Appendix A20 – Options and Phasing Study Report

Northern Gas Networks

East Coast Hydrogen - Pre-FEED Study

Options and Phasing Study Report

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NGN Reference: REP 008

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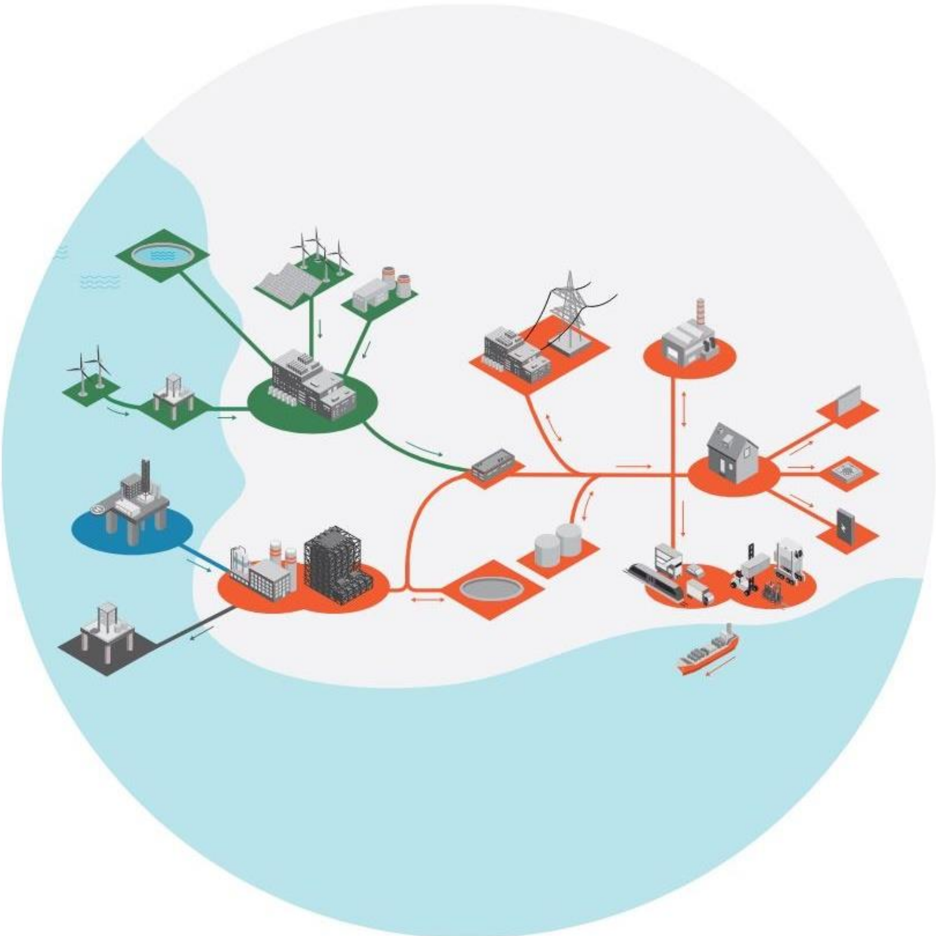

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Ove Arup & Partners International Limited
12 Wellington Place
Leeds
LS1 4AP
United Kingdom
arup.com

ARUP

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1. Executive Summary

Connecting UK industry with low carbon hydrogen production is a key requirement for the UK decarbonising its emissions. About 25% of the UK's total emissions come from industry with the majority of the emissions coming from industrial clusters (Zero Carbon Hubs, 2023). These clusters will be connected with a hydrogen transmission "backbone", Project Union.

The transmission network will have pipelines feeding to and from them, ensuring that local users and producers of hydrogen are connected together. This enables businesses such as hospitals, glass manufacturers, refineries, pharmaceuticals, food and beverage factories and more to decarbonise. The pipelines which connect the producers and users are the gas distribution network, which in this geography is owned and operated by Northern Gas Networks (NGN).

Developing the optimal future network of pipelines is complex due to the infancy of the industry driving an ever-evolving scope. Users and producers need identification and commitment to the availability of a low carbon hydrogen connection. Without commitment, the business case weakens. Additionally, navigation of private pipelines, existing pipelines and dis-used pipelines (that could be re-purposed) requires mapping of the pipelines and running through modelling software to find the optimal routing that is most cost efficient. A key consideration to the development of the network this is the phasing of the grid transition from natural gas to hydrogen, any pressurising or decompression requirements and finally the storage and network balancing capability of the proposed network.

This report explores what the future, optimal network of hydrogen pipelines looks like for East Coast Hydrogen (ECH). It has funnelled the broad range of options into a preferred routing for ECH to further develop in later project stages. This milestone achievement is the first step of work required to move into Front End Engineering Design (FEED). It has proven the project feasibility and has pulled together all the fundamental technical aspects for inclusion into the business case.

