the facilitation of biomethane injection into our network and demonstrating the potential of hydrogen. We consider there is strong potential for both biomethane and hydrogen in our network through to 2050.

Our Sustainable Heat Solutions pathway is set out in Figure 12 below.

Figure 12: Sustainable Heat Solutions pathway



4.1.2 Our role and approach

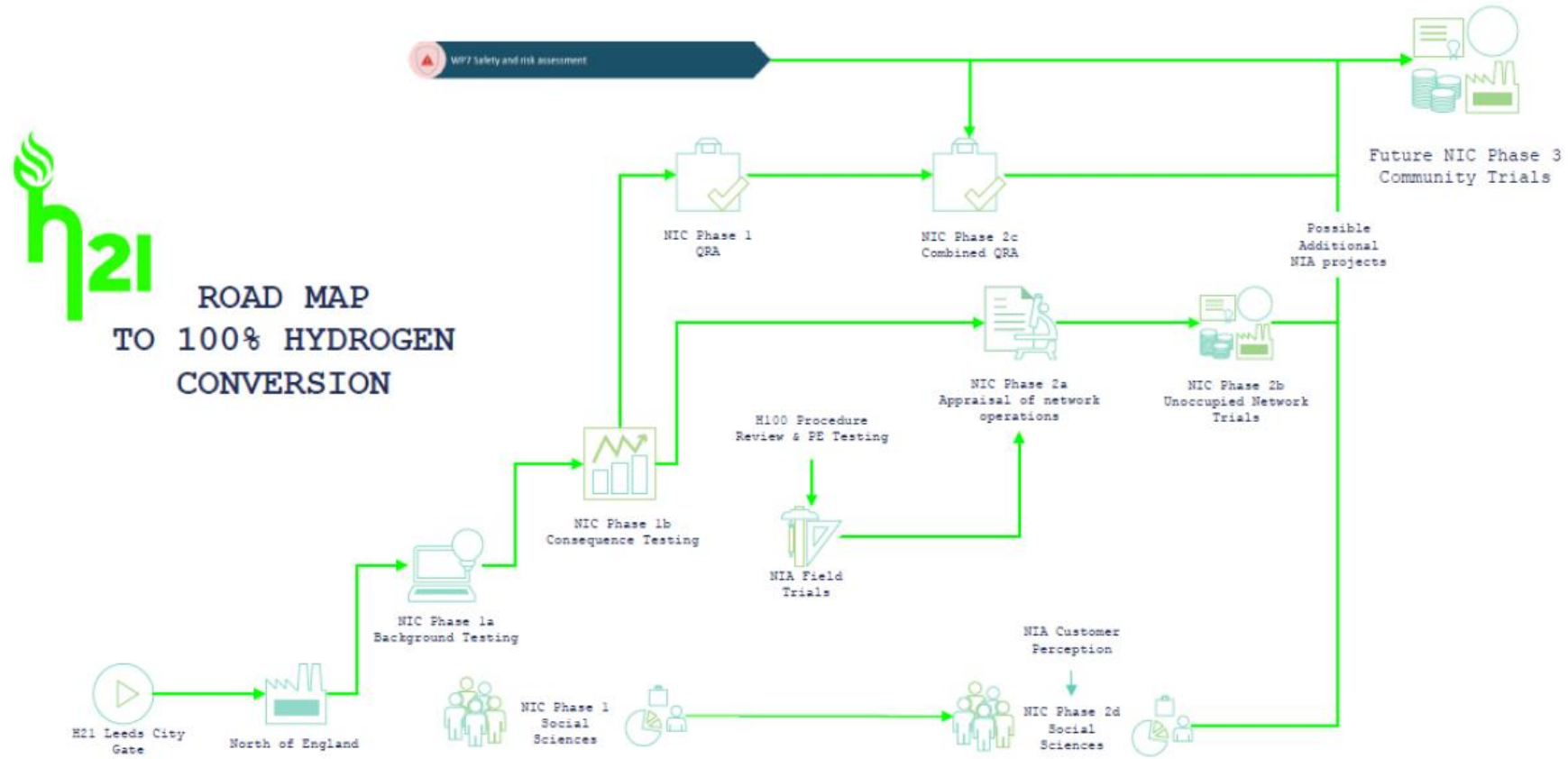
Our key role in relation to Sustainable Heat Solutions is to demonstrate that our network can perform safely and reliably, whilst transporting green gases such as biomethane and hydrogen.

Given the chemical composition of biomethane is largely similar to natural gas, the technical challenges of demonstrating performance of assets while transporting biomethane are not significant. Instead, our focus has primarily been around facilitating injection of biomethane and managing capacity constraints to ensure biomethane plants can inject as much biomethane as possible. By early 2020, we will have 17 biomethane plants connected to our network with an injection capacity of around 16,000scm/hour. These plants have the potential to provide enough biomethane into our network to heat around 60,000 homes.

We are also heavily invested in demonstrating the potential of hydrogen through Phase 1 of our H21 project, and are about to commence Phase 2. In RIIO-2, we will seek funding for Phase 3 of our H21 work program, and together (if successful) delivery of each of these phases will deliver the evidence needed to demonstrate the safety case for hydrogen.

Our roadmap to 100% hydrogen conversion is set out in Figure 13 below.

Figure 13: H21 roadmap to 100% hydrogen conversion



Box 8: About H21

In 2016, Northern Gas Networks, the gas distributor for the North of England, produced the H21 Leeds City Gate feasibility study.

Based on a blueprint of the city of Leeds, this report concluded it was technically possible and economically viable to decarbonise the UK's gas distribution networks by converting them from natural gas to 100% hydrogen. Leeds City Gate also demonstrated that this could be achieved at an acceptable cost to the customer.

Before the vision of a hydrogen gas network can be fully realised, the critical safety-based evidence for such a conversion, upstream and downstream of the meter, must be provided. Without it, a credible government policy decision on decarbonisation of heat cannot be made.

On behalf of the UK gas networks (Northern Gas Networks, Cadent, SGN and Wales & West Utilities), a Network Innovation Competition bid was successfully submitted to OFGEM in 2017, as a first step towards providing this evidence.

After securing £9 million Ofgem funding, with a further £1 million contributed by the UK networks, H21 NIC is working to present the quantified safety evidence between natural gas and 100% hydrogen used within the existing UK gas distribution networks.

H21 NIC

The H21 NIC will be delivered by 2020, followed by field trials. Phase 1 of the NIC project is being carried out in two parts:

- *Phase 1a* – Background testing at the Health and Safety Laboratories, Buxton. These tests, on a huge variety of network assets including pipes, valves and joints, will confirm potential changes in background leakage levels.
- *Phase 1b* – Consequence testing at the DNV-GL facility at RAF Spadeadam in Cumbria. This phase will involve tests to confirm any changes to safety risk under background conditions, failure and operational repair on a hydrogen gas network.

Following on from the evidence found in Phase 1a and 1b the project will move forward into Phase 2. Phase 2 will involve testing of operational procedures.

Conversion of the North of England

Underpinning the safety case is the H21 North of England, a strategic report presenting a conceptual design for converting the gas networks of the North of England to hydrogen between 2028 and 2035.

This report builds on the original Leeds City Gate study, as a solution for deep decarbonisation of heat.

This includes 3.7 million meter points (circa 85 TWh per annum, 12.5% of net UK population) across the major urban conurbations of Leeds, Bradford, Wakefield, Huddersfield, Hull, Liverpool, Manchester, Teesside, Tyneside and York. The design incorporates a 12.15GW hydrogen production facility, 8TWh of inter-seasonal storage, all associated onshore infrastructure and the requirements of the associated carbon capture and storage scheme, scaling to 20 million tonnes per annum by 2035.

H21 North of England represents one scenario for hydrogen gas grid conversion, a credible engineering solution following completion of the last pieces of critical safety evidence, which will be provided by the Hy4Heat and H21 NIC programmes by 2023. The H21 programme is supported by a range of strategic Network Innovation Allowance projects, which feed into both the NIC and North of England.

For more information, please visit our website: https://www.h21.green/

Box 9: Our international influence

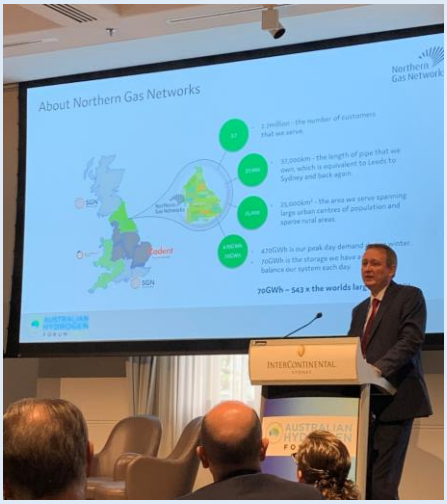
Our thought leadership in this space has been recognised internationally. In September 2019, NGN was invited to speak at two key events in Australia; the inaugural Australian Hydrogen Conference and the International Conference on Hydrogen Safety.

The aim of this visit was to share UK developments in relation to investigating the potential for hydrogen for heat with a global audience and understand the views across Australia and Asia around the future production, transportation and deployment of hydrogen and associated technologies. NGN also engaged with Australia's Chief Scientist (Dr Alan Finkel) in relation to the UK's latest views and progress.

Across the two events it was clear the work being undertaken in the UK (and particularly through our H21 work programme) is keenly observed internationally and many countries are now beginning to develop their own research programmes as a result.

Specifically, Australian Gas Infrastructure Group (AGIG, NGN's sister company) are particularly active in this space, with the development of their own hydrogen blending project, Hydrogen Park SA (more information is available online here: https://www.agig.com.au/hydrogen-park-south-australia) and involvement in Australia's Future Fuels Cooperative Research Centre (https://www.futurefuelscrc.com/).

Whilst in Australia, NGN also actively participated in a joint workshop with AGIG, the UK's Health and Safety Executive (HSE), IGEM and DNV GL to provide an update on current activities as well as share current limitations in knowledge. NGN are continuing to share information with AGIG in order to help inform our mutual hydrogen visions as well as understand how we can collaboratively address information gaps to ensure we're progressing the hydrogen agenda across both countries.



Keith Owen (Head of Systems Development and Energy strategy), presenting at the inaugural Australian Hydrogen Conference on progress with our H21 work programme

In 2019, we have also seconded a Senior Analyst from AGIG, with direct involvement in the development of the Hydrogen Park South Australia project and briefing paper to the Council of Australian Government's Energy Council in relation to the potential of hydrogen for Australia. We expect this secondment will support continued sharing of learnings and knowledge across the two businesses.

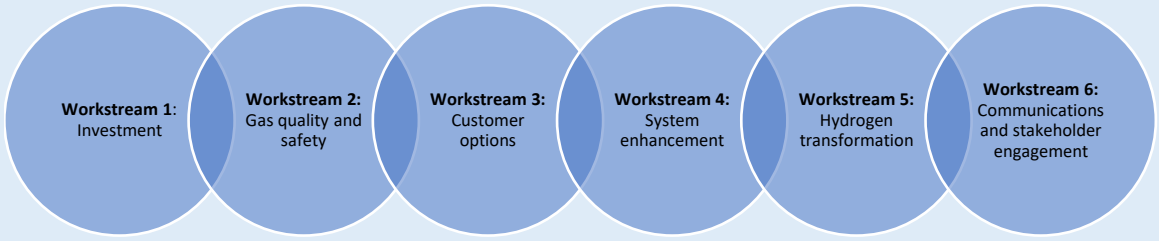
Box 10: Hydrogen Programme Development Group and ENA Gas Decarbonisation Pathways

We are an active member of the Hydrogen Programme Development Group (HPDG, chaired by the Department for Business, Energy & Industrial Strategy) and are currently working through this group to outline a programme of work on the following three areas in terms of a conversion to 100% hydrogen:

- Gas network safety testing;
- Distribution network operations and impact testing; and
- System optimisation.

We will continue to play an active role in the development of this work programme to help support the government in its consideration of options to achieve its net zero emissions target by 2050.

Separate, but related to this group is the ENA's Gas Decarbonisation Pathways work program which was launched on 30 October 2019. This work program outlines a clear pathway forward for both hydrogen and biomethane in achieving our net zero emissions target by 2050 and has identified six key workstreams that GDNs will need to drive forward in collaboration with key stakeholders.



Our most significant contribution to the hydrogen pathway component of this work program, is delivering the safety case for hydrogen through our H21 work program. We have so far completed Phase 1 of this work program and if our NIC bid is successful, Phase 2 will commence in January 2020.

