ProjectUnion

Net Zero Pre-construction Work and Small Net Zero Projects Re-opener Submission

16th December 2022

Gas Transmission and Metering

V2.0

ProjectUnion

Key Contacts

Please direct any questions or comments regarding this submission to

Danielle Stewart, Project Director, Project Union
Danielle.stewart@nationalgrid.com

Antony Green, Hydrogen Director
Antony.green@nationalgrid.com

Tony Nixon, Head of Regulation
Tony.nixon@nationalgrid.com

ProjectUnion
Feasibility Phase

Key Deliverables

1 Phasing Strategy

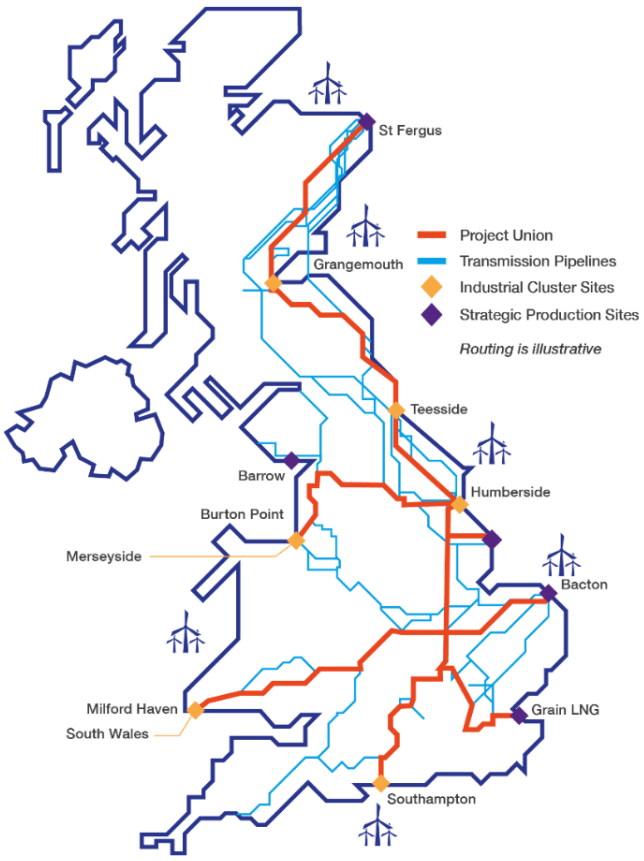
Providing a clear plan for Project Union's Delivery with prioritisation and timing for each section of the hydrogen backbone. This will ensure security of supply on the remaining methane network and provide a staged approach to project delivery and funding.

2 Pre-Front End Engineering and Design

As per any large scale network investment we will undertake the pre-FEED activities for the entire hydrogen backbone, delivering an appraised set of routing options, a constructability assessment and a planning and consenting strategy based on enhanced cost estimates and asset data.

3 Hydrogen Market Enabling Activities

The hydrogen network can not be progressed without the design of regulatory and commercial frameworks for hydrogen infrastructure and delivery of the required customer and stakeholder engagement for the sections proposed.



Allowance Required **£7.912m** 18/19 Prices

Benefits that will be unlocked

Decarbonisation of industry and power

Fair access to low carbon hydrogen enabling businesses and decarbonise. Access to transmission enable hydrogen production at scale

Flexibility and Optionality

Flexibility in power generation, storage and consumption. Optionality in future hydrogen decisions whilst maintaining gas networks delivery

Consumer-centric

Innovative, cost effective consumer focused energy solutions – for example the pilot hydrogen town brings scalability and expansion

Promote energy independence

Enable transport of and fair access to indigenous supplies around the UK and opens up the potential for export opportunities by connecting to the European Hydrogen Backbone

Energy Storage and Resilience

System resilience to move and store sufficient volumes across the country

Connectivity and Efficiency

Connect production and storage with demand, enabling system efficiency through shared infrastructure

Market Coupling

Connect isolated production sites enabling competition, reducing costs and improving security of supply

Levelling up and jobs

Project Union will directly support approx. £300m annual GVA and 3100 jobs at peak construction

Global Leader in Green Innovation

Attract global investors by getting best value from national infrastructure and enabling rapid scale up

Document control

Version	Status	Date	Author(s)	Summary of changes
V1.0	Final Draft	Jul-22	Craig Neilson Matthew Sumerling Derek Radburn Raveena Virk	
V2.0	Final Version	Dec-22	Emily Ly Matthew Sumerling Malcolm Arthur Francis Dike Craig Neilson Derek Radburn	• De-scoped East Coast Hydrogen Pre-FEED, System Operator Review, and Regulatory Framework review – to be funded under Net Zero UIOLI • Re-scoped to include the phasing strategy and pre-feed for the full hydrogen backbone

Reviewers

Name	Organisation	Role Title	Review Date
Carole Hook	Regulation	Head of Future Frameworks	15/12/2022
Corinna Jones	Hydrogen	Head of Hydrogen Innovation	15/12/2022
Tom Neal	Hydrogen	FutureGrid Manager	15/12/2022
Danielle Stewart	Hydrogen	Hydrogen Programme Manager	16/12/2022

Management approval

Name	Organisation	Role Title	Approval Date
Martin Cook	Commercial	Chief Commercial Officer	16/12/2022
Antony Green	Hydrogen	Hydrogen Director	16/12/2022
Tony Nixon	Regulation	Head of Regulation	16/12/2022

This document has been produced pursuant to Special Condition 3.9 of National Grid's Gas Transporter Licence ('the Licence') which relates to the Net Zero Pre-construction Work and Small Net Zero Projects Re-opener ('NZASP') mechanism.

Contents

1. Executive Summary

Project Union is a pioneering project led by National Grid Gas Transmission (NGGT) to create a UK hydrogen backbone, transporting 100% hydrogen, while connecting hydrogen production and storage with end users. Through the phased repurposing of existing gas transmission network infrastructure, the backbone will comprise 1,500 to 2,000km of repurposed assets, representing up to 25% of the UK's current methane transmission network, with minimal new infrastructure by the early 2030s.

Development of a UK hydrogen "backbone" by repurposing ~2,000 km of existing assets through a phased approach

Enable hydrogen transmission whilst ensuring security of methane supply for consumers

Aligned to green and blue hydrogen developments and CCUS clusters

Decarbonise industry, power and create optionality for heat and transport

Connect cross GB supply, demand and strategic storage sites, enabling growth of UK hydrogen economy

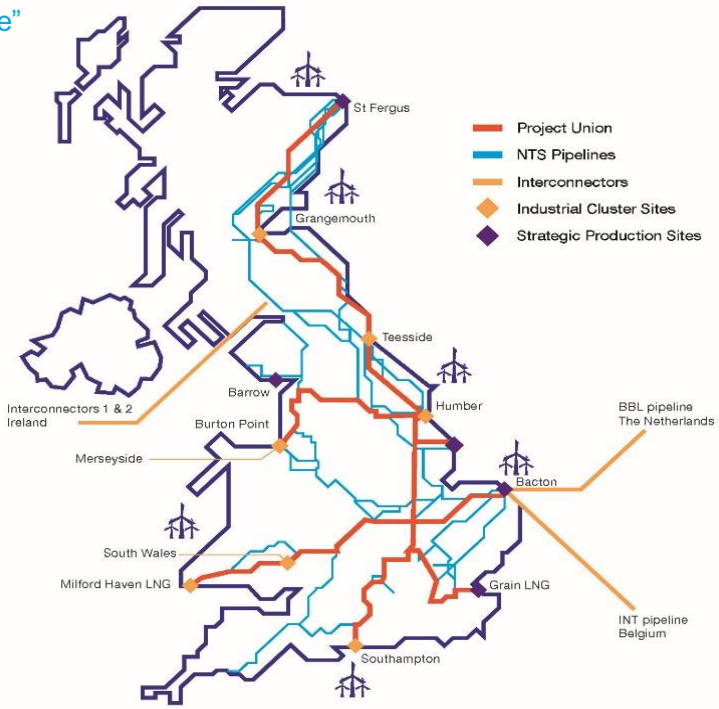


Figure 1 Project Union overview – routing of the hydrogen backbone is illustrative

Extensive engagement with our customers and stakeholders has demonstrated that hydrogen transmission infrastructure will be essential to providing a dynamic and resilient physical system on which to operate a liquid and competitive hydrogen market within the UK, lowering costs for the consumer and providing the opportunity to import and export hydrogen with international markets.

- Power stations are telling us that access to a national hydrogen transmission system is critical to provide transition options for decarbonisation
- Industrial clusters and blue hydrogen producers (using steam methane reformation to produce hydrogen) require access to a hydrogen backbone to create an open liquid hydrogen market and provide essential resilience for supply and demand.
- Industry outside of clusters that cannot electrify their production processes require access to hydrogen
- Green hydrogen producers (using renewable energy to produce hydrogen) need to understand timelines for pipeline transition and optimum locations for their production sites especially where their role is to de-constrain the electricity network.
- Storage sites need the connectivity and capacity of Project Union to coordinate with their own development plans to facilitate long term storage.

Complementary independent studies have shown that development of a hydrogen backbone is critical to enabling decarbonisation plans for the UK and is integral to achieving the lowest overall energy system. Two recent studies from Afry[1] and Guidehouse[2] show using hydrogen in a future energy system to complement the growth of renewables can reduce overall infrastructure and system costs compared to an all-electric system by £13-24bn and £38bn respectively.

Concurrently, the Department for Business, Energy and Industrial Strategy (BEIS) recently highlighted a compelling vision in the Hydrogen Transport and Storage Consultation for 'a large, integrated, and resilient hydrogen network supported by storage' from the mid-2030s, to link multiple producers and consumers[3]. Repurposing the UK's existing gas transmission system to transport hydrogen represents good value for the consumer, with current estimates showing that it could be 20% of the cost of building a new network[4].

Project Union will help the UK achieve secure and reliable access to hydrogen across the country enabling the UK to achieve its Net Zero goals in the most cost-effective way, with a full hydrogen backbone facilitating optimum whole energy system design[2]. But if we are to realise these goals we must start now with design and planning; this provides value to consumers and society through retaining optionality for widespread, cost-effective hydrogen transportation while building early evidence to inform strategic policy decisions.

The purpose of this document is to provide robust evidence for the requirement of additional regulatory funding during the RIIO-2 price control period under the Net Zero Pre-construction Work and Small Net Zero Projects Re-opener (NZASP) mechanism to the value of **£7.912m**[5] for the Feasibility Phase, which will deliver the following outputs over a 12-month period:

- A **Phasing Strategy**, including prioritisation and timing for delivery of each section of the hydrogen backbone while ensuring security of supply on the remaining methane network. It will also deliver a staged approach to project delivery and funding.
- **Pre-Front End Engineering and Design** (pre-FEED) activities for a full hydrogen backbone[6], delivering an appraised set of routing options, a constructability assessment and a planning and consenting strategy based on enhanced cost estimates and asset data. A full engineering policy review will also be undertaken.
- **Hydrogen market enabling activities** including development of options for the design of regulatory and commercial frameworks for hydrogen infrastructure and ongoing customer and stakeholder engagement.

Given the length of time required to plan for and deliver critical national infrastructure, if the UK is to deliver 10GW hydrogen production capacity and support an affordable energy system with 50GW offshore wind by 2030 whilst achieving its Net Zero targets by 2050, there is a clear need to act now and at pace. Over a 12-

[1] AFRY, (2022). 'Benefits of Long Duration Electricity Storage', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1095997/benefits-long-duration-electricity-storage.pdf

[2] Guidehouse, (2022). 'Gas and Electricity Transmission Infrastructure Outlook 2050'. Stakeholder Engagement Slides delivered in November 2022. GETIO is a Network Innovation Allowance (NIA) project between Gas Transmission, Electricity System Operator and Electricity Transmission.

[3] BEIS (2022). 'Hydrogen transport and storage infrastructure consultation'. https://www.gov.uk/government/consultations/proposals-for-hydrogen-transport-and-storage-business-models

[4] EHB (2020) https://www.ehb.eu/files/downloads/2020_European-Hydrogen-Backbone_Report.pdf

[5] 2018/19 Prices – base year for the RIIO-2 price control period

[6] Pre-FEED activities for one section of the backbone, Teeside to Humber, are being undertaken separately within the East Coast Hydrogen project

month period from January 2023, the Feasibility phase of Project Union aims to develop the strategy, alongside technical, social, and economic evidence, for a credible and deliverable transition of the NTS to carry 100% hydrogen, while retaining security of supply on the remaining methane network. The evidence and outputs will support future policy decisions related to the Net Zero energy transition, many of which are critical to ensure sufficient time is available to deliver the required infrastructure developments.

Proposed increases to RIIO-2 NZASP allowances are presented in *Table 1*. Justification for the scope and level of this increase is made throughout this document, broadly grouped into establishing the needs case, policy justification, value for money and regulatory treatment and impact.

Activity	Price Base	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Feasibility Phase	[redacted]						
	2018/19	[redacted]					**7.912**

Figures shown in £m and inclusive of ongoing efficiency reduction and contingency

Table 1 Proposed increase to RIIO-2 NZASP allowances

In accordance with the relevant terms of the Licence, this application is made at the invitation of Ofgem following a 15-month period of pre-application engagement, and the agreement of a needs case in principle. As required by the Licence, this document is produced in compliance with the relevant governance and guidance documents as published by Ofgem[7] (*Supplementary Document A – Mapping to regulatory requirements is included with this submission).*

[7] Ofgem: Net Zero Pre-construction and Small Net Zero Projects Re-opener Governance Document

Ofgem: RIIO2 Re-opener Guidance and Application Requirements Version 2

2. Document structure

This document comprises eight core chapters, supported by additional appendices, designed to provide clear explanation and justification for the proposed scope and funding requirement to deliver the Feasibility Phase to assess the transportation of hydrogen through repurposing existing gas transmission assets and which are based on our assessment of the regulatory information requirements specified in Ofgem's guidance and governance documents for RIIO-2 re-openers.

- **Context**: Provides an overview of the long-term aims and objectives for repurposing part of the gas transmission asset base.
- **Project Description**: This chapter describes the alignment of this funding proposal to National Grid Gas Transmission's (NGGT) overall business strategy and commitments, articulates the key problems the Feasibility Phase is aiming to address, the specific scope of proposed funding requirement and justification of the "right sizing" of planned activities.
- **Needs Case:** Describes the current Government policy position and our understanding of the future landscape, with a demonstration of strategic fit and alignment with current policy objectives. This chapter includes an overview of key stakeholder engagement undertaken to date and the key learnings arising from this, concluding with independent analysis of the benefits of Project Union.
- **Scope of work and evidence mapping**: This chapter provides detail on the key outcomes and outputs anticipated for the Feasibility Phase, and how these map to key evidence points to support Government decision making on the long-term role of the hydrogen backbone.
- **Value for money**: This chapter outlines our approach for developing project costs and provides headline costs by work package and project outcomes. We describe the methodology adopted for the treatment of ongoing efficiency, real price effects and general inflation aligned to RIIO-2 framework principles, and how risk and contingency has been reflected in our cost plan. We demonstrate how minimum cost has been assured to support value for money for gas network users and consumers.
- **Project Union Delivery Strategy**: This chapter describes the intended project delivery plan, a summary of supporting projects to date, and an explanation of our internal project structure and governance framework.
- **Regulatory treatment and bill impacts**: provides a statement of the funding principles adopted when considering the appropriate regulatory treatment for the project, based on feedback provided by Ofgem. The chapter confirms the eligibility of this project for funding under the Net Zero Pre-Construction Works and Small Net Zero Projects Re-opener and proposes the specific regulatory treatment that could be adopted under this mechanism, with reference to the stated funding principles. The expected allowed revenue and customer and consumer bill impacts based on funding requirement and regulatory treatment are shown.
- **Assurance**: outlines the key assurance activities undertaken on the re-opener submission.
- **Appendices**: a listing of additional information products submitted in support of this re-opener application, which are referenced where relevant throughout the document.

3. Context

In June 2019, the UK became the world's first major economy to legally commit to a Net Zero greenhouse gas emissions (GHG) target by 2050. The Scottish government has committed to Net Zero by 2045.

To achieve Net Zero by 2050, we must move away from our reliance on fossil fuels to cleaner alternatives that meet our environmental, social, and economic needs. Low carbon hydrogen can offer a solution by replacing natural gas, delivering the flexibility the energy system needs at the lowest cost to the consumer[8]. A UK hydrogen economy could also support over 9,000 jobs by 2030, and up to 100,000 jobs by 2050[9].

In all credible pathways to Net Zero, hydrogen is required[10,11]. The UK Hydrogen Strategy states low carbon hydrogen will be critical to achieving a Net Zero future, with analysis by the Department for Business, Energy and Industrial Strategy (BEIS) identifying that 250-460 TWh (~70-130 billion cubic meters) of hydrogen will be needed in 2050, representing 20-35% of the UK's energy consumption[12]. Today, ~80 billion cubic meters[13] per annum of methane is transported through the 7,627km of gas National Transmission System (NTS), safely and reliably. This indicates that there is a need for a hydrogen system in 2050 of a similar or greater scale to today's methane system, depending on hydrogen uptake. This is supported by BEIS' vision set out in the hydrogen transport and storage infrastructure consultation[14] *"our vision for hydrogen transport from the mid-2030s onwards is for a large, integrated, and resilient hydrogen network with multiple entry and exit points within and across regions and/or nationally".*

In August 2021, the UK Hydrogen Strategy set a target of 5GW of production capacity by 2030. Within 12 months the British Energy Security Strategy[15] increased this target to 10GW by 2030 recognising the greater role hydrogen has to play. At the same time, the European Union (EU) published it's RePower EU strategy[16], targeting 20Mt hydrogen production capacity by 2030, with half coming from imports. In Dec 2022 the Scottish Government stated an ambition of 5 GW of hydrogen production capacity by 2030 and 25 GW by 2045. These strategic government ambitions signal a clear need to invest in hydrogen infrastructure in the UK with the potential to connect to European hydrogen network infrastructure for import and export opportunities.

Our stakeholder engagement has consistently gathered a need for a hydrogen network with a strategy to deliver this, allowing hydrogen producers, storage operators and end users to plan their own schemes and to enable a hydrogen market to develop as early and efficiently as possible. A common theme appearing in our engagement is the role of the gas network in providing a diverse, resilient, and secure source of hydrogen that enables market competition, ultimately reducing costs for the consumer.

---

[8] Guidehouse (2022). 'Gas and Electricity Transmission Infrastructure Outlook 2050'. Stakeholder Engagement Slides delivered in November 2022.

[9] UK Hydrogen Strategy, August 2021 <https://www.gov.uk/government/publications/uk-hydrogen-strategy>

[10] https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

[11] https://www.nationalgrideso.com/future-energy/future-energy-scenarios

[12] UK Hydrogen Strategy, August 2021 <https://www.gov.uk/government/publications/uk-hydrogen-strategy> [Accessed 01/02/2022]

[13] UK Energy in Brief 2022 – 2021 Total Annual Natural Gas demand of 856.7TWh converted using CV of 39.6MJ/m3 <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1094025/UK_Energy_in_Brief_2022.pdf>

[14] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1101296/hydrogen-transportation-storage-consultation.pdf

[15] https://www.gov.uk/government/publications/british-energy-security-strategy

[16] European Commission REPowerEU Plan: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483

Project Union has developed in response to market, Government, and environmental need. This vital project will develop and deliver a hydrogen backbone for the UK, reliably connecting hydrogen production to diverse demand and strategic storage sites across the country using existing gas transmission network infrastructure where possible to minimize new build. Retaining and repurposing existing gas transmission assets to efficiently transport large volumes of hydrogen can minimise consumer disruption as well as environmental impact and it could be as much as five times cheaper than building new dedicated hydrogen infrastructure[17].

The project will support future UK energy security and independence by providing the critical infrastructure to connect a flexible and long-term energy transport and storage solution, whilst opening up potential import and export opportunities to Europe and beyond. Early commitment to a hydrogen network to support market needs will promote private sector investment and de-risk planned projects by providing the necessary confidence that there will be access to a diverse UK-wide consumer hydrogen market.

Project Union will develop the strategy to realise these benefits to through a measured and managed transition to hydrogen, whilst continuing to deliver a secure methane supply on the existing gas network, ensuring no-one is left behind in the transition to Net Zero.

Given the length of time required to plan for and deliver critical national infrastructure, if we are to retain the option for large-scale hydrogen networks and the UK is to achieve its Net Zero targets by 2050, there is a clear need to act now and at pace.

[17] Table 2, Extending the European Hydrogen Backbone, April 2021 <https://ehb.eu/files/downloads/European-Hydrogen-Backbone-April-2021-V3.pdf>

4. Project Description

Project Union will deliver a hydrogen transmission backbone for the UK, Figure 2. The backbone will initially link strategic hydrogen production sites, including the industrial clusters, with storage and users across the UK by the early 2030s and provide the option to expand beyond this initial hydrogen transmission network to connect additional consumers. Through the phased repurposing of existing assets alongside some new infrastructure, a hydrogen backbone of 1,500 to 2,000km will be created, representing up to 25% of the UK's current natural gas transmission pipelines. This approach of primarily repurposing assets is up to five times more cost effective compared to new build[18], minimises environmental impact and avoids asset stranding risk for methane and energy consumers, who would likely fund any decommissioning as methane is phased out.

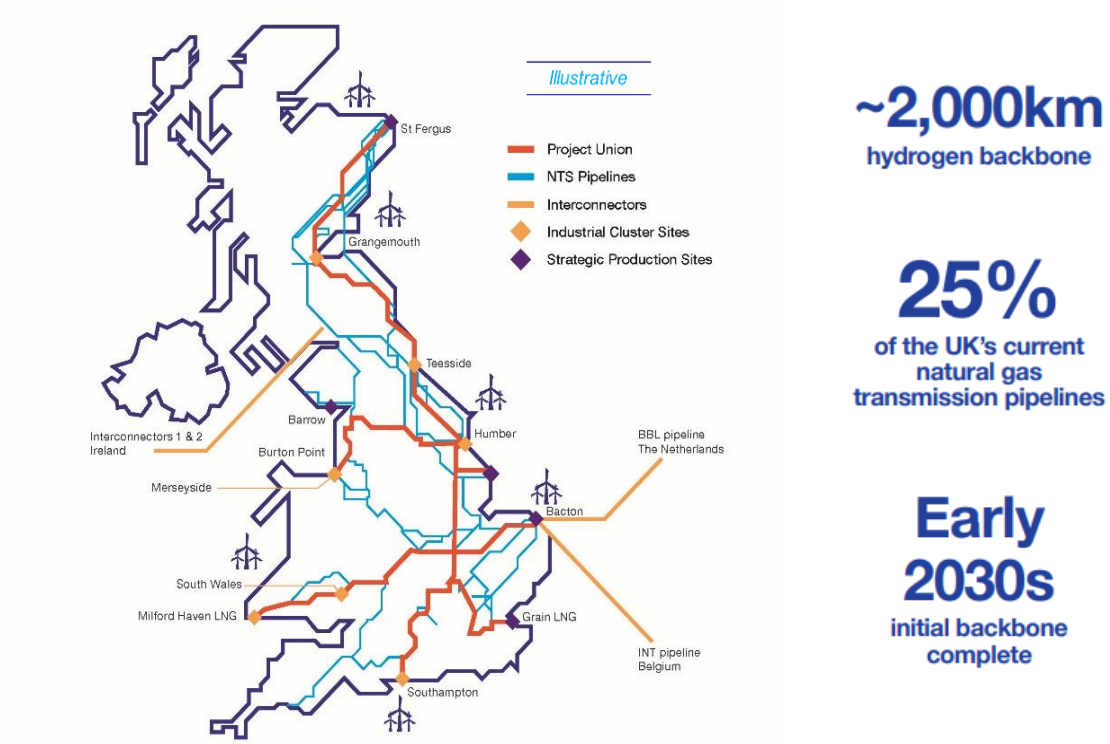


Figure 2 Project Union map – routing of the hydrogen backbone is illustrative

A hydrogen backbone will be at the heart of a Net Zero future, acting as a key enabler for developing a hydrogen economy and realising UK Government's target of 10GW low carbon hydrogen by 2030. The project will explore how and when to convert existing pipeline infrastructure for a hydrogen backbone to enable effective market growth and efficient scaling up. Concurrently to Project Union, projects such as FutureGrid[19] will demonstrate the safety case and technical viability of the proposed conversion. These infrastructure investments will support a green future while delivering UK-wide economic benefits and ensuring energy security.

The Feasibility phase of Project Union aims to develop the evidence and strategy for a credible and deliverable transition of the NTS away from transporting methane to transporting 100% hydrogen. The

[18] Table 2, Extending the European Hydrogen Backbone, April 2021 <https://ehb.eu/files/downloads/European-Hydrogen-Backbone-April-2021-V3.pdf>

[19] https://www.nationalgrid.com/gas-transmission/insight-and-innovation/transmission-innovation/futuregrid

approach will consider Government policy, stakeholder insights, critical analysis and the evidence provided by wider internal and external innovation projects.

The Feasibility phase will deliver the following outputs over a 12-month period;

- A **Phasing Strategy**, including prioritisation and timing for delivery of each section of the hydrogen backbone while ensuring security of supply on the remaining methane network. It will also deliver a staged approach to project delivery and funding.
- **Pre-Front End Engineering and Design** (pre-FEED) activities for a full hydrogen backbone[20], delivering an appraised set of routing options, a constructability assessment and a planning and consenting strategy based on enhanced cost estimates and asset data. A full engineering policy review will also be undertaken.
- **Hydrogen market enabling activities** including development of options for the design of regulatory and commercial frameworks for hydrogen infrastructure and ongoing customer and stakeholder engagement.

The outputs will be used to gather the evidence required to deliver a cost-effective and minimally disruptive transition of the UK's gas transmission infrastructure to carry 100% hydrogen, enabling informed policy decisions to be made.