The final pipeline route suggests a mix of repurposed and new pipelines, prioritising repurposing to reduce costs and disruption. The areas specifically reviewed are Tyneside, Humber, Teesside, Towton – Asselby, Leeds – Bradford and Bishop Auckland – Pannal. Each review covers the identified users and clusters them into logical groupings which are then investigated for optimal routings based on the existing infrastructure, any private infrastructure and cost. Challenges and opportunities for each area are also highlighted, such as natural barriers (rivers, flood plains etc.) and the opportunity to repurpose other pipelines for future users (e.g. domestic) or connections.

2. Acronyms

Name	Acronym
Above Ground Installation	AGI
East Coast Hydrogen	ECH
Front End Engineering Design	FEED
High Pressure	HP
Hydrogen gas	H2
Low pressure	LP
Medium Pressure	MP
Multi Criteria Analysis	MCA
Capital Expenditure	CAPEX
Gas distribution network	GDN
Health and Safety Executive	HSE
Local Transmission System	LTS
Natural Gas	NG
Quantified Risk Assessment	QRA

Name	Acronym
National Gas Transmission	NGT
Department of Business, Energy & Industrial Strategy	BEIS
National Transmission System	NTS
Net Zero and Small Projects	NZASP
Northern Gas Network	NGN
Department for Energy Security and Net Zero	DESNZ
Town and Country Planning Act	TCPA
Dangerous Substances and Explosive Atmospheres Regulations	DSEAR
European Union	EU
Return on investment	ROI
Pressure System Safety Regulations	PSSR
Pipelines Safety Regulations	PSR
Institution of gas engineers and managers	IGEM
Annual Quantity	AQ

3. Introduction

In 2020, the UK Government released their 10-point plan for the UK to become net zero by 2050. They identified and are subsequently funding the decarbonisation of industrial clusters using hydrogen – a low carbon fuel alternative. The hydrogen produced will need to be transported across the UK in a high-pressure transmission pipeline (being developed by National Gas called Project Union) and then through gas distribution networks to users. This will contribute to the decarbonisation and balancing demand across the UK. The network will also connect to smaller-scale producers and users; one of the key focusses of this study.

Arup have been commissioned by Northern Gas Networks (NGN), a gas distribution network in the North of England covering West, East & North Yorkshire, the Northeast and Northern Cumbria. The commission is to carry out a pre-FEED study for the NGN region, of the East Coast Hydrogen (ECH) industrial cluster to support the Net Zero and Small Projects (NZASP) Reopener in subsequent project phases e.g., FEED study.

Other key elements of this scope include:

1. The transition process
2. Storage and network balancing
3. Locations for pressure and compression where required

This is a collaborative programme between NGN, Cadent Gas and National Gas Transmission, and represents an opportunity for the Government and the private sector to work together in delivering on the ambitious decarbonisation targets. ECH has the potential to connect over 7GW of hydrogen production by 2030, alone exceeding the UK Government's 10GW by 2030 target in a single region.

A key backbone of this project is Feeder 7, a pipeline part of Project Union which is linking the industrial clusters within ECH together with a hydrogen high pressure pipeline. This feeder pipeline will be utilised in connecting more local hydrogen producers and users; without this connector main, producers and users of hydrogen will become stranded, and the transition timescales and costs will worsen.

ECH can utilise the existing natural gas assets of the North of England, including existing natural gas storage and potential hydrogen storage facilities. It will build on the hydrogen production in two of the UK's largest industrial clusters in the and in turn ensure significant private sector investment in the UK's industrial heartlands. ECH is a 15-year programme that will be carried out in multiple discrete phases to decarbonise industrial processes and potentially domestic heating in the East Coast region. Proposed phases can be seen in Figure 1, this is further detailed in the phasing plan in section 10.

This report brings together a series of documents, covering optioneering for six regions in the NGN area (excluding Cumbria), phasing plan, transition process, storage and network balancing, pressure and compression and finishes with key findings. It also suggests next steps which will cover under-researched areas as well as developments on the researched areas, and ratification of the existing list of producers and off-takers and their expected timescales for the transition. A high level phasing plan of the ECH network can be seen in Figure 1.

Figure 1: ECH high level phasing

4. About Arup

Arup is an independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services. We aim to help our clients meet their business needs by adding value through technical excellence, efficient organisation and personal service. We provide the engineering and related consultancy services necessary to every stage of the project, from inception to completion. These are available to clients individually or in combination, to suit the particular circumstance of the job.

Throughout the world we aim to provide a consistently excellent multi-disciplinary service, which also incorporates our concern for the environment. Arup is committed to sustainable design, to its increasing incorporation in our projects and to industry-wide sustainability initiatives.

Founded in 1946, Arup now has more than 18,000 people working in 94 offices in 34 countries and our projects have taken us to more than 130 countries. Arup is a wholly independent organisation owned in trust for the benefit of its employees and their dependants. With no shareholders or external investors, the firm is able to independently determine its own priorities and direction as a business. A substantial proportion of the firm's income is devoted to improving its technical standards through the continuing professional development of its members and by developing new techniques of engineering design and management.