This is a critical, foundational piece of work that needs to be delivered in order to enable further consideration of hydrogen as a net zero alternative for heat and we are committed to delivering this key piece of evidence for the industry and more broadly, the UK.

We will work through both groups and work programs to ensure a cohesive approach is taken to progressing the role of gas in meeting our net zero emission targets, by working to ensure:

- Effective collaboration with other GDNs to pool resources where we can and ensure projects delivered are complementary in nature and building on from the findings in other projects;
- There is alignment between work being undertaken through the HPDG and the ENA's Gas Decarbonisation Pathways work programs; and
- We bring the supply chain along with us, to ensure that we're delivering projects collaboratively and in support of other hydrogen supply chain stakeholders.

4.1.3 Our focus areas

So far, we have focused our efforts on demonstrating the technical suitability of green gases (including safety) as a replacement for natural gas. This is an appropriate focus for us to have as it is our area of technical expertise and we need to demonstrate the technical feasibility of transporting green gases through our network in order for these alternative gases to support the achievement of our net zero emission targets. We will continue our focus in this area, particularly in relation to developing the evidence base needed to demonstrate the safety case for conversion to hydrogen.

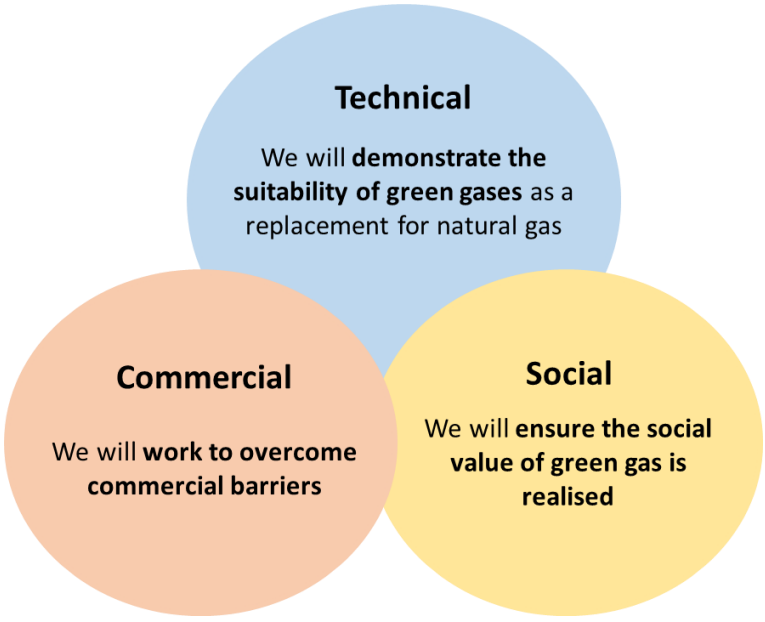
That said, going forward, we will expand our focus to include both commercial and social considerations to ensure that we are actively involved in:

- *Overcoming commercial barriers* – this will involve market development activities such as advocating for government subsidies to support pre-commercial hydrogen production projects or adopting innovative approaches to increase the capacity of biomethane that can be injected into our network.

- *Ensuring the social value of green gas is realised* – this will involve advocating for the continuation of the Renewable Heat Incentive, understanding customer perceptions relating to hydrogen and working with stakeholders to ensure that gas is appropriately considered in Local Area Energy Plans.

We consider that this more holistic approach will support the development of required supply chains to roll out green gas solutions at the scale needed to meet our net zero emission targets.

Figure 14: Sustainable Heat Solutions



Box 11: The ongoing importance of biomethane

On our pathway to net zero (Figure 5), we are forecasting a significant increase in the availability and injection of biomethane into our network. Currently, biomethane accounts for around 1% of total throughput, but by 2040 we are expecting this to have increased to 15% (or around 8TWh of energy per year).

That said, there is some uncertainty around the long-term utilisation of biomethane through gas network infrastructure in the UK. By 2050, we consider that most of our network will have been converted to 100% hydrogen, with the potential for biomethane to still supply areas of our network that have been segmented. The contribution of biomethane through our network could range anywhere from 0% to 45%, depending on how the market develops over time.

Despite this uncertainty, there is still a strong need for biomethane in our economy through to 2050 and beyond – if this isn't through injection into gas networks, then biomethane will remain in demand for alternative applications, such as transport and electricity generation.

Based on the findings of our engagement with biomethane stakeholders (including mapping the biomethane customer journey) and to support the important role that biomethane will play in achieving our net zero emissions target, in RIIO-2 we are proposing to focus our efforts on delivering a range of initiatives to provide biomethane producers with a better, faster and cheaper service:

- ***Better*** – We need to deliver a better service to biomethane producers. We will do this through better understanding their needs and working to minimise barriers to injecting into our network.
- ***Faster*** – We need to be more responsive to the needs of biomethane producers and commit to providing relevant information quicker and responding to technical challenges sooner.
- ***Cheaper*** – We will seek opportunities to standardise our approach across the industry, to ensure consistency and a least cost approach for biomethane producers.

	Initiative	Description	Cost
BETTER	Overcoming capacity constraints	We're invested in delivering a range of innovation projects looking at alternative ways of overcoming constraints on biomethane injection. E.g. our Remote Pressure Profiling project, which (based on initial modelling), has the potential to almost double injection volumes with a 25% reduction in outlet pressure (on an average day in "shoulder" months).	Funded through Innovate UK
	Further stakeholder engagement	We are committed to ongoing engagement with biomethane producers (including an annual workshop) to ensure we're focusing our efforts on areas that will deliver greatest benefit for our customers. This is a specific Price Control Deliverable.	N/A
FASTER	Initial Capacity Studies	Reducing time taken to deliver reports from 15 working days to 5 working days. This is a specific Price Control Deliverable.	N/A
	Detailed Capacity Studies	Reducing time taken to deliver reports from 30 working days to 20 working days. This is a specific Price Control Deliverable.	N/A
	Improved response times to operational faults on gas producer sites	Respond within four hours to rectify faults quicker to get the gas flowing to the network again. This is a specific Price Control Deliverable.	N/A
CHEAPER	Opportunities to standardise across industry	We will work collaboratively with other GDNs to exploit opportunities to take a standardised approach across the industry. E.g. in relation to siloxane levels and processes for measurements, the Connection Standard Methodology Framework and grid entry unit design).	N/A
	Biomethane injection hub	We will investigate the feasibility of establishing a biomethane hub on our network, so that biomethane producers can transport their biomethane to a central hub for injection. We expect this will assist with mitigating capacity constraints and also avoid connection costs for new biomethane plants.	Funded through NIC in RIIO-2

Table 14 below provides an overview of the key projects we will be focused on in relation to demonstrating the technical suitability of green gases as substitutes for natural gas.

In terms of projects relating to the commercial and social streams of our approach to Sustainable Heat Solutions, we will proactively consider how we work with stakeholders to address these areas (specifically through the ENA's Gas Decarbonisation Pathways work program) and do not anticipate any additional costs associated with these activities.

Table 14: Sustainable Heat Solutions projects

Project	Description and Project Deliverables	Status & Funding
Feasibility / Enabling Initiatives		
H21 Phase 1	Phase 1 of the H21 work program is close to conclusion and has delivered a range of projects aimed at establishing a baseline of information on the feasibility of converting our network over to 100% hydrogen. This has included the development of the H21 Leeds City Gate study, establishment of testing facilities at Spadeadam and Buxton as well as other key strategic modelling and desktop studies. Phase 1 has also started to deliver initial safety-based evidence to support the safety case on hydrogen.	Phase 1 is due to be complete by mid-2020. This phase costs £12.5 million, spread across NIA and NIC.
H21 Phase 2	Phase 2 of the H21 work program aims to provide the evidence to demonstrate what is required to maintain and manage a 100% hydrogen network and what further investment may be needed to address any unsuitable operations or procedures. It will also continue to build on the foundational work of Phase 1 in the continued assessment of relative risk and building the required safety-based evidence.	Received confirmation of £6.8m in NIC funding in Dec 2019. This project will be delivered Jan 2020 to Dec 2021.
H21 Phase 3	Phase 3 of the H21 work program will build on from Phase 2 by addressing remaining practical considerations with hydrogen conversion, such as options relating to telemetry systems, developing a hydrogen training scheme, customer billing and undertaking community trials.	We will develop a project proposal for consideration in RIIO-2, costs are still to be reviewed but funding will be sought either through the NIA or a third party.
Remote pressure profiling	This project will test our ability to use smart pressure control, keeping pressures on the medium pressure network as low as possible in order to facilitate greater volumes of biomethane injection. In looking at the potential of remote pressure profiling, we have modelled that flexible reductions in grid pressure over summer and shoulder months may be able to provide increased capacity in the network for biomethane plants to inject without restrictions under normal operating conditions. For example, one scenario we have modelled indicates that a 25% reduction in outlet pressure may be able to almost double the available capacity in our network, during the shoulder months of April/May and October/November.	Currently underway, funded through third party funding from Innovate UK.
Biomethane injection hub	This project will establish a virtual pipeline through creating a centralised biomethane injection hub with a large capacity for biomethane plants to inject into. Biomethane plants without a gas connection, or those with a limited injection capacity would benefit by being able to tanker gas to the reception site and inject into the network	For delivery in RIIO-2, subject to funding through the NIC.
Infrastructure Development Initiatives		
HyDeploy	The project builds on the foundational work at Keele University to demonstrate on public distribution networks that natural gas containing levels of hydrogen beyond those in GS(M)R can be distributed and utilised safely.	Currently delivering this project at Keele University in Staffordshire, utilising £7 million in NIC funding.

	This project will involve a 10 month demonstration project at Keele University from autumn 2019 on a closed gas network supplying around 100 homes and 30 university buildings.	NGN is contributing £382,000.
HyDeploy 2	The second phase of HyDeploy will follow the same approach as the initial project, but will be delivered with a customer base that is more representative of the UK as a whole, on a public gas network. This project will involve two public network trials: • North East – NGN is leading this project which will commence in December 2020 • North West – Cadent is leading this project which will commence in December 2021 Both trials will involve around 700 homes and businesses, over a period of 10 months.	This project has received £15 million in funding, through the NIC. NGN is contributing £749,000.

4.2 Sustainable Transport Solutions

Signposts	• Appendix 18: Innovation Strategy • Appendix 8: Environmental Action Plan

4.2.1 Background

Although public debate on the decarbonisation of transport currently focuses on electrification, there is increasing recognition that the gas sector has an important and enduring role to play in this energy vector. There is also increasing acknowledgement that there are limitations with electric battery vehicles, primarily in relation to the finite nature of lithium batteries and the environmental impacts associated with disposing of these batteries once they're depleted.

> "Toyota places great importance on the environment and a key issue for sustainable transport is reducing the material input, increasing product life and reducing end of life waste through reuse and recycling. Batteries have a finite life and it is challenging to reuse, refurbish or recycle a degraded battery. A key advantage of fuel cell, which is often overlooked, is that they have lower material input, much longer lifetimes and can easily be reused in multiple applications and when no longer required have virtually 100% recyclability. As a result, [fuel cell electric vehicles] are likely to deliver far greater environmental benefits than [battery electric vehicles] and lower costs to customers."
>
> ***Jon Hunt, Alternative Fuels Manager, Toyota***

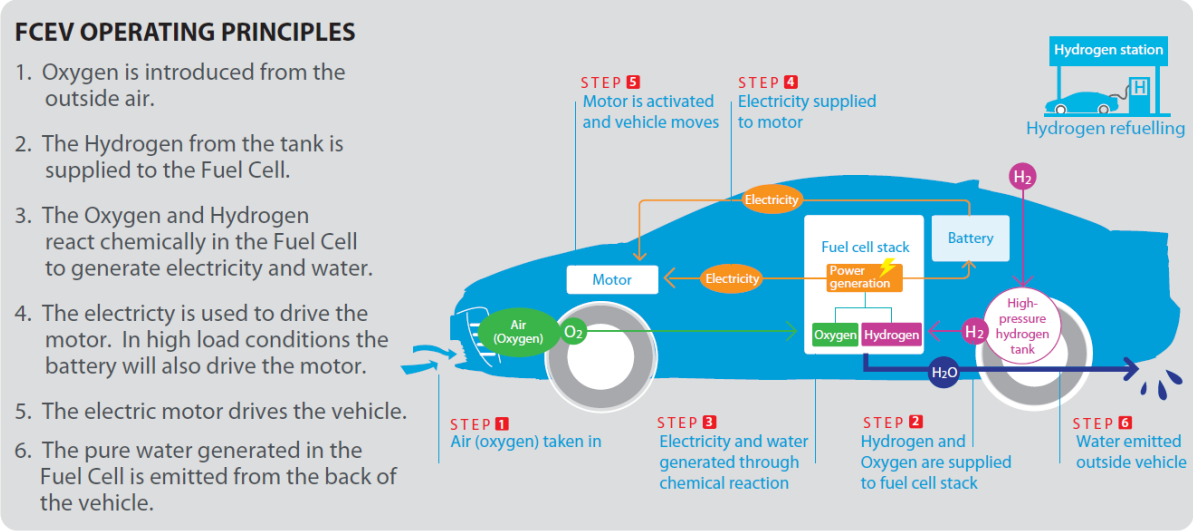
Source: Progressive Energy, HyMotion, https://hynet.co.uk/app/uploads/2019/06/15480_CADENT_HYMOTION_PROJECT_REP.pdf, page 26.