The total cost to deliver the Feasibility phase will be **£7.912m**[21] over a 12-month period.

For Project Union to deliver a significant impact to Net Zero targets and value to consumers, early works will need to commence through 2022-25 to enable the commencement of conversion of the first methane assets in 2026, for an initial backbone ready for future hydrogen supply by the early 2030s, Figure 3.

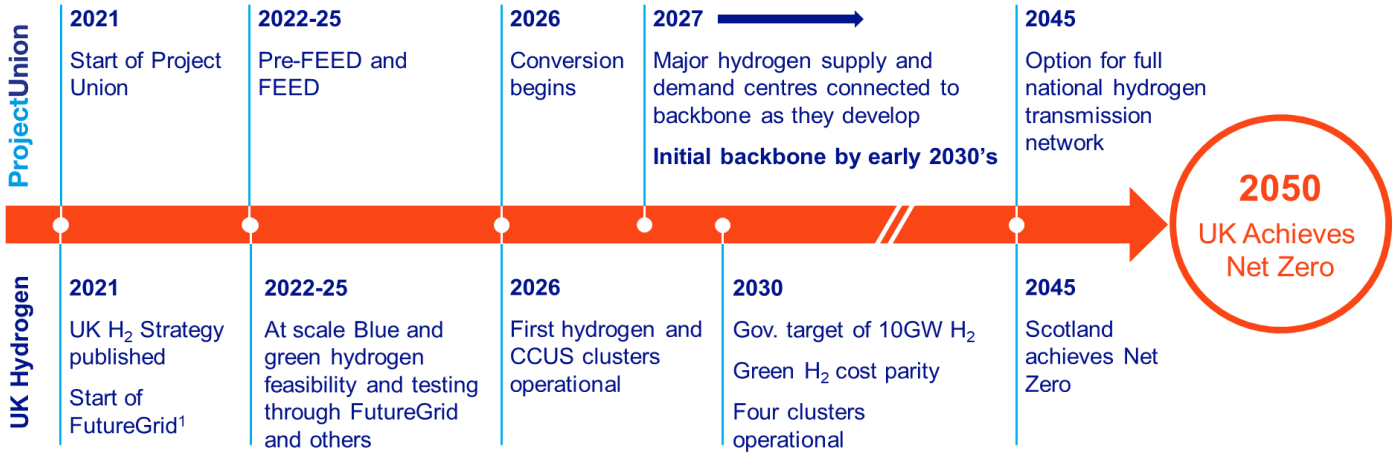


Figure 3 Project Union outline delivery roadmap

Figure 4 shows an illustrative timeline for the delivery of Project Union, including the Phasing Strategy, Pre-FEED and market enabling activities taking place over a 12-month period. Subsequent FEED and construction activities for each section of the backbone will take place in stages. The Phasing Strategy will determine the routing and delivery strategy, which will update the timeline accordingly. Our proposed staged

[20] Pre-FEED activities for one section of the backbone, Teesside to Humber, are being undertaken separately within the East Coast Hydrogen project

[21] 2018/19 Price – base year for RIIO-2 price control period

delivery approach will account for evolving market and customers' needs and deliver optionality for consumers whilst limiting their exposure to cost and risk of the transition.

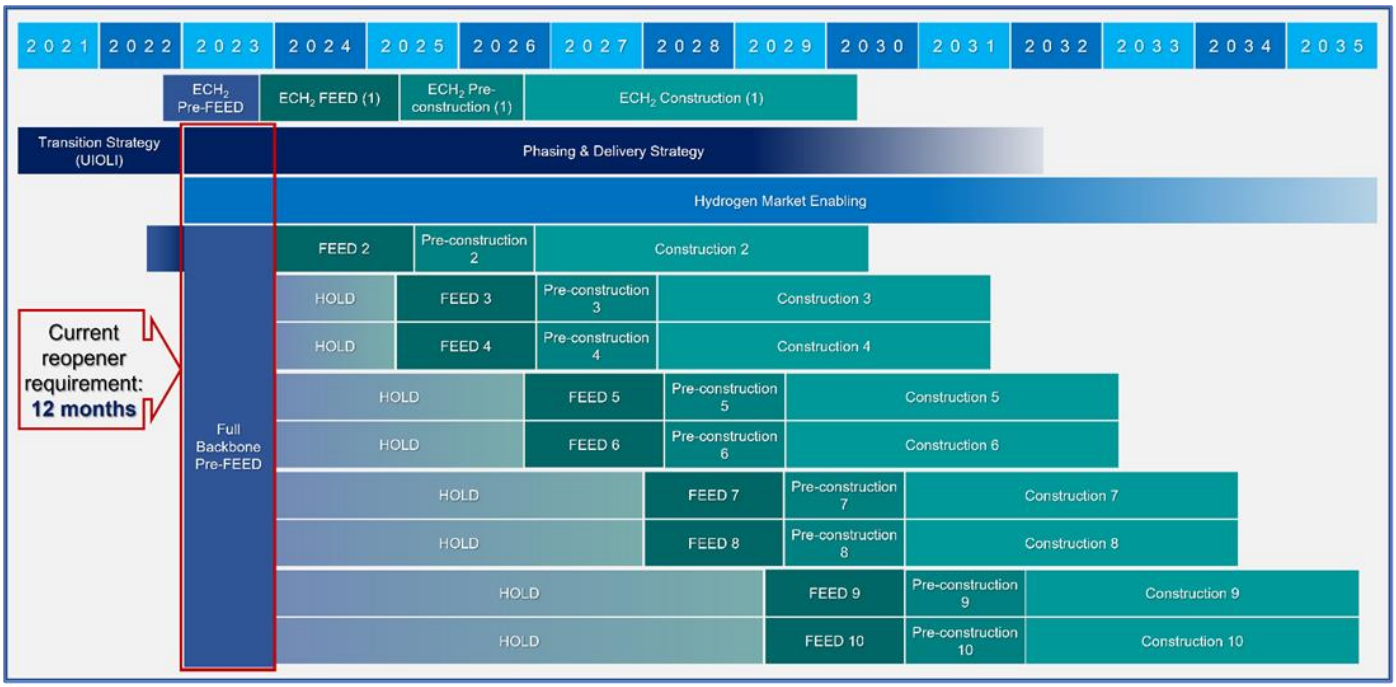


Figure 4 Illustrative delivery timeline for Project Union

Delivering a full backbone Pre-FEED, rather than a partial backbone pre-FEED, enables

- Improved alignment with emerging and established hydrogen developments, such that we can better inform stakeholder timelines and deliver whole system efficiencies.
- Enables retention of optionality for all regions in the UK whilst we further our knowledge through the Feasibility Phase and prevents any future option being precluded too early due to committing to a specific investment too soon.
- Limits exposure to the risk of viable solutions for one area of the country being discounted due to early over-commitment to another area before sufficient information is known and whilst the level of investment is relatively low.
- Limiting the funding proposal to the immediately required activities allows Government and Regulatory policy to evolve alongside
- Focussing scope only on the necessary enabling activities at this stage ensures congruence with the current policy position, and significantly protects against the risk of sunk investment now and in the future
- Cost and risk exposure to bill payers is minimised whilst ensuring sufficient funding to avoid regulatory burden for multiple separate submissions

Overall, it enables a more informed, credible Phasing Strategy and pipeline routing earlier, to provide increased confidence to key stakeholders and inform the plans of producers, connected networks and direct connects.

4.1 Alignment with overall business strategy and commitments

A key element of NGGT's strategic priorities is "shaping the energy market of the future". NGGT sits at the heart of the gas market being the sole owner and operator of the UK gas National Transmission System (NTS), with a strong purpose of "Leading a Clean Energy Future for Everyone". We will need to continue to ensure that we operate a secure, resilient network, making the necessary investments on the remaining gas network to enable the transition to the hydrogen network of the future.

When we built our RIIO-2 business plan, our stakeholders told us that they wanted us to deliver an environmentally sustainable network by;

- Caring for the environment and the communities; and
- Maintain a safe and resilient network; and
- Facilitating the whole energy system of the future - innovating to meet the challenges ahead.

We committed to:

- Be ready to start conversion to hydrogen by 2026;
- Facilitate the use of green gas;
- Provide resilience to renewable generation; and
- Deliver the transition as a responsible business

These commitments are supported by Uncertainty Mechanisms. Special Condition 3.9 of the Licence, *Net Zero Pre-construction Work and Small Net Zero Projects Re-opener (NZASP),* provides a mechanism for us to deliver on those commitments.

Project Union aligns to these commitments through:

- Delivering a UK Hydrogen backbone through a phased approach that will link gas distribution networks, power generators and large industrial gas users to production and storage of low-carbon hydrogen, creating a resilient and dynamic low-carbon hydrogen system.
- Providing access to low-carbon hydrogen for consumers outside the industrial clusters enabling widespread decarbonisation.
- Minimising disruption and cost of the transition to hydrogen by maximising the repurposing of existing assets and minimising the amount of new build.
- Providing options for hydrogen in transport and for consumers to decarbonise heat in homes
- Support a whole UK energy system approach to decarbonisation by:
    - Providing critical resilience and flexibility to the electricity system during periods of low renewable electricity generation.
    - Reducing whole system costs by enabling an alternative to curtailment of renewable generation through the provision of energy storage
    - Enabling options for future whole system infrastructure investment to be taken forward in an optimal way across vectors, potentially reducing energy consumer costs

The Feasibility Phase of Project Union will undertake the necessary activities to identify the potential routing and phasing strategy for the UK hydrogen backbone. Following this, a Front End Engineering Design (FEED) for the priority phases will be undertaken to bring the project to a funding decision point which could enable a conversion of the network from 2026.

The next regulatory period will be critical in the development of the hydrogen backbone. Our aim would be for the Feasibility Phase outputs to inform the development of our business plans for the next regulatory period.

5. Needs Case

The Needs Case was developed through exploration of and alignment with the policy landscape, extensive stakeholder engagement and independent analysis.

As a brief overview, the needs case for Project Union:

- is aligned with UK energy strategy and policy developments
- is aligned with EU (and worldwide) energy strategy and policy developments
- will help inform future energy policy developments in industry, power, transport and heat
- has been reviewed with a wide range of stakeholders to better understand their needs and objectives that helped us better recognise the opportunities and benefits that Project Union can deliver
- includes an independent assessment of the benefits that identified six key areas where the transition of gas infrastructure on a path to Net Zero could impact UK society – Environment; Cost; Deliverability; End User and Societal Impact; Uncertainty; Security of Supply and Flexibility
    - analysis indicates that a wider 'UK backbone' hydrogen grid rollout could directly support approximately £300m annual GVA and 3,100 jobs at peak construction

5.1 Strategic fit and alignment with UK and EU policy objectives

Since Net Zero Greenhouse Gas Emissions by 2050 was set into UK legislation in 2019, the decarbonisation policy landscape has continued to evolve, Figure 5.

Figure 5 Policy landscape evolution

Several Government policies highlight targets and ambitions relating to hydrogen:

- 10GW Hydrogen production capacity by 2030 (UK)
- 5GW Hydrogen production capacity by 2030 and 25GW by 2045 (Scotland)
- Supporting infrastructure needed in the 2020s to support delivery of the 2030 10GW low carbon hydrogen production capacity ambition
- By 2023, testing 20% blending of hydrogen in the gas distribution grid complete
- Large hydrogen village trial by 2025 and a hydrogen town by 2030
- Decision on hydrogen in homes in 2026
- Net Zero Power System by 2035

These targets are key steps to ensuring the development of a hydrogen economy. The UK Hydrogen Strategy set out a target of 5GW of production capacity by 2030, and within a year, this target was increased to 10GW by 2030 as detailed in the British Energy Security Strategy released in April 2022. Across the devolved Governments, policies are developing in parallel which also highlight the importance of hydrogen in achieving Net Zero. Project Union will account for and support the delivery of these critical targets.

In Europe, policy for hydrogen continues to evolve with 20Mt of hydrogen production capacity targeted by 2030, half of which are imports. Project Union can connect to a wider European Hydrogen Backbone[22] and enable continued cross border trade and access to emerging European and Global hydrogen markets.

Developing the ability to efficiently transport hydrogen from production to storage and users that connects with a European hydrogen network is aligned with UK Government and EU policies, enables the ambition to deliver Net Zero by 2050, and does so in an environmentally protective, cost-effective way. The Feasibility Phase of Project Union will help de-risk and validate the hydrogen evidence base, enabling informed and timely Government decarbonisation policy decisions to be made, including decisions contingent on the feasibility of repurposing the existing gas network for hydrogen.

Table 2 highlights Government policy position, with a demonstration of Project Union's strategic fit and alignment with current policy objectives.

[22] https://ehb.eu/

Government Polices	Policy objectives	Project Union alignment with policy
The Ten Point Plan for a Green Industrial Revolution (Nov 2020)	It describes an approach to 'build back better, support green jobs, and accelerate our path to Net Zero'[23]. Objectives included driving the growth of low carbon hydrogen, a production target of 5GW of low carbon hydrogen by 2030 and completing testing to allow up to 20% blending of hydrogen into the methane network by 2023.	Project Union will provide the infrastructure to enable the growth of a low carbon hydrogen market by connecting hydrogen supply, storage, and demand. Project Union is integrated with FutureGrid where blending of hydrogen will be tested up to 100% at an offline purpose-built facility representative of the NTS.
Energy White Paper (Dec 2020)	Sets out how the UK will decarbonise its energy system and reach Net Zero by 2050 through a strategy to transform energy, support green recovery and create a fair deal for energy consumers. The paper commits to setting out the revenue mechanism to bring through early-stage private investment in industrial carbon capture and hydrogen projects.	Project Union will provide prospective hydrogen market participants with investment confidence to promote private sector investment by ensuring there will be access to a hydrogen market
Hydrogen Strategy (Aug 2021)	Sets out Government's plan for scaling up the investment, testing and adoption of hydrogen technologies across the UK. The strategy sets out the approach for developing a thriving low carbon hydrogen sector in the UK to meet our ambition for 5GW of low carbon hydrogen production capacity by 2030.	Project Union will deliver the hydrogen transmission infrastructure required to connect supply and demand to support delivery of the UK Hydrogen Strategy. Project Union is highlighted within the UK Hydrogen Strategy as a key project that will generate the evidence base for developing hydrogen network Infrastructure.
Industrial Decarbonisation Strategy	Sets out how industry can decarbonise in line with Net Zero. Fuel switching to hydrogen has been identified as an option for UK industries to decarbonise.	Project Union will enable industrial sites within and outside of clusters to decarbonise through providing fair and widespread access to hydrogen through transmission infrastructure.
Net Zero Strategy (Oct 2021)	Sets out a delivery pathway showing indicative emission reductions across sectors to meet targets up to the sixth carbon budget (2033-2037). The strategy cites Hydrogen as supporting up to 10,000 jobs in 2030 and starts to mobilise additional public and private investment in line with the strategy's proposed delivery plan[24].	Project Union will enable the delivery of meeting targets set out in the 6th Carbon Budget and contribute to job creation for society. Project Union could directly support approximately £300m annual GVA and 3,100 jobs at peak construction[25].
Cluster sequencing (Nov 2021)	A minimum of two industrial clusters would be established by the mid-2020s and four by 2030s. HyNet and East Coast Clusters were confirmed as the Track-1 clusters for the mid-2020s, and the Scottish Cluster was announced as a reserve cluster.	The Project Union delivery strategy will be aligned with the cluster announcements to provide transmission infrastructure for where and when it is needed, connecting supply, storage and demand for resilience and a competitive hydrogen market.
Decarbonisation of Power Generation (Oct 2021)	The UK committed to decarbonise the power system by 2035. This will help boost the country's efforts in achieving Net Zero by building a secure, home-grown energy sector that reduces reliance on fossil fuels and exposure to volatile global wholesale energy prices.	Project Union enables decarbonisation of power generation by providing low carbon hydrogen as fuel for flexible power generation across the country to meet peak demand and to plug the gap of intermittent renewables to help balance the electricity grid thereby maximising generation asset productivity.
Heat and Buildings Strategy (Oct 2021)	Sets out the immediate actions the UK Government will take for reducing emissions from buildings, including deploying energy-efficient measures, and transitioning to low-carbon heating. In 2026 a critical decision is due from Government on the whether the future of domestic heating includes the use of hydrogen.	Project Union provides future optionality for demand from the domestic heating sector.
British Energy Security Strategy (BESS) (Apr 2022)	Billed as the plan to ensure we have "a power supply that's made in Britain, for Britain", this signals the Government commitment to double hydrogen production ambition to 10GW by 2030, with at least half of this from electrolytic hydrogen.	Project Union will provide the infrastructure to enable the growth of a low carbon hydrogen market by connecting hydrogen supply, demand, and storage.
Hydrogen Transport and Storage Infrastructure – Consultation (Nov 22)	This consultation seeks views on the design options of hydrogen and transport business models to meet the commitments set out in BESS and enable a hydrogen economy. BEIS reinforce the need for a large, integrated, and resilient hydrogen network, supported by storage, to link multiple producers and consumers.	Project Union will enable the development of a hydrogen economy by providing the necessary hydrogen transmission infrastructure so that hydrogen can play a key role to contributing to UK decarbonisation targets.

Table 2 Project Union alignment with policy

[23] UK Government, Nov 2020, The Ten Point Plan for a Green Industrial Revolution. <https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution>

[24] UK Government, Oct 2021, Net Zero Strategy: Build Back Greener. <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf>

[25] [redacted] (2022). Project Union Economic Assessment We commissioned [redacted] to undertake an economic appraisal (*Supplementary Document C*

5.2 Future Government policy horizon

Policies for hydrogen will continue to develop over coming years with further policy decisions to be made as the economic, technical, and social evidence becomes available. For example, a policy decision on the strategic role that hydrogen plays in heating is expected in 2026 and a consultation on hydrogen ready boilers has recently been launched. Although the need for a UK hydrogen backbone is not contingent on a positive hydrogen in heating decision, Project Union will provide critical evidence needed to support this decision and the wider rollout of hydrogen networks.

Economic, technical and safety evidence is being developed through the BEIS-Industry Hydrogen Grid Research & Development (R&D) activities under three workstreams: System Transformation, Network Safety and Impacts and End User trials. Project Union will contribute key evidence to the System Transformation stream, which aims to answer the following policy questions.

- How much would it cost to transition gas system infrastructure to hydrogen?
- What other impacts and benefits are associated with the transition?
- Can the transition of gas system infrastructure be feasibility delivered?
- What decisions are required and when? When is the opportunity to transition lost?

The outcomes of the Feasibility phase will provide evidence including costed and appraised pipeline routing options and the feasibility of repurposing routes to support a cost-effective transition. It will also support wider considerations including hydrogen supply chain readiness so that an informed policy decision can be made.

There is work being progressed to better understand what role hydrogen can play in heating our homes, with Government targeting a village trial on hydrogen by 2025 and a town pilot before the end of the decade. As part of the End User workstream, there are two detailed design studies for hydrogen village trials by Cadent and Northern Gas Networks (NGN) who were awarded regulatory funding by Ofgem in May 2022. The Cadent project is based in Whitby, Ellesmere Port and has a total project value of £8.3m (2018/19 prices), with the NGN project being based in Redcar, Teesside with a value of £6.4million (2018/19 prices)[26].

Early work on the development on a hydrogen town pilot has been started by the gas networks, aligned with the UK Hydrogen Strategy for a hydrogen town pilot by 2030. NGGT is working collaboratively with the GDNs and BEIS on the proposals, in line with the Hydrogen Heating Town Pilot open letter[27] published by BEIS stating that "*Gas Distribution Networks (GDNs) will be expected to work closely with National Grid in considering the requirements and options for gas transmission at the higher-pressure tiers".* Project Union is a key contributor to realising a town pilot at the scale required, providing the energy resilience and security needed. It also enables a wider rollout, connecting hydrogen towns with supplies and storage. Starting work on the Feasibility Phase now enables delivery of hydrogen transmission pipelines in time to support the town

[26] Ofgem, (2022). Hydrogen Village Trial Detailed Design Studies Decision https://www.ofgem.gov.uk/publications/hydrogen-village-trial-detailed-design-studies-decision

[27] BEIS, (2022). 'Hydrogen Heating Town Pilot: open letter to Gas Distribution Networks', https://www.gov.uk/government/publications/hydrogen-heating-town-pilot-open-letter-to-gas-distribution-networks

pilots. The locations of the proposed hydrogen towns will be a key consideration on the phasing and selection of routing options through the Feasibility Phase.

In October 2021, the UK Government committed to decarbonise the electricity system by 2035, subject to security of supply. The UK's Net Zero Strategy[28] recognised that to ensure the system is reliable, intermittent renewables need to be complemented by known and flexible technologies; this will also minimise the amount of generation and network capacity needed to meet demand. Hydrogen was recognised as one such technology "*The use of hydrogen to generate electricity can reduce reliance on unabated natural gas. It can also provide additional system flexibility if produced through electrolysis and where there is hydrogen storage. This could contribute to energy security, lowering emissions and system costs.*". With power generation geographically spread, a hydrogen network can ensure fair access to hydrogen all over the country.

Two recent studies show using hydrogen in a future energy system to compliment the growth of renewables can reduce overall infrastructure and system costs compared to an all-electric system.

- Long Duration Electricity Storage undertaken for BEIS by AFRY[29] concluded that hydrogen would play a vital role in de-constraining renewables by providing long duration storage. A hydrogen backbone of 3000km would be required and a whole system approach would achieve £13-24bn savings.
- Gas and Electricity Transmission Infrastructure Outlook 2050 undertaken by Guidehouse[30] indicates that in all net-zero scenarios, integrated infrastructure planning across electricity and hydrogen transmission can provide energy system savings up to £38bn by 2050, which will be supported by no regret network investments, common across all scenarios, over the next decade.

Project Union will develop the hydrogen transmission infrastructure required to support a whole system approach to achieving net zero. Starting the Feasibility Phase now ensures that the infrastructure is in place to support a resilient approach to decarbonising the electricity system by 2035.

The Government's Ten Point Plan for a Green Industrial Revolution[31] committed to establishing two low carbon industrial clusters by the mid-2020s with four sites by 2030. The diversity of industry means that decarbonisation will need to be achieved through a combination of different technologies, so we need progress now in both low carbon hydrogen and electricity. In March 2021, the Industrial Decarbonisation Strategy[32] stated that "*Shared infrastructure is crucial to establishing low carbon and net zero clusters but will require significant investment*", recognising that hydrogen networks will need to play a role, especially for providing access to hydrogen to businesses outside of the clusters, which represent almost half of UK

[28] BEIS (2021). 'Net Zero Strategy; Build Back Greener', https://www.gov.uk/government/publications/net-zero-strategy

[29] AFRY, (2022). 'Benefits of Long Duration Electricity Storage', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1095997/benefits-long-duration-electricity-storage.pdf

[30] Guidehouse, (2022). 'Gas and Electricity Transmission Infrastructure Outlook 2050'. Stakeholder Engagement Slides delivered in November 2022. GETIO is a Network Innovation Allowance (NIA) project between Gas Transmission, Electricity System Operator and Electricity Transmission with the final report due in December 2022.

[31] UK Government (202). 'The Ten Point Plan for a Green Industrial Revolution'. https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

[32] BEIS (2021). 'Industrial Decarbonisation Strategy'. https://www.gov.uk/government/publications/industrial-decarbonisation-strategy

industrial emissions. The Industrial Decarbonisation Strategy shows that extensive national infrastructure networks for CCUS and hydrogen can lower overall residual emissions from UK industry due to reaching dispersed sites that cannot fully electrify e.g., energy intensive sites and the cement industry. Project Union will connect the large industrial clusters with strategic production sites and storage and provide hydrogen access to dispersed sites to ensure a resilient hydrogen economy and a liquid hydrogen market that lowers costs for consumers. The Feasibility Phase will account for geographic spread of consumers, the timing and ordering of low carbon clusters coming online, as well as hydrogen volume expectations, when determining the phasing strategy and network design.

In the transport and storage business model consultation[33], BEIS reinforce the need for a large, integrated, and resilient hydrogen network (supported by storage) to link multiple producers and consumers. Further, this is not contingent on the use of hydrogen in heating.

Decisions about infrastructure networks for low carbon hydrogen will shape the route to net zero, therefore it is imperative that all options for achieving net zero remain open as evidence develops on the role of hydrogen and networks in a Net Zero economy. The costs, benefits and feasibility of different options will inform future government decisions about the location of infrastructure networks. Over the next 12 months the Feasibility Phase of Project Union will develop the technical and economic evidence base for the rollout of hydrogen transmission network infrastructure to enable informed and timely policy decisions. Large scale infrastructure projects have long lead times and require co-ordination across multiple parties, which is why we are planning today.

Figure 6 illustrates how the development and delivery of Project Union fits in with wider strategic policy decisions and ambitions.