Each project is the responsibility of a Project Director who has access to specialist skills within the firm, whether those skills are in the project office or elsewhere. We work in multi-disciplinary teams to ensure co-ordination between the disciplines. We operate formal quality management systems, routinely reviewing and auditing our work. We structure our project teams to achieve clear lines of responsibility and communication with the client and other consultants. By these measures, we add value to our clients’ projects and achieve quality on which they can rely. Our energy sector is committed to decarbonisation; we have expertise in all sustainable energy generation methods such as wind, solar, hydroelectric, tidal, and future fuels such as sustainable aviation fuel, e-methanol, ammonia and hydrogen. In fact, Arup was one of the first partners in the Hydrogen Global Charter in 2020, a global initiative to drive hydrogen-based projects worldwide, led by the World Energy Council (WEC).

The agreement sees Arup draw on its global technical expertise to support the evaluation, application and deployment of effective hydrogen-based solutions to help promote clean hydrogen worldwide. Arup is at the forefront of hydrogen development across the world including commercial and private projects from transport to supply. We will annually submit our progress towards enabling low carbon hydrogen to the World Energy Council.

Arup offers services to hydrogen and decarbonising the gas grid in many ways such as; digital, planning, infrastructure advisory, investment appraisal and due diligence, engineering design and economic / financial modelling. We are a truly flexible firm and are dedicated to helping our clients achieve sustainable and efficient outcomes to protect and enhance the future generations.

4.1 Continuum

Continuum Industries are the provider of an AI-powered infrastructure development platform “Optioneer”, that enables power, utility and renewables companies to instantly visualise, analyse and comprehensively assess routing options for power lines, cables and pipelines. Started in 2016 out of a project at Edinburgh university, their software has helped companies optioneer to linear infrastructure. What the software does and how it was used is detailed in section 9.2.

5. Network development overview

The optioneering for Pre-FEED followed a step wise approach to identify and confirm the preferred options for modelling. The focus was on linking the top industrial off-takers, production and storage potential town trials to the. The approach consisted of the following steps:

- Step 1 – Identify and confirm the East Coast Hydrogen backbone.
- Step 2 – Identify and confirm suitable supply (spurs) and offtake points.
- Step 3 – Identify and confirm suitable hydrogen supply options for agreed supply and offtake points.
- Step 4 – Evaluate hydrogen supply options using multi criteria analysis.
- Step 5 **-** Confirm preferred option for each supply spur, which may be new build, repurposing/ temporary lines or a combination of these.
- Evaluate options for extending the network to Cumbria and other further afield offtakers.

A number of studies have been conducted to provide the optimised solution for the network. The flowcharts below (Figure 2 and Figure 3) have been produced to signpost what documents have been produced and the sequence of work required to ultimately conclude the scope of pipeline routing.