In the short-term, CNG vehicles provide a commercially-viable option for large fleet operators to reduce the emissions and air quality impacts of their operations. Over the medium to long-term, we expect that hydrogen vehicles will enter the market and provide further benefits on CNG vehicles in terms of further reducing emissions and improving air quality.

We consider that these technologies will be rolled out alongside further electrification of the transport sector, as complementary transport solutions that will ensure decarbonisation of this energy vector is delivered in a least-cost way.

Importantly, we consider that gas and electricity utilities should work together to explore how best to deliver new refuelling or recharging facilities of the future, whether in relation to battery electric vehicles or hydrogen fuel cell electric vehicles.

Figure 15: Operating principles of a fuel cell electric vehicle



Source: Toyota from Hydrogen Mobility Australia's "The Facts about Hydrogen", 2017.

4.2.2 Our role and approach

Our objective is to work with stakeholders to support the uptake of Sustainable Transport Solutions across our network area, with a focus on rolling-out refuelling infrastructure to enable the uptake of CNG, hydrogen and electric vehicles.

There is a role for all sustainable transport solutions to play in meeting our net zero emission targets, and by working collaboratively with electricity networks and other transport-related stakeholders, we consider we will ensure that this transition will be managed in a way that is least cost to end customers.

Partnership is again a key component in our approach to achieving this objective and we need to make sure that we identify and work with key strategic partners in the industry to deliver. We have started to do this in RIIO-1, but this will continue to be an area of focus for

us in RIIO-2 and beyond. Specifically, we are working with the Gas Vehicle Network to set out the role that gas vehicles have to play now and transitioning toward 2050 as well as an infrastructure developer to establish a CNG refuelling station at our site in Lamesley, Gateshead.

We also consider that we should lead by example, through the conversion of our own fleet to sustainable options. More detail on how we are intending to lead the industry is provided in Section 5.4, relating to Sustainable Business Solutions.

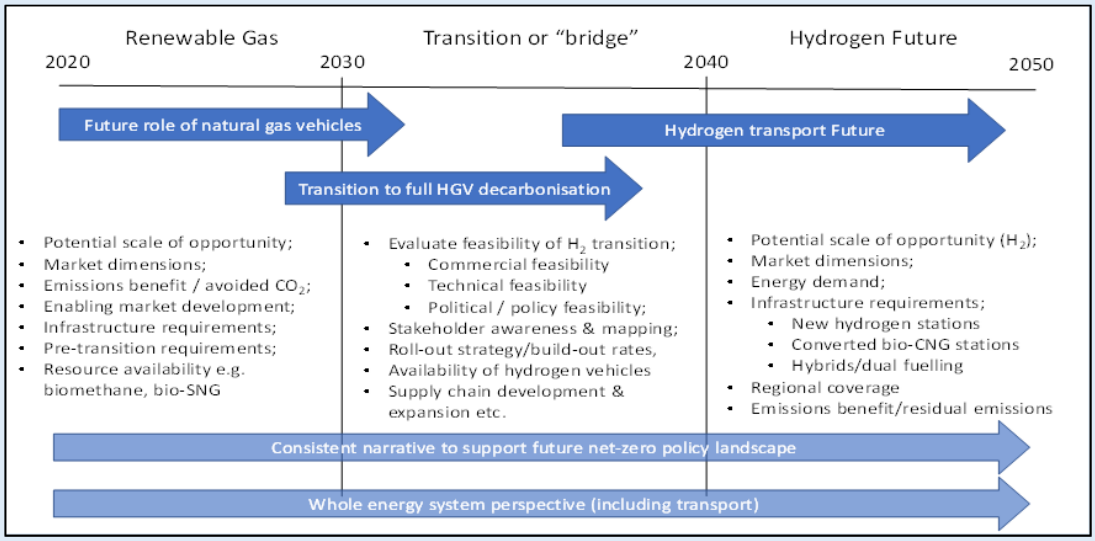
Our Sustainable Transport Solutions pathway is outlined in Figure 16 below.

Figure 16: Sustainable Transport Solutions pathway

Box 12: Gas Vehicle Network

We are a Board member of the Gas Vehicle Network and have been involved in this organisation since 2017.

The role of this organisation is to evaluate the future of low cost, low carbon gas in achieving the government's net zero emissions target by 2050. We are working with the GVN to develop a practical transition pathway from a fossil fuel based transport system today, toward a net zero hydrogen transport future.



For further information, please visit https://www.ngvnetwork.co.uk/.

4.2.3 Our focus areas

Table 15 below outlines specific projects that we are either currently focused on or have identified as a project for delivery in RIIO-2. These projects have been split into feasibility/enabling initiatives and infrastructure development initiatives.

Table 15: Sustainable Transport Solutions projects

Project	Description and Project Deliverables	Status & Funding
Feasibility / Enabling Initiatives		
Future role of gas in transport: A transition pathway for renewable gas alternatives	We have worked collaboratively with Cadent and the Gas Vehicle Network to develop a report evaluating the future role of low cost, low carbon gas in achieving our net zero emission targets and setting out a practical transition pathway from fossil/renewable gas today to a net zero hydrogen transport future. Importantly, this report will help us to identify future projects that we will need to invest in, to support the transition of the transport sector through the uptake of gas vehicles.	We have developed a draft scope of works and are working with other GDNs to gain support for this project. Project will be funded through the NIA.

Develop and promote map of optimised low emission transport solutions	We will develop a map of optimised sustainable transport solutions across our network area, to inform our approach to supporting the roll-out of refuelling and charging infrastructure in our network area. We will look to deliver this piece of work in collaboration with YW, NPG and NW, given we each have substantial fleets of vehicles that operate in similar geographical areas and together we may be able to provide the critical mass needed to support the development of sustainable refuelling infrastructure in our network area.	This project will be funded through the NIA in RIIO-2.
Infrastructure Development Initiatives		
Lamesley CNG Development	We have identified an opportunity for a very low cost connection to our network to help support a CNG refuelling development at our site at Lamesley, Gateshead. To promote this opportunity, we worked through a pseudo-procurement process, seeking proposals from interested parties and assessing the proposals received against pre-determined criteria (including the potential of the project to contribute to the development of the CNG industry). This project will deliver a CNG refuelling station, with potential for further developments to establish a green mobility hub incorporating additional hydrogen refuelling and electric vehicle charging facilities. Once we have finalised the project agreement for this development, we will assess whether we can identify other sites we own that are suitable for similar developments.	We have identified our preferred applicant and are currently working through the details of a project agreement. No funding requirement.
Market development through facilitating cheaper connections	We commit to proactively reviewing the potential of installing a CNG connection when we undertake significant work at any of our sites (e.g. major site upgrades). This is because it is significantly cheaper for us to install a connection upfront, rather than retrospectively.	No funding requirement.
Tees Valley Hydrogen Transport Initiative – Phase 1	This project will: • establish a basic hydrogen refuelling station network (two stations); • establish a scalable hydrogen distribution system; • introduce fuel cell electric vehicles (FCEVs) to the local area for the first time; and • catalyse further use of hydrogen as a fuel for transport (and other sectors such as heat. Tees Valley Combined Authority (TVCA) is the lead project partner, and we are supporting the project by committing to purchase one hydrogen FCEV. Materials Processing Institute is also a project partner.	TVCA has submitted a funding application for £2 million to the Office for Low Emission Vehicles to deliver this project. Our contribution is the purchase of one hydrogen FCEV, at an estimated cost of £55,000. We expect to have our funding application confirmed by early 2020.

Flagship hydrogen refuelling station	Through our Sustainable Heat Solutions objective, we are targeting delivery of our first 100% hydrogen community trials by the end of RIIO-2. Based on this, we will work with stakeholders to deliver a flagship hydrogen refuelling station to demonstrate the synergies between hydrogen for heat and hydrogen for transport.	We've started discussions with Leeds City Council and local anchor institutions on establishment of a hydrogen refuelling station in Leeds. We will also work with the Hydrogen Programme Development Group to ensure hydrogen refuelling is considered in scope of delivering a community trial. It is assumed that third party funding will be sought to deliver this project.
Fleet initiatives	By the end of RIIO-2 we will have: • converted 100% of our company cars to "ultra low emission" or hybrid alternatives; • converted 20% of our commercial fleet to "ultra low emission" or hybrid alternatives; and • installed electric vehicle charging infrastructure at all of our offices and depots. In parallel, we will be proactively promoting the availability of electric vehicle charging infrastructure at our sites, encouraging other electric vehicle owners to use our facilities. We also hope that these facilities will encourage other, similar organisations (such as YW, NPG and NW) to convert their fleets over to electric options.	These initiatives will be delivered in RIIO-2 and will be funded through our base totex allowance.
Vehicle to Grid Capability	NPG and Newcastle University are planning to instal a 10kW Vehicle to Grid charger at the InTEGReL site. This will enable electric vehicles to discharge back on to the electricity network, with the potential for excess solar generation at the InTEGReL site to be stored in electric vehicles and then discharged at a later time. This facility will add to the capabilities being developed at InTEGReL to investigate optimisation of electricity generation, storage and usage.	NPG is intending to allocate a charger to the INTEGREL site.

4.3 Sustainable Power Solutions

Signposts	• Appendix 18: Innovation Strategy • Appendix 8: Environmental Action Plan

4.3.1 Background

Although we are not an electricity business, we currently play an important role in facilitating the uptake of renewable electricity (e.g. wind and solar) across our network area, through the gas we supply to gas-fired electricity generators.

Gas-fired generators are being increasingly relied upon in the UK to provide base load electricity to support the intermittency of electricity generated from renewable sources such as wind and solar farms. Currently, gas is used to generate about 40% of electricity in

the UK which has been a rising trend since 2015.[12] This is due to gas being an effective energy storage vector, that can be drawn upon when needed.

Going forward, we expect this trend to continue and consider there needs to be greater focus on how electricity generation is managed in order to ensure it supports networks across both electricity and gas vectors.

4.3.2 Our role and approach

As set out in Figure 17 below, our long-term objective is to strengthen the integration of gas and electricity networks to ensure efficient investment in renewable energy demand and supply in our network area.

Figure 17: Our Sustainable Power Solutions pathway

We see our role in relation to Sustainable Power Solutions, as partnering with stakeholders to support decision-making that optimises investment in energy infrastructure (i.e. across all energy vectors). This will ensure that energy customers in the UK do not have to pay any more than what is necessary to meet our net zero targets.

[12] Navigant, "Pathways to Net-Zero: Decarbonising the Gas Networks in Great Britain", October 2019, page 2 (available online here: http://www.energynetworks.org/gas/futures/gas-decarbonisation-pathways/pathways-to-net-zero-report.html).

Partnership is a key theme of our approach to Sustainable Power Solutions and we are committed to strengthening the relationship we have with both NPG and Electricity Northwest in RIIO-2.

4.3.3 Our focus areas

Our key objective in relation to Sustainable Power Solutions is to support the integration of gas and electricity networks in our network area.

To support this objective, we have so far worked closely with NPG and other key stakeholders (including academia) to develop a range of projects outlined in Table 16.