[33] BEIS (2022). 'Hydrogen transport and storage infrastructure consultation'. https://www.gov.uk/government/consultations/proposals-for-hydrogen-transport-and-storage-business-models

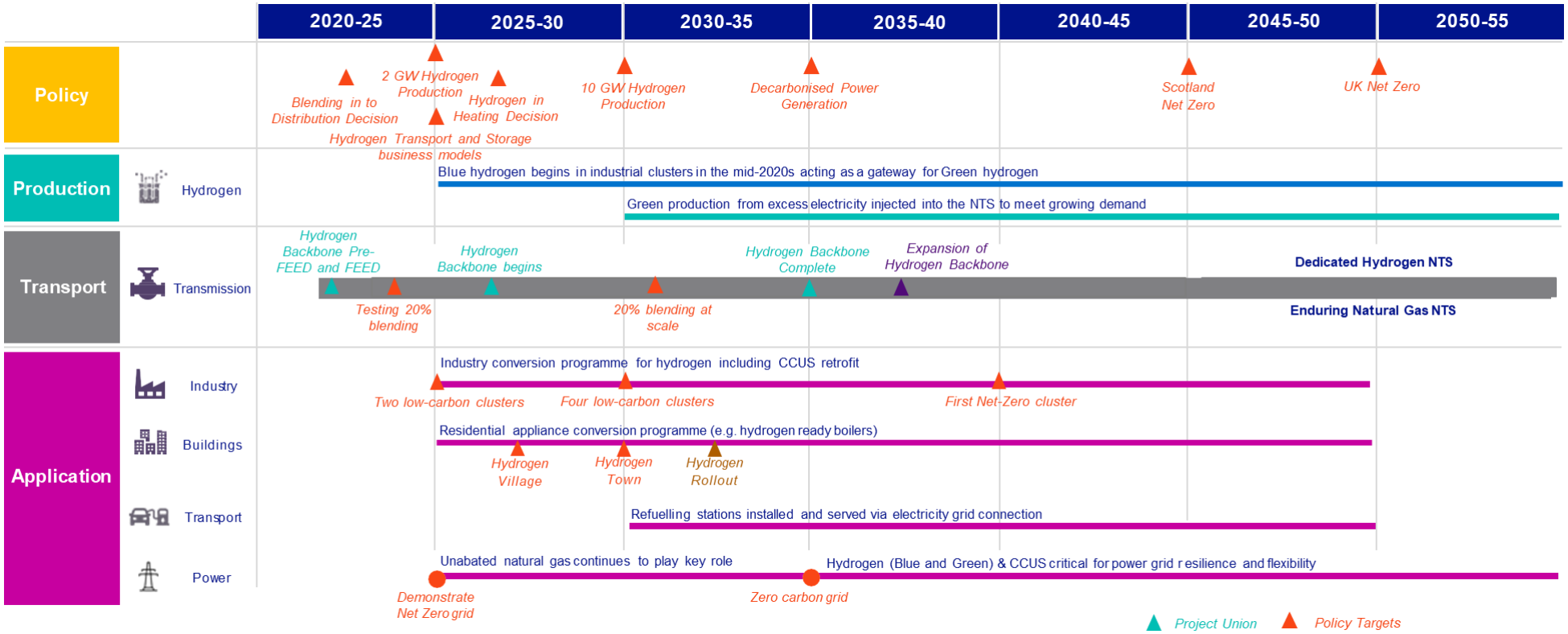


Figure 6 Project Union alignment with wider strategic goals

5.3 Externally supported evidence

To develop the needs case, we have engaged a wide range of stakeholders across the methane NTS and the hydrogen value chain as well as commissioning independent analysis to help with quantification of benefits. This section summarises the outputs and evidence.

5.3.1 Customers and Stakeholder Engagement

Extensive industry engagement with over 75 organisations was undertaken during the strategy phase to understand industry and market demand for Project Union including UK Government, regulators, consumers, networks, producers, industrial clusters, and other hydrogen projects, Figure 7.

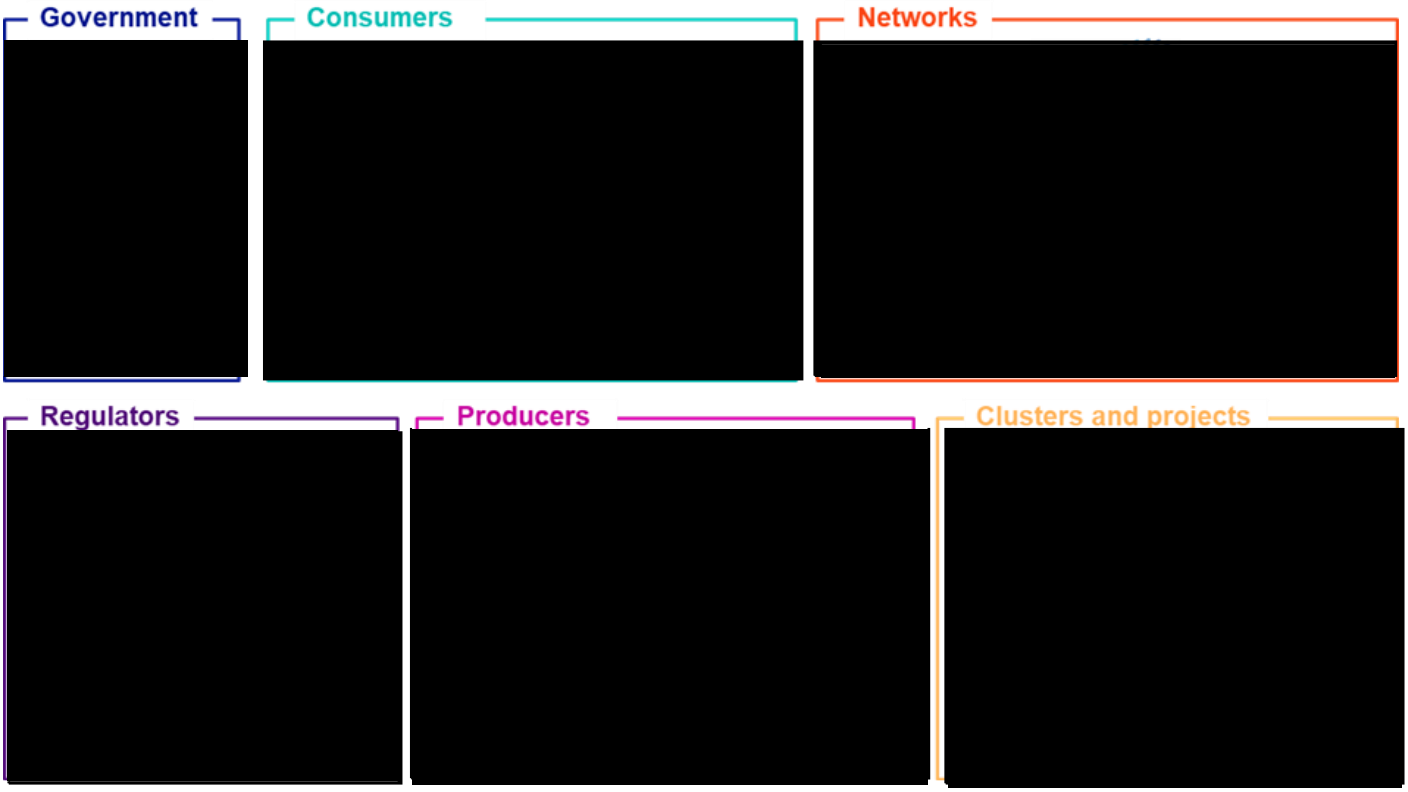


Figure 7 Project Union stakeholder engagement

We now have many stakeholders telling us the NTS is critical to enable their decarbonisation plans.

- Power stations are telling us that access to a national hydrogen transmission system is critical to provide transition options for decarbonisation.
- Industrial clusters and blue hydrogen producers require access to a hydrogen backbone to create and open liquid hydrogen market and provide essential resilience for supply and demand
- Industry outside of clusters that cannot electrify their production processes require access to hydrogen
- Green hydrogen producers need to understand timelines for pipeline transition and optimum locations for their production sites especially where their role is to de-constrain the electricity network
- Storage sites need the connectivity and capacity of Project Union coordinate with their own development plans to facilitate long term storage.

The opportunities and benefits that Project Union can deliver are summarised in Table 3.

	**Consumer-centric**	Project Union facilitates decarbonisation for all consumers. It will enable access to cost-effective low carbon hydrogen across the UK, enabling widespread decarbonisation of industry, power, transport, and heat. Project Union will provide key evidence for future policy decisions by providing a blueprint for a minimally disruptive, cost-effective rollout of hydrogen. It can also support a hydrogen town trial, demonstrating a scalable end-to-end process for decarbonising homes and business.
	**Levelling up and jobs**	A national transmission system will provide fair access to hydrogen infrastructure across the UK and enable existing industries to decarbonise, while continuing to attract capital as global investors target net zero. Project Union will directly support approximately £300m annual GVA (2021 prices) and 3100 jobs at peak construction.
	**Connectivity and efficiency**	A hydrogen transmission system connects hydrogen production and strategic storage locations with demand inside and outside of industrial clusters. This enables greater system efficiency and flexibility through coordinated and shared infrastructure, lowering the cost to the consumer. Without a hydrogen transmission system, each industrial cluster and project will require independent capacity to provide flexibility, resilience and to handle peak demand, resulting in over-built, duplicate transmission and storage systems.
	**Providing flexibility and optionality**	A repurposed national transmission system will provide the fastest and cheapest transport option for hydrogen. This will deliver flexibility in power generation, storage, and consumption, at the scale required to meet net zero across the whole energy system. Creating an initial hydrogen backbone now will also provide decarbonisation opportunities sooner with the option for future expansion of the network at a lower overall cost, pending hydrogen and heat related decisions to be made by the UK Government.
	**Market coupling**	A hydrogen transmission system connects otherwise isolated production sites to enable competition, driving costs down for consumers, and improving security and certainty of supply. It also provides access for producers to larger markets, enabling faster scale-up of low carbon hydrogen in line with Government targets and ensuring an efficient transition to net zero. In support of the Government's hydrogen strategy, it will additionally enable access to import and export opportunities to Europe by the mid-2030s.
	**Decarbonisation of industry and power**	Around 50% of industrial emissions are outside of the industrial clusters. Project Union will reach consumers inside and outside of industrial clusters, connecting a wide range of sectors to a resilient, low-cost hydrogen supply. An integrated, large scale network of hydrogen, natural gas and CCUS, will support the UK's net zero targets by providing fair access to a range of decarbonisation solutions.
	**Energy storage and resilience**	National Grid Electricity System Operator's Future Energy Scenarios found that the UK would require at least 15TWh of inter-seasonal hydrogen storage capacity by 2050. Further industry engagement has indicated that 100TWh storage capacity may be required by 2050. A hydrogen transmission system is needed to connect hydrogen production hubs with hydrogen storage and hydrogen users which are geographically dispersed across the country. This will provide a flexible energy system to meet peak energy demand which can't be delivered by intermittent renewables alone.
	**Global leader in green innovation**	The UK has an opportunity to position itself as a global leader in green innovation in a rapidly growing hydrogen economy, attracting talented people and global investment. A national hydrogen transmission system will support the market's emergence and growth by providing a route to market for hydrogen suppliers and access to hydrogen for a range of sectors in geographically disperse locations. Market growth will drive innovation and attract technology developers to secure the best value from the UK's national infrastructure – all of which will enable a rapid scale-up of a UK hydrogen industry, with the opportunity to export hydrogen capability globally.
	**Energy independence**	Project Union will enable transport of and access to indigenous hydrogen supplies and storage around the UK. With energy independence the UK will have increased flexibility reducing the impact the global gas market has on the UK consumer.

Table 3 Project Union benefits

Engagement has increased proactively through a combination of bilateral meetings, interactive targeted and broad webinars, regional stakeholder engagement groups (pre-existing and initiated by NGGT), consumer listening events, social media articles, podcasts, a Project Union launch report[34] and the Project Union launch event.

A summary of how we engaged with our customers and stakeholders is summarised in Appendix *A*, as well as plans for engagement during the Feasibility Phase.

5.3.2 Independent Assessment of Benefits

A common framework methodology has been developed alongside BEIS, and the Gas Distribution Networks to assess gas infrastructure options in the transition to Net Zero. This framework has been applied to the Economic Appraisal for Project Union, which in turn supports the Real Options Analysis.

Assessment methodology

Utilising Network Innovation Allowance (NIA) funding, we collaborated with the Gas Distribution Networks, BEIS and [redacted] to develop a new, common framework methodology for the assessment of key strategic options for gas network infrastructure in the transition to Net Zero, in a piece of work entitled the Assessment Methodologies (AM) project.

The Assessment Methodology project is part of a programme of work with the aim of improving the evidence base to support BEIS in its strategic policy decisions on the nature and extent that low carbon hydrogen will play in home heating in the future. The Assessment Methodology project focussed on developing, articulating, and testing a methodology and evidence base for appraising alternative gas network and storage infrastructure configurations from 2025 – 2050.

[redacted] identified six key areas where the transition of gas infrastructure on a path to Net Zero could impact UK society – Environment; Cost; Deliverability; End user and societal impact; Uncertainty; Security of Supply and Flexibility. This criterion was developed alongside BEIS, having been identified as key criteria that would help inform the strategic policy decision. Where sufficient evidence exists, [redacted] developed a quantitative or qualitative methodology against each of the criteria. This framework was applied to a selection of seven gas network and storage configurations (also known as test cases) that could support the energy system as it transitions to Net Zero, based on three Net Zero-consistent scenarios of High Hydrogen, Mid-Heat and High Electrification.

Notably, it exemplified that:

- Those test cases where networks were without a hydrogen backbone transmission network may be less adaptable to changes in the geographic distribution of hydrogen demand and have a lower level of security of supply.
- The High Electrification test case, which included significant decommissioning of the NTS and the <7barg network with no new hydrogen transmission infrastructure, could provide end users with the poorest choice of fuel options from the early-2030s as most end users would only be able to choose

[34] National Grid Gas Transmission, (2022). 'Project union Launch Report', https://www.nationalgrid.com/gas-transmission/document/139641/download

electric heating (or fuels such as bio-LPG). This was considered to particularly be the case for domestic end users as industrial users in clusters may be able to access hydrogen.

These two results support our assertion that Project Union would provide optionality for future policy decisions on domestic heat and enable flexibility and supply resilience to geographically dispersed demand yet unknown, by connecting it to large scale hydrogen production and storage.

This newly developed common framework has been used to undertake an economic appraisal for Project Union as described below.

More detail on the Assessment Methodologies project can be found in *Supplementary Document B*. The Assessment Methodology was utilised to support the Economic Appraisal and Real Options Analysis described below.

Economic Appraisal

We commissioned [redacted] to undertake an economic appraisal (*Supplementary Document C)* to support the needs case for the Project Union Feasibility Phase, drawing on baseline funding from the RIIO-2 Net Zero and Re-Opener Development "Use It or Lose It" (NZARD UIOLI) allowance.

The overarching aim of this work was to provide initial confidence on the societal value of the anticipated initial routes for a hydrogen backbone, and the broader proposition for Project Union as a whole. Accordingly, the work included a societal Cost Benefit Analysis (CBA) for a section of the backbone connecting the East Coast Cluster (Humber to Teesside), and a broader assessment on the contribution to jobs and Gross Value Added (GVA) for a full UK backbone connecting all industrial clusters. The East Coast Hydrogen (ECH2) point-to-point connection was selected as a case study since it is likely to be an early section of the full hydrogen backbone to be required given the cluster sequencing announcement, and the timing at which the ECH2 is likely to develop. Some pre-FEED activities for the ECH2 section have since started as part of the East Coast Hydrogen programme, funded under the NZARD UIOLI allowance to enable work to progress at pace.

[redacted] economic appraisal builds upon the methodologies developed with BEIS and industry as part of the 'Assessment Methodologies' project described above to ensure consistency and utility for future BEIS policy decisions. The appraisal consists of two components:

- Cost-Benefit Analysis (CBA) of a section of the backbone connecting the East Coast Cluster (Humber to Teesside). This estimates a net benefit of £82m (NPV terms) in Frontier's central scenario. This is based on comparing the projected costs for the ECC connection with a counterfactual where the same level of hydrogen demand and security of supply is met, but with alternative storage infrastructure.
- An assessment of the potential contribution of the ECH2 section to employment and the economy. This finds that it could directly support £16m – £27m of GVA per annum to the UK economy and 110 – 190 jobs during the peak construction period. This analysis has also been provided for a wider 'UK backbone' hydrogen grid rollout, for which [redacted] finds that Project Union could directly support approximately £300m annual GVA and 3,100 jobs at peak construction[35].

[35] The estimates do not represent an estimate of the net (economy-wide) impact of Project Union. They do not (for example) include adjustments for employment/GVA displacement ('crowding out' of employment/GVA in other sectors of the economy). They also consider only the direct employment/GVA of Project Union, and do not consider possible effects in the Project Union supply chain.

Real Options Analysis

[redacted] were also commissioned to undertake a Real Options Analysis (ROA) (Supplementary Document D), which builds on the Economic Appraisal CBA to assess the value of starting pre-FEED and FEED work on the ECH2 section now, rather than delaying this early work. While the study only considered a single section of the backbone, many of the principles still apply for the full hydrogen backbone.

Real Options Analysis is essentially a decision evaluation approach that considers the opportunity cost of continuing or abandoning a project. It has been employed in the context of this re-opener submission to provide confidence that there is societal benefit to commencing work now, even if alternative pathways emerge in the future.

The approach has the benefit of explicitly considering uncertainty regarding the pace at which demand in industrial clusters might switch to hydrogen. Early work on feasibility will create the option to build an initial cluster link as quickly as possible, reducing the risk of incurring societal costs that could arise in the early 2030s if the early work is delayed. [redacted] find that early spend is valuable to society, even if only a low probability (c. 16%) is assigned to the scenario where the hydrogen market in the Humber & Teesside industrial clusters grows at least as quickly as in the CCC's net-zero compliant 'balanced pathway'[36], and the ECH2 link is needed by 2031 to support continued growth in hydrogen demand. This shows that even if we took a highly pessimistic view about the speed of future hydrogen uptake, it would still be valuable to society to start pre-FEED/FEED activities as soon as possible. The cost of early feasibility work is relatively small compared to the potential benefits (and avoided costs of delay) that would arise from creating the option to have a cluster link in place by 2031. The work therefore demonstrates that initiating feasibility spend as soon as possible delivers the best outcome for society, despite uncertainty around the pace of growth in hydrogen demand.

The intention is to re-run both the Economic Appraisal and ROA exercises during the Feasibility phase, with the benefit of improved information and data on potential routes and associated costs.

The combined scope of [redacted] work on Economic Appraisal and ROA is summarised in the diagram below. In tandem these analyses illustrate the societal and economic value of an early cluster link, and the benefits of getting started today. While [redacted] has focussed on the Humber to Teesside link, [redacted]

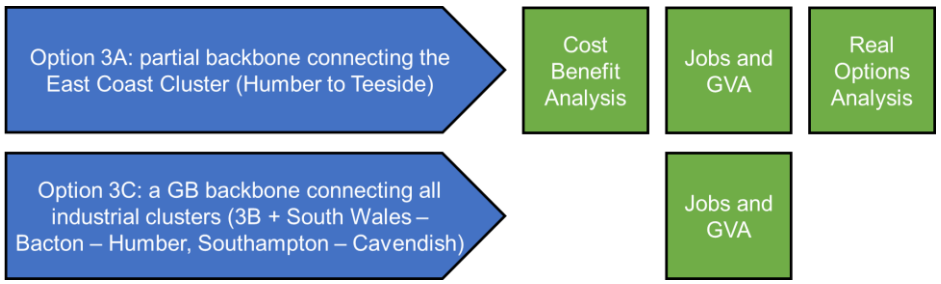


Figure 8 Scope of [redacted] work

[36] Most of the CCC scenarios are similar or higher than the balance pathway through 2020s/30s. Widespread innovation is lower during 2020s but involves rapid update during 2030s. CCC scenarios were developed before 10GW hydrogen production target in April 2022 Energy Security Strategy.

Delivering benefit and avoiding costs to Energy Consumers

In addition to the societal benefits examined by [redacted] beginning the Feasibility Phase now will also support the realisation of several benefits to existing and future energy network users.

As discussed earlier in section 5.2 two recent studies from Afry and Guidehouse show using hydrogen in a future energy system to complement the growth of renewables can reduce overall infrastructure and system costs compared to an all-electric system by £13-24bn and £38bn respectively.

To realise these benefits without expensive new build of pipelines extensive studies are underway around the world to prove the viability of repurposing assets. Here in the UK our FutureGrid[37] hydrogen transmission test facility will be commissioned early in 2023 utilising decommissioned NTS assets to provide essential insight and evidence.

Repurposing of assets would avoid decommissioning costs in the longer term and the mitigate stranding risks and further acceleration of RAV regulatory depreciation profiles, resulting in an increase to bills in the nearer term. Demonstrating the viability of repurposing assets for hydrogen also incentivises investment in the maintenance and upgrade of the methane network in the near term and mitigates the risk of the methane network moving into a "managed decline" scenario to the detriment of performance and reliability (subject to underlying minimum standard obligations).

Further, in a transitional period, the methane and hydrogen networks would coexist, which would result in company level business support costs required to support both networks would be shared over a wider asset base. There may also be opportunity to lever greater buyer power in the relevant marketplaces, and greater efficiency in work planning and scheduling where internal resources and capabilities are interchangeable between methane and hydrogen assets.

Finally, in a future scenario where a RAB based model is adopted for both the methane and hydrogen networks, collective management of investments would provide the opportunity to pool financial risks. This might further mitigate the need to accelerate depreciation of the methane RAB, potentially supporting lower and flatter bill profiles for methane users during the Net Zero transition.

5.3.3 Ofgem Engagement

In additional to stakeholder feedback, we also considered feedback from Ofgem throughout the Pre-Trigger engagement phase, and we have provided a summary playback of the feedback and our corresponding actions in *Appendix B*.

[37] FutureGrid, https://www.nationalgrid.com/gas-transmission/insight-and-innovation/transmission-innovation/futuregrid

6. Scope of work and evidence mapping

This chapter outlines the programme of work to be undertaken in the Feasibility Phase including how the scope has been formulated through the strategy development work. It highlights how delivering this feasibility phase of Project Union will close evidence gaps that exist today.

6.1 Aims and objectives for the Feasibility Phase

The Feasibility Phase, will deliver a Phasing Strategy, Pre-Front End Engineering and Design (pre-FEED) and Hydrogen market enabling activities over a 12-month period. The broad outcomes of the Feasibility Phase are to:

- Demonstrate how a cost-effective hydrogen transmission network can be delivered and how the transition could be phased and implemented, from both a physical and commercial perspective, whilst maintaining a resilient continuity of supply on the methane network.
- Enable critical technical, economic, societal, environmental, and logistical evidence to inform policy decisions.
- A narrowed set of appraised routing options for the Project Union 100% hydrogen backbone to carry over to FEED for detailed development.

The purpose of the Feasibility Phase will be to identify potential pipeline routes, assess the readiness of existing assets and determine an overall transition plan for delivery, aligned with industrial cluster developments, policy and customer and stakeholder needs. Specifically, in the Feasibility Phase we will:

- Investigate the optimal development options for a UK hydrogen backbone, linking industrial clusters, storage and strategic connection points across the country
- Establish optimal phasing for repurposing the National Transmission System, to create a hydrogen transmission ‘backbone’ for the UK through engagement with customers and stakeholders and network analysis to maintain close alignment with developing supply and demand signals for both hydrogen and methane.
- Evaluate the options that deliver best value for money and optimum economic and societal benefits to the UK, across the whole energy system
- Assess deliverability of the possible UK hydrogen backbone options and timescales
- Assess the readiness of existing assets to transport hydrogen and determine a transition plan to hydrogen, including blending, through engagement with industry, suppliers and the market
- Review and assess strategies for integration with other European hydrogen transmission projects such as the European Hydrogen Backbone
- Engage with our connected industrial consumers, power generators and Gas Distribution Networks (GDNs) to understand industrial and market demand, and supply chain hydrogen readiness
- Develop costings for delivery of a UK hydrogen backbone options that delivers optimal value for money

- Further develop the potential phasing of pipeline conversion and identify the priority sections for Front End Engineering and Design (FEED) works
- Determine the outcomes, phasing, and associated costs of delivering FEED for the priority sections
- Understand the regulatory and commercial landscape to meet the needs of current and future consumers
- Review policies, procedures and safety standards required to operate a future hydrogen transmission network
- Develop robust plans to demonstrate that the project can be successfully delivered

6.2 Formulation of scope

Ofgem's guidance[38] on the structure and content of a re-opener submission is reflective of a more traditional investment decision on methane network assets. As part of building a compelling needs case, this entails a systematic approach to options identification, assessment and selection. However, the funding proposed in this submission covers necessary preparatory work that is much earlier in the lifecycle of project development than might usually be the case and is centred on building the evidence base that will enable more informed decision making in future phases.

The approach taken to formulate the scope for this proposal is based on the particular circumstances of the challenge. We have drawn upon a range of top-down and bottom-up approaches, using a combination of internally developed evidence, externally supported evidence and stakeholder engagement. The overall approach to needs case and scope formulation is characterised in Figure 9. This remainder of this chapter outlines in detail the approach and outcomes of the Internally Developed scope and Stakeholder Engagement. The Externally Supported evidence can be found in section 5.3.

It was agreed with Ofgem during pre-application engagement that an Engineering Justification Paper would not be required for this submission given the nature of the work proposed.