5.1 Flow chart of documents and work done to date

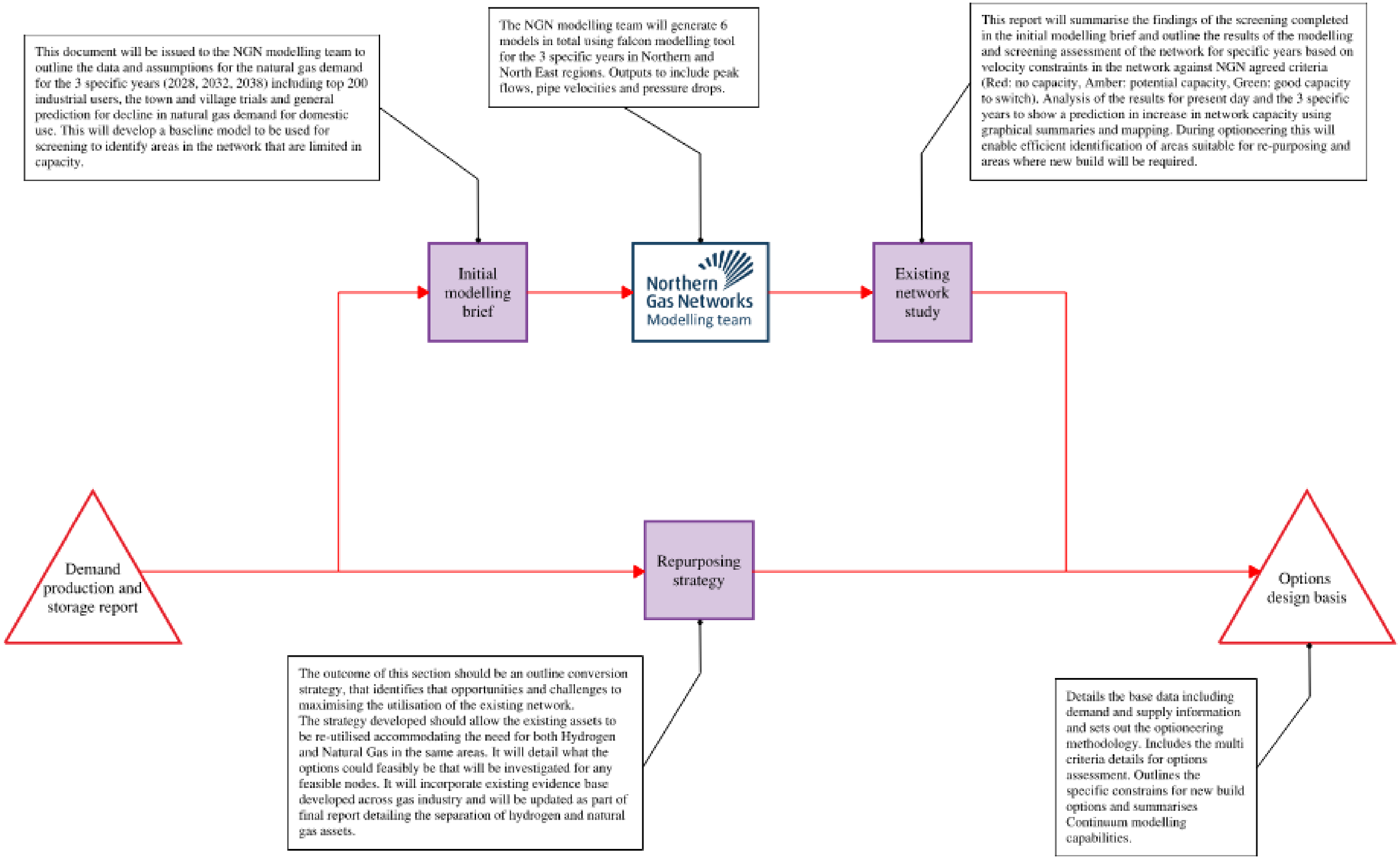


Figure 2: Stage 1b preparation for optioneering workflow

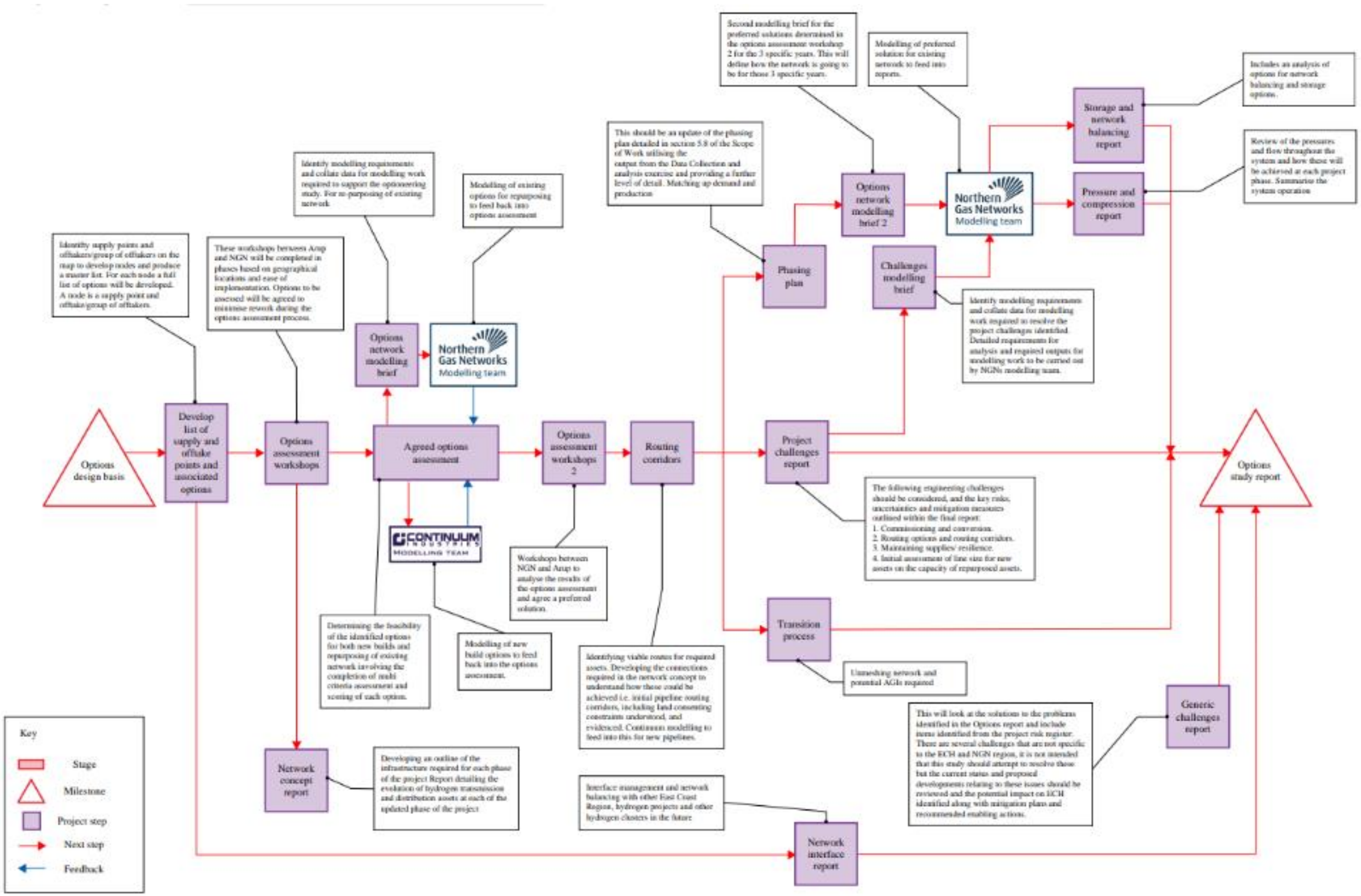


Figure 3: Stage 2 Optioneering workflow

5.2 Production, storage, stakeholders

To develop the network options for the Options Study Report, the production, storage and consumption sites were mapped to visually assess the geographic distribution and locations with respect to the overall NGT and NGN networks, and particularly the sections where repurposing was identified as likely.

The producers were identified in the Production Study (293805-ARUP-PRS), these were selected based on the level of advancement and certainty of each scheme. Consumers were then mapped from the demand study (293805-ARUP-DMS), these were based on their current natural gas consumption figures, taking the largest users within the NGN network (approximately 250 users). Analysis was carried out to determine each user's potential uptake of hydrogen in 2028, 2032 and 2037. This was based on multiple factors including industry, combustion equipment on site, company strategy, distance from assumed hydrogen feeders and primary engagement with the users. Further to this, a large amount of stakeholder engagement was undertaken to obtain qualitative information on the users potential demand for hydrogen. Usage was also included for anticipated transport sites. Similarly, storage sites identified from the Storage Study (293805-ARUP-STS) were identified and included in the potential network options.