Table 16: Sustainable Power Solutions projects

Project	Description and Project Deliverables	Status
Feasibility / Enabling Initiatives		
Control Rooms of the Future: Coordinating Supply and Demand in Integrated Energy Systems	Together with NPG, we are working with Newcastle and Durham Universities to deliver this project which will assess key barriers and opportunities for the integration of electricity and gas network control systems and identify areas that require further in-depth research. Specifically, the project will: • explore the divisions of labour in control rooms; • the division of responsibilities across utilities and between owners, operators, and regulators in the integrated energy system; • map the range of commercial, governmental and regulatory actors who may have a stake in the combined control room operation; and • outline the potential legal and governance issues associated with the practice of integrated energy control.	Phase 1 of this project is almost complete, and we are currently in discussions in relation to Phase 2.
Net Zero Customer Energy Village	We are working together with Newcastle University, NPG and NW, to support a funding application to the NELEP (through their Energy for Growth Fund) to deliver a Net Zero Customer Energy Village. This project will deliver: • A Net Zero Customer Energy Village consisting of typical domestic dwellings for the region (i.e. 1930s-1980s buildings), that will be used to test and demonstrate low carbon technologies. • Key outcome of the project will be to improve the capabilities of local communities to achieve net zero by 2030. It's intended that all outputs from the project will be shared with Local Authorities to inform their decision-making. • Project will enable comparison of outcomes across electric heat, hybrids and decarbonised gas.	We submitted an Expression of Interest to the NELEP in October 2019.
Infrastructure Development Initiatives		
Solar installation	We are investing in the installation of a solar facility at our InTEGReL site, of at least 300kW. This site will enable us to test the optimisation of renewable energy generation, storage, usage on site (including EV charging) as well as potential to feed back into the local electricity network.	Looking to deliver this in RIIO-2.
NPG's Battery Installation	NPG is investing in the establishment of a battery installation at our InTEGReL site, to leverage and also build on to the capabilities that have already been established. Our contribution to the project is access to our land, at no cost.	Construction is due to commence in 2020. No NGN funding requirement.

	This facility will be used as a testbed for various electricity-focused research projects between NPG, Newcastle and Durham universities, with the learnings also shared with us. Specific projects will be focused on investigation into how best to optimise solar electricity generation on-site by considering and comparing on-site electricity usage, electric vehicle charging (and discharging), battery storage and export back to the electricity grid.	
Vehicle to Grid Capability	As described in Section 3.2.3.	NPG is intending to allocate a charger to the INTEGREL site.

As Table 14 demonstrates, we are currently involved in a range of projects that are contributing to research and development activities relating to Sustainable Power Solutions, centred around our InTEGReL site. Specifically, we have been able to develop the InTEGReL site into a true test-bed for whole systems technologies and consider that this site will contribute to better informing efficient investment in energy infrastructure in the UK.

Whilst there is some uncertainty associated with some of these projects, we consider seeking third party funding for these projects is appropriate as direct benefits for our customers are less tangible than other projects we are looking to fund ourselves.

We will continue to invest our time into these projects and will consider the findings from these projects as we determine next steps for our efforts re: Sustainable Power Solutions.

4.4 Sustainable Business Solutions

Signposts	• Appendix 8: Environmental Action Plan • Appendix 10: Workforce Resilience Strategy • Appendix 18: Innovation Strategy

4.4.1 Background

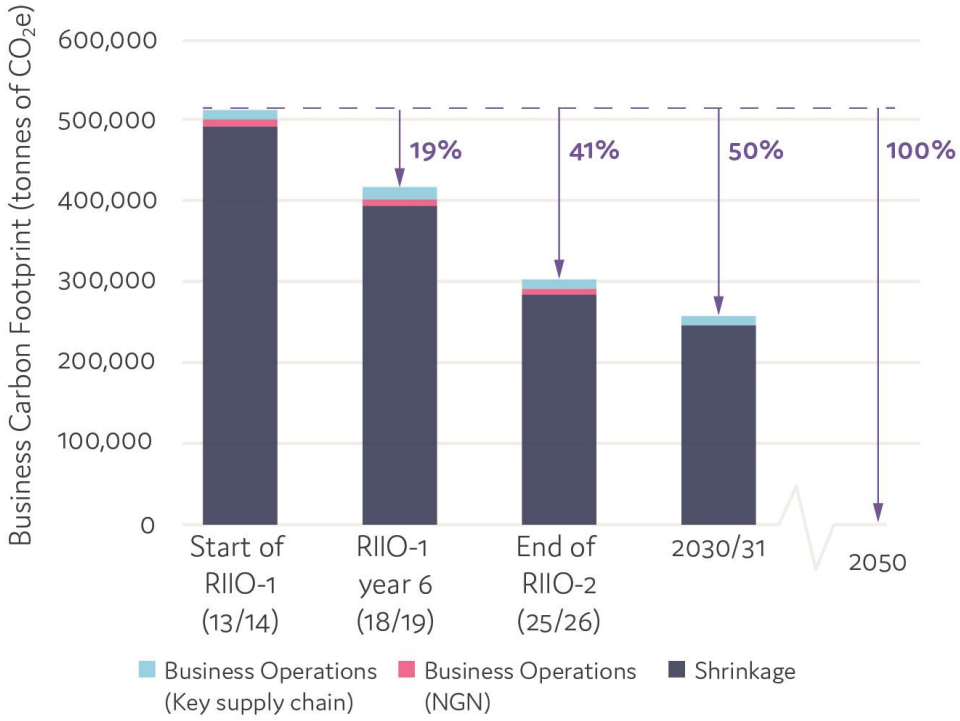
Given the nature of our business, we are contributing significantly to the transition of the energy sector to meet our net zero emission targets. However, we are also just like any other business and need to make more conscious decisions around the sustainability of our business operations.

In 2018, we launched our long-term Environment Strategy to drive NGN to deliver a decarbonised energy network with reduced operational environmental impacts that would enable the transition to a sustainable low-carbon energy system. Over RIIO-1, we have made significant progress against our strategy, delivering reduced shrinkage volumes and a reduced business carbon footprint (among other initiatives).

Figure 18 below demonstrates the significant achievements we've made so far, and also our trajectory through to reaching net zero by 2050. Importantly, we are targeting a medium-

term objective for our business operations to be net zero by 2031 (this excludes the impact of shrinkage and key supply chain emissions).

Figure 18: Business Carbon Footprint trajectory



We also acknowledge the importance of ensuring we have a sustainable business across the board, such as in relation to sustaining a workforce that continues to deliver for our customers now and in the future and understanding the needs and preferences of our future customers so that we can proactively ensure that we're able to provide value for money.

Our Sustainable Business Solutions pathway is set out in Figure 19 below.

Figure 19: Sustainable Business Solutions pathway

4.4.2 Our role and approach

Our objective in relation to Sustainable Business Solutions is to lead the energy sector in the adoption of sustainable, net zero business practices for the benefit of both current and future customers.

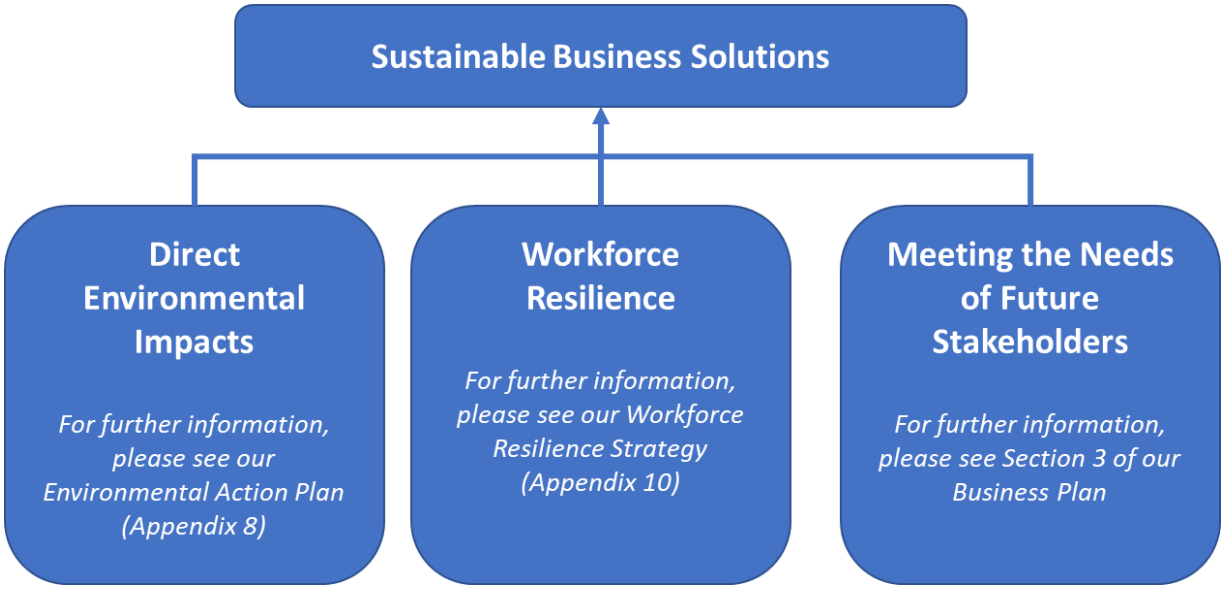
We see three key areas which will require focus for us to deliver on this objective:

- *Reducing our direct environmental impacts* – reducing the environmental impact of our operations (including the impact of gas shrinkage and supply chain emissions). Importantly, we are targeting to reduce our non-shrinkage Scope 1 and 2 business carbon emissions to net zero by 2030/31.
- *Improving workforce resilience* – developing a safe, skilled and resilient workforce that is diverse and inclusive and consistently delivers high quality and efficient services to our customers, both now and in the future.
- *Ensuring we're meeting the needs of future stakeholders* – understanding and meeting the needs of future stakeholder priorities (e.g. customers, communities and investors).

By focusing on these three areas, we will ensure that NGN is a sustainable business both in terms of meeting external expectations and ensuring that we are continuing to meet the changing needs of our own people.

Further details relating to each of these focus areas have been provided in other documentation provided with our Business Plan. Figure 20 provides a document map of where you can find out more.

Figure 20: Sustainable Business Solutions document map



4.4.3 Our focus areas

Further detail on our focus areas for RIIO-2 is outlined in each of the documents mentioned above, however Table 17 below provides a high level summary of key initiatives.

Table 17: Key Sustainable Business Solutions initiatives

Area	Key Initiatives	Status & Funding
Direct Environmental Impacts	• NGN commits to reducing our non-shrinkage Scope 1 and 2 business carbon emissions to net zero by 2030/31. • A 22% reduction in gas shrinkage by the end of RIIO-2. • Conversion of 50% of our total vehicle fleet to ultra low emission or hybrid vehicles by the end of RIIO-2. • Installing electric vehicle charging facilities at all offices and depots. • Installing on site renewable energy generation across all of our offices and depots. • Reducing material wastage. • Planting 40,000 trees. Further details are provided in our Environmental Action Plan as Appendix 8 to our Business Plan.	These initiatives will be delivered in RIIO-2 and will be funded through our base totex allowance.

Workforce Resilience	• Developing a best practice Diversity and Inclusion Strategy. • Gaining accreditation to a national diversity and inclusion standard. • Partnering with Solutions for the Planet. • Upskilling and training around 25 apprentices and graduate trainees across the network per annum. • Development Centre offering training to all colleagues. • Annual statistical analysis on resourcing levels. Further details are provided in our Workforce Resilience Strategy as Appendix 10 to our Business Plan.	These initiatives will be delivered in RIIO-2, and funded through our base totex allowance.
Meeting the Needs of Future Stakeholders	We are committed to continuing to understand the needs of future customers in RIIO-2. This is outlined in Section 3 of our Business Plan.	These activities will be funded through our base totex allowance.

5. Summary

Our Whole Systems Strategic Framework provides the foundation for our contribution to meeting our net zero emission targets by 2050.

We have identified a set of key initiatives for delivery in RIIO-2, however we also understand that we need to be flexible and able to respond to changes in the market, government policies and stakeholder needs. As such, we acknowledge that we will need to flex our plans throughout RIIO-2 and stand ready to do so.

Importantly, we will continue to seek feedback and refine our approach to ensure that we are working collaboratively with stakeholders. In particular, we understand that electricity distribution businesses are just starting their planning processes in the lead up to RIIO-ED2 and we have a role to play in contributing to their plans in relation to whole systems.