[38] RIIO2 Re-opener Guidance and Application Requirements Version 2

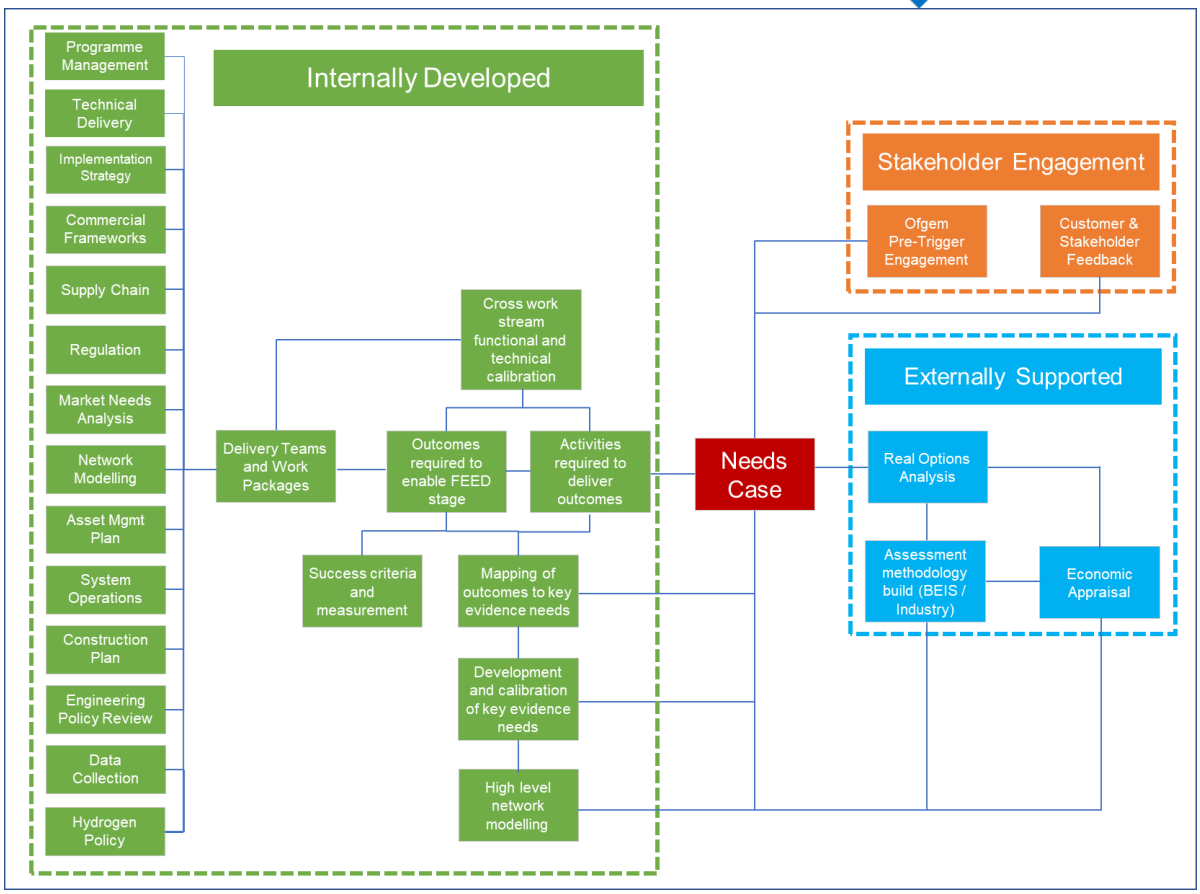


Figure 9 Approach to Feasibility Phase needs case and scope formulation

6.2.1 Internally developed evidence

The centrepiece to the internally developed evidence is the identification of key evidence gaps that the Feasibility Phase is aiming to address, and a mapping of planned outcomes and activities these to ensure that work is appropriately targeted to the right issues. Given the breadth of evidence needed to support future policy decisions and support the shaping of a hydrogen economy, we have carried out pre-application engagement with both BEIS and Ofgem to support the identification of evidence gaps and develop the scope of the Feasibility Phase.

At the same time, a key objective of the Feasibility Phase is that there is information and evidence sufficiency to enable moving the project into the Front-End Engineering and Design (FEED) stage, which will be the subject of a future funding application. The activities and outcomes required to support this have been assessed on a bottom-up basis by our internal project delivery teams, which reflect breadth of functional and technical specialism across the organisation. Teams are individually responsible for the development and delivery of work package scopes. Each team has formulated a set of the critical outcomes required to support the Feasibility Phase and to enable the subsequent stage of project development (FEED stage). Careful cross calibration of individual work package scopes has been undertaken to ensure alignment (particularly where work package input requirements straddle functional teams), drive internal efficiency and to eliminate duplication of activity.

This approach enables mapping and calibration of planned bottom-up activities to a top-down assessment of future evidence need. This in turn enables the identification of appropriate criteria on which to assess the ultimate success of the project.

The Feasibility Phase outcomes developed through this process for the System Operations workstream were separated out from the scope of this reopener and are being funded through NZSAP UIOLI. However, we will maintain alignment with the outcomes through our internal governance process.

A supporting programme of work undertaken through Network Innovation Competition (NIC), Network Innovation Allowance (NIA) and Strategic Innovation Fund (SIF) provide technical information regarding the transition and evidence to enable the repurposing of assets, whilst also considering any new systems required to enable project union. These are summarized in Appendix D - Supporting Project Summary is included with this submission, summarising the role of supporting projects and their relationship to Project Union.

6.2.1.1 Internal delivery teams and work packages

A summary of the key role of each work package follows below:

1. **Programme Management:** The Programme Management stream will operate as a central hub to drive project delivery. It will embed project management processes and be accountable for driving adherence to programme, outcomes and cost. The stream will perform assurance for the project and also provide consolidated reporting.
2. **Technical Delivery:** Responsible for delivering both technical and non-technical work packages for the Feasibility Phase. The stream will lead development and co-ordinate individual work packages in delivering the scope for FEED, provide alignment with wider innovation work packages and deliver specifications for procurement of FEED services.
3. **Implementation Strategy:** Provide overall integration into the project of technical, non-technical and wider work packages. It will develop the future funding strategy and be responsible for submissions of future funding requests. The stream will also develop the short- and long-term phasing strategy for Project Union.
4. **Commercial Frameworks:** Identifying commercial framework options for Project Union. This project will build on completed work delivered by National Grid Gas Transmission's (NGGT) Hydrogen Gas Market Plan project that involved NGG collaborating with expert industry stakeholders to explore the challenges from the development of Project Union to the existing gas commercial framework and potential solution options. This workstream will undertake the next level of detailed exploration required to enable Project Union from a commercial framework's perspective.
5. **Supply Chain:** Assessment of procurement needs for goods and services to enable the Project Union FEED stage. Engaging with the market to assess asset readiness, supply chain capability and capacity, and to inform future project plans. Select the most suitable supply partners and ensuring value is achieve through Most Economically Advantageous Tender (MEAT) procurements activities. Supported by the SIF Supply Chain Resilience project looking at the opportunity for novel arrangements to ensure access to the assets required for the transition.

6. **Regulation:** Ongoing development of options for the regulatory framework for Hydrogen, focussing on planning for RIIO-3, alignment to policy and market development, cost allocation models and asset stranding risk mitigation, regulatory considerations for asset repurposing, and appropriate funding routes for future work stages, and continuous engagement with the Regulator and BEIS throughout the Feasibility Phase.
7. **Market Needs Analysis:** Deliver a comprehensive, commercially sensitive and detailed hydrogen market analysis for current and new demand and production NTS customers. Prioritising direct connected due to inflight third party work, we will deliver via NDA arrangements market maturity, scale (MWh) and enabler overview for hydrogen market: technical, commercial, funding, legislative etc.
8. **Network Modelling:** To demonstrate the potential to repurpose elements of the existing methane NTS to blended or 100% hydrogen and assess the impact and interventions that are needed to maintain reliability and operability on the resultant methane network risk and operability.
9. **Asset Management Plan:** Ensuring we have an integrated Asset Management Plan (AMP) for the whole network during the transition from methane to hydrogen
10. **Construction Plan:** To consider the construction implications and developing scope as a result of desktop feasibility assessments and modelling and planning and development of the FEED work stage. Develop cost estimations.
11. **Engineering Policy Review:** Current engineering policies are based around methane and include specifications, management and work procedures. The working assumption is that the same structural policy approach, replicated for 100% hydrogen and a blend of hydrogen / methane. The resulting engineering policies would formalise the learning from the hydrogen research & development projects within National Grid and industry. For the Feasibility Phase, this work package will: review work done to date by FutureGrid Phase 1 and HyTechnical, propose the policy structure, governance arrangements for technical approval, assess existing policies, identify the priority policies to be developed and work with industry to identify safety case requirements.
12. **Data Collection:** Defining the “must have” data specification for a future hydrogen network. Collation and feedback on data gaps and quality. Assessment of information requirements; linear and non-linear. Data enrichment via desktop exercises or physical data collection. Costing and plan for any future data collection and potential engineering requirements (e.g., specialist In-Line Inspection (ILI) run). Capturing any additional data requirements (e.g., geospatial to support route mapping). Supported by work commenced in the HyNTS Pipeline Dataset SIF project and systems planned to be further developed.
13. **Hydrogen Policy:** Identifying and influencing the impacts of relevant hydrogen policy on Project Union. Project Union will deliver hydrogen to power producers, industry and transport, whilst providing the option to deliver hydrogen for heat. Understanding and responding to existing and new policies will be critical in helping deliver the hydrogen network and will better inform the design of Project Union, helping meet stakeholder needs. To work with internal and external stakeholders to develop policy proposals that will help deliver Project Union and to inform policy makers of policy impacts.

6.2.1.2 Linking Feasibility Phase scope to evidence needs

The top-down calibration of the Feasibility Phase scope is driven by the identification of evidence gaps that the 12-month programme will be aiming to address. With input from Ofgem and BEIS, we identified 12 separate evidence points which were then grouped into three higher level evidence categories. The allocation of project costs to these evidence groups and categories is shown below. This demonstrates a balanced weighting of effort to evidence groups.

Evidence Grouping	Cost Allocation (£m 2018/19Prices)	% Weighting	Evidence Point	Cost Allocation (£m 2018/19 Prices)	% Weighting
The role of a hydrogen backbone in a future energy system	[redacted]		How initial investments and later evolution of network can be achieved in a coordinated manner	[redacted]	
			Evaluate options for hydrogen 'backbone' against objectives and plans for the UK energy system, environment, economy and society including in Net Zero Strategy and Energy Supply Strategy		
			Evaluate potential role of hydrogen 'backbone' in supporting integration of renewables		
			Identify impact of hydrogen transmission 'backbone' on future energy system and how this should be reflected in the design of wider energy markets and policies		
			Explore synergistic benefits of dual hydrogen and methane operation and planning		
			Explore how the hydrogen 'backbone' could facilitate the concept of hydrogen towns		
Engineering and Asset Readiness	[redacted]		First of a kind demonstration of phased repurposing of the NTS to carry hydrogen and create hydrogen transmission 'backbone' for the UK, whilst maintaining security of supply on methane and hydrogen networks		
			Assess readiness of existing assets and determine transition plan to hydrogen, including blending, through engagement with industry, supply chain and the market		
Regulatory framework and funding options	[redacted]		Provide evidence/input to the Hydrogen Transportation and Storage business model by developing options for regulatory and commercial landscape (supporting the ambition to have initial regulatory and commercial framework in place by mid 2020s)		
			Develop options for funding mechanisms to support future phases and implementation of a hydrogen 'backbone'		
			Evaluate which options deliver best value for money and optimum economic, societal and consumer benefits to the UK across the whole energy system and how a 'hydrogen backbone' could support opening the UK hydrogen market to the benefit of consumers		
			Develop roadmap for optimal infrastructure planning to support the most economic and efficient energy transition		
Totals	7.912	100%		7.912	100%

Table 4 Feasibility Phase allocation of project effort to evidence points (project level)

The alignment of activities and outcomes to evidence points has been integrated at the lowest possible level in the design of our Feasibility Phase costing model. This provides a variety of views at differing levels of detail. For instance, below shows the contribution of individual work packages to the key evidence groups.

Work Package	The role of a hydrogen backbone in a future energy system	Engineering requirements and asset readiness	Regulatory framework and funding options	Work Package Total
Programme Management	[redacted]			
Technical Delivery				
Implementation Strategy				
Commercial Frameworks				
Supply Chain				
Regulation				
Market Needs Analysis				
Network Modelling				
Asset Management Plan				
Construction Plan				
Engineering Policy Review				
Data Collection				
Hydrogen Policy				
Feasibility Phase Total				

Table 5 Feasibility Phase allocation of effort to evidence points by work package

Supplementary Document D - Outcomes to Evidence Need Mapping is included with this submission. This document provides a more detailed view of the linkage of work package outcomes to evidence need, with summary narrative on how each outcome supports each evidence point where applicable.

6.2.1.3 Outcomes and success criteria

This section outlines the scope of the thirteen work packages identified, and the specific outcomes for each.

Programme Management

The Programme Management stream will operate as a central hub to drive project delivery and will adopt agile working practices to enable parallel working across multiple workstreams. It will embed project

management processes and be accountable for driving adherence to programme, outcomes and cost. The stream will perform assurance for the project and also provide consolidated reporting.

Outcome	Success Criteria
Delivery of Feasibility Phase: Project Management & delivery of plan	• Establish and embed Project Management standards and governance • Adherence to programme, outcomes and cost • Provision of project assurance. • Provision of consolidated reporting • Drive and support development of work package inputs, governance, milestones and products • Completion & lessons learned from Feasibility Phase Re-opener

Table 6 Programme Management outcomes

Technical Delivery

The Technical Delivery stream will be responsible for delivering both technical and non-technical work packages for the Feasibility Phase. The stream will lead development and co-ordinate individual work packages in delivering the Pre-FEED studies, developing the scope for FEED, provide alignment with wider innovation work packages and deliver specifications for procurement of FEED services.

Outcome	Success Criteria
Technical options agreed to take forward to FEED	• Pre-FEED studies (outputs = strategic options, basis of design document). • Alignment with FutureGrid and other technical innovation outcomes. • Technical stage gates throughout Feasibility Phase passed. • Management & resolution of technical dependencies and risks. • Technical scope developed for procurement of FEED services. • Overall scope and strategy for FEED phase defined. • Defined scope, plans, resources and costs for all FEED work packages. • Overall scope and strategy for FEED phase defined. • Defined scope, plans, resources and costs for all FEED work packages.
Non-technical – commercial, markets, regulatory frameworks	• Obtain visibility of all the workstreams and requirements, to facilitate and coordinate work required and the outputs, in order to provide a

	scope of work for the next phase of funding, aligned to FEED timescales. • Deliverables of non-technical work packages brought together to form an overarching hydrogen transition roadmap.
FEED scope & delivery plan developed	• Overall scope and strategy for FEED phase defined • Defined scope, plans, resources and costs for all FEED work packages

Table 7 Technical Delivery outcomes

Implementation Strategy

The Implementation Strategy stream will provide overall integration into the project of technical, non-technical and wider work packages. It will develop the future funding strategy and be responsible for submissions of future funding requests. The stream will also develop the short- and long-term phasing strategy for Project Union.

Outcome	Success Criteria
Phasing Strategy	• Long term delivery plan for Project Union developed out to construction, aligned with inputs from innovation projects and regional groups.
Funding Strategy	• Funding business outcomes - future funding strategy for Project Union developed. • Ascertain funding approval short term and long term • Assess broader / longer term grants / funding options • Future phases and Funding Strategy defined and required
Submission of funding request documents for FEED as per PreFEED outcomes, Phasing and Funding Strategy.	• Delivery of work packages for Feasibility Phase • Delivery of Economic Analysis and CBA to support funding decision • Delivery of Hydrogen Backbone pre-FEED study • Development of technical and non-technical scope for FEED • Delivery of technical specification for procurement • Integration with wider Hydrogen projects within Gas Transmission

	• Overall integration (tech, non tech, and wider work packages) • Developing funding submissions for BEIS / Ofgem • Integration with wider Hydrogen projects within Gas Transmission

Table 8 Implementation Strategy outcomes

Commercial Frameworks

The Commercial Frameworks work package will explore a possible commercial framework for Project Union building upon and delivered by Gas Transmission's Hydrogen Gas Markets Plan (GMaP). Key commercial framework challenges and solution options will be explored collaboratively with an expert industry working group. The key areas of focus will include: System Operation, Balancing, Trading, Gas Quality, Capacity, Charging and Connections. The aim of the work package is to aggregate and build on current market thinking to identify and undertake the next level of detailed exploration required to enable Project Union from a commercial frameworks perspective.

Outcome	Success Criteria
Explore best-fit commercial framework solution options to identified key challenges required to enable Project Union and agree the prioritised commercial framework areas that will need further detailed exploration to enable Project Union.	• Develop options that could provide solutions to the commercial issues and barriers. • Refinement of best-fit solution options for the selected seven areas of the commercial framework (System Operation, Balancing, Trading, Gas Quality, Capacity, Charging and Connections).
Build on output of (above) hydrogen GMaP project to launch detailed refinement of commercial framework for Project Union, with external consultancy support.	• Collaborate with external consultancy as well as external expert working group to develop detailed exploration of commercial framework for Project Union. • Final report published online, with additional webinars to share findings.

Table 9 Commercial Framework outcomes

Supply Chain

The Supply Chain work package will provide an assessment of procurement needs for goods and services to enable the Project Union FEED stage. Engaging with the market to assess asset readiness, supply chain capability and capacity, and to inform future project plans. Select the most suitable supply partners and ensuring value is achieve through Most Economically Advantageous Tender (MEAT) procurements activities.

Supported by the SIF Supply Chain Resilience project looking at the opportunity for novel arrangements to ensure access to the assets required for the transition.

Outcome	Success Criteria
Procurement requirements are defined, and stakeholders assigned to support Feasibility procurement(s).	• Requirements are defined to the extent that the procurement route, quantity of procurements and timeframes can be estimated.
The Most Economically Advantageous Tender (MEAT) procurements are awarded for enabling Goods or Services/ Works to support the FEED design or scope.	• The procurements required to support feasibility are awarded and commenced.
FEED procurement plan (Pre-Gate 0 strategy agreed) as early as possible during the Feasibility phase.	• High level FEED scope, milestones and dates are established.
Market Engagement implemented from the outputs of Feasibility to gain insight, such as asset readiness, supply chain capability or capacity, to inform and develop the plans for later stages.	• Market engagement and/or insight is gained for the purpose of informing later stages.

Table 10 Supply Chain outcomes

Regulation

The Regulation work package will provide ongoing development of options for the regulatory framework for Hydrogen, focussing on planning for RIIO-3, alignment to policy and market development, cost allocation models and asset stranding risk mitigation, regulatory considerations for asset repurposing, and appropriate funding routes for future work stages, with continuous engagement with the Regulator and BEIS throughout the feasibility stage.

Outcome	Success Criteria
Regulatory framework development: Ongoing development of options for the regulatory framework for Hydrogen, with alignment to developing regulatory policy, focussing on fair value treatment of asset repurposing, cost allocation and mitigation of asset stranding risks for natural gas users.	• Written output at end of project stage reflecting options considered and developed including stakeholder input captured throughout delivery. Outputs to include recommendations on options and next stages of development.
Regulatory delivery: Inflight monitoring of regulatory deliverables and development of needs case and funding submission for future work stage.	• Ofgem and BEIS engagement plan in place to develop funding options and minimum information requirements. Sufficient pre-application engagement and information provision to support in principle needs cases for future project phases. Well developed funding request and justification in line with internal and external timelines. Bridging funding requirements considered to enable smooth transition between project phases.

Stakeholder engagement: Proactive stakeholder with BEIS, Ofgem and key industry stakeholder groups to capture feedback and insights to support the development of regulatory policy, and monitor inflight delivery of Project Union.	• Demonstrable stakeholder engagement on development of regulatory options (including capturing and responding to feedback) with BEIS, Ofgem, GMAP and other key identified stakeholders. Engagement phases to reflect early input into scoping and mid and end of plan delivery engagement.

Table 11 Regulation outcomes

Market Needs Analysis

The Market Needs Analysis work package will deliver a comprehensive, commercially sensitive, and detailed hydrogen market analysis for current and new demand and production NTS customers. Prioritising direct connected due to inflight third-party work, we will deliver via NDA arrangements market maturity, scale (MWh) and enabler overview for hydrogen market: technical, commercial, funding, legislative etc.

Outcome	Success Criteria
Fully informed stakeholder landscape. Incorporating: • Communications and logistics • Create advocacy + letter of support • Visibility across consumer sectors of H2 • Fully informed stakeholder landscape	• Consumer research confirms increased advocacy for hydrogen • Number of letters of support • Favourable strategic direction from policy makers • Campaign analytics • Engagement with hub/online content
Gathering intelligence to feed into business case, evidence base and transition plan. Incorporating: • Clear understanding of direct connects • Consumer value of hydrogen • Cost socialisation and risk of stranding (consumer reps and industry) • Assessment of new connects • Regional transition plan • Analysis and modelling	• Customer impact assessment • Articulation of the value of hydrogen transmission to consumers • New relationships developed across potential sectors • Market assessment report • Regional groups developed and Net Zero roadmap created • Holistic view of how Union/NTS can support regional decarbonisation plans

Table 12 Market Needs Analysis outcomes

Network Modelling

The Network Modelling work package will demonstrate the potential to repurpose elements of the existing methane NTS to blended or 100% hydrogen and assess the impact on the resultant methane network risk and operability.

Outcome	Success Criteria
Defined specific assumptions for modelling activity to be actioned/progressed (methane and hydrogen – volume and energy by network zone).	• Assumptions document (as per methane) produced and tested.

Agreed list of assets to be used in the modelling whether reused, refurbed, or new including all flow characteristics and parameters.	• Specific assets listed, confirmed by Asset, that can be assumed for repurposing.
Defined assessment of asset and network flow characteristics boundaries (pressure, velocity, quality.).	• Linked to asset assumptions, network modelling inputs/parameters defined.
Agreed/updated list of assets to be used in the modelling whether reused, refurbished or new including all flow characteristics and parameters.	• Updated parameters for existing assets, following further Asset / Integrity review.
Benchmarking of modelling outcome (and agreed assumptions) with other Transmission System Operators and stakeholders.	• Externally verified results and input assumptions.
Review of Acorn modelling results and output report for use in Union modelling assessment.	• Critical assessment of previous work, lessons learnt assessment, training for Project Union modelling team.
Network modelling assessment of potential new build options high-level range of new build scope and likelihood.	• Full modelling assessment of specific new build options alongside repurposing.
Assessment and input to a go/no go date for hydrogen asset transfer based on modelled outcome.	• Collated modelling results and risks in agreed format.
Assessment of risk (operational, constraint etc.) on the methane network from repurposing infrastructure.	• Full assessment of existing network using existing parameters (constraint modelling, ANCAR etc.), documented constraints and risks under agreed scenarios.

Table 13 Network Modelling outcomes

Asset Management Plan

The Asset Management Plan work package will ensure Gas Transmission has an integrated Asset Management Plan (AMP) for the whole network during the transition from methane to hydrogen.

Outcome	Success Criteria
Gather the right information to make informed AM decisions.	• Ensure FEED is designed to plug into NGGT AMP processes and resource is prepared for and handover is succinct for Engineering Justification Paper writing
Confidence in our ability to estimate costs across all investments, including refurbish / replace options	• Enables optioneering and CBA. • Assets in scope can be defined for cost book application.
High-level range of new build scope and likelihood - Develop business cases for specific hydrogen investments via Engineering Justification Papers (EJPs)	• High-level scopes for options are defined.
Assess hydrogen projects impact on existing NTS	• Methane business plan impacts (cost and risk) can be assessed.

Data and assumptions are consistent across submissions (Uncertainty Mechanisms and the next regulatory period)	• Assumptions align to AMP and other Uncertainty Mechanisms. No risk of misalignment and regulator issue.
Hydrogen projects into plan	• Go/No go date for inclusion in the next regulatory business plan is agreed. RACI for project development agreed.
CBA of PU options	• We can value Net Zero driven projects effectively.
Build Net Zero Asset Management strategies and AMSO	• Effort required to build Hydrogen asset management strategy understood. Priority changes to AMSO (Asset Management Strategy & Objectives) and SAS (Specific Asset Strategies) delivered (dependent on policy framework changes).

Table 14 Asset Management Plan outcomes

Construction Plan

The Construction Plan work package will consider the construction implications and developing scope as a result of desktop feasibility assessments and modelling, and planning and development of the FEED work stage

Outcome	Success Criteria
Cost estimation of options to be taken forward into FEED to focus activities and option selection.	• Sufficient level of information gathered & appropriate level of detail for options cost estimation to enable focusing on cost drivers.
Management of construction related risk and assumptions register to inform options selection. Provide risk profile for FEED contract.	• Identification of risks and opportunities at the appropriate level of detail to enable differentiation between options with the appropriate levels of contingency range and confidence.
Environmental and consenting strategy for Project Union to establish cost implication and risk profile. Develop consenting strategy involving legal issues and land issues. Develop commercial contracting strategy for FEED contracts. Provide Support for FEED tendering process.	• Information gathered by environmental, lands and consenting officers to enable assessment of access issues and associated costs to include in the options estimates and develop mitigation plans and consenting strategy.

Table 15 Construction Plan outcomes

Engineering Policy Review

Current engineering policies are based around natural gas and include specifications, management and work procedures. The working assumption is that the same structural policy approach, replicated for 100% hydrogen and a blend of hydrogen / natural gas. The resulting engineering policies would formalise the learning from the hydrogen research & development projects within National Grid and industry. For the

Feasibility Phase, the Policy work package will review work undertaken by FutureGrid and HyTechnical, propose the policy structure, governance arrangements for technical approval, assess existing policies, identify the priority policies to be developed and work with industry to identify safety case requirements.

Outcome	Success Criteria
We will have determined an engineering policy framework that will work for natural gas, 100% hydrogen and a blend.	• Policy framework for natural gas and hydrogen defined within a report.
Existing engineering policies will have been reviewed to determine the priority and work effort to meet the Project Union delivery programme.	• The hazard identification workshop identifies any technical or safety gaps to repurposing. A prioritized list of policy updates is produced.
Reviewed existing industry hydrogen policies e.g. IGEM TD supplements.	• Industry documents reviewed.
Established governance arrangements for safety & technical approval.	• Safety & technical approval governance arrangements defined, within a report.
The requirements for changes to the GSMR safety case will have been identified.	• GSMR safety case requirements identified, within a report.

Table 16 Engineering policy review outcomes

Data Collection

The Data work package will define the "must have" data specification for a future hydrogen network. It will collate and feedback on data gaps and quality. The work package will provide assessment of information requirements; linear and non-linear. It will conduct data enrichment via desktop exercises or physical data collection. The work package will cost and plan for any future data collection and potential engineering requirements (e.g., specialist ILI run). The work package will also capture any additional data requirements (e.g., geospatial to support route mapping). Supported by work commenced in the HyNTS Pipeline Dataset SIF project and systems planned to be further developed.