The key areas which were not assessed were Cumbria, Northern Northumberland, Yorkshire Moors and Yorkshire Wolds. The primary reason for these not being assessed was their distance from Feeders which are proposed to be converted to Hydrogen by NGT as part of the ECH project. Furthermore, there was little concentrated demand in these areas identified through the demand study, meaning that providing hydrogen connections for industrial users was anticipated to be cost prohibitive during the timescales of ECH and prior to further transition and the ability to repurpose more existing network when methane demand reduces.

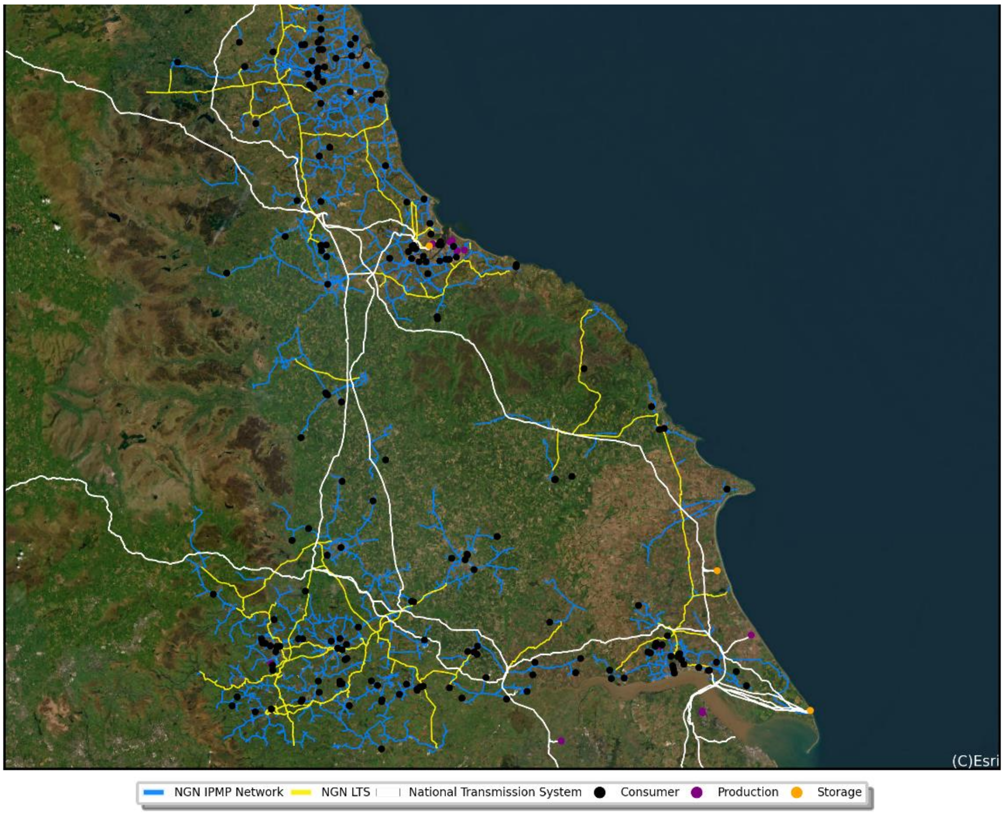


Figure 4: Demand, consumption and storage

The assumptions regarding which feeders could be repurposed are discussed further in section 6, but primarily it has been assumed that Feeder 7 would form the backbone of the NGT hydrogen network for the ECH project. NGTs Project Union is identifying which of the network feeders will be converted to hydrogen to provide the hydrogen backbone for the country. Throughout the project NGN and NGT have been collaborating with regards to the most beneficial feeder selection for both parties with regards to the ECH project. Feeder 7 within the ECH area is shown below (Figure 4).