Annex A | Stakeholder Consultation

For the development of its Whole of System strategy, NGN has consulted the following stakeholders to ensure its strategy incorporate their views and addresses the opportunities identified by them:

Stakeholder	Interview date	Interviewees
Cadent	2 April 2019	• Dave Tilley • Damien Hawke
Durham University	26 March 2019	• Simone Abram
Electricity North West	29 March 2019	• Christos Kaloudas • Simon Brook
National Centre for Energy Systems Integration	19 March 2019	• Phil Taylor
Northern Powergrid	15 March 2019 11 April 2019	• Jim Cardwell • Chris Goodhand
Scottish Power Distribution	25 March 2019	• Geoff Murphy
Western Power Distribution	1 April 2019	• Roger Hey
National Grid SO	11 April 2019	• Mark Herring (WoS Strategy lead)

A.1 Electricity Distribution Stakeholder Comments

A.1.1 Current Activities

- The DNO would like a heat map of energy needs from developers. NB: local planning rules affect what can be done.
- The DNO expects to see electrolysis plants become more common, but they would need a say in where the plants are to be located and their capacity to achieve optimal Whole System benefits.
- The DNO thinks hybrid heat pumps and CHP boilers will be relevant but would like to understand how they will switch between vectors.
- Gas and Electricity Distribution control rooms will need to share data about flexible connections, flexibility usage rules, electrolysis plants, CHP.
- Hybrid heat pumps have been demonstrated to be as economical as gas (given 1/3 of the energy used) and significantly cheaper than oil and solid fuel. See Freedom project for details.
- Heat pumps have been installed in addition to gas central heating in existing housing stock.
- The flexibility given by such a scheme would reduce the need for spinning reserve and make the Whole System cheaper to run.
- Sharing of Data has been done between United Utilities and ENWL for vulnerable and priority customers (the two companies used to be integrated).

- The DNO is adopting innovation from Gas network projects. The biggest areas of Whole System innovation/collaboration with DNOs are Excavation, Roadworks, Scheme Planning, Civils, Streetworks, Health & Safety, Customer service.

A.1.2 Decarbonisation

- Decarbonisation of heat could be a significant driver if CO2 reductions go from 80% to 85%. This will likely entail the use of hydrogen, biogas, CCS. A low carbon gas network could be used for peak lopping or connecting customers currently on LPG or off-grid. The preferred technology that crosses gas and electricity vectors is "hybrid heat pumps" (see WPD's Freedom project). These are as cost effective as conventional gas boilers for heating, but uptake has been low, and it is hard to see when gas would be more expensive than electricity.
- If the CO2 reduction target reduces to 80%, decarbonising off-grid customers and industry would be sufficient.

A.1.3 Resilience

- Duel fuel energy supplies increase resilience. Most people in the UK can heat water with electric water heaters and air with electric radiators when the gas supply fails. They can also cook on gas hops when the electricity fails.

A.1.4 UK Whole System Status

- There is currently no one-size-fits-all strategy for decarbonisation.
- Local authorities and city regions are starting to come up with decarbonisation schemes. They could be interested in schemes that replace CH4 with H2 or green gas supplies (rather than electrification). Leeds has an H2 project and Liverpool is interested in H2 powered cars.
- Manchester has heat pumps in its 5-year smart energy plan, with ambitious plans to fit in existing housing stock.
- The DNO has heard that other gas companies are pushing CHP technology.
- Heat networks will become more relevant.
- Gas DGMs are helping balance connections between the two vectors. Some are offsetting electricity with gas connections, others are withdrawing gas for new homes.
- There have been many WoS discussions, but the DNO will implementing more WoS technology and processes in GD2/ED2.
- There are many parts of the electrical grid that have no gas network, so Ofgem's view of WoS is not possible in these areas unless the gas network is extended.
- The DNO and NGN are in early discussion on control room interaction. The DNO is interested in collaborating with NGN in GD2.
- The DNO sees next steps for WoS as working through future energy scenarios and trialling interactive DSO measures. InTEGReL is part of this. Future DSO technology could be extended to include gas and hydrogen solutions.

A.2 Gas Distribution Stakeholder Comments

A.2.1 Policy

- Electrifying heat or transport is do-able, but both would not make sense economically.
- GD2 will be about removing the barriers for Hydrogen.
- There will be no renewable heat incentive in GD2, which may slow down biomethane uptake

A.2.2 System planning

- Collaboration between Gas Transmission and Gas Distribution is good (the companies were integrated until recently).
- More collaboration between Electricity and Gas distribution planners would make the overall system more efficient.
- Gas planners need to know the level of generation planned on electricity DSOs. This generation is mostly peaking plant, which causes the gas networks issues at peak times, which in turn necessitates reinforcement on the gas networks.
- There are currently hundreds of enquiries for embedded gas peaking plants, which are usually sited near electricity distribution infrastructure. There needs to be joined up thinking on how generation should be managed to support networks across both vectors for the good of customers.
- Regarding the existing distributed generation, and DER, connected to the electricity distribution networks, Gas planners need to know how they will be used. Currently reinforcement decisions are based on capacity (not likely usage patterns).
- Gas planners also need a better understanding of housing growth, and more collaboration with electricity DSOs and developers would lead to better decisions about how to meet future energy needs.
- ICTs (biggest of which is GDC) now manage connections. They are an important stakeholder.
- Information on available capacity on both gas and electricity distribution networks should be shared (between utilities and also with developers) to enable better decisions for supplying heat.
- The use of biogas to generate electricity can be inefficient. There should be a mechanism by which some of it enters the gas grid to be used directly for heating.

A.2.3 Operation

- There is currently strong cooperation between Gas Transmission and Distribution.
- Both undertake separate operational forecasts, but there is a reasonably good match between them.

- Gas networks can be used as a storage medium and to offload excess electricity through electrolysis. The practicalities of how this will work needs to be agreed.

A.2.4 Data

- Re-Gen is an example of how companies could share data.

A.2.5 Procurement

- Joint procurement will be blocked by OJEU rules until we leave the EU.

A.2.6 Resilience

- Given the high reliability of gas networks, the concept of using heat pumps to increase reliability will not be a practical benefit. The argument may be more economic.

A.3 Electricity Transmission Stakeholder Comments

- The TSO is working with SGN on options for storing excess electrical energy as hydrogen gas (using gas pipelines for storage).
- Very little work has been done by the TSO on gas/electricity Whole System activities, but they see value in electrolysis/hybrid heat pumps for peak shaving.
- Main touchpoints likely to be optimised connection agreements and planning/balancing services.

A.4 GB System Operator (Elec and Gas) stakeholder comments

- The new ENA Whole of System workstream (which the ESO is part of) is an important forum with a remit that includes setting our processes and figuring out practically how to be more joined up
- The TSO is looking out to 2030 to consider “who has a new need for energy” in a more holistic way. E.g. local planning authorities; developers. This need then needs to be evaluated together by the different suppliers of energy in its various forms. In effect he is highlighting “new energy development connections with scale” as an important touchpoint for WoS.
- The TSO also flagged a second priority touchpoint for outage and constraint management.
- The third touchpoint mentioned by the TSO is gas peaking plant connection – any generation that connects to both networks is strongly in focus. The Gas distribute companies commented on this in detail.

A.5 Academic stakeholder comments

- The university is working on the InTEGReL project, so the focus is electrolysis to generate hydrogen and then the interaction between electricity and gas vectors. In this context, gas networks can be a useful way of storing energy. The university mentioned line-packing, which increases gas pressure to store gas.
- Forecasting will be key to the operational touchpoint. Both electricity and gas vectors perform forecasting in their control rooms to work out energy demand and where it will come from. Cooperation could optimise the overall system and open up cross-vector opportunities (e.g. electrolysis).
- The amount of H2 that can be feasibly blended into natural gas is under review, but it could be much more than the 20% currently allowed.

A.6 Letters of support

Through our engagement on our Whole Systems Strategy, we have received letters of support from the following key stakeholders:

- North East Local Enterprise Partnership;
- Northumbrian Water;
- Northern Powergrid;
- Yorkshire Water; and,
- Newcastle University

Copies of these letters have been provided in the following pages
.

North East
Local Enterprise Partnership

Mr Keith Owen
Head of Systems Development and Energy Strategy
Northern Gas Networks
1100 Century Way
Thorpe Park
LS15 8TU
Leeds

07th November 2019

Re: Whole Systems Strategic Framework

Dear Keith,

The North East Local Enterprise Partnership (NELEP) works with partners to develop our economy by exploring sector-wide initiatives, and connections to cross cutting agendas such as energy, digital and data, infrastructure and skills. Earlier this year the NELEP developed its Energy for Growth strategy identifying regional strengths, challenges and opportunities aligning to national energy policy.

Our strategy raises awareness of our regional offer encouraging partnerships and collective buy-in for collaborative delivery, and to help shape a pipeline of projects to further strengthen the energy sector across our region. At the epicentre of delivery is the 'Energy Catalyst', a partnership which unites the North East's leading energy innovation and demonstration and delivery capabilities, bringing together industry, public sector and universities to drive programmes of delivery.

NGN area a key partner within the Catalyst and having reviewed NGN's strategic framework for implementing a whole systems approach in RIIO-2. We consider this approach together with our Catalyst partnership provides a solid foundation on which to build further collaboration with other organisations and value the opportunity to input into the development of your approach.

Through our Catalyst partnership, we are already demonstrating the value of adopting a whole systems approach and the long-term customer benefits that this will deliver.

We look forward to continuing to strengthen our partnership through the Energy Catalyst going forward.

Kind regards,

David Lynch

Energy Innovation Partnership Manager

North East Local Enterprise Partnership

North East LEP 1 St James Gate, Newcastle upon Tyne, NE1 4AD
Tel: 0191 561 5420 | Email: info@nelep.co.uk | nelep.co.uk | @northeastlep

NORTHUMBRIAN WATER living water

T - +44 (0) 845 604 7468
F - +44 (0) 191 301 6202

Website: www.nwl.co.uk

Abbey Road
Pity Me
Durham
DH1 5FJ

21 November 2019

Mr Greg Dodd
Head of Strategic Planning
Northern Gas Networks
1100 Century Way
Thorpe Park
LS15 8TU
Leeds

Dear Greg

Re: Whole Systems Strategic Framework

Thank you for providing us with an overview of NGN's strategic framework for implementing a whole systems approach in RIIO-2. We are grateful that you engaged with Northumbrian Water in the development of your strategy and that we have identified similar priorities in order to facilitate a whole systems approach across our network areas.

We note our ongoing collaboration in relation to innovation across our two businesses and NGN's involvement in our annual Innovation Festival. Specifically, we are working together to develop your Integrated Transport, Electricity, Gas, Research Laboratory (InTEGReL) site particularly in relation to its Internet of Things (IoT) capabilities.

In addition to these areas, we see significant scope to deliver more immediate consumer benefits through ongoing collaboration, with a view to establishing a stronger ongoing relationship with you across all areas of our business.

This includes the specific initiatives we identified when we met, including collaboration in relation to:

- Delivering innovation projects that may deliver mutual benefits to both businesses;
- Considering low emission fleet alternatives and potentially sharing access to refuelling/recharging infrastructure; and
- Longer-term opportunities, such as exploring the potential for an integrated service provision delivered to customers.

We also welcome the collaborative approach that we have jointly established with anchor institutions in our network area, namely Northern Powergrid and Yorkshire Water. We consider further mutual benefit for consumers can be gained through a co-ordinated approach amongst these organisations.

We look forward to working with you closer going forward and acknowledge the long-term customer benefits that adopting a whole systems approach will deliver.

Kind regards,

Ceri Jones
Assets and Assurance Director

Lloyds Court
78 Grey Street
Newcastle Upon Tyne
NE1 6AF

Mr Gareth Mills
Head of RIIO-2
Northern Gas Networks
1100 Century Way
Thorpe Park
Leeds
LS15 8TU

29 November 2019

Northern Powergrid engagement with NGN's Whole Systems Strategy

Dear Gareth,

Thank you for providing us with an overview NGN's strategic framework for implementing a whole systems approach in RIIO-2. We are grateful that you engaged with Northern Powergrid in the development of your strategy and that our priorities have been reflected in the Action Plans you have developed. These short-, medium- and long-term actions are important to facilitate a whole systems approach to an efficient energy system to ensure resilience, value and decarbonisation pathways to 2050 or earlier.

We note the collaborative work that we have already delivered through the ENA's cross-sector Core Energy Scenario project, which outlined the future scenarios that might influence network companies' business plans. We also see significant scope to deliver more immediate consumer benefits through on-going collaboration, with a view to establishing a stronger on-going relationship with you across all areas of our business. It is encouraging that we are routinely engaged together with our regional stakeholders such as local authorities and we will continue to seek further opportunities.