Outcome	Success Criteria
Asset differentiation (hydrogen to methane)	• Data Specification created for existing (to be repurposed) and new assets. Specification shared to relevant workstreams for data capture.
Environmental impact of new pipelines/assets	• GIS features identified to support the impact modelling for proposed routes or sites. Project areas created in GIS to capture options and geospatial data.
Critical national infrastructure (CNI) assessment	• Impacted CNI and Cyber assets understood. Data capture and governance in place for existing and new data capture. Physical security data requirements defined for modification to existing assets and new assets.

Data provision and enrichment	• Data gap analysis completed based on data specification. Priorities plan and methodology created and in delivery. Feasibility datasets available for advanced modelling and options analysis Note: availability aligned to route phasing.

Table 17 Data Collection outcomes

Hydrogen Policy

Identifying and influencing the impacts of relevant hydrogen policy on Project Union. Project Union will deliver hydrogen to power producers, industry and transport, whilst providing the option to deliver hydrogen for heat. Understanding and responding to existing and new policies will be critical in helping deliver the hydrogen network and will better inform the design of Project Union, helping meet stakeholder needs. To work with internal and external stakeholders to develop policy proposals that will help deliver Project Union and to inform policy makers of policy impacts.

Outcome	Success Criteria
Review of existing policy on hydrogen in power, industry, transport and heat. Outline the potential impact on Project Union.	• Existing Policy potential impacts on Project Union are fully reviewed, understood and documented.
Evaluate new policies as published and their impact on Project Union. Respond to any relevant consultations providing information on the interaction of the development of policies and the development of Project Union.	• Risk and Opportunities from emerging policy are understood and documented and Project Union lens applied to all relevant consultations.
Discuss and develop policy proposals with external (and internal) stakeholders.	• Positive engagement with external stakeholders resulting in policy proposals that accommodate Project Union to the benefit of the UK.
Outline what is needed from upcoming policy to help deliver project union and use evidence gathered from the development of Project Union to help inform policy development.	• Policy makers are fully informed of the emerging outcomes and evidence provided by Project Union and policies are shaped by the evidence such that optimal policy decisions can be made.

Table 18 Hydrogen Policy outcomes

7. Value for money

This chapter outlines our approach for developing project costs and provides headline project costs by work package and project outcomes. We describe the methodology adopted for the treatment of ongoing efficiency, real price effects and general inflation, aligned to RIIO-2 framework principles, and how risk and contingency has been reflected in our cost plan. We demonstrate how minimum cost has been assured to support value for money for gas network users and consumers.

7.1 Project costs

A high-level summary of proposed project costs is shown in Table 19. Costs are shown inclusive of inflation adjustment, ongoing efficiency and contingency.

Activity	Price Base	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Feasibility Phase	[redacted]						
	2018/19	[redacted]					7.912

Figures shown in £m and inclusive of ongoing efficiency reduction and contingency

Table 19 Headline project costs

The table below summarises the steps to convert raw bottom-up project costings into a final 2018/19 price based position.

Feasibility Phase Internal/External Summary by Price base	Internal (£m)	External (£m)	Total Cost (£m)
Raw costs (2022/23 prices)	[redacted]		
Conversion to 2018/19 prices			
Efficiency commitment (2018/19 prices)			
Contingency (2018/19 prices)			
Total costs post efficiency and contingency (2018/19 prices)			7.912

Table 20 Raw cost to final 2018/19 position

7.2 Cost plan build

Our approach to project cost development was a complex and detailed exercise, as characterised in the diagram below. However, the overarching aim was to ensure full integration of scope build, evidence need mapping and activity costings, and transparency of assumptions throughout, Figure 10.

Supplementary Document E - Feasibility Phase Costing Model is included which provides the functional specification used for the purpose of this submission, methodological steps, and the key assumptions made.

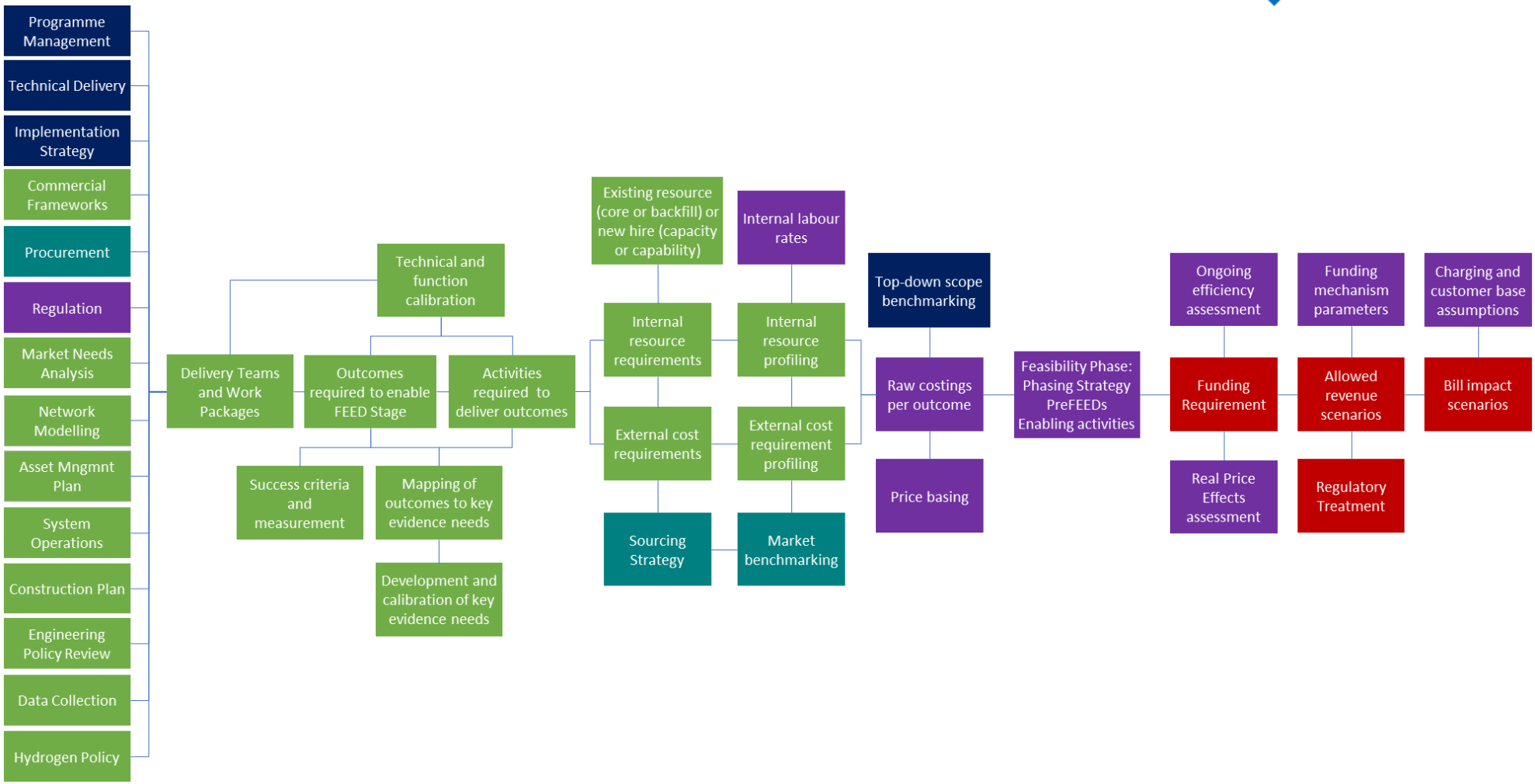


Figure 10 Schematic of cost plan build

7.3 Feasibility Phase project cost composition

The core of the funding proposal can be broken down into the following key areas, which collectively comprise the Feasibility Phase:

- A **Phasing Strategy**, including prioritisation and timing for delivery of each section of the hydrogen backbone, as well as a staged approach to project delivery and funding.
- **Pre-Front End Engineering and Design** (pre-FEED) activities for a full hydrogen backbone, delivering an appraised set of routing options, a constructability assessment and a planning and consenting strategy based on enhanced cost estimates and asset data. A full engineering policy review will also be undertaken.
- **Hydrogen market enabling activities** including development of options for the design of regulatory and commercial frameworks for hydrogen infrastructure and ongoing customer and stakeholder engagement.

In practice, these core activity areas are highly interactive making it challenging to draw a pure boundary between the areas, particularly between Phasing and Pre-FEED activities as they are closely linked. However, we estimate a rough 70 / 30 weighting of costs in favour of Phasing and Pre-FEED activities per Table 21 below:

		£m 2018/19 prices (inc. Efficiency and Contingency)		
Work Package	**High Level Scope**	**Phasing & Pre-FEED**	**Enabling**	**Total**
Programme Management	The Programme Management stream will operate as a central hub to drive project delivery. It will embed project management processes and be accountable for driving adherence to programme, outcomes and cost. The stream will perform assurance for the project and also provide consolidated reporting.	[redacted]		0.339
Technical Delivery	The Technical Delivery stream will be responsible for delivering both technical and non-technical work packages for the Feasibility Phase. The stream will lead development and co-ordinate individual work packages in delivering the scope for FEED, provide alignment with wider innovation work packages and deliver specifications for procurement of FEED services.			1.270
Implementation Strategy	The Implementation Strategy stream will provide overall integration into the project of technical, non-technical and wider work packages. It will develop the future funding strategy and be responsible for submissions of future funding requests. The stream will also develop the short- and long-term phasing strategy for Project Union.			0.859
Commercial Frameworks	Identifying market framework options for Project Union. This project will build on completed work delivered by NGGT Hydrogen Gas Market Plan project that involved NGG collaborating with expert industry stakeholders to explore the challenges from the development of Project Union to the existing gas market framework and potential solution options. This workstream will undertake the next level of detailed exploration required to enable Project Union from a market framework's perspective.			0.332
Supply Chain	Assessment of procurement needs for goods and services to enable the Project Union FEED stage. Engaging with the market to assess asset readiness, supply chain capability and capacity, and to inform future project plans. Select the most suitable supply partners and ensuring value is achieve through Most Economically Advantageous Tender (MEAT) procurements activities			0.462

Regulation	Ongoing development of options for the regulatory framework for Hydrogen, focussing on planning for RIIO-3, alignment to policy and market development, cost allocation models and asset stranding risk mitigation, regulatory considerations for asset repurposing, and appropriate funding routes for future work stages, with continuous engagement with the Regulator and BEIS throughout the feasibility stage.	[redacted]	0.343
Market Needs Analysis	Deliver a comprehensive, commercially sensitive and detailed hydrogen market analysis for current and new demand and production NTS customers. Prioritising direct connected due to inflight third-party work, we will deliver via NDA arrangements market maturity, scale (MWh) and enabler overview for hydrogen market: technical, commercial, funding, legislative etc.		0.694
Network Modelling	To demonstrate the potential to repurpose elements of the existing methane NTS to blended or 100% hydrogen and assess the impact on the resultant methane network risk and operability		1.051
Asset Management Plan	Ensuring we have an integrated Asset Management Plan (AMP) for the whole network during the transition from methane to hydrogen		0.178
Construction Plan	To consider the construction implications and developing scope as a result of desktop feasibility assessments and modelling and planning and development of the FEED work stage. Develop cost estimations		1.039
Engineering Policy Review	Current engineering policies are based around natural gas and include specifications, management and work procedures. The working assumption is that the same structural policy approach, replicated for 100% hydrogen and a blend of hydrogen / natural gas. The resulting engineering policies would formalise the learning from the hydrogen research & development projects within National Grid and industry. For the feasibility stage, this work package will: propose the policy structure, governance arrangements for technical approval, assess existing policies, identify the priority policies to be developed and work with industry to identify safety case requirements.		0.559
Data Collection	Defining the "must have" data specification for a future hydrogen network. Collation and feedback on data gaps and quality. Assessment of information requirements; linear and non-linear. Data enrichment via desktop exercises or physical data collection. Costing and plan for any future data collection and potential engineering requirements (e.g., specialist ILI run). Capturing any additional data requirements (e.g., geospatial to support route mapping).		0.678
Hydrogen Policy	Identifying and influencing the impacts of relevant hydrogen policy on Project Union. Project Union will deliver hydrogen to power producers, industry and transport, whilst providing the option to deliver hydrogen for heat. Understanding and responding to existing and new policies will be critical in helping deliver the hydrogen network and will better inform the design of Project Union, helping meet stakeholder needs. To work with internal and external stakeholders to develop policy proposals that will help deliver Project Union and to inform policy makers of policy impacts.		0.108
Feasibility Phase Total			7.912
Feasibility Phase Total (%)			100%

Table 21 Categorisation of Feasibility Phase activities and costs

Total Feasibility Phase costs carry a [redacted] internal resource / external cost weighting. Internal labour costs have been established based on anticipated resource utilisation by staff grade, using system labour rates as reflected in our core accounting system in the first instance. For certain new hire roles, an uplift has been applied to the system labour rates to reflect recent recruitment experiences.

External costs have been minimised but reflect the necessary externally procured costs required to deliver the specified outcomes and outputs. Table 22 below shows a categorisation of Feasibility Phase costs by work package and split into internal and external cost requirements.

Work Package	Internal Costs		External Costs								Total
	FTE	£m	Economic Consultancy	Stakeholder Engagement	Benchmarking	Licences and hardware	Specialist Labour	Contract Labour	Project Workspace	Total	£m
Programme Management	[redacted]										0.339
Technical Delivery											1.270
Implementation Strategy											0.859
Commercial Frameworks											0.332
Supply Chain											0.462
Regulation											0.343
Market Needs Analysis											0.694
Network Modelling											1.051
Asset Management Plan											0.178
Construction Plan											1.039
Engineering Policy Review											0.559
Data Collection											0.678
Hydrogen Policy											0.108
Feasibility Phase Total (£m)											**7.912**
Feasibility Phase Total (%)											**100%**

Table 22 Feasibility Phase costs by work package and cost type (2018/19 Prices including Efficiency and Contingency)

A further breakdown of the external costs and their derivation can be found on the External Cost Analysis tab on the Supplementary Document E - Feasibility Phase Costing Model is included which provides the functional specification used for the purpose of this submission, methodological steps, and the key assumptions made.

The following sections describe external costs in more detail:

7.3.1 Economic Consultancy

[redacted]% of total project cost requirements ([redacted]% of external costs) are driven by the need for economic consultant support. This is required in the following areas:

- **Commercial Frameworks**: The commercial frameworks work package will build on the outputs of a NGGT Hydrogen Gas Market Plan (Hydrogen GMaP) project focused on Project Union. This pre-feasibility Hydrogen GMaP project involves experts from NGGT collaborating with an expert industry working group to explore the challenges from the development of Project Union to the existing commercial framework, and identify potential solution options. Building on the outputs of the NGGT and stakeholder driven project, this commercial work package will drive further value by partnering with an economic consultant to provide expertise and the next level of detailed refinement in order to deliver fit for purpose commercial framework options for Project Union. This workstream will focus on seven key areas of the commercial framework including system operation, balancing, trading,

charging, capacity, connections, and gas quality. Cost estimates are based on previously completed work packages and assume economic consultant support for a [redacted] period. The commercial work package will deliver stakeholder tested outputs, including with decision makers BEIS and Ofgem, on refined options for a commercial framework for Project Union. It is key to emphasise that this commercial work package will be closely aligned to the Regulation work package to ensure market principle consistency.

- **Regulation**: our work with [redacted] on developing options for the future hydrogen regulatory framework to this point has provided valuable output with which to engage stakeholders. This has also specifically benefited the evaluation of the needs case for this proposal, resulting in the production of the Real Options Analysis which has been used in this context to give confidence to starting work on transmission asset repurposing now. It is important that ongoing development of options is supported by independent expertise, [redacted] throughout the delivery of the Regulation work package specified outcomes and outputs. Cost estimates are based on previously completed work packages and assume economic consultant support [redacted] programme period. As detailed in the 'Scope of work and evidence mapping' chapter, the Regulation work package will be aiming to deliver stakeholder tested output on options for the regulatory framework for Hydrogen, focussing on planning for the next price control, alignment to policy and market development, cost allocation models and asset stranding risk mitigation, regulatory considerations for asset repurposing, and appropriate funding routes for future work stages, with continuous engagement with Ofgem and BEIS throughout the Feasibility Phase.

- **Implementation Strategy**: our work with [redacted] throughout the Transition Strategy Phase of Project Union provided valuable output that has demonstrated the value and economic benefits of delivering our proposed transmission infrastructure and has supported the development of the needs case for this reopener. It is important that ongoing development of options is supported by independent expertise, delivering Cost Benefit Analysis (CBA) and Real Options Analysis (ROA) to inform decisions on section phasing, and hence the intention is to continue to partner with an economic consultant throughout the delivery of the Feasibility Phase such that future funding requests can be similarly supported. Cost estimates are based on previously completed work packages and assume economic consultant support [redacted] programme period, culminating in an Economic Assessment Report and Cost Benefit Analysis for each Project Union Section.

7.3.2 Stakeholder Engagement

[redacted]% of total project cost requirements ([redacted]% of external costs) are driven by the need for Customer and Stakeholder engagement support. This is required in the following areas:

- **Engagement Hub:** Technical expertise to support development a central channel through we can communicate and monitor stakeholder needs as they develop. Cost estimates are based on C&S Workstream Lead knowledge and experience of previous similar works.

- **Hydrogen acceptability and system cost study**: Independent expertise to further develop our understanding of expected use of hydrogen in the future energy system. This project will provide information and insight into three critical areas, aiding investigation into the strategic role of hydrogen

to support NGG's Net Zero transition. These areas are: understanding the nature and magnitude of constraints and solutions for NTS direct-connected sites to accept an initial blend of hydrogen (up to 20 vol%) within their existing natural gas supply; understanding the nature and magnitude of constraints and solutions for NTS direct-connected sites to fuel-switch to 100% hydrogen; and understanding the techno-economic impacts for total energy delivery across a spectrum of domestic heating solutions (100% hydrogen to 100% electrification). Cost estimates are based on a scope proposal received from [redacted] for the scope of works.

7.3.3 Benchmarking

[redacted]% of total project cost requirements ([redacted]% of external costs) are driven by the need for benchmarking of network analysis outcomes and input assumptions with other TSOs and stakeholders. The process of validating the baseline NTS network model against real data for methane investment planning purposes is well understood and accepted process carried out by internal modelling resource. However, the first of a kind nature of the Project Union, presents an additional layer of uncertainty requiring review and possible adaptation of our modelling assumptions and the outputs, particularly for hydrogen modelling. It is therefore prudent to externally verify our network modelling outcomes and input assumptions to externally benchmark our modelling. We have not yet tendered for the service, so until then the value is an estimate of how much it could cost to have an independent review of our approach and our outcomes. This is based on experience of the workstream lead, [redacted]

7.3.4 Licences and hardware

[redacted]% of total project cost requirements ([redacted]% of external costs) are driven by the need for additional licences and hardware to enable the additional modelling to be completed in line project timescales. Cost estimates are based on sizing of the work by Workstream Lead and based on licence costs for previous analyses.

7.3.5 Specialist Labour

[redacted]% of total project cost requirements ([redacted]% of external costs) are driven by the need for Specialist Contract Labour. This is required in the following areas:

- **Construction Plan:** Technical expertise in regard to environmental, lands and consenting to enable identification and assessment of any significant issues impacting the routing options being considered. Delivery of this work will include a desktop assessment of access issues and costs to include in estimate and develop mitigation plans and consenting strategy. Cost estimates are based on sizing of the work by environmental SME's and based on previous legal support costs for obtained early works on previous construction projects.
- **Engineering Policv Review:** External hazard identification workshop leads required to facilitate the identification of any technical or safety gaps to repurposing, support the production of a prioritised list of policy updates required. Cost estimates are based on previous similar workshops for methane works and utilise the baseline developed in innovation workstreams.

- **Technical Delivery:** There is a need for Engineering Consultancy support, either bringing in a contractor to work within the internal delivery team or to contract out specific areas of work to provide rigour and a technical expertise into the optioneering of repurposed and potential new build sections of the overall backbone solution. This will support the development of optimised routes and phasing for the sections of Project Union. The cost estimate for this work has been informed by a joint workshop with an external Engineering Consultancy to gain understanding of what they would define as scope requirements and initial estimates of the costs of PreFEED delivery. We have then assessed this scope, identifying and removing some of the components where we are planning on delivering this work internally. The resulting cost estimate is reflective of the low end of the cost estimate from the external consultancy.

7.3.6 Contract Labour

[redacted]% of total project cost requirements ([redacted]% of external costs) are driven by the need for Procurement Contract Labour. This is considered the most economic and efficient approach to delivering the Procurement outcomes due to the short-term nature of the work and it is a typical way of delivering Procurements. Cost estimates are based on day-rate figures provided by the Procurement workstream lead using their recent experience of recruiting in this market.

7.3.7 Project Workspace

[redacted]% of total project cost requirements ([redacted]% of external costs) are driven by the need for Project Workspace. The increase in internal resource to deliver Project Union to deliver this phase of work will be significant and the team will need a space in which to co-locate in order to effectively collaborate and coordinate to optimise delivery of all the project outcomes. [redacted]

7.4 Cost efficiency

Due to the first of a kind nature of many of the outcomes proposed in this Feasibility Phase, cost estimation has been challenging in many areas. Very early high-level estimates for the creation of a GB Hydrogen Backbone indicate an investment programme of £[redacted] out to the early 2030s. Early feasibility work for Project Union will provide greater clarity on investment requirements, but based on current estimates, Feasibility Phase costs would represent less than [redacted]% of the overall programme.

To assure the efficient level of proposed costs, we have taken the following actions:

- **Optimisation of internal resource:** our cost plan is based on optimised utilisation of enduring internal resource. This has numerous advantages, not limited to growth and retention of hydrogen specific skills and capabilities, synergistic knowledge pooling between methane and hydrogen assets, protection of ongoing resilience and capability of the methane network and overall efficient delivery of RIIO-2 business plan commitments. Where resource requirements are transient or general, we look to the external labour market to support needs. As shown above, external resource costs are limited to those that are vital to the delivery of the specified programme outcomes and outputs.

- **Ongoing efficiency commitment**: our cost plan includes an ongoing efficiency overlay in a manner consistent with the approach taken by Ofgem in establishing baseline totex allowances for the RIIO-2 Final Determinations. A compound annual efficiency assumption of 1.25% has been assumed from the start of the price control and applied to the annual pre-efficiency cost profile derived from our costing model. This results in an ongoing efficiency commitment of 3.5% on raw costs.
- **Cost risk sharing:** as described in the Regulatory Treatment and Impact chapter, we propose that any cost increase risk is borne by NGGT, and that any unspent allowances are returned to consumers in full.

7.5 Allowing for inflation and real price effects

Our cost plan has been prepared in a 2022/23 price base and wound back to a 2018/19 equivalent using the forecast inflation indices included in the RIIO-GT2 Price Control Financial Model (PCFM) as published by Ofgem in December 2022[39]. The inflation indices published in the PCFM cover actual published RPI and CPIH data points up to June 2022. This means that inflation indices for the 2022/23 financial year are predominantly based on forecasts. Accordingly, we recommend that price basing is revisited at the point of final determination to ensure that allowance are based on the most accurate and up to date inflation data.

Given that the cost plan has been produced in current prices, the weighting of costs to internal or external labour, and the 12-month time frame for the core Feasibility Phase proposal, we do not consider that any separate adjustment for real price effects (RPEs) is warranted, and that standard indexation of allowed revenues to general inflation would adequately cover any risk in this regard.

7.6 Allowing for project risk

We have undertaken a risk assessment of all the workstreams delivering outputs in the Feasibility Phase of Project Union. In this assessment, each of the delivery leads has considered risks to delivering their objectives at the estimated cost.

As is typical at the early stages of a project, the vast majority of the costs for the Feasibility Phase can be attributed to people resources, and the risks identified are reflective of this. Therefore, our approach to assessment and mitigation of the risks has considered how many FTE are incremental (not currently in the business), how readily available each type of FTE will be across the workstreams and what risks there are to paying premiums for particular skill sets. Our general approach has been to deliver outcomes using internal resource as far as possible, either by internal or external recruitment. However, the potential for outsourcing work to consultants due to lack of internal resources and the uncertainty in consultancy costs has also been factored in, although it is much harder to estimate the costs of outsourcing work without engaging with the market.

We have called out the top 5 risks and how we have been and plan to mitigate their impact from our risk register, this can be found in *Appendix C C - Risk Register*

Taking these risks in the round, a contingency level of [redacted]% has been applied to post efficiency costs.

[39] RIIO-2 Annual Iteration Process 2022 for Transmission and the Electricity System Operator

7.7 Company contribution

Ofgem's Net Zero Pre-Construction Work and Small Net Zero Projects Re-opener Governance Document[40] requires networks to consider a direct company contribution where a potential NZASP project is substantially innovation related (for example, it could also be eligible for funding under either the Strategic Innovation Fund or Network Innovation Allowance). For the reasons highlighted in the 'Regulatory Funding Justification' section of the 'Regulatory treatment and impact' chapter, these mechanisms are not suitable to fund this project.

Whilst this project is certainly first of a kind in nature, and key knowledge and learnings will be shared across the industry, it is not an innovation project as defined by RIIO-2 innovation funding mechanisms, which in summary describe innovation projects as collaborative projects involving research, development and demonstration. Instead, the proposed Feasibility Phase involves early development of future network infrastructure and is therefore more akin to a totex funded project (notwithstanding the specific proposals included in the 'Regulatory treatment and impact' chapter).

Furthermore, amidst policy and regulatory uncertainty regarding a level of future financial benefit to NGGT is impossible to assess at this stage. Accordingly, we propose that the Feasibility Phase is not subject to totex incentivisation or capitalisation to the RAV, and that unspent funds are returned to consumers, which are all measures intended to remove the prospect of financial gain to NGGT for this work.