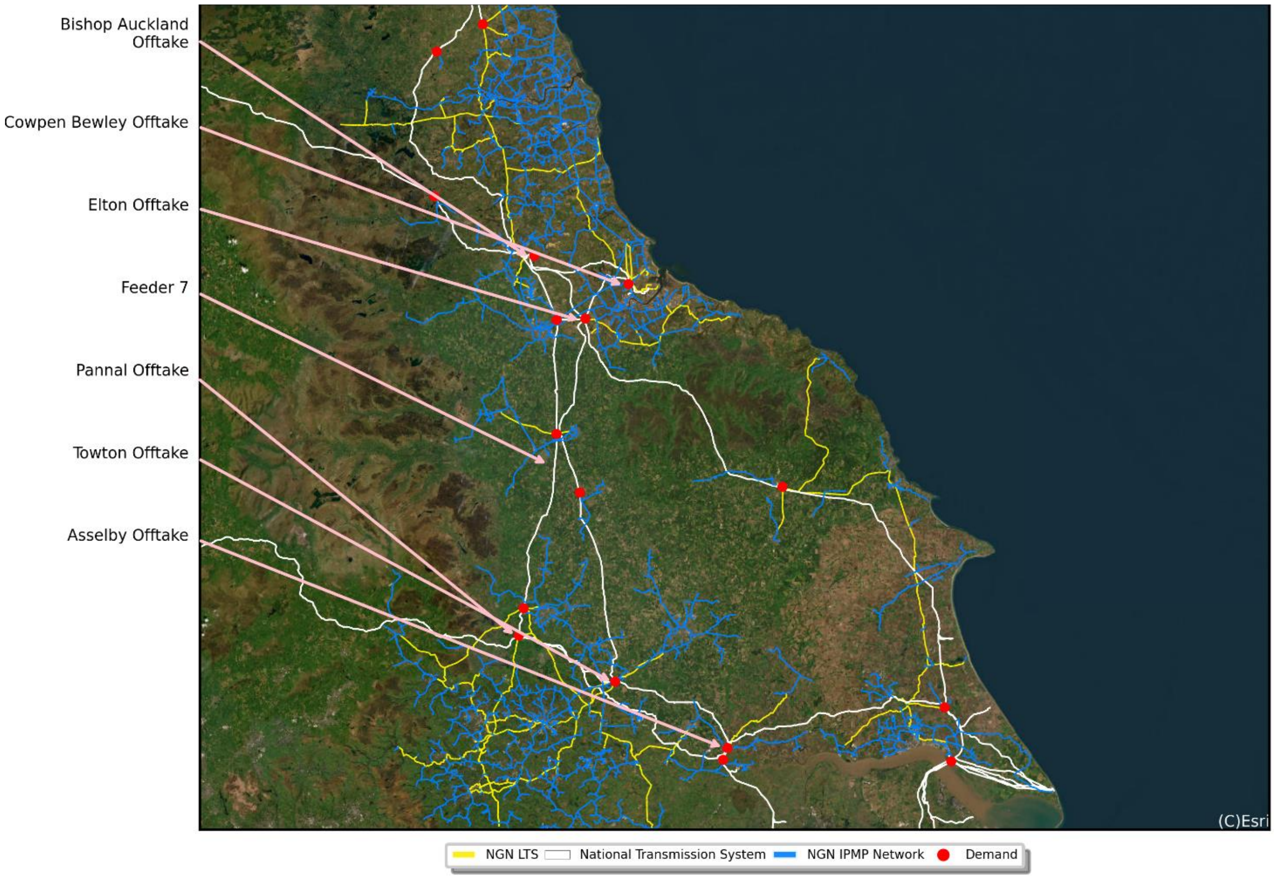


Figure 5: Assumed hydrogen backbone

Once the existing infrastructure and connection points were established, the region was split into areas for assessment. The six areas were:

- Teesside
- Bishop Auckland to Pannal
- Leeds / Bradford
- Towton to Asselby
- Humber
- Tyneside