We note that you have included the specific initiatives as well as the delivery pathways we discussed through our engagement this year. Specifically:

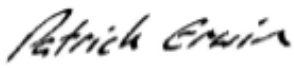
1. *Operationally*:
    a. Investigating the potential to establish a live operational feed into each other's control rooms. This could be a project undertaken through the National Centre for Energy Systems Integration (CESI) and we note the collaboration we've already established in relation to your InTEGReL site.
    b. Committing to considering potential alignment of streetworks, particularly in Bradford where there are significant work programmes for NGN and NPg going forward. This will be an interesting project to see to what extent we can minimise disruption through closer co-operation.
2. *Information sharing*:
    a. Increasing information shared between the organisations relating to demand forecasting.
    b. Sharing information around managing spoil to landfill and use of recycled aggregate.
3. *Connections* – Exploring potential to streamline connections processes with a view to offering an integrated service to customers across both gas and electricity networks.

4. *Fleet initiatives* – Considering options relating to mutually decarbonising vehicle fleets (e.g. optimising refuelling infrastructure needed for either electric or hydrogen fuel cell vehicles).

We also welcome the collaborative approach that we have jointly established with other 'anchor institutions' in our network area, namely Yorkshire Water and Northumbrian Water. We consider further mutual benefit for consumer can be gained through a co-ordinated approach across water as well as energy. Achieving the region's net zero ambitions will require closer working and commitment.

We look forward to working with you closely going forward and acknowledge the long-term customer benefits that adopting a whole systems approach will deliver.

Yours sincerely,



Patrick Erwin

Policy & Markets Director

YorkshireWater

Mr Greg Dodd
Head of Strategic Planning
Northern Gas Networks
1100 Century Way
Thorpe Park
LS15 8TU
Leeds

22 November 2019

Re: Letter of Support for NGN Whole System Strategy

Dear Greg,

Thank you for meeting with Yorkshire Water on 8 July 2019 to provide an overview of your strategic framework for implementing a whole systems approach. We are grateful that you engaged with Yorkshire Water in the development of your strategy and that we have been able to identify mutual areas where we can collaborate to deliver further benefit to our consumers. Please accept this letter indicating our support in working together to deliver mutual objectives for our customers by implementing a whole system approach.

We also see significant scope to deliver more immediate consumer benefits through ongoing collaboration, with a view to establishing a stronger ongoing relationship with you across all areas of our business.

This includes the specific initiatives we identified when we met, including collaboration in relation to:

- Delivering innovation projects that may provide mutual benefits to both businesses;
- Opportunities to improve data sharing and minimise customer disruption between the businesses; and
- Considering low emission fleet alternatives and potentially sharing access to refuelling/recharging infrastructure.

We also welcome the collaborative approach that we have jointly established with anchor institutions in our network area, namely with Northern Powergrid. We consider further mutual benefit for consumers can be gained through a co-ordinated approach amongst these organisations.

We look forward to working with you closer going forward and acknowledge the long-term customer benefits that adopting a whole systems approach will deliver.

Kind regards,

David Hibbs
General Transport Manager – Yorkshire Water

Registered Office Yorkshire Water Services Limited Western House Halifax Road Bradford BD6 2SZ
Registered in England and Wales No.2366682 yorkshirewater.com

CARBON TRUST

School of Engineering
Merz Court
Newcastle University
Newcastle upon Tyne
NE1 7RU

Mr Keith Owen
Head of Systems Development and Energy Strategy
Northern Gas Networks
1100 Century Way
Thorpe Park
LS15 8TU
Leeds

05 December 2019

Dear Keith,

Re: Whole Systems Strategic Framework

As you know at Newcastle University we lead the EPSRC National Centre for Energy Systems Integration (CESI) where we work with Industry to tackle the challenges of making the transition to a low carbon energy system. At CESI we collaborate with Industry and take a multi-disciplinary approach to identify the risks and benefits of different pathways to a net zero energy system. We see Northern Gas Networks as a crucial partner in this work and have benefitted hugely from working with you and your colleagues over the last three years. I am very pleased to see that a lot of our combined thinking about whole systems approaches is becoming part of your business strategy and really appreciate the opportunity to review and provide feedback on your whole systems approach in RIIO-2.

At CESI we consider the approach provides a solid foundation on which to build further collaboration with other organisations and value the opportunity to input into the development of your approach. We also note our collaboration in relation to the development of the exciting whole systems research and demonstration facility, InTEGReL, where we have been working with you to explore multi-vector-control rooms of the future, the use of Hydrogen and coupled electrical and gas distribution networks.

Through these projects, we've been able to demonstrate the value of adopting a whole systems approach and the long-term customer benefits that this will deliver.

We look forward to continuing to strengthen our partnership going forward.

Yours sincerely

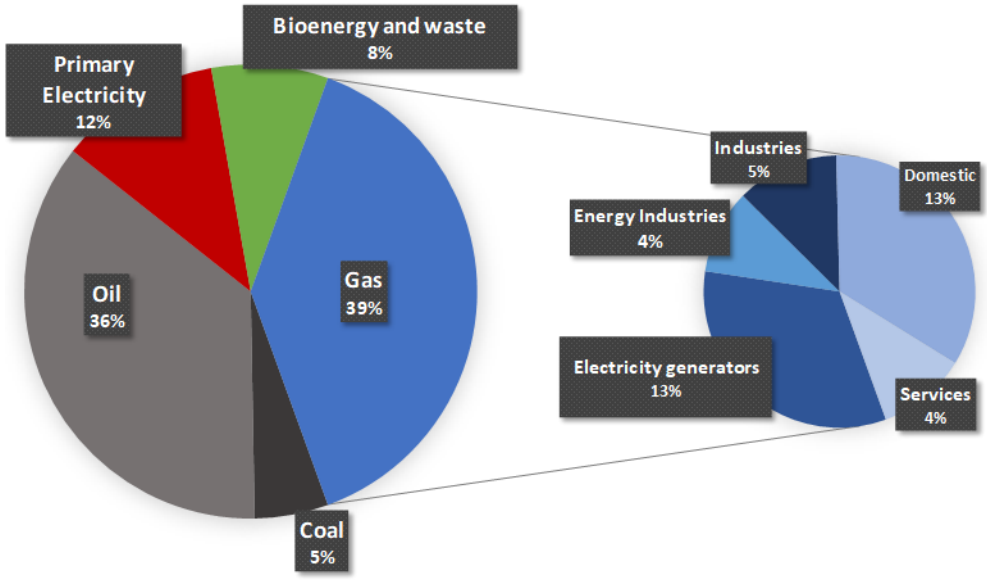
Professor Phil Taylor
BEng EngD CEng SMIEEE FIET FHEA
Head of the School of Engineering
Siemens Professor of Energy Systems

Annex B | Developing our Whole Systems Thinking

B.1 Introduction

There are three main drivers responsible for the significant change that the energy resource system is undergoing: resource depletion, energy independency and climate change, with the latter being the most prominent one. The necessary decarbonisation that results from this requires us to manage the emissions from fossils fuels through a combination of carbon capture utilization and storage, whilst reducing our dependence on fossil fuels and replacing them with renewable resources. The energy system that results from this transformation needs to be safe, reliable, affordable and sustainable. The ongoing work on Future Energy Scenarios by National Grid underlines the magnitude of the challenge.

Figure B.1: Share of the inland energy consumption for various energy carriers and sectoral breakdown for gas, illustrating the UK's dependency on fossil fuels and the role of gas. Data from 2017, BEIS.



The UK has a long history in recognizing and battling climate change and is a signatory to achieving the Paris Agreement goals. The Climate Change Act 2008 set in legislation the UK's approach to tackling and responding to climate change. It introduced the UK's long-term legally binding 2050 target to reduce greenhouse gas emissions by at least 80% relative to 1990 levels. In June 2019, this target was strengthened, with the UK becoming the first major economy in the world to pass a law to reduce emissions to net zero by 2050.

The UK is leading the world in transitioning to a low carbon economy. According to PwC's Low Carbon Economy Index (LCEI) 2018, the UK remains at the top of the G20 leader board for its long-term low carbon transition since 2000, decarbonising at 3.7% per year. In

response to these fast-moving changes, network operators are developing new tools and resources to deploy and optimise flexible responses to the intermittent output of renewable energy sources. Cross-sector energy management and planning is required to efficiently manage interactions between electricity, gas and heat networks.

Progress is being achieved through innovation incentives, such as the Innovation Funding Incentive scheme, the £500 million Low Carbon Networks Fund and more recently the Network Innovation Competition and Network Innovation Allowance schemes. These incentives have enabled the network companies to develop new approaches to enabling the energy transition over the last 15 years, and the focus on how whole systems interactions can further increase the benefits of the DSO transition. The focus of initiatives like this on the power sector has helped electricity decarbonise more rapidly than other sectors.
We will support the Two Degrees and Community Renewables visions for 2030 and 2050 set out in National Grid's Future Energy Scenarios (FES) by actively working towards a future safe, reliable, affordable and sustainable future-proof energy system, we need to collaborate with all actors in the energy value chain to realize and incorporate transformational changes. This will affect the following areas:

- **Energy sources and use** – Decarbonisation of space heating through the use of hydrogen and biomethane, augmented or replaced by (locally generated) renewable electricity from sun and wind where insulation levels of buildings allow this, and electrification of transport using battery-powered electric vehicles and, likely to a lesser extent, hydrogen fuel cell vehicles.

- **Assets and grids** – Decarbonisation of space heating and electrification of transport will require an increase in electricity transport and distribution capacity, storage assets and resilience. Increased demand for power is currently partly met through deployment of smart technologies. This aggregates the resilience model for electricity and ICT systems together, and it is not obvious this leads to an improved position. The gas infrastructure then can play a key role in adding resilience, capacity and response to the electricity network. The introduction of power-to-gas solutions and new gases results in new requirements for gas infrastructure and it will be coupled stronger to the electricity grid. Clusters coupling local generation and demand will become more and more important to reduce conversion and transport losses and to increase the system's resiliency.

- **Roles and responsibilities** – Existing actors will take on additional roles and responsibilities and new roles will emerge. End-users, individually, through local energy corporations or via commercial actors will increasingly become active players in the energy system and thus influence the direction in which it will develop. The coupling of the electricity and gas sector at every level demands high levels of information sharing and close collaboration in planning and operation between grid operators within and across sector boundaries to ensure optimal investment and running of whole systems. Emerging technologies like AI and IoT can be profound

agents of change, both unlocking the information that enables new behaviour and roles and making that information actionable.

- **Markets and services** – Increased interconnectivity and integration of European markets are key contributors to the UK's security of supply while local flexibility markets facilitate commodity arbitration and system cost optimization. New Demand Response and Energy-as-a-Service propositions for end-users help manage the electricity and gas grids concurrently, effectively resulting in multi-commodity smart grids. In this scenario, both grids will leverage sensors, actuators and communication infrastructures at near equal levels, enabling a commodity-agnostic whole systems optimization. Grid operators need to both facilitate the development of these new services and plan for their impact across all energy vectors.

Ofgem recognizes the need for Network Companies and System Operators to ensure that the development of the energy system as a whole is effectively coordinated, to deliver best value for customers.

B.2 The future role of gas

As outlined in Section 5 of the FES view of energy supply scenarios for 2030 and 2050, the role of gas in the energy system is changing, due to the push towards renewable energy which is currently largely electric in nature. The development and use of gas infrastructure in the future will therefore be coupled more strongly to developments in the buildings sector (traditionally fuelled by hydrocarbons that are predominantly gaseous in nature) and the transport sector. There is a common sentiment among many stakeholders that as a result of this electrification, the electricity grid will grow while simultaneously the gas grid will shrink. In addition to climate and environmental concerns, geopolitical and security of supply considerations also factor into this discussion.

Gas was seen for a long time as a transition fuel, but it is now becoming increasingly clear that it is likely a destination fuel that has an important role to play in a (largely) decarbonized energy system due to the advent of safe green gases such as hydrogen, biomethane and syngas. Its high energy density and robust and reliable infrastructure contribute to the unique capability of gas to transport large volumes of energy across space and time, in a safe, reliable and low-cost manner and to provide efficient energy storage in ways that electricity struggles to match.

A successful, integrated multi-vector energy system recognizes the strengths of the individual commodities, their infrastructures and supporting organizations to deliver maximum value to the customer in terms of security of supply, safety, affordability and comfort.

For the role of gas, four key contributions stand out, that all have a strong link to a whole systems approach:

- **Space heating** – The current gas system has been built to provide the capacity needed to heat our homes, also during extreme, prolonged periods of cold, known as the 1 in 20 peak demand. In a decarbonized energy system, the same levels of resilience and comfort should be maintained. Gas is ideally positioned to continue to fulfil that role through the use biomethane and (methanized) hydrogen. This is especially true when insulation levels are not increasing rapidly enough to enable electric heat pumps to become a leading heating technology for the existing building stock, and/or when the availability of renewable electricity for space heating is insufficient to meet the UK's decarbonization goals.