In summary, we therefore propose no direct company contribution, but instead make the following proposals in lieu of this, which are intended to shield bill payers from unnecessary cost:

- National Grid Gas Transmission will fully assume upward cost risk relative to the proposed funding request
- A commitment to ongoing efficiency has been incorporated into costings, equivalent to 3.5% of total project costs
- Project costs are excluded from totex incentivisation and RAV capitalisation.
- We propose that any underspend at the end of the project is fully returned.

In addition to this, we have made and will continue to make significant direct funding contributions to multiple projects being delivered in RIIO-2 that are contributing to building the evidence base for hydrogen transmission. As of December 2022, we are forecast to contribute £[redacted] across 74 projects. These projects are NIC, NIA or SIF funded projects that are either complete, live or sanctioned in RIIO-2 thus far.

Furthermore, we have also committed time and resource into driving forward knowledge on hydrogen transmission, the cost of which is absorbed with the delivery of our Net Zero activities. For instance, we are members of a number of hydrogen industry working groups such as H2GAR (Hydrogen Gas Assets Readiness) and GERG (European Gas Research Group) and MarcoGaz where we are working with European Transmission System Operators and Gas Goes Green which involves collaboratively working with other UK gas network operators.

[40] Ofgem: Net Zero Pre-construction and Small Net Zero Projects Re-opener Governance Document

8. Project Union Delivery Strategy

This chapter describes:

- the intended project delivery plan,
- a summary of supporting projects to date, and,
- an explanation of our internal project structure and governance framework.

8.1 Project history to date

We carried out some early-stage pre-work analysis to understand the technical viability of developing a hydrogen backbone, this work also included the development of NetStrat, a tool that has the capability to model hydrogen and varying scenarios.

Subsequently, three previous project phases for Project Union have been funded under the RIIO-2 Net Zero and Re-opener Development 'Use It or Lose It' allowance. The key deliverable and outcomes for these phases are summarised in Table 23.

Project Phase	Key deliverables and outcomes	Cost (£m) (Nominal Prices)[41]
Early-stage pre-work analysis	• Network modelling case studies have been completed for initial iterations to investigate the potential of a Project Union HyNTS backbone for 2030 and the transition to 2050 Net Zero targets. Below are projects that have been completed to support the Feasibility Phase of Project Union: 1. 2050 Repurpose NTS vs New Build HyNTS – The result of this case study highlighted that the NTS had the ability to transport the equivalent energy volume of hydrogen as it currently does methane. 2. Project Union 2030 HyNTS Backbone - . The result of this case study highlighted that, at a first pass study, the repurposing of ~2000km was achievable to support a transition to a hydrogen backbone for 2030 to connect hydrogen hubs in Scotland, Merseyside, East Coast, Wales and Southern regions. 3. Project Union 2030 HyNTS Backbone Pathways Study - The result of this case study derived a RAG status of current NTS feeders that have the potential to be repurposed to form a Project Union hydrogen backbone. This case study highlighted the opportunities for repurposing and also increased the understanding of conversion risks for operability and capacity.	-

[41] Sanction value in nominal prices as of 12.12.2022, total is under £2m UIOLI cap in 18/19 prices

	• Develop a new decision support tool known as NetStrat, which can continuously model the impact of various hydrogen scenarios on the proposed hydrogen network and can highlight the potential risk(s) or constraints on a scenario or range of scenarios.	
Strategy Phase	• Project Union vision and narrative • Project Union Delivery roadmap aligned to Hydrogen Strategy • Stakeholder Engagement Strategy • Funding Strategy Paper • Scope and resource approach for Transition Strategy Phase	[redacted] (UIOLI)
Transition Strategy Phase	• First pass network modelling to define potential backbone solutions. • Deliver a Strategic Outline Case for Project Union • Demonstrate strategic alignment with policy • Establish stakeholder engagement groups to begin assessing readiness and to inform Project Union strategy • Assess wider economic and societal benefits • Develop the scope and plan for the Feasibility Phase, including the assumptions to be tested. • Project Union formal launch. • Critical enabling tasks for transition into Feasibility Phase	[redacted] (UIOLI)
Project Union Economic Appraisal	• Cost Benefit Analysis for Option 3A (Humber to Teesside) • Jobs and GVA appraisal for Option 3A and 3C (wider UK backbone)	[redacted] (UIOLI)

Table 23 Summary of previous Project Union work phases

8.2 Project delivery and monitoring plan

The project is being delivered through thirteen work packages as described in section 6.2.1. The Project Delivery workstream will be responsible for overall delivery of the collective feasibility phase outcomes and will provide all project management oversight to ensure adherence to time, cost and quality requirements. The Project Delivery team will be led by dedicated resource within the Gas Transmission Hydrogen Team, with individual work packages providing cross functional input as approved resource from their base department within Gas Transmission, Figure 11.

A project reporting structure will be put in place to monitor adherence to project requirements, with key performance indicators developed to monitor project performance against time, cost and quality metrics. These reporting mechanisms will be conducted on a monthly cycle to align with project governance reporting requirements. A governance structure has been set up to support the feasibility phase as detailed in section 8.3.1.

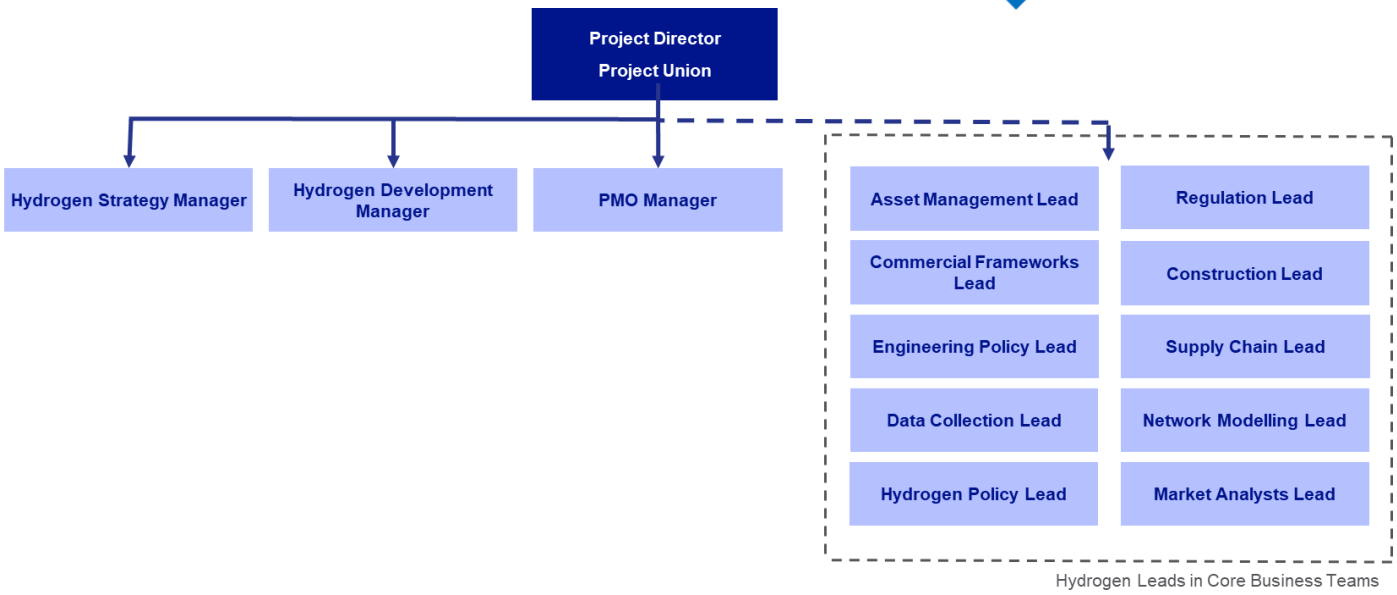


Figure 11 Delivery Structure

During the Transition Strategy Phase, a Detailed Feasibility Phase Delivery Plan has been developed with input from work package Delivery Leads through a series of Feasibility Phase planning workshops and individual offline work. The aim of the planning was to develop a plan encompassing all work packages that must be delivered during the Feasibility Phase to enable Project Union to progress to a FEED phase for the initial connections, including development of key enabling activities.

An aggregated outcome plan has been developed to define the outcomes that must be delivered. The approach to develop this plan was to:

1. Determine the outcomes to be delivered for each work package
2. Determine the quarterly sequencing of outcomes to be delivered over a 12 month period
3. Identify which outcomes are 'critical' (i.e. outcomes on which the project is dependent)
4. Identify interdependencies between work packages
5. Refine sequencing of outcomes based on interdependencies identified

Building on from the aggregated outcome plan individual work package profiles have been developed to provide more detail and refinement to the planning. The work package profiles align activities, success criteria and resource plans against the work package outcomes, with any assumptions or interdependencies captured.

Supplementary Document F - Detailed Feasibility Phase Delivery Plan is included with this submission. The key critical milestones for the Feasibility Phase as determined through the planning phase are summarised in Table 24.

Work Package	Critical Outcome	Milestone Date
Network Modelling	Defined assumptions for modelling activity	February 2023
Network Modelling	Working network model per scenario	February 2023
Implementation Strategy	Phasing Strategy	March 2023
Supply Chain	Supply Chain Assessment	March 2023
Market Needs Analysis	Market Analysis	March 2023
Supply Chain	The procurements required to support feasibility are awarded and commenced.	April 2023
Construction Plan	Cost of Options – First Draft	September 2023
Construction Plan	Options risk registers and plan	September 2023
Engineering Policy Review	Existing engineering policies will have been reviewed to determine the priority	October 2023
Engineering Policy Review	The requirements for changes to the GSMR safety case will have been identified.	October 2023
Data Collection	Data provision and enrichment	October 2023
Technical Delivery	Pre-FEED Studies Complete	October 2023
Technical Delivery	FEED scope & delivery plan developed	October 2023
Asset Management Plan	Hydrogen projects into plan	November 2023
Asset Management Plan	CBA of Project Union options	November 2023
Construction Plan	Final Options Estimate for CBA	November 2023
Implementation Strategy	Submission of funding request documents for FEED	November 2023
Construction Plan	Final Options Risk and Plans for CBA	December 2023
Regulation	Regulatory framework development written output	December 2023
Commercial Frameworks	Refinement of commercial framework final report	December 2023

Table 24 Critical milestone plan

8.3 Project structure and governance

For Project Union, we intend to follow a broadly similar approach to the existing Gas Network Development Process known as ND500, adapting where necessary to accommodate the specific challenges presented by the first of a kind nature of the transition process to hydrogen.

Over the next 12 months as the project progresses into the Feasibility Phase, Project Union will be governed through the ND500 stage gate process. An overview of this process can be seen in Figure 12. The Feasibility Phase will cover stage 4.1 and critical activities identified from stage 4.2 of the ND500 process which are anticipated to require a greater amount of time to complete for activities related to hydrogen transmission due to the novel nature of the work.

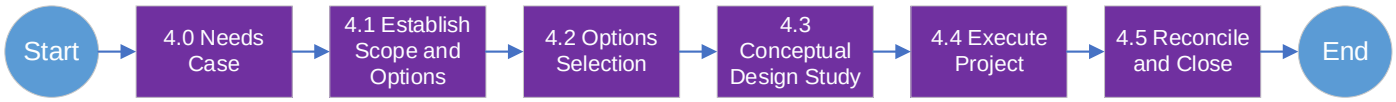


Figure 12 ND500 process overview

8.3.1 Feasibility Phase Project Governance

A governance structure to support the Project Union Feasibility Phase has been established in Figure 13 Project Union Feasibility Phase governance structure.

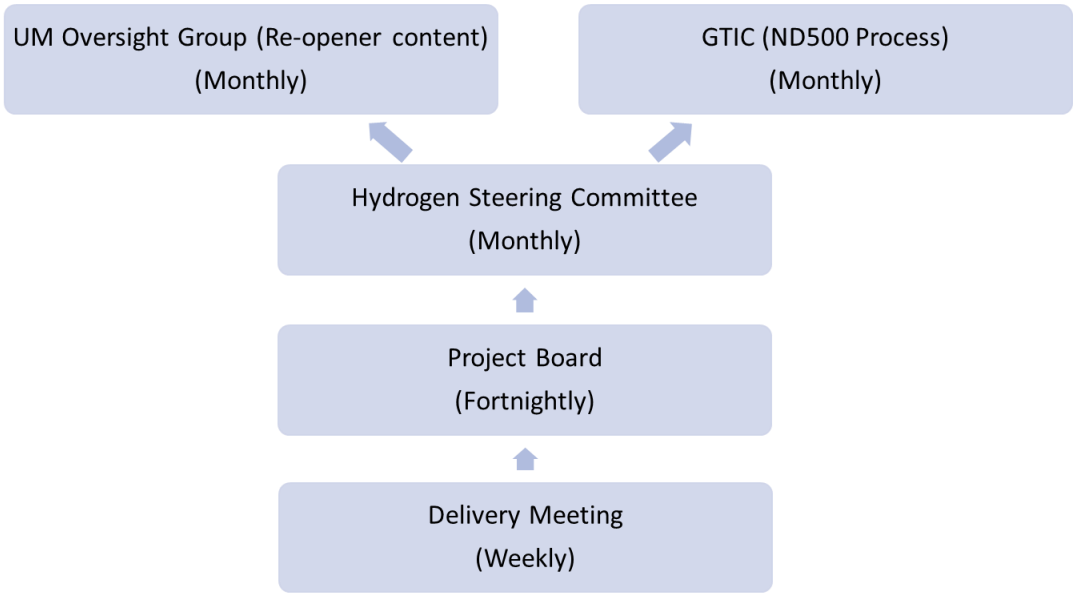


Figure 13 Project Union Feasibility Phase governance structure

8.3.2 Executive Meetings

There are two established executive level meetings that Project Union with report into.

The Uncertainty Mechanism (UM) Oversight Committee is responsible for management and decision making across the Uncertainty Mechanism portfolio which Project Union forms a part of. Approvals for reopener content will flow through this meeting. Once the reopener has been approved and submitted regular monthly updates will be provided to this board. These will measure progress through reporting on KPIs for quality, time and costs (plan, risk, resource, cost confidence as examples)

Gas Transmission Investment Committee (GTIC) is responsible for the management of investments through the ND500 process mentioned in the previous section and Project Union updates will flow through to this board as funds are required to proceed to the next phase of work.

8.3.3 Hydrogen Steering Committee

The purpose of the Hydrogen Steering Committee is to set strategic objectives for the project resolve any blockers that may arise during delivery. This group manages inter-departmental priorities and challenges and drives alignment of strategic views across teams.

8.3.4 Project Board

The purpose of the Project Board is to share progress with the Project Sponsor and resolve issues within control of the Project Team. The Project Board supports alignment to Project Union's vision and strategy, as well as providing consistency across individual work packages.

8.3.5 Delivery Team and Work Packages

Thirteen work packages have been established to support the delivery of the Feasibility Phase outcomes. The work package structure provides breadth of functional and technical specialisms across the organisation. A work package Delivery Leads meeting will be held on a weekly basis to provide a progress update on each work package and to raise and concerns or risks. The specific activities and outcomes to be delivered by each work package are described in Chapter 6.

8.4 Supporting projects

Project Union is directly and indirectly supported by a number of related projects funded under various mechanisms. These projects are being run alongside Project Union and will provide crucial inputs and evidence into the feasibility of a hydrogen backbone and how it can be delivered for the best of value to the UK as a whole.

Gas Transmission's innovation strategy consists of three RIIO-2 Innovation themes: '*Fit for the Future'*, *'Ready for Decarbonisation'* and '*Decarbonised Energy System'*, that support the business in preparing for Net Zero.

Fit for the Future focuses on extending the pipeline lifetime and enabling its use for the Net Zero future, *Ready for Decarbonisation* looks at those key assets and technologies that will be needed for the integration of Net Zero gases into the National Transmission System (NTS) and *Decarbonised Energy System* develops the systems and processes that are needed to run a Net Zero gas network.

These themes provide a roadmap of projects through to 2050. To further support this strategy, five Innovation Technology Portfolios have been established, each with its own technology roadmap and specific project pipeline. All five technology portfolios focus on Net Zero in some way, across their project pipelines. These Net Zero projects focus on hydrogen and are delivered through the HyNTS (Hydrogen in the National Transmission System) programme of work. This programme aims to examine the suitability of hydrogen as a cleaner alternative to methane and identify what changes may be needed across Gas Transmission to accommodate this.

Under the HyNTS programme the five technology portfolios are:

- Asset development for risk mitigation: focuses on developing an understanding of the current asset landscape and its capability with future Net Zero gases. This includes developing solutions for compression and storage of hydrogen.
- Automation and measurement: focuses on all sensing systems within the gas network, as well as assessment methodologies such as the use of pipeline inspection gauges and robotic assessments.
- Digital systems and simulation: links with Automation and Measurement to develop Internet of Things (IOT) solutions that provide real insights for the core Gas Transmission teams and looks at the future options for digital twin solutions and the use of machine learning (ML) and artificial intelligence (AI).
- Materials and processing: focuses on solutions to help improve our materials resistance for current and future scenarios, whilst developing novel robust techniques to repair the National Transmission System (NTS) assets more efficiently and help extend their lifetime.
- Business strategy and development: focuses on the operation of the NTS and builds an understanding of how this may evolve with the market changes through the energy transition.

Appendix D - Supporting Project Summary is included with this submission, summarising the role of supporting projects and their relationship to Project Union.

9. Regulatory treatment and impact

This chapter confirms the eligibility of this project for funding under the Net Zero Pre-Construction Works and Small Net Zero Projects Re-opener (NZASP) mechanism and provides a statement of the funding principles adopted when considering the appropriate regulatory treatment for the project, based on feedback provided by Ofgem through our pre-application engagement. We propose the specific regulatory treatment that could be adopted to best align to these funding principles and show the expected allowed revenue and customer bill impacts that would arise from this.

9.1 Regulatory funding justification

In the context of its RIIO-2 innovation stimulus package, Ofgem notes the uncertainty associated with the need for and cost of investment in hydrogen but has set baseline funding for National Grid Gas Transmission to support hydrogen projects within the RIIO-2 framework in two ways:

- Network Innovation Allowance (NIA): baseline funding of £25m across the five-year price control period can be used to fund small and repeatable hydrogen projects, and the Gas Transporter licence has provision for an increase in innovation funding specifically for hydrogen projects should Ofgem deem this necessary, and through consultation with relevant stakeholder groups.
- Net Zero and Re-opener Development 'Use It or Lose It' Allowance: this mechanism provides £8.3m of baseline funding across the RIIO-2 period which can be used for low or no regret small Net Zero projects and for early development work on Net Zero projects to be brought forwards under the two Net Zero re-opener mechanisms Ofgem has established for RIIO-2. The mechanism is subject to a £2m cap per project.

The RIIO-2 framework provides three other potential routes to fund hydrogen projects:

- Strategic Innovation Fund (SIF): this is the successor mechanism to the RIIO-1 Network Innovation Competition (NIC) and is specifically targeted towards decarbonisation. The SIF is a competition-based mechanism which allows networks to apply for project funding against specific innovation "challenges" issued by Ofgem. A total funding pot across all electricity and gas networks of up to £450m has been signposted by Ofgem. SIF projects will follow three distinct phases, with individual applications required for each stage. Successful applications for earlier stages do not guarantee an outcome for subsequent stages. Materiality thresholds for project stages are specified as follows:
    - Discovery stage: capped at £150k
    - Alpha stage: capped at £500k
    - Beta stage: starting at £500k with any upper cap established in challenge round documentation
- Net Zero Pre-Construction Works and Small Net Zero Projects Re-opener: this mechanism allows Gas Transporter licensees to undertake early design, development, general pre-construction work, and Net Zero facilitation capital projects that will enable the achievement of Net Zero Carbon Targets. Broadly, the mechanism covers:

- Early development/design and pre-construction work which is too material to be covered by the Net Zero and Re-opener Development Use It or Lose It allowance
- Net Zero projects that are too material for the Net Zero and Re-opener Development Use It or Lose it allowance, but not material enough, or appropriate for the Net Zero Re-opener (see below)

The mechanism can only be triggered by Ofgem based on a detailed engagement phase where it will establish the needs case in principle. Project must exceed £1m in value, but there is no specified upper limit under this mechanism. We have undertaken valuable and constructive engagement with Ofgem through a series of regular bilateral discussions over a 15-month period commencing September 2021. IIn additional to stakeholder feedback, we also considered feedback from Ofgem throughout the Pre-Trigger engagement phase, and we have provided a summary playback of the feedback and our corresponding actions in *Appendix B*

- Net Zero Re-opener: this is an Ofgem triggered mechanism designed to support larger scale Net Zero projects. Projects brought forwards under this mechanism must exceed a materiality threshold of £10.7m. Triggering of the mechanism is contingent of the occurrence of a significant "Net Zero development" the detailed definition of which is included in the Gas Transporter licence.

The key regulatory policy hurdles are centred around project type, scale, non-duplication, the background government policy landscape, and a demonstration that gas network users will benefit from the expenditure.

In support of the case to fund this Feasibility Phase through RIIO-2 mechanisms:

- **Project type**: the proposal is to fund a Feasibility Phase for the potential repurposing of the transmission system only. The nature of the work to be undertaken would qualify under the Net Zero Use It or Lose It allowance, however this mechanism has a preventative upper limit of £2m per project.
- **First of a kind**: repurposing gas transmission systems is a first of a kind for the UK. It is therefore innovative in nature, although does not meet the strict definitions of an "innovation project" as they pertain to the NIA and SIF mechanisms.
- **Policy alignment**: as demonstrated in "Needs case" chapter, repurposing gas transmission assets is well aligned to relevant Government strategies. We note though that key decisions on the framework regarding who should pay for hydrogen investment are yet to be made. Accordingly, the scope of this proposal is limited to the necessary activities required to complete a feasibility assessment for a UK Hydrogen Backbone and that which will reduce uncertainty in the optimising the prioritisation and timing of subsequent project phases. In addition, the Feasibility Phase outcomes will provide substantial evidence in support of Government decision making on policy.
- **Scale:** we anticipate that future phases will require more significant investment should the policy landscape support the need. However, for the scope of this proposal, project costs of £7.912m represent an increase of just 0.1% on baseline Gas Transmission totex funding for RIIO-2, this has a very modest impact to bill payers. Ofgem has recently made funding decisions on projects developed by GDNs under the Net Zero Pre-Construction Works and Small Net Zero Projects Re-opener mechanism namely:

- SGN LTS Futures: £26.9m of customer funded project expenditure agreed (current prices)
- Hydrogen Village Trials: £10.2m of customer funded project expenditure agreed (current prices)

Accepting that these projects have been assessed on their own merits, from a scale only perspective, the proposed funding in this application is substantially lower in value than previous funding decisions under this mechanism.

- **Interdependency of major projects**: Project Union will have implications for producers, transporters and consumers. There is a significant complexity and lead-time associated with readying the hydrogen value chain, aligning any physical testing/trials and enabling regulations, codes, standards and commercial arrangements for changes in gas supply.

  Project Union will act as a central contributor to aligning deliverables, assumptions and inter-dependencies allowing projects to link together in the most efficient manner to deliver Net Zero ambitions.

  Project Union will provide a key link to major regional projects to contribute to an overall national UK approach. Regional projects such as East Coast Hydrogen will utilise re-purposed or new build infrastructure developed through Project Union highlighting the crossover between the two projects and the role Project Union will play in regional net-zero targets.

  Through the Hydrogen in the National Transmission System (HyNTS) programme of work an extensive number of projects are being run alongside Project Union which will provide input and evidence into the feasibility of a hydrogen backbone and how it can be delivered for the best of value to the UK as a whole.

- **Benefit to gas network users**: the proposed activity for the Feasibility Phase will support the realisation of a number of benefits to existing and future gas network users that repurposing can offer, including:

  - *Avoided decommissioning costs*: where elements of the existing methane network can be re-purposed, this would avoid the need for decommissioning costs in the longer term.
  - *Mitigation of stranding risks*: CMA and GEMA both signalled in RIIO-2 appeals that it is possible that methane network stranding risk could lead to further acceleration of RAV regulatory depreciation profiles, resulting in an increase to bills in the nearer term. Asset repurposing offers the opportunity to mitigate future stranding risks and costs, and potentially support maintenance of lower bill profiles in the near term (subject to the emerging situation ahead of RIIO-3).
  - *Incentives to enhance and maintain the methane network*: it will be more attractive to invest in maintaining and upgrading the methane network in the near term if there are viable futures to repurpose well maintained assets to transport hydrogen. Without such incentives, ongoing investment in the methane network could move into a “managed decline” scenario to the detriment of performance and reliability (subject to underlying minimum standard obligations).

- *Operational synergies*: in a transitional period, the methane and hydrogen networks would coexist. This would mean that company level business support costs required to support the methane and hydrogen networks (for instance head office costs, IT costs and centralised functions such as finance, procurement and legal) would be shared over a wider asset base. There may also be opportunity lever greater buyer power in the relevant marketplaces, and greater efficiency in work planning and scheduling where internal resources and capabilities are interchangeable between methane and hydrogen assets.
- Financial benefits: where a RAV based model is adopted for both, collective management of methane and hydrogen investments provides the opportunity to pool financial risks. This might further mitigate the need to accelerate depreciation of the methane RAV, potentially supporting lower and flatter bill profiles for methane users during the Net Zero transition.

Specifically, we proposed that the Net Zero Pre-Construction Works and Small Net Zero Projects Re-opener is the most appropriate mechanism to fund this proposal *Appendix EE - Funding Mechanism Appraisal* is provided as an appendix to this submission, which supports how we have arrived at this conclusion. This includes an assessment of non RIIO-2 funding mechanisms that were considered as part of the Strategy phase.

9.2 Funding mechanism and eligibility

The previous section supports the conclusion that the RIIO-2 NZASP mechanism is the most appropriate route to fund this proposal.