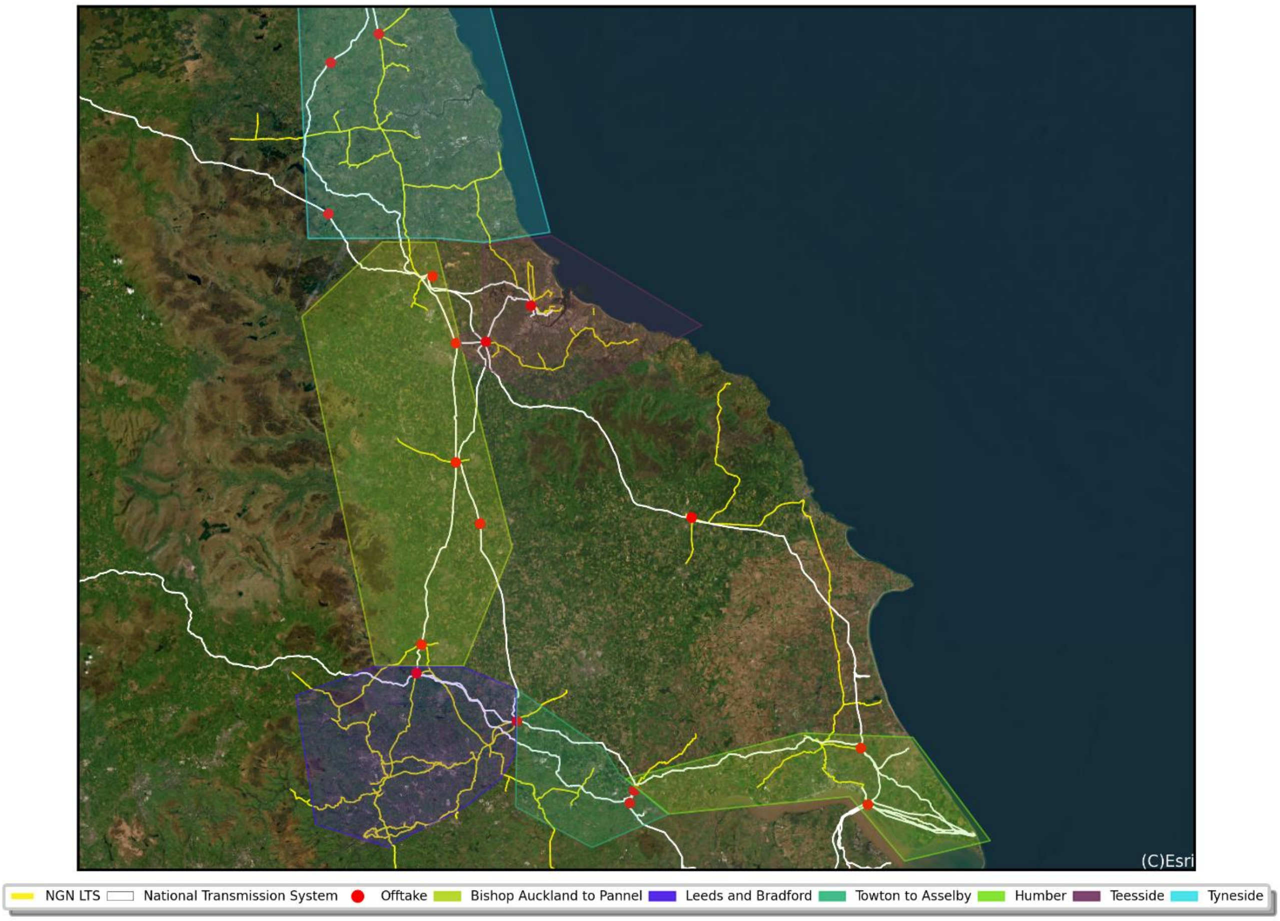


Figure 6: Map of areas under investigation

Within the defined geographic areas, the producers, storage sites and users were grouped into clusters to enable the development of network options.

5.3 Pipeline options

Network concepts were developed for each area which aimed to link up the production, storage and users with the NGT hydrogen backbone.

Repurpose

The primary aim was to repurpose as much of the existing network as possible since this has a lower CAPEX compared to newbuild pipelines. The project's approach to repurposing is detailed in the Repurposing Strategy report (293805-ARUP-RPS). Where lines were identified to be repurposed, other existing infrastructure would be required to accommodate additional natural gas flow via a series of disconnections from the repurposed line. To initially assess the feasibility of this, a repurposing assessment was undertaken to establish if the alternative routes had sufficient capacity. Where this was acceptable, the routes were then provided to the NGN network modelling team to further assess the impact on the existing network and identify what works were required to unmesh the repurposed line from the existing network and where reinforcements were required.

To further support repurposing assessment of the network, a capacity assessment of the NGN network was undertaken. Network modelling was undertaken to focused on analysis of the existing network, utilising the predicted future reduction in natural gas demand due to the uptake of hydrogen and other alternative energies. The modelling scenarios were based on an anticipated phased reduction in natural gas demand, corresponding with three key adoption periods (2028, 2032 and 2037) and three key categories (Large industrial loads and domestic). A summary of the assessment of the existing network is detailed in the Existing Network Study (293805-ARUP-ENS).

Private

Producers such as BP, Kellas and Equinor are proposing to build their own distribution networks to users within the vicinity of their plants. This has been a necessity for the producers to enable a robust business case in the absence of firm plans to develop any wider reaching network. It has been assumed that certain producers' pipelines will be constructed as part of the network development undertaken, this is further discussed in section 6. Later stages of this project will allow for further engagement with producers to establish which party is best placed to construct and operate these pipelines.