  Electrification of heat demand using renewable energy would present a huge challenge: not only would the peak electricity demand be very high (due to reduced Coefficient of Performance and increased demand), the production of renewable energy can simultaneously drop.[13] Electrification of transport intensifies this challenge.

  To keep energy system costs low, prevent stranded gas assets, prevent overinvestment in electricity grid reinforcements, maintain customer choice and protect vulnerable customers, renewable gas should be considered as the main energy source for domestic heat for existing buildings and can act as back-up through hybrid heat-pumps for buildings with medium to good insulation levels. Planning the decarbonisation of heat demand in an economical way requires strong coordination and planning between electricity and gas TSOs and DSOs.

- **Feedstock and process heat** – Natural gas and hydrogen both play an important role in industry, either as feedstock or as source for generating process heat. Green hydrogen can serve as a long-term sustainable alternative for both, either directly or in methanized form. These applications of gas are not easily electrified. Although these use cases occur predominantly at the transport level, the adoption of power-to-gas facilitates the introduction of hydrogen at the distribution level.

- **Transport** – Decarbonisation of transport currently strongly focusses on electrification, specifically when it comes to passenger vehicles. Preliminary results from analyses like those in the "Decarbonisation pathways for the GB gas networks" project for ENA indicated there is a substantial role for gas too, specifically for international shipping, with LNG being the dominant fuel, and hydrogen-powered heavy road transport. Hydrogen for transport can gain in importance when hydrogen-hubs[14] emerge and ambitions for increased production of fuel-cell

[13] Due to lack of wind in high-pressure weather causing low temperatures and lack of solar PV production at this latitude in winter.

[14] Clusters of economic activity where hydrogen is produced and used for feedstock, heat production and transport, with these clusters being linked through road and shipping transport corridors where hydrogen charging infrastructure is available. Main ports like Rotterdam and transport hubs like Luxemburg are examples where such a concept is considered.

passenger vehicles become reality. Hydrogen-powered vehicles offer benefits in terms of longevity, range and fuelling times. Gas and electricity utilities should work together to explore how best to deliver these new refuelling facilities of the future be it battery or hydrogen powered EVs.

- **Flexibility provider for the power sector** – In addition to being a driving force behind the decarbonisation of the UK energy system through the large-scale adoption of sustainable gases like green hydrogen, the gas sector can support the power sector in its decarbonisation efforts by offering flexibility to the power system.

    - *Storage and conversion* – With the increasing amounts of (offshore) wind and solar energy being produced the rate of occurrence of temporary renewable energy overproduction (resulting in part from planned overcapacity to deal with intermittency) will increase. Rather than curtailing this overproduction, which is considered wasteful and undesirable, the excess energy should be stored to maximise the value from these renewable energy investments. Different storage technologies should be applied for different use cases. Under current technological and market conditions, battery storage is the preferred technology when rapid response and/or short time, local storage is required, but this form of storage is not economical for storage scenarios, where larger volumes and longer time scales apply. Conversion of electricity into hydrogen, potentially followed by methanation to facilitate grid integration, is increasingly seen as the preferred storage technology in this case. Local peaking plants, in the form of small-scale generation and CHPs enable transfer of energy from the gas to the power grid.

    - *High-volume transport and distribution* – The gas transport and distribution grids transport large volumes of energy efficiently and can provide valuable flexibility and transport capacity to the energy system. The coupling of electricity and gas infrastructures can reduce the expansion need for the electricity grid, but this requires careful coordination and planning of power-to-gas conversion points to ensure final consumption demands can be met at any point in time.

    - *Asset and Congestion Management* – A key characteristic of electrical infrastructure equipment is the special relationship between the load on the asset and the impact on its service life. Long-term heavy loads ensure high operating temperatures and (exponentially) accelerated aging of insulation materials. From the point of view of security of supply and affordability, it is therefore of great importance to protect the electrical assets against long-term high loads. Also, simple capacity constraints arising from electrification might give to the need for congestion management on the power distribution grid. Next generation heating systems like hybrid heat pumps and CHPs can be leveraged for smart asset management, requiring operational coordination and bilateral renumeration agreements between gas and

electricity DNOs and potentially third-parties offering services that leverage such capabilities of an integrated multi-commodity grid.

As can be concluded from the above, gas and the gas infrastructure have a long term and positive role to play in decarbonising the UK energy system, both directly and indirectly. Next to decarbonising heat and transport through the use of biomethane and hydrogen, gas is a key enabler for providing the flexibility required by the power sector for electrification of demand and the integration of renewables. The increasing interplay between the four network sectors justifies the development of a whole systems approach that addresses innovation, development, planning and operation across energy vectors and sectors to bring maximum value and minimal carbon to the grid customer.

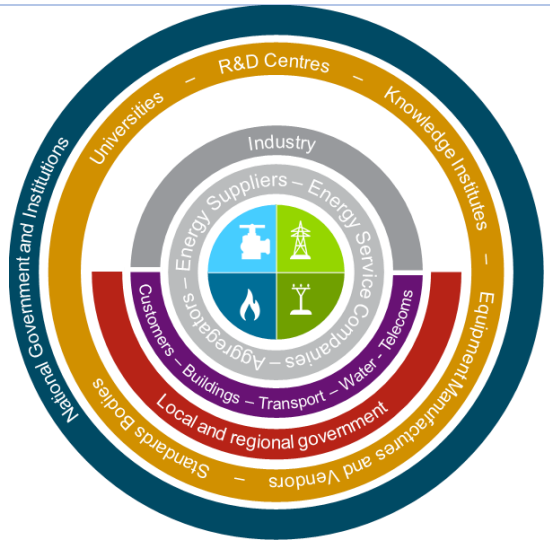
"Whole systems" is by its very definition a large, complex topic with many aspects. In this Chapter we look at the different dimensions of whole systems, the key stakeholders and dependencies and their relevance to us.

B.3 Key stakeholders for a whole systems approach

The energy transition results in changing roles and responsibilities for existing actors in a sector. New roles emerge, such as the role of flexibility aggregator, and sectors like the transport and building sectors not only undergo a massive transformation due to the need to meet the Paris Agreement requirements but also become active actors in the energy sector through the deployment of building-to-grid and vehicle-to-grid platforms. The set of relevant stakeholders is becoming more complex.

In Figure B.2 a high-level stakeholder map for a whole systems approach is shown to illustrate this.

Figure B.2: Stakeholder Map for a whole systems approach from the perspective of the Gas (Blue) and Electricity (Green) TSO (top half of centre) and DSO (bottom half of centre) perspective. Key dependencies relevant for whole systems are detailed in Table 2.



B.4 Key stakeholder interactions and dependencies

Key stakeholder interactions and developments that impact a whole systems strategy are described briefly in the table below, using the colour coding introduced in Figure B.2.

For each stakeholder interaction the main topics are discussed and for each topic the impact for us is stated, using a qualitative assessment by Navigant subject matter experts and stakeholder consultation.

Table B.1: Key interactions and developments between stakeholders that are relevant for a whole systems approach

Interaction	Description	Impact
Supplier – GDN	Digesters producing biomethane inject this into the gas distribution grid. Biomethane is a renewable gas but its quality needs to be closely controlled to ensure safety and longevity of gas equipment, especially with the strong expected increase in biomethane production. This requires GDNs to co-innovate with Suppliers and Equipment Manufactures and interact with governmental stakeholders to ensure innovation outcomes inform standards and regulation.	Medium
ESCo – GDN	New actors like Energy Service Companies and Aggregators, and energy suppliers moving beyond just selling energy result in new products and services being offered to the market. To enable these services, these parties might call on grid operators for data sharing or other market facilitation activities. Depending on the uptake of these new products and services there might be a shift in commodity preference with customers, which in turn impacts capacity needs. GDNs need to interact with these stakeholders as to meet their information needs in a timely manner and to assess how new products and services impact their planning and operation.	Medium-Low
G-TSO – E-TSO	The Gas and Electricity sector are currently strongly coupled at the transmission level, with gas-fuelled power plants accounting for close to 40% of the UK's electricity generation. Gas-fired central generation demand will become more variable within-day, and day-to-day as a result of increased renewables uptake. The impact of this intermittency is already being seen at the distribution level through requests for small scale generation connections and current indicators suggest this will become ever more pronounced. Mutual information sharing	High

	between GDNs and these stakeholders is required to ensure robust and cost-effective planning and implementation of gas grids.	
 **GDN – DNO**	Decentralization of electricity production from gas in impacting the gas demand on the distribution grid. New small-scale Open Cycle Gas Turbines (OCGTs) and Recip Engines are typically below 20MW and connected to the distribution grid and a major driver for new gas demand. Information sharing and integrated of planning between GDNs and DSOs is needed to ensure capacity expectations are met in a timely manner.	High
 **G-TSO – E-TSO**	Increasing (off-shore) wind and solar PV farms might result in excess renewable energy at certain times in the near future, prompting a conversion to hydrogen to store and use the energy later for, for example, space heating. The future role of hydrogen strongly impacts both the required gas transport and distribution capacity requirements as well as gas quality/methanation requirements. GDNs require strong stakeholder management at both the policy and implementation level to contribute to an optimal Whole of System design.	Medium-High
 **G-TSO – GDN**	Capacity and gas quality requirements resulting from the production of (methanized) hydrogen at the transport level directly impacts the gas distribution grid as the vast majority of end-use of it will occur on the distribution grid. Close collaboration of GDNs with the gas TSO from both a planning and operational perspective is required to ensure seamless integration of new gases into the energy system.	High
 **GDN – DNO**	Decarbonizing heat in the build environment can lead to a large influx of hybrid heat pumps, ENA's aforementioned "Decarbonisation pathways for the GB gas networks" project for example results in a net zero-emission energy system for GB in 2050 with a 75% hybrid heat pump penetration rate, with hydrogen and biomethane acting as back-up fuel for renewable electricity. These devices have the ability to relieve the electricity grid in time of high electricity demand and can be operated as a Virtual Power Plant (VPP). Additionally, their ability to generate heat from gas adds resilience and redundancy to the energy system. Many pathways to low-carbon heating exist, and innovation and pilot projects are needed to understand how to shape the transition to sustainable heat. GDNs are well-positioned to provide open innovation environments where the novel solutions and services can be trialled.	High
 **Customers – GDN**	Customers become prosumers, start generating their own energy and interact differently with the energy sector. Although cost and comfort are still the two main drivers for customer behaviour, increasingly sustainability and wanting to be in control impact their decisions. Two extremes can be observed: moving towards Energy-as-a-Service solution where the customer takes a commodity-agnostic approach towards energy and autarky, where customer defect from the grid and become self-sufficient. Whereas the former puts strong requirements on market facilitation and coordination and helps vulnerable customers decarbonise, the latter raises issues around safety, cost-effectiveness and fairness. Grid operators have to decide on whether to take a mitigating or facilitating position around these topics and can leverage innovation outcomes and their neutral position in the market to engage in a dialog with customers to share information on opportunities and solutions related to Energy-as-a-Service.	Medium-Low
 **Building Sector – GDN**	Natural gas fulfils 80% of the UK's heating needs and heat accounts for close to 40% of the energy use in the UK. To decarbonize the energy use in buildings, roughly two main approaches can be identified: electrification of space heating, requiring massive retrofitting and increasing of insulation levels, or decarbonizing the gas system by switching to new gases like biomethane, syngas or hydrogen, or blends thereof. Intermediate solutions leveraging hybrid heat pump technology are a very likely part of this future landscape, because of their ease of deployment and availability in the market. Policy will be a huge determining factor for which a mix of solutions will prevail. For local grid operators, again the required future capacity and gas quality factors are key issues to decide on (replacement investments in the grid). It is therefore crucial to share innovation results to inform policy and in a more practical sense engage with the building sector to jointly building renovation and infrastructure upgrades.	Medium-High