In accordance with Ofgem's supporting governance document[42], projects put forwards under this mechanism must meet the following criteria:

- The mechanism is intended to have broad scope, but noted examples of eligible projects in the governance document are:
  - Early development, design and general pre-construction work that will enable the achievement of Net Zero Carbon Targets
  - Front-End Engineering Design (FEED) studies, conceptual design pre-FEED and general feasibility work required for large capital projects
  - Net Zero projects that exceed the £2m materiality cap of the Net Zero and Reopener Development Use It or Lose It Allowance or are otherwise not suitable for that mechanism
  - Net Zero projects that do not meet the materiality threshold for the Net Zero Reopener
  - Net Zero facilitation (green gas and hydrogen) projects and hydrogen projects that are required as part of the Department for Business, Energy & Industrial Strategy Hydrogen Grid Research and Development Programme, including projects that may be interpreted as innovative – where there is a clear need and it is appropriate for network consumers to fund.
- A minimum materiality threshold of £1m per project

[42] Ofgem: Net Zero Pre-construction and Small Net Zero Projects Re-opener Governance Document

The scope of this proposal is therefore well aligned to the eligibility criteria for the re-opener mechanism.

9.3 Funding principles

Linked to the Regulatory Funding Justification' section above, our pre-trigger engagement with Ofgem has provided valuable insight into key funding principles to be observed in the formulation of this re-opener application, and which can be used to inform the specific mechanics of regulatory treatment of proposed costs within the boundaries of established parameters for RIIO-2.

Of particular relevance to regulatory treatment are the following key principles:

- Bill payers should be protected from undue cost exposure whilst the policy for the full role of hydrogen evolves. A stage gated approach to project funding, and targeted funding for critical activities required to inform policy and enable future project phases during the Feasibility Phase will minimise customer bill impact and if actual costs materialise lower than the requested funding, this should be returned to customers in full.
- The full role of hydrogen is yet to be established, and regulatory and market mechanics will evolve over time. Using a RAV based model to recover costs has the effect of allocating costs to an uncertain future, thus creating cost stranding risks. The implication for regulatory treatment is therefore that capitalisation of Feasibility Phase costs to the RAV should be avoided at this stage, and costs recovered within the RIIO-2 period.
- Net Zero funding mechanisms within the RIIO-2 framework are primarily aimed at lower scale innovation and enabling works. This has two broad implications for regulatory treatment of the proposed Feasibility Phase costs:
    - Minimisation of funding requests to reasonable and justifiable materiality thresholds
    - This further underlines a view that totex incentivisation as applied to investment in the methane network is not appropriate for Project Union Feasibility phase costs, and any cost savings should be returned in full.
- Other gas network hydrogen projects have been funded on the basis that they support building the evidence base needed to support Government policy and decision making

These principles directly guide the proposed regulatory treatment that follows in this chapter.

9.4 Proposed regulatory treatment

Proposals made in this chapter are intended to apply on a non-precedential basis. This is because future policy clarifications may inform appropriate funding routes and specific regulatory treatments for subsequent project phases.

Cost recovery speed and totex incentivisation

Under the standard parameters included in the RIIO-2 Price Control Financial Model (PCFM), the Net Zero Pre-Construction Works and Small Net Zero Projects Re-opener mechanism would be subject to totex incentivisation with RAV capitalisation at 75%. However, for the reasons noted above, we propose that the

Feasibility Phase is not subject to totex incentivisation and carries a 0% RAV capitalisation rate. The desired effect could be achieved in one of two ways:

- Specific totex incentivisation and capitalisation treatment could be configured within the RIIO-2 PCFM. This would require structural changes to the PCFM.
- Alternatively, the Net Zero Pre-construction Work and Small Net Zero Projects Re-opener pass through term of the Licence and PCFM (NZPSt) could be utilised. This would avoid the need for structural change to the PCFM, however the current drafting of the Gas Transporter Licence would need to be adapted, as this is currently designed to facilitate the pass though of Gas Distribution Network funding of Net Zero Pre-Construction Works and Small Net Zero Projects Re-opener projects r recovery through Gas Transmission charges. We note that Ofgem's November 2022 consultation which proposes this option.[43]

9.4 Allowed revenue and bill impacts

The impact of proposed project costs and regulatory treatment to allowed revenue and consumer bills are shown in Table 25. Bill impacts are based on current Gas Transmission chargeable base position and using a methodology for estimated domestic bill impact previously agreed with Ofgem.

Under our proposed regulatory treatment, all investment would be recovered in the RIIO-2 price control, resulting in a 0.1% increase to allowed revenues and an 8p increase to domestic bills in the period.

Please note that for simplicity, these analyses cover direct investment recovery only. Additionally, they are presented in 2022/23 prices rather than 2018/19 prices, in order to be more reflective of actual impacts through revenues and transportation charges:

[43] Statutory consultation on modifications to the Gas Transporters' RIIO 2 NZASP re-opener licence conditions

Table 25 Impact on bills (based on current NTS charging parameters)

10. Adopting a proportionate approach to evidence

Network companies are required to consider the proportionality of the evidence provided in support of re-opener applications, and to that end the following key factors have shaped the structure, content and scope of this application:

1. Government policy on the full role of hydrogen in a Net Zero future continues to evolve. However, policy indicates a clear signal for hydrogen, and it is essential that this is supported with the development of infrastructure and a liquid, competitive UK wide market.
2. Market conditions for a hydrogen economy are in their very early stages and will rapidly advance over the next decade.
3. Our stakeholder engagement has consistently demonstrated a need for Project Union to allow hydrogen producers, storage operators and end users to plan their own schemes and to enable a hydrogen market to develop as early and efficiently as possible.
4. Taking a holistic approach by considering the whole network in the Feasibility Phase will enable a credible phasing strategy, timeline and coherent routing for the full hydrogen backbone to be determined in the most efficient way. Additionally, conducting the pre-FEED work for the full hydrogen backbone creates efficiencies for data collection and network modelling.
5. European policy for hydrogen continues to evolve with targets of 20Mt of hydrogen production capacity targeted by 2030, half of which are imports. A UK hydrogen backbone connected to a wider European Hydrogen Backbone will enable continued cross border trade and access to emerging European and Global hydrogen markets.

6. The uncertain landscape creates a risk of inefficient and uneconomic investment, and the potential for asset and cost stranding where the full future customer base is as yet unknown. As part of building a compelling needs case for the investment proposed in this request, in conjunction with [redacted], we have undertaken an economic appraisal to estimate the societal benefit of the Hydrogen pipeline route that our Feasibility Phase of Project Union will support and have employed a Real Options Analysis to validate and value commencing work now amidst this uncertainty. This work concluded that investing now to scope out the work to repurpose gas transmission assets for hydrogen transportation is low risk and there is significant benefit in retaining optionality for future decisions as more information becomes available (for example, through policy decisions for hydrogen on blending and hydrogen's role in heat, and the outcomes of FutureGrid and other in-flight innovation projects). Critically, exploring the viability and phasing of asset repurposing now postpones decommissioning and prevents evolving hydrogen options being limited to expensive new build options.
7. Given the length of time required to plan for and deliver critical national infrastructure, if the UK is to achieve its Net Zero targets by 2050, there is a clear need to act now and at pace. Delivering this relatively low-cost preparatory work now will position the UK to progress more swiftly on the most economically advantageous and effective pathway to a hydrogen economy by enabling infrastructure to keep pace with developing hydrogen supply and demand.
8. Net Zero mechanisms were introduced by Ofgem under the RIIO-2 framework designed to work as a coherent package of measures to ensure network companies have sufficient flexibility to bring forward both strategic network investments for Net Zero and respond to changes in network requirements. Until alternative arrangements for the funding of hydrogen activities can be implemented, utilisation of the RIIO-2 Net Zero mechanisms provides the best currently available option to undertake necessary preparatory work, and we consider this to be appropriate given that the scope of this submission relates to current regulated assets, offering significant benefits to existing consumers either by avoiding asset stranding or future decommissioning costs, or through providing future options to access zero carbon energy.

The evidence provided in this submission reflects the nature of these important considerations, and we have aimed to strike an appropriate balance given the uncertainties involved, the "first of a kind" nature of the project, and the relatively low materiality[44] of the funding proposed:

- We demonstrate how our proposed works address key gaps in the evidence base required to support future policy decisions regarding hydrogen infrastructure across topics of the role of a hydrogen backbone in a future energy system, engineering and asset readiness and regulatory framework and funding options.
- An initial assessment of the societal benefit of the anticipated hydrogen pipeline route this funding will support has been undertaken to ensure a compelling needs case that is robust to future uncertainty.

[44] Proposed project costs of £7.935m would represent an increase of 0.4% on total baseline Gas Transmission totex funding in RIIO-2

- Real Options Analysis has been employed to give confidence that acting now provides value to society through optionality amid uncertainty.
- We show how we have optimised the use of existing Net Zero baseline and innovation funding routes to minimise the amount of additional funding being proposed.
- A stage gated approach to project development has been adopted, meaning that funding is proposed only for those critical activities and outcomes that will allow the project to progress through a Feasibility Phase and that are enabling to future project phases. This approach has a number of benefits:
    - Limiting the funding proposal to the immediately required activities allows Government and Regulatory policy to evolve alongside
    - Focussing scope only on the necessary enabling activities at this stage ensures congruence with the current policy position, and significantly protects against the risk of sunk investment now and in the future
    - Cost and risk exposure to bill payers is minimised whilst ensuring sufficient funding to avoid regulatory burden for multiple separate submissions
- The proposed funding is primarily aimed at building evidence where this does not currently exist. As such the current maturity of information and data does not lend itself to the level of quantified analysis that might support a typical methane network investment decision. Instead, we seek to evolve and iterate over time through a phased approach, at each stage making step changes in the level and quality of information available. Undertaking Pre-FEED activities for the whole hydrogen backbone now will enable the broadest evidence base to be collected and assessed, thereby removing as much uncertainty as possible from future decisions on phasing whilst investment costs remain relatively low. This approach will help ensure the most optimum solutions are progressed to the FEED phase in alignment with developing policy and need.
- Despite the relatively low value of the proposal, it is imperative that the project has demonstrable value to current bill payers under the Gas Transmission RIIO-2 framework, which we address within this submission.

11. Assurance

As a part of our assurance requirements required under Ofgem's Re-opener Guidance we will provide confirmation from our Regulation Director who is accountable for the RIIO-2 regulatory allowances to provide assurance that the three assurance points requested by Ofgem have been met in our final submission. These three points and activities that will be undertaken include:

It is accurate and robust, and that the proposed outcomes of the Re-opener are financeable and represent good value for consumers

- The application that will be submitted will have been prepared by a multi-disciplinary team involving leaders from UK Regulation, Gas Transmission and System Operations. Iterative internal challenge and review between these teams supports the accuracy and robustness of the proposals.
- The relevant senior leaders will confirm support for the re-opener proposals in terms of needs case, consumer benefits, deliverability inside RIIO-2 years 1 to 3 and alignment with wider business strategy.
- Value to consumers is demonstrated through investment to develop a Hydrogen ready network to align with Government Net Zero targets.

There were quality assurance processes in place to ensure the licensee has provided high-quality information to enable Ofgem to make decisions which are in the interests of consumers

- The information in the submissions and supporting files will, as a minimum, been subject to both peer review and approval by a manager more senior than the author.
- Calculations of proposed allowances presented in the re-opener submissions will be assured by the relevant Finance Business Partners.
- The applications will be subject to robust assurance and are accompanied by supporting information which includes the relevant DAG Submission Assurance Reports and Risk Assessments.
- The application will include a table that maps out which sections of the application relate to individual requirements as set out in the relevant re-opener license condition and NZASP guidance.
- Draft contents of the applications will have been shared in advance with Ofgem through this draft and will be discussed in a series of pre-application bi-lateral meetings during July 2022. The purpose of these sessions is to support the agile, efficient and proportionate process for re-openers outlined by Ofgem in Final Determinations. We will take on board Ofgem's feedback from those sessions leading us to understand that our applications provide a proportionate amount of evidence having regard to the values of allowances and complexity involved.

The application has been subject to internal governance arrangements and received sign off at an appropriate level within the licensee

- The submission has and will be subject to internal governance through monthly meetings chaired by the Asset Director.

The above points will be re-confirmed within our final submission of this re-opener alongside our DAG assurance assessment. *Supplementary Document G - Assurance letter* is included with this submission.

12. Glossary of terms

Term	Definition
AM	Assessment Methodologies
AMP	Asset Management Plan
AMSO	Asset Management Strategy and Objectives
ANCAR	Annual Network Capability Assessment Report – Reporting document in which National Grid Gas Transmission calculate and demonstrate the physical capability of the NTS and how that capability compares to the needs of our customers now and into the future.
BEIS	Department for Business, Energy and Industrial Strategy
Benchmarking	The process used to compare a company's performance (e.g. its costs) to that of best practice or to average levels within the sector.
Blue Hydrogen	"Blue" hydrogen splits natural gas into hydrogen and carbon dioxide, with the carbon captured and stored.
CBA	Cost Benefit Analysis
CCC	Committee for Climate Change
CNI	Critical National Infrastructure
CMA	Competition and Markets Authority
Consumer	In considering consumers in the regulatory framework, we consider users of network services (for example generators, shippers) as well as domestic and business end consumers, and their representatives.
Depreciation	Depreciation is a measure of the consumption, use or wearing out of an asset over the period of its economic life.
ECH2	East Coast Hydrogen. A collaborative project between National Grid, Cadent and Northern Gas Networks
Economic Life	The period over which an asset performs a useful function.
FEED	Front End Engineering and Design
GDNs	Gas Distribution Networks- There are 8 individually licenced gas network areas operated by 4 companies: Cadent, Northern Gas Networks (NGN), SGN and Wales & West Utilities (W&WU). The GDNs are supplied with most of their gas from the NTS and deliver it to industrial, commercial and domestic customers.
GIS	Geographic Information System
GEMA	Gas and Electricity Markets Authority

Green Hydrogen	“Green” hydrogen uses electrolysis, passing electricity through water to separate out the hydrogen and oxygen
GSMR	Gas Safety Management Regulations
GTIC	Gas Transmission Investment Committee
GVA	Gross Value Added- The value generated by any unit engaged in the production of goods and services.
ILI	In-Line Inspection – an internal inspection technique for our pipelines
Licence Conditions	An obligation placed on the network companies to meet certain standards of performance. The Authority (GEMA) has the power to take appropriate enforcement action in the case of a failure to meet these obligations.
Low Regrets	Actions that are relatively low cost and provide relatively large benefits under predicted future climates.
LTS	Local Transmission System- The pipeline system operating above seven bar that transports gas from national transmission system offtakes to distribution systems.
MEAT	Most Economically Advantageous Tender
NGN	Northern Gas Networks
No Regrets	Actions that are cost-effective under current climate conditions and are consistent with addressing risks of climate change, they possess no hard trade-offs with other policy objectives.
NPV	Net Present Value- The discounted sum of future cash flows- whether positive or negative, minus any initial investment.
NTS	National Transmission System- The high-pressure gas transmission system in Great Britain
NZASP	Net Zero Pre-construction Work and Small Net Zero Projects Re-opener- This mechanism allows Gas Transporter licensees to undertake early design, development, general pre-construction work, and Net Zero facilitation capital projects that will enable the achievement of Net Zero Carbon Targets.
Ofgem	Office of Gas and Electrical Markets
Option 3A	The base case option subjected to Cost Benefit Analysis, Economic Assessment and Real Options Analysis by [redacted] It describes a partial hydrogen backbone connecting the East Coast cluster (Humber to Teesside).
Option 3B	A partial hydrogen backbone connecting the East Coast, HyNet and Scottish clusters (3A + Teesside to Grangemouth, Grangemouth to St. Fergus, Humber to Merseyside).
Option 3C	The high-case option subjected in the Economic Assessment carried out by [redacted] It describes a UK hydrogen backbone connecting all industrial clusters (3B + South Wales-Bacton-Humber, Southampton-Cavendish).

PCFM	Price Control Financial Model
Price Control	The control developed by the regulator to set targets and allowed revenues for networks companies.
RAV	Regulatory Asset Value- The value ascribed by Ofgem to the capital employed in the licensee's regulated transmission business.
Regulatory Burden	A term used to describe the cost- both monetary and opportunity- of regulation.
RIIO	Revenue=Incentives + Innovation + Outputs (Ofgem's regulatory framework)
ROA	Real Option Analysis- A decision evaluation approach that considers the opportunity cost of continuing or abandoning a project
RPE	Real Price Effects- Expected changes in input prices, e.g. wages, relative to the Retail Price Index (RPI)
RPI	Retail Prices Index- An aggregated measure in changes in the cost of living in the UK.
SGN	A gas distribution company, previously known as Scotia Gas Networks, that operates the networks in Scotland and Southern England (including South London).
TOTEX	Total expenditure- Totex generally consists of all the expenditure relating to a licensee's regulated activities but except for some specified expenditure items. The annual net additions to RAV are calculated as a percentage of the Totex.
UIOLI	Use It or Lose It. A funding approach whereby unspent money is clawed back.
UMs	Uncertainty Mechanisms – A process that allows price control arrangements to respond to change within a price control period. They protect both end consumers and licensees from unforecastable risk or changes in circumstances.

13. Figures, Tables and Supplementary Documents

Supplementary Document A – Mapping to regulatory requirements
Supplementary Document B - Assessment Methodologies
Supplementary Document C - Economic Appraisal
Supplementary Document D - Real Options Analysis
Supplementary Document E - Outcomes to Evidence Need Mapping
Supplementary Document F - Feasibility Phase Costing Model
Supplementary Document G - Detailed Feasibility Phase Delivery Plan
Supplementary Document H - Assurance Letter

14. Appendices

Appendix A - Customer and Stakeholder engagement
Appendix B - Ofgem Pre-Trigger Engagement
Appendix C - Risk Register
Appendix D - Supporting Project Summary
Appendix E - Funding Mechanism Appraisal

Appendix A – Customer and Stakeholder Engagement

To ensure we have a clear understanding of our stakeholders' decarbonisation plans and the interactions with Project Union, we have developed a comprehensive stakeholder map. We have taken a two-stage approach to our engagement. The first stage has focussed on engaging directly affected stakeholders who we will work with to develop our plans going forward. A summary how we have engaged can be seen in Table 26 Table 26 Stage 1 engagement. Stage 2 of our engagement will be delivered in the Feasibility Phase. We will continue to engage with stakeholders outlined in Stage 1 as well as engage more broadly with non-directly affected stakeholders who we feel need to have visibility of and input into the planning process.

Stakeholder feedback has helped to understand the opportunities and benefits that Project Union can deliver and identified challenges and questions that need to be addressed. These have been incorporated in the programme of work.

Stage 1 Engagement

Stakeholder Group	Approach
Directly connected Power Stations	• One to one meetings • Targeted and broad webinars • Regional working groups
Directly connected Industrials	• One to one meetings • Targeted and broad webinars • Regional working groups
Industrial Clusters	• Regional groups • Webinars • Regional working groups
Local Authorities	• Regional groups • Webinars
Hydrogen Producers	• One to one meetings • Webinars • Regional groups
Interconnectors	• One to one meetings • Webinars • Regional groups
Consumer and Consumer Representatives	• Consumer listening events • Consumer research studies • Webinars • One to one meetings
Government	• Project Union Launch • One to one meetings

Table 26 Stage 1 engagement approach

Stage 2 Engagement

Following our stage 1 engagement we need to deepen relationships with production and demand centres to collect data around production and demand scenarios and timing of developments to allow us to develop routing options and understand phasing requirements.

Stakeholder groups	Outcomes	Engagement
Directly connected customers including power stations and industrial consumers	• Progress relationships • Inform customers about decarbonisation aspirations • Understand customers' decarbonisation plans including flows and timescales • Understand technical capabilities of customers assets including any sensitive users • Support engagement with OEMs to build H2 readiness and transition plans • Identification of delivery of new collaboration opportunities	Quarterly working meetings Strategic engagement Hydrogen Acceptability research Regional working groups Webinars Customer engagement hub
Gas Distribution Networks	• Progress relationships • Understand decarbonisation plans including flows and timescales • Collaboration opportunities	Strategic engagement Regional collaboration projects Webinars Customer engagement hubs Collaborative consumer research
Hydrogen producers	• Progress relationships • Understand production plans including flows and timescales • Identification of new collaboration opportunities	1-1 meetings Strategic relationships Modelling studies Connections engagement
Key stakeholders	• Develop relationships • Understand and align strategies • Understand concerns/blockers to decarbonisation • Create advocates	Strategic engagement with key customers and stakeholders Webinars Research pieces to inform thinking

Table 27 Stage 2 engagement approach

We recognise there is a need to engage more widely than those stakeholders directly affected to build out and garner support for our transition plans. This forms a second aspect of Stage 2 in our engagement strategy and will involve webinars, events and a social media campaign to create visibility of our plans across a wider audience.

Stakeholder groups	Outcomes	Engagement
Connecting demand and Production centres		
Unimpacted customers Broader stakeholders	• Inform customers/stakeholders about decarbonisation aspirations • Provide opportunity to get involved and have their say in approach • Identification of new collaboration opportunities • Understanding of blockers/challenges • Whole energy system plans	Conferences Webinars 1-1s Newsletters Research studies
Hydrogen sceptics	• Understand challenges to hydrogen • Inform with latest research and plans • Develop relationships • Feed challenges and insights into our plans	1-1 meetings Research studies to inform thinking Social media
Trade bodies	• Inform customers/stakeholders about decarbonisation aspirations • Provide opportunity to get involved and have their say in approach • Gather the voice of their membership i.e. supply chain challenges, major energy user insights • Whole energy system view	Attend trade body meetings Dedicated webinars/events Surveys to members
Industry stakeholders	• Greater visibility and understanding of the project • Greater understanding of the role methane /hydrogen can play to support decarbonisation • One stop shop allowing stakeholders to self-serve the information they need	Create online presence including social media (LinkedIn, Twitter) Webinars Industry conferences
Local government	• Inform and update with latest research and plans – Relevance to their area • Ensure gas/hydrogen is a consideration and part of the decarbonisation plans for the region • Understand their plans to decarbonise and how gas can support the transition	Feed into local energy planning Site visits Webinars
All stakeholders with an interest	• To inform and update with latest research and plans • Understand stakeholder priorities/concerns and broaden the knowledge of the role hydrogen can play in the transition to Net Zero	Summit/Events Webinars Social media

Understanding Potential Growth		
Maritime, aviation, freight	• Develop relationships • Understand current decarbonisation plans, timings, challenges and enablers • Inform and signpost how gas/h2 could support decarbonisation aspirations • Identification of new collaboration opportunities	1-1s with trade bodies Discussion panels Presenting at events
Major energy users not connected to the NTS	• Inform and signpost potential for NTS to support decarbonisation • Understand segment decarbonisation plans, blockers and landscape	Attend Trade body conferences and direct engagement Market analysis and horizon scanning
Hydrogen for Domestic Customers		
Consumer supply chain i.e. Plumbers, Builders, Housing	• Raise visibility of the role methane and hydrogen can play in transition to Net Zero • Provide reassurance and signpost the research that's going on to allow them to inform their clients • Provide mechanism to ask questions	Consumer supply chain trade press Conferences Targeted social media Thought pieces
Citizens, consumers – each campaign will be targeted at a different audience)	• Value of gas and the role it plays in society is recognised • Raise visibility of hydrogen in broader public consciousness • Hydrogen is seen as a renewable gas • Understand key questions consumers have around hydrogen • Develop and implement an engagement programme to address key questions	Social media campaign Consumer research 1-1's with consumer representatives

Table 28 Stage 2 engagement

See Supplementary Document F - Detailed Feasibility Phase Delivery Plan is included with this submission. The key critical milestones for the Feasibility Phase as determined through the planning phase are summarised includes a milestone plan

Appendix B – Ofgem Pre-Trigger Engagement

Where a licensee intends to access funding via Net Zero Re-Opener mechanisms, Ofgem's associated governance and guidance document require that networks undertake a period of pre-trigger engagement with the regulator in order to establish a needs case in principle.

We have undertaken valuable and constructive engagement with Ofgem through a series of regular bilateral discussions over a 15-month period commencing September 2021.

The table below summarises this engagement, linked to the required topic areas specified in the governance document:

Engagement Requirement	Information Shared	Key feedback and actions taken
What is being proposed?	• Initial structural skeleton for the re-opener submission linked to requirements, and updates thereon • Draft of the re-opener document ahead of submission • Build out of mapping of project outcome and effort to key evidence needs • Expansion of the proposed scope from 2 initial links to the full backbone was discussed and the merits explored	**Feedback:** linking project activity and outputs to policy gaps is critical given the stage of maturity of the hydrogen market and provides a basis to ensure effort is targeted to the right issues. **Action:** the culmination of the discussion on linking scope to evidence needs is reflected in the 'Needs Case' chapter above.
The project cost	• An evolution of developing thinking on project costs, and how this has taken shape alongside refinement of the needs case and scope	**Feedback:** valuable discussion on the composition of costs (internal / split and weighting), treatment of Real Price Effects and assumptions for ongoing efficiency. **Action:** the 'Value for Money' chapter aims to provide a transparent articulation of project cost composition.
The aim of the project and evidence that it fits into wider strategic goals	• This formed the basis of early pre-trigger discussion, articulating the vision and aims for NGGT asset repurposing and alignment to strategic objectives • Being a vital stakeholder, Ofgem representative were invited to the Project Union launch event hosted by National Grid in May 2022.	**Action**: the underlying benefit of the expected initial routes has been assessed through CBA undertaken by [redacted] Confidence in the value of starting work now (on the initial route) is underpinned by [redacted] work on Real Options Analysis. These aspects are covered earlier in the 'Needs Case' chapter.