 **Transport Sector – GDN**	The decarbonisation of transport is widely regarded as one of the more disruptive developments for our energy system as it would mean a substantial increase in electricity consumption, and thus distribution. Despite a currently unfavourable policy context, a good case can be made too for fuel cell cars. Recent announcements by Japan's leading car manufacturer in combination with local hydrogen ambitions yield credibility to a scenario where fuel cell cars are important part of the mobility mix. If this scenario materializes there are strong implications for the gas distribution grid and for the electricity distribution grid (leveraging the fleet's grid support capacity through vehicle to grid services), with potentially peak generation capacity at the transmission level being impacted too, as a hydrogen car fleet represents a sizable mobile generation capacity. The electrification of transport will lead to more small-scale generation to support demand. The increase in hydrogen transport will support the socialisation of hydrogen in society and benefit the adoption of hydrogen for heat. GDNs need to proactively engage with the power sector, transport and building sectors to optimally use, from a low cost, low carbon and system resilience perspective, the available renewable power and gas and build out the supporting infrastructure.	Medium-High
 **Water & Telecommunications – GDN**	There are operational efficiencies that can be realized for both GDNs and third-parties like municipalities by strategically cooperating on topics like grid replacement/extensions planning, shared infrastructure for smart metering, market platforms and data management. The advent of AI and IoT solutions and next generation telecommunication solutions opens up possibilities for new and more granular and autonomous ways of managing the state of gas and power grids, which is important to optimize and operate the system as a whole. These solutions should be developed together with the power sector and market parties in an open innovation setting, recognizing the importance of maintaining cyber security standards and system resilience. GDNs can provide the open innovation setting to speed this up.	Medium
 **GDN – Local Authorities**	In the UK there's a currently a strong variation in approaches to decarbonizing the energy system and the economy as a whole. Climate action and local development plans differ considerably from region to region, with regions opting for solutions that match local conditions and might give it an economic advantage. As an example, Leeds is heavily focusing on leading the transition to an energy system with a key role for hydrogen. Learnings from local initiatives impact both GDNs and DNOs, in terms of required infrastructure, capacity, (gas) quality, connection with transmission grids. Strong stakeholder management from the GDN contributes to development of realistic local decarbonisation goals and can contribute to local economic growth and resilience.	Medium-High
 **GDN – Academia**	Many innovations required for a Whole of System approach originate from R&D done in universities, knowledge institutes and R&D centres. To field-test, mature and scale-up these innovations, close collaboration between them, the GDN and other partners in the energy value chain is needed. GDNs are ideally positioned to lead this effort due to their expertise and neutral position. We founded open innovation environment InTEGReL, which is a leading example of this approach.	Medium
 **GDN – National Government**	The national government is the key influencer of what the future energy system in the UK will look like. It is responsible for translating international commitments like those resulting from the Paris Agreement into policy and through its institutions like Ofgem for providing the regulatory frameworks and incentives schemes that enable implementation. Divergent positions from government-driven bodies, with Ofgem emphasizing an entirely economic assessment of GD2 with minimum cost and BEIS favouring GD2 investments to cover a hydrogen community trial, leads to uncertainty and reduces the changes of the UK meeting its carbon targets. It is therefore of paramount importance that GDNs communicate about the results from their innovation projects and lessons-learned from the Whole-of-System efforts in order to contribute to a clear and stable policy and regulatory framework that furthers the Whole of System goals of creating a decarbonized, affordable and resilient energy system.	High

B.5 Stakeholder consultation and views

This strategy is informed by the views of other UK gas distribution companies, electricity distribution companies, the transmission system operators and academia.[15]

During a series of meetings, the consulted stakeholders described the potential touch-points between the network companies, and in the longer term, with other stakeholders across the energy industry. Some of the key views expressed are summarised below:

- The gas distribution companies have been leading innovation in aspects of street works, customer service and HSE. The DNOs are working with the GDCs to find whole systems approaches that improve the service that the network companies deliver to customers.
- There have been many whole systems demonstration projects and conversations between network companies about whole systems actions, but GD2 will be the time to implement the first steps.
- There should be a short-term focus on collaborating in the areas of network planning, connections, streetworks, operations, forecasting and customer service.
- The network companies can benefit from sharing data on assets and vulnerable customers, as well as collaborating on resources, major project planning and delivery, emergency response and customer service.
- Hydrogen will become more important for the UK energy mix from RIIO-3, so the GDCs will innovate in RIIO-2 to ensure that they are ready for the possible future energy scenarios.
- Changes in energy supply mixes are currently driven by local authorities and organisations at regional levels.

B.6 Whole systems from a technological, economical and societal perspective

In the previous section the key interaction points and dependencies between stakeholders, from the perspective of a regional gas grid operator were discussed. In this section different lenses are applied, looking at whole systems from a technological, economical and societal perspective.

B.6.1 The technological perspective

The tighter integration of the gas and electricity systems that results from the energy transition requires new technology to develop intra- and inter-sector. Both (investment) planning and operations will need increased visibility into forecasted grid usage. This requires data and model sharing to allow for cross-vector, cross-domain (transport and distribution) simulation and optimization. The adoption of open asset data could facilitate replacement planning and decarbonization. Additional sensors and actuators will need to be

[15] Please see Annex A for a full list of consulted organisations.

installed to act on fluctuating supply and demand conditions associated with the integration of intermittent renewables and changing consumption patterns.

For the gas sector there are specific challenges with the introduction of new gases and the resulting variations in gas quality. Many of these challenges are being met already, and there's a substantial body of work underway to address the open issues. The integration of biomethane into the distribution infrastructure requires it to free of water, CO_2, and siloxanes to prevent condensate. This is well understood by the sector and managed as part of business as usual activities.

The integration of hydrogen is not expected to cause issues at the lowest pressure (sub 20bar) and our H21 programme seeks to deliver evidence that will show the existing infrastructure can transport pure hydrogen across all pressure regimes in the distribution grid.

There is a need for further innovation in end-use equipment and metering. Future boilers (and fires and cookers[16]) either in a stand-alone configuration or as part of a dual-fuel setup like a hybrid heat pump, need to be able to consume new green gases/hydrogen. Hydrogen-boilers do exist[17] but are largely at the proof-of-concept stage. Depending on deployment paths of these new gases, there might be a need for broadband boilers that can run on a range of gas qualities.

In would be desirable for gas meters to be able to determine the instantaneous calorific value of gas and measure kWh instead of m^3. In the Hy4heat programme work is ongoing to develop hydrogen gas meters that could be delivered as kWh meters and are compliant with the SMETS2 standard.

Finally, dual-fuel devices like hybrid heat pumps need the ability to react to signals to switch from electricity to gas and vice versa, depending on market and grid conditions. Fuel cell and CHP-based systems can be paired with batteries or heat vessels, respectively, to enable them to cost-effectively provide power grid support services. This coupling of the gas and power grids introduces a dependency on IT and telecommunications and requires reliable high resilience secure communication and data systems.

Whole Systems Example 1	Dutch DNO Stedin publishes gas grid replacement data online to help municipalities plan for getting neighbourhoods off natural gas and to enable efficient combination of excavation work across utilities.

B.6.2 The economical perspective

[16] The Hy4Heat project plans to develop 5 of each for different developers.
[17] Italian firm Giacomini, Belgium's Beckeart and Dutch firm Remeha all have early-stage models.

A strong electrification of the energy system mandated by a large influx of renewably generated power requires substantial reinforcements and extensions of the electricity grid. Going 100% renewable, or 100% electric, might not be the optimal solution as the last ~20% of electrification carries a disproportionate cost, and affordability is key for continued support for the energy transition. Additionally, a more diverse energy supply limits the UK's vulnerability and enhances its attractiveness for energy intensive industries. The existing gas infrastructure can play a key role here, especially when it comes to space heating and process heat.

For newly built homes, with a very high degree of insulation, all-electric is a realistic decarbonization option provided sufficient amounts of renewable power and storage is available on the grid. But for the existing building stock that requires deep retrofitting of insulation, second infrastructure is probably needed to guarantee security or supply for space heating. In many cases the existing gas infrastructure (distributing renewable gas) will take on that role, although a local heat network could also be a viable option.

Three infrastructures (Electricity, Gas, Heat) might not be economically optimal and individual customer preferences should be carefully balanced against public interest. By making their expertise available to the local government, network operators can ensure the economically optimal choice at the district level, based on state of the infrastructure, housing stock and heat sources. Taking on a role as local systems architect, we can bridge knowledge and capability gaps that exist with local authorities in understanding and meeting the needs of the community. However, a word of caution should be issued against an overly localized approach, as the lack of scale of locally designed solutions will likely mean higher costs levels. Innovative solutions should have national potential and tie in with national policy to be truly cost-effective.

Whole Systems Example 2

UK Power Networks lead a multi-partner innovation project in which the possibilities for energy saving through energy efficiency and demand-shifting propositions for fuel-poor customers were piloted. In the project commodity arbitration by customers was observed, switching between gas and electricity for heating to minimize their overall bill, and thereby showing a rudimentary form of Heat-as-a-Service.

In an optimally integrated multi-vector energy system, the use of individual infrastructures is continuously optimized to leverage the capabilities of each individual infrastructure vis-à-vis the availability of the commodity. Such cross-commodity optimization, translating to Energy-as-a-Service propositions for end-users, exploits the flexibility of the system. These operational efficiencies through better collaboration and knowledge sharing result in smarter investments and lower overall system costs and delayed and/or deferred grid investments. For vulnerable and fuel poor customers, Energy-as-a-Service or Heat-as-a-

Service removes the need for investing in new heating equipment and enables them to participate and generate income from participating in demand-response schemes.

B.6.3 The societal perspective

A whole systems approach to energy has the potential to greatly benefit society by contributing to a clean, reliable and affordable energy system through increased renewables integration, improved customer choice and commodity-agnostic Energy-as-a-Service propositions. Both gas-only heating solutions like fuel cells, (Micro)CHPs or next generation boilers fuelled by biomethane or hydrogen, as well as dual fuel solutions combining an (air-source) heat pump with a boiler are likely to be part of the future energy system.

However, the customer impacts of the switch to a less traditional heating solution are significant. Moving from a combi boiler to a CHP or Heat Pump requires a significant investment that will be difficult to carry by a large part of the customer base; adoption of an Energy-as-a-Service approach could mitigate this. Space constraints and noise concerns in buildings might impact installing heat pumps and CHPs, and the use of hydrogen comes with perceived safety risks that may hamper adoption. Next to these, there are 'softer' aspects like the inconvenience of having invasive work done to a property and having to get used to a new heating system.

Access to bi-fuel heating systems (like electricity and gas in the case of hybrid heat pumps) provides better comfort guarantees over an electricity-only solution. Gas grids have stellar records in terms of uptime and ensuring security of supply and as such provide a good insurance against prolonged outages of the electricity grid[18], or periods of reduced availability of renewable energy that coincide with a large heat demand. In such so-called "windless winter weeks", sustainable energy supply won't be sufficient to meet the electricity demand from a large base of hybrid heat pumps and renewable gas can step in to fill that void.

Another category of societal risk stems mainly from a lack of coordination and policy at the national level, and regions pursuing their own localized solutions. In addition to the technological and economic risks identified above, there is a risk related to portability of end-user assets, like cars and hobs. In a scenario where gas quality varies regionally (e.g. localized pockets of hydrogen use), or where charging infrastructure is only available locally, customers will be reluctant to invest in assets tied to that, as a move out of the region would strongly reduce their value. Both cases could apply to the integration of hydrogen into the energy system, depending on the approach taken (maximum admixture, methanation or dedicated infrastructure).

Many of these issues are already being addressed and will continue to be a focus area for RIIO-2. Our H21 programme seeks to deliver evidence that will show the existing infrastructure can transport pure hydrogen, thereby removing the need for purpose-built

[18] Assuming the gas-fired boiler of a hybrid heat-pump features back-up power to ignite.

infrastructure. Perceived uncertainties around these topics might hamper their uptake and thereby the success of a local policy that is not firmly grounded in national policy. Continued significant research and demonstration is required to remove these uncertainties and deliver change, accompanied by consistent, fact-based messaging and customer engagement to ensure successful application of green gases at scale.

B.7 Summary

Whole systems involves a wide range of stakeholders and touches on all aspects of the traditional energy sector, and beyond. Whole systems interactions can be observed at all levels and across all sectors.

For us, the focus is on decarbonizing heat through the use of hydrogen, biomethane and other synthetic (safe for entry) gases, and assessing how new, green gases can facilitate decarbonization of the electricity sector as a flexibility provider.

Many of the technological challenges of moving to a hydrogen-dominated gas system are already being addressed in innovation projects like H21, Hy4Heat and InTEGReL and continuation of this work to provide the evidence required for setting policy and creating the right incentive schemes will be a key ingredient of our whole systems activities in RIIO-2.

From an economic perspective, operational efficiencies resulting from closer collaboration between the gas and electricity sectors can serve as a stepping stone for smarter investments and joint operation of a true multi-vector energy system.

In creating such a system, care should be taken that it offers at least the same level of resilience as the current gas system, and that all customer groups can enjoy the same or better comfort levels as today, at acceptable costs levels.