Why it is appropriate for this to be funded by network consumers through this re-opener?	• Initial drafts of gas network user benefits prepared in conjunction with [redacted] • Early views of domestic bill impact under different regulatory funding models (Innovation vs Totex)	**Feedback**: if the project is to be funded though the RIIO-2 price control, vital that the benefit and value to gas network users is clearly demonstrated **Action:** anticipated benefits to gas network users are included in the 'Funding Justification' sub section of the 'Policy Justification' chapter. Estimated domestic bill impacts are shown in the 'Regulatory Treatment and Impact chapter'
How the funding should be treated from a regulatory point of view?	• Pro and cons of different regulatory treatment under Innovation and Totex models • Forecast allowed revenue and bill impacts under the two models	**Feedback**: discussion on funding principles for the NZASP mechanism, particularly regarding concerns for asset stranding where a hydrogen customer base does not yet existing, and the extent to which it can be assumed (at this stage) that gas users become the hydrogen users of the future. **Action:** the general approach for this application is to limit proposal to only the necessary activities at this time, and seek funding on a stage gated basis, all with a view to limiting bill payer exposure. Additionally, the rationale for our proposed regulatory treatment is intended to be aligned to this key concern (please see 'Regulatory Treatment and impact' chapter)
The timelines for the project including its anticipated length and the submission dates for the detailed assessment phase	• Updates to expected project timelines were shared on a regular basis • The timings for detailed submission evolved as part of the engagement	**Feedback:** the appropriateness of funding hydrogen infrastructure projects through the RIIO-2 price control was a regular feature of discussion. **Action**: we have aimed to address Ofgem's key areas of concern throughout the document. Understandably, this important debate has been consequential to project delivery timeframes. However, discussion with Ofgem has helped to ensure optimised use of the NZ UIOLI funding allowance in the interim. Please see the 'Value for Money' section for more information.

Table 29 Summary of Ofgem Pre-Trigger Engagement

As a part of our pre-trigger engagement with Ofgem we have held several meetings since 2021 to discuss the progress and strategic direction of Project Union. These meetings have been informative in helping us to build out our re-opener scope and structure. A summary of the engagement held with Ofgem to date is included in the table below.

Date	Topic	Attendees	Key Discussion Points
30/9/2021	Project Union	[redacted]	• Project Union deep dive on key messages and strategic narrative • Role of Union in wider context, including interactions with East Coast and other live projects • Understanding Ofgem's pre-trigger requirements

			Alignment to Ofgem engagement activity: What is being proposed? And The aim of the project and evidence that it fits into wider strategic goals
21/10/2021	Project Union	[redacted]	• Overview of Project Union • Need for Project Union to be established to meet wider strategic goals in line with Net Zero targets • Delivery Roadmap and funding requirements • Stakeholder Engagement Alignment to Ofgem engagement activity: What is being proposed? The aim of the project and evidence that it fits into wider strategic goals, and How funding should be treated from a regulatory point of view
2/11/2021	NZ tracker: Ofgem/NGG	[redacted]	Discussion around how Project Union and East Coast Hydrogen work together Alignment to Ofgem engagement activity: What is being proposed?
10/11/2022	NZ overview: Ofgem, NGG	[redacted]	• Reopener Build discussion. It was acknowledged that the reopener build and policy challenge would need to be built in parallel but separating them to allow progress to be made. It was recognised that the importance of working in principle and detailed application in parallel was needed. • Acknowledgement of the high level scope of work Frontier are working on with us to address some of the challenging regulatory framework questions. • Agreement of a 6 weekly cycle of overview meetings which will be complimented by project level deep dives as appropriate. Alignment to Ofgem engagement activity: What is being proposed? And The aim of the project and evidence that it fits into wider strategic goals
11/1/2022	Project Union	[redacted]	• Discussion around the funding of hydrogen projects such as Project Union • Clarity that the re-opener will not be triggered in April 2022 whilst the question of funding route is established • Ofgem discussed that they had been talking to BEIS on the issue of funding and would continue to do so in the coming months • Ofgem noted that the high level material shared on the planned re-opener was reasonable and did not need a full EJP for pre-FEED. Alignment to Ofgem engagement activity: What is being proposed? And How the funding should be treated from a regulatory point of view?
26/1/2022	Project Union	[redacted]	• Noted that Ofgem found the articulation of the needs case helpful. With a request that NGGT provide: a. For the pre-FEED be specific on what evidence will be generated and how it will feed policy decisions b. Quantification of benefits

			• Noting that Ofgem found the conversation helpful re soft accounts unbundling (and particularly welcomed that the context that we recognised the message re the need for policy to steer decisions) Alignment to Ofgem engagement activity: What is being proposed? The aim of the project and evidence that it fits into wider strategic goals, and project cost
28/2/2022	Project Union	[redacted]	• Discussion on how NGGT will articulate: Specifics on what evidence will be generated and how it will feed policy decisions; quantification of benefits. • Noted that against each output the key to identify how output will link to evidence base for Gov; demonstrate proportionate benefit to cost. Alignment to Ofgem engagement activity: What is being proposed? And The aim of the project and evidence that it fits into wider strategic goals
7/4/2022	Project Union	[redacted]	• Discussion of funding routes and discussions between Ofgem and BEIS to date Alignment to Ofgem engagement activity: How the funding should be treated from a regulatory point of view
28/4/2022	Project Union	[redacted]	• Request for Information - Confirmed this covers all Net Zero hydrogen projects within RIIO2 - Aim is to get an understanding of what we see the projects potentially being used for and evidence generated An overview of the Evidence Mapping – which was received well by Ofgem and BEIS • Economic Appraisal Summary and questions around the testing boundaries of assumptions and impact on output. Alignment to Ofgem engagement activity: What is being proposed? And The aim of the project and evidence that it fits into wider strategic goals
12/05/2022	Project Union	[redacted]	• Real Options Analysis (ROA) Overview from [redacted] Agreement that NGGT will spend more time working with [redacted] on how we can learn and apply ROA across our activities • Request for Information follow up discussion. Alignment to Ofgem engagement activity: What is being proposed? And The aim of the project and evidence that it fits into wider strategic goals
25/05/2022	Project Union	[redacted]	• ROA [redacted] talked through the updated output and the sensitivity re impact of a pause after completing pre-FEED/FEED • NGGT discussed emerging project costs for the upcoming pre-FEED activity and our considered appropriate phasing which would be discussed in the next meeting. Alignment to Ofgem engagement activity: The aim of the project and evidence that it fits into wider strategic goals and the project cost

21/06/2022	Project Union	[redacted]	• Update from GEMA Board Hydrogen discussion. It was noted that Ofgem expect to be in a position to share outcome early July • NGGT gave an update on the phasing of Project Union • Cost update discussion and agreement from Ofgem to take away the question or reopener funding "paying back" UIOLI money spent now we are in the transition phase Alignment to Ofgem engagement activity: The aim of the project and evidence that it fits into wider strategic goals and the project cost
18/07/2022	Project Union	[redacted]	• GEMA funding discussion update • GEMA needs to be clear on the benefit to current and future natural gas consumers to see a way to funding hydrogen projects via RIIO. To be discussed further at September GEMA meeting • Ofgem not yet in a position to trigger for Project Union • NGGT agreed to share narrative on how current and future natural gas consumers will benefit from Project Union • Mapping of how the next phase of PU will support Government decision making Alignment to Ofgem engagement activity: The aim of the project and evidence that it fits into wider strategic goals and why it is appropriate for it to be funded by network consumers through this reopener.
04/08/22	Project Union	[redacted]	Draft reopener shared in advance of the meeting. Presented slides covering: • Direct benefit to methane customers • Update on reopener progress, including work to expand scope to multiple links and appropriate transfer of activities to separate UIOLI projects to enable progress • Regulatory tools to retarget investment recovery once enduring arrangements emerge • Received feedback on draft reopener Alignment to Ofgem engagement activity: The aim of the project and What is being proposed and evidence that it fits into wider strategic goals and why it is appropriate for it to be funded by network consumers through this reopener.
05/10/22	Project Union	[redacted]	• Shared outcome of recent GEMA meeting on funding • Hydrogen feasibility activities can be progressed through RIIO • For Project Union, NGGT needs to provide clarity on remaining cost in scope for reopener to move to trigger • Opportunity to spend at risk following trigger ahead of decision Alignment to Ofgem engagement activity: Why it is appropriate for it to be funded by network consumers through this reopener.
16/11/22	Project Union	[redacted]	• Update of finalising trigger document • Feedback from Ofgem to include an update on what 'top up' feasibility work may be needed on later links, articulation of benefit of doing full backbone now and timings set against the wider hydrogen strategy Alignment to Ofgem engagement activity: The aim of the project and why it is appropriate for it to be funded by network consumers through this reopener.

Table 30 Summary of Ofgem Pre-Trigger engagement

Appendix C – Risk Register

The top 5 risks to delivery of the Feasibility Phase are identified below. Although these are not monetised, they are a key consideration in the establishment of the contingency cost in this submission.

Work package/ Area Name	Risk statement	Impact	Probability	RAG	Risk Escalation	Risk response	Mitigation
Planning Scenario	*There is risk that our planning scenario does not reflect our customer and stakeholder requirements due to insufficient data and information resulting in potentially losing credibility and wrong solutions being proposed.*	[redacted]	[redacted]	[redacted]	Hydrogen SteerCo	[redacted]	*We have engaged with and will continue and expand our engagement with Customer and Stakeholders to gather data through Transition Strategy Phase and will gather further data as we progress which we will feed into the decision making process for PreFEED and Phasing Strategy.* *We have agreed a plan decision point for baselining the network modelling and established the minimum data requirements to support the modelling.*
[redacted]							

Work package/ Area Name	Risk statement	Impact	Probability	RAG	Risk Escalation	Risk response	Mitigation
[redacted]							

Table 31 Risk Register

Appendix D – Supporting Project Summary

Project Union is directly or indirectly supported by a number of related projects funded under various mechanisms. These projects are being run alongside Project Union and will provide crucial inputs and evidence into the feasibility of a hydrogen backbone and how it can be delivered for the best of value to the UK as a whole.

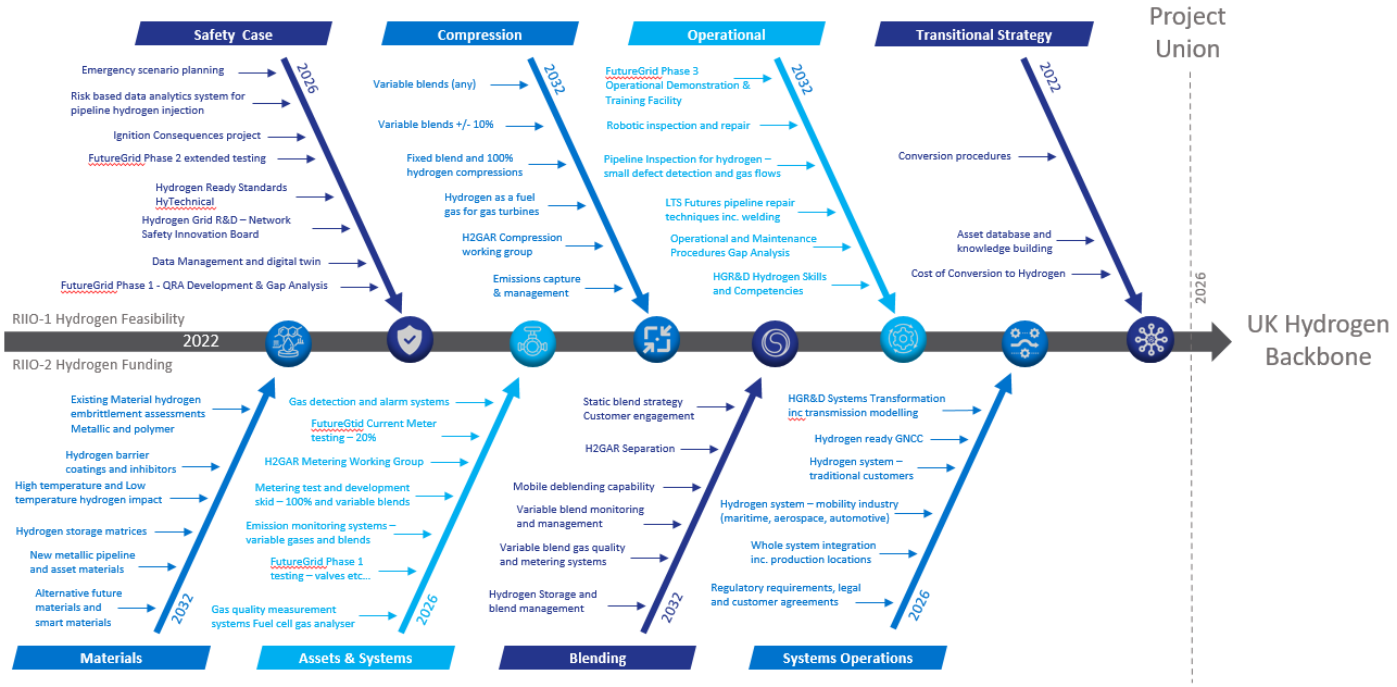


Figure 14 Supporting projects fishbone diagram

A summary of the supporting projects, and their relationship to Project Union is included in the table below. Values shown are project sanction values in nominal prices as of December 2022 where projects are open.

Project	Funding Mechanism	Overview and supporting role	Cost (£m)	Status
East Coast Hydrogen	NZ UIOLI	A collaborative project between Gas Transmission, Northern Gas Networks and Cadent Gas to enable regional decarbonisation through both repurposing and building new pipeline infrastructure. NTS infrastructure would crossover and contribute to Project Union and East Coast Hydrogen. .		Open
Real Options Analysis (ROA)	NZ UIOLI	The ROA framework will look for optimal decisions over time and given uncertainty, it allows decisions to be made later if proven to be optimal, by allowing all inputs to be captured in a robust decision-making framework. The framework will demonstrate that uncertainty is being properly accounted for, reducing the risk of consumers paying "too much" now or in the future.		Complete
Economic Appraisal	NZ UIOLI	This project examined the short list of project options through an economic appraisal and Cost Benefit Analysis (CBA) following HM Treasury Green Book and National Grid's investment guidance.		Complete

European Hydrogen Backbone (Phase 2)	NZ UIOLI	This project will provide understanding on the interactions for the UK transmission networks with regional characteristics involved in a European wide backbone		Open
GERG H2 Velocities	NZ UIOLI	This project will determine what the impact is of using an existing natural gas transmission network for transporting hydrogen with the same energy capacity as for natural gas to assess if increasing flows is a viable solution in this scenario.		Open
Capital Hydrogen	NZ UIOLI	A collaborative project with Cadent and SGN to deliver a hydrogen vision for London with supporting evidence-based cases for early investments in the gas network and hydrogen infrastructures, detailing the scale of pre-and post-2030 emissions that could be abated using hydrogen.		Complete
Hydrogen Valley	NZ UIOLI	A collaborative project with Cadent to deliver a design of a hydrogen vision for the West Midlands and the East of England with supporting evidence-based cases for early investments in the gas network and hydrogen infrastructures		Open
Pan-European integrated hydrogen infrastructure	NZ UIOLI	This project will look to strengthen the narrative surrounding the value of the European Wide Hydrogen Backbone through assessing the benefits of a pan-European interconnected hydrogen backbone vs disconnected hydrogen clusters. Outputs can be extrapolated across to Project Union to assist in decision making.		Open
Hydrogen System Operator	NZ UIOLI	Development of options for future hydrogen system operations to meet the proposed hydrogen transition. To consider both physical and commercial aspects of the system operator.		Open
Hydrogen Regulatory Framework	NZ UIOLI	This project will involve a deeper assessment of regulatory framework options aligned to the timing of the BEIS consultation, and also to inform the early development of the RIIO-3 framework.		Open
FutureGrid	RIIO-2 NIC & NIA	The project is a collaboration between project partners including DNV, the Health and Safety Executive, Northern Gas Networks (NGN), Fluxys, Durham University and Edinburgh University. The project aims to demonstrate that the NTS can be repurposed to transport hydrogen, by constructing an offline hydrogen test facility to assess the impact of blends (including 2, 5, 20 and 100%) of hydrogen at transmission pressures on existing assets performance and identify appropriate safety standards required to operate a hydrogen transmission network.		Open
HyNTS Compression	RIIO-2 SIF	Investigate the key challenges associated with compression of hydrogen using existing national transmission system (NTS) assets. This work will take learning for desktop studies and lab testing to determine the most cost-effective compression option for the gas networks and demonstrate the capability at a suitable site.		Open
Hydrogen as a Fuel Gas for NTS Compressors	RIIO-2 NIA	Feasibility study to examine safety, environmental, technical, operational and economic issues in blending 30% hydrogen / methane blends and 100% hydrogen for combustion in a gas turbine (GT) driving NTS compression.		Complete
Variable Hydrogen Blend Compression	RIIO-2 NIA	Desktop study to understand how compression of variable blends of hydrogen and natural gas in the NTS could be managed at minimal cost.		Open
Hazardous Areas for AGIs – ATEX / SR25	RIIO-2 NIA	This project will determine the impact on existing natural gas transmission and distribution assets from conversion to a 100% hydrogen network, specifically targeting electrical and instrumentation assets with regards to hazardous area classification.		Open

New Pipeline AI Routing Planning	RIIO-2 NIA	The aim of this project is to utilise an AI based tool or platform to enable the rapid exploration of pipeline routing options for these new pipeline		Open
Hydrogen Metering	RIIO-2 SIF	Investigate how gas metering will change as the network is transitioned to hydrogen. There will be scope for demonstration of new technology potentially at FutureGrid.		Open
HyNTS Pipeline Dataset	RIIO-2 SIF	This project will address several challenges within the Inline Inspection industry as the pipelines are transitioned to hydrogen. Different inspection tools, techniques and criteria.		Open
HyNTS 100% hydrogen metering test system	RIIO-2 NIA	The focus of this project is on the development and demonstration of a new metering technology that can enable metering at 100% hydrogen.		Open
Gas Analyser Systems for Hydrogen Blends	RIIO-2 SIF	To demonstrate a fuel cell gas analyser for blends of hydrogen and natural gas up to 100% hydrogen in the NTS.		Open
Multiple Gas Detection	RIIO-2 NIA	This project aims to test and demonstrate Nevada Nano's MPS multi-gas sensor technology at our operational and test facilities, namely the FutureGrid test facility, and Bacton where the similar MoRFE project has already taken place.		Open
Precision Thermography for Pipeline Inspection	RIIO-2 NIA	The project will review the potential to utilise thermography as a method of inspecting pipelines driven by the need to understand more about pipelines in operation as a result of hydrogen injection in the network.		Open
Hydrogen Barrier Coatings	RIIO-2 SIF	This project looks into the potential for deployment of hydrogen barrier coatings via electrodeposition onto the internal surface of a pipelines and other assets.		Open
Inhibition of Hydrogen Embrittlement	RIIO-2 NIA	This study will evaluate the impact on tensile strength, fracture and fatigue properties in hydrogen with oxygen concentrations up to 1000 ppm, focusing on NTS specific materials and operating conditions.		Open
NTS Materials Testing to Enable Hydrogen Injection	RIIO-2 NIA	This work will deliver an evaluation of the actual line pipe materials to be used for the FutureGrid facility to determine fracture toughness and fatigue crack growth rates in hydrogen which are essential to allow the planned loop test programme to be performed at NTS pressures.		Open
Assessment of Legacy Gas Pipeline Steels	RIIO-2 NIA	This research will use the results of detailed characterisation to fully document steel microstructure and rigorously track hydrogen interaction with specific features. The results will be directly relevant to assessing the suitability of the current network for hydrogen gas transport.		Open
HyNTS Defect fatigue behaviour	RIIO-2 NIA	Effect of hydrogen on the fatigue behaviour of defected metallic materials used in the UK's gas pipeline network		Open
Research the Impact of Hydrogen on CP & Degradation of Coatings	RIIO-2 NIA	The project will include a literature review of the impacts of hydrogen on coating performance adhesion and CP polarization.		Open
Impact of Hydrogen on NTS Polymer Materials	RIIO-2 NIA	To compile a full list of all polymeric materials on the NTS alongside the expected hydrogen environments for these components. The determine functional and material requirements of the polymers to inform definition of a test programme.		Open
Green Hydrogen Injection into the NTS	RIIO-2 SIF	This project focuses on the technical challenges of injecting and blending small volumes of 'green' hydrogen into the NTS, focussed on the localised impact of hydrogen.		Open

Hydrogen Skills and Competencies	RIIO-2 NIA	The project will develop methodologies for skills training and the development of hydrogen competencies in the gas transmission industry of the UK.	[redacted]	Open
HyNTS Deblending	RIIO-2 SIF	To provide an offline demonstration of gas separation or 'deblending' technology on a gas network scale. The project aims to develop a skid mounted, mobile solution to demonstrate hydrogen fuelling from the NTS for the future transport network.	[redacted]	Open
Gas & Electricity Transmission Infrastructure Outlook	RIIO-2 NIA	To understand on a whole systems approach how gas and electricity transmission systems will interact in order to balance energy production and use.	[redacted]	Open
Common Transition Pathways	RIIO-2 NIA	This project will develop a set of credible and compatible ends states, pathways to those end states and scenarios that can be used as test cases for the System Transformation programme, including any underlying assumptions, to allow comparison of the benefits and challenges associated within each.	[redacted]	Complete
Assessment Methodologies	RIIO-2 NIA	To assess the key strategic gas system options, impacts, barriers and opportunities in order to support policy decisions on whether to proceed with a transition to hydrogen to produce heat across domestic, commercial and industrial sectors.	[redacted]	Complete
Hydrogen Blending Infrastructure	RIIO-2 NIA	This project seeks to establish at a high level the constraints for blending and the physical equipment and controls required to blend hydrogen into the gas network.	[redacted]	Open
Ignition Consequences	RIIO-2 NIA	A programme of research into the various phenomena contributing to the severity of hydrogen explosions in weak structures	[redacted]	Open
FutureGrid 5% Hydrogen Testing	RIIO-2 NIA	Additional test in FutureGrid programme to support an EU consultation to understand the impacts of 5% hydrogen blend on the NTS.	[redacted]	Open
Safe Venting and Recompression of Hydrogen	RIIO-2 NIA	This project will understand the safety and procedural changes needed for venting, flaring, and purging activities. The project will also understand how to transition the network to hydrogen vent free.	[redacted]	Open
Hydrogen Fuel Gas for GTs – Emissions Impact	RIIO-2 NIA	Whilst the burning of hydrogen releases water vapour, there is an anticipated increase in NOx. This project will understand the impacts of NOx on the NTS.	[redacted]	Open
ESO – Hydrogen Thermal Constraint Management	RIIO-2 NIA	This project will investigate how hydrogen can support electricity constraint management to provide cost saving.	[redacted]	Open
NGET – Energy Water Nexus	RIIO-2 NIA	The project will define technology-based temporal and geospatial water constraint to 2050	[redacted]	Open
Impact of Hydrogen and Blends on Linepack	RIIO-2 NIA	This project understand the impact of hydrogen on linepack, calculations and storage.	[redacted]	Open
Fire & Gas Detection and Suppression	RIIO-2 NIA	This project will look at how fire & gas suppression systems will need to change for hydrogen.	[redacted]	Open
New Pipeline AI Routing Planning	RIIO-2 NIA	There is likely to be increased route planning needs as part of Project UNION, this project will look at AI technologies to support the increased data demands and shorten time for decision-making.	[redacted]	Complete

Table 32 Supporting Projects

Appendix E – Funding Mechanism Appraisal

Mechanism	Type	Mechanism Scope	Baseline Funding	Materiality Thresholds	Triggers and conditions	Link to relevant documentation	Suitability Assessment
Network Innovation Allowance	RIIO-2 Innovation	Innovation R&D demos New learning Collaboration	£25m	None	Energy transition Vulnerable customers Strict eligibility criteria Option to increase H2 funding	**RIIO-2 NIA Governance Document**	Intended for smaller scale collaborative projects Unsuitable eligibility criteria
Strategic Innovation Fund	RIIO-2 Innovation	Strategically responsive innovation projects	-	Discovery: £150k Alpha: £500k Beta: > £500k	Decarbonisation focussed Decarbonisation focussed 3 stage project funding Independent assessment	**SIF Governance Document**	3 stage process unsuitable Projects need to satisfy innovation challenges
Net Zero and Re-opener Development 'Use It or Lose It' Allowance	RIIO-2 Net Zero UIOLI	Low / no regret Net Zero projects NZ Re-opener development	£8m	Max £2m per project	Projects must meet eligibility criteria as specified in associated governance document Option to increase funding pot	**NZ and Re-opener Development Fund Governance Document**	Cap of £2m per project Otherwise would meet eligibility criteria
Net Zero Pre-Construction Works and Small Net Zero Projects Re-opener	RIIO-2 Re-openers	Early development > than UIOLI or < NZ re-opener	-	Projects > £1m	Ofgem triggered Needs case in principle required to trigger	**NZ Pre-construction Work and Small NZ Projects Reopener Governance Doc**	Eligibility criteria fit Meets materiality threshold
Net Zero Re-Opener	RIIO-2 Re-Openers	NZ projects > £10.7m	-	Projects > £10.7m	Ofgem triggered Requires occurrence of a "Net Zero development as defined by Gas Transporter Licence	(No supporting governance document yet)	No triggering event as defined by licence
BEIS Low-carbon hydrogen supply 2 competition	Other	Small projects funding for h2 supply tech innovation	£6m feasibility £24m demo	Max £300k per project in feasibility	BEIS competition Due by Aug 9th 2021	**Low Carbon Hydrogen Supply 2 Competition**	Unsuitable scale and timeframes
Horizon Europe	Other	Funding to cover R&D > demo projects	-	€25m max funding per project	40 projects, administered by EU ETS	**Horizon Europe**	Required consortium of 3+ organisations from 2+ countries

Table 33 Funding Mechanism Appraisal