New build

Where pipelines could not be repurposed or private lines utilised, then new build piping has been assessed. The approach to the development of new build pipelines is discussed in more detail in section 11.

6. Assumptions and key decisions

Due to the infancy of the hydrogen networking sector and the multiple parties involved, the development of the network has relied on some key assumptions. These have been rationalised and reviewed on a regular basis throughout the project to ensure they remain the most reasonable way to progress with a feasible network. A full key assumptions and decisions log has been maintained. Some of the most fundamental assumptions with regards to the network options development are listed below.

Table 1: Key assumptions

Title	Assumption
Feeder 7	Feeder 7 is repurposed for use with 100% hydrogen between Bishop Auckland offtake, Elton offtake and Asselby offtake. Existing methane offtakes on feeder 7 which supply methane networks which need to be maintained can be relocated onto other feeders such as 29 and 13 to allow the repurposing of feeder 7.
Feeder 7 vs 29 Pannal to Asselby	Feeder 29 could be an alternative to Feeder 7 south of Pannal offtake. It is assumed that this will not be the option taken forward since feeder 29 is a higher grade of steel and is larger in diameter which will be required to maintain methane network flows. Feeder 29 would be closer to the potential users within that area and reduce the amount of new build pipeline required by NGN, therefore the assumption of Feeder 7 being repurposed represents a worst-case scenario between the two for the development of the NGN network.
Cowpen Bewley	Hydrogen will be available at Cowpen Bewley offtake, this will be from the NGT Elton to Cowpen Bewley line to the West and the BP private pipeline to the East.
Pipeline transport	It is assumed that pipelines are the only way that makes sense to transport hydrogen on this scale.
Feeder 29 Asselby to Easington	Feeder 29 will not be repurposed by NGT between Asselby and Easington
Saltend	There will be hydrogen production at Saltend chemicals park which will need to be connected to the network
Aldbrough	There will be hydrogen storage at Aldbrough, a pipeline connecting Saltend chemical park and Aldbrough will be constructed by a private party.
Saltend to Easington	The Low Carbon Humber Pipeline (LCHP) would connect Saltend chemical park to Easington. If the LCHP does not progress, NGT will construct or repurpose a feeder to connect these sites.
Flow direction	Hydrogen flow will be in both directions on any given pressure tier.
AGI NG and hydrogen	AGIs will be able to have hydrogen and NG within the same site boundary. The physical infrastructure will be separate and hazardous area zoning will be larger for hydrogen installations.
Production pressures	The hydrogen from production sites does not require any compression by NGN since this will be done by the producers.
AGIs	The AGI’s included in the routings have been classified as: 1. New; if there is no existing AGI on the plot 2. Modified; if some existing assets are retained for use in natural gas network Repurposed; if existing assets are to be fully converted for hydrogen use.

7. High level challenges

This section lists the challenges associated with converting NG networks to hydrogen and identifies potential impacts and what mitigations could be utilised. The project specific challenges that relate to the NGN ECH region are covered in the Repurposing Strategy report (293805-ARUP-RPS) and the route optioneering section of this report (section 9).

Many of the challenges associated with converting NG infrastructure to hydrogen are linked to the high level of uncertainty around aspects of the transition. For example, there is little research in many of the relevant discipline areas relating to the transition, and a whole system plan for the transition to hydrogen has yet to be developed, so a lot of high-level assumptions are currently being made. There is therefore an overarching level of uncertainty and risk which adds to some of the more specific challenges covered in this report.

7.1 Technology challenges

There is limited research into many of the areas associated with the transition to hydrogen in NG pipelines, and a high level of uncertainty around what technological challenges will appear exactly. However, some specific areas of concern include the customer transition, specification development, and pressure and flow optimisation. These are covered in this section. Other topics including equipment suitability, pipework materials suitability and the transition of the NG grid are detailed in the Repurposing Strategy report.

Many possible consumers are unaware of the potential of hydrogen as a replacement for NG or are unaware of the possibility of the NG pipelines transitioning to hydrogen pipelines. This limited awareness has resulted in little push from customers for the change. Even where consumers are aware of the potential for transition, without firm plans and industry coordination, it is not possible for consumers to build a business plan around a potential hydrogen supply which may not be realised.

Another concern is that the majority of NG fuelled equipment cannot currently run on blended or 100% hydrogen. One option is to ensure equipment is "hydrogen-ready". "Hydrogen-ready" machines run on NG with to up to a 20% hydrogen blend, then require minimal retrofitting to be compatible with 100% hydrogen. Hydrogen-ready equipment may require some components to be swapped out, for example burners, or it may have hydrogen compatible parts built-in with a different set of connections. Some hydrogen-ready equipment is in existence and currently in use, however, it is not currently widely available. There is currently no requirement for natural gas combustion equipment to be hydrogen-ready, and whilst there is a proposal to mandate that boilers will need to be hydrogen-ready from 2026, this has not been confirmed.

As most equipment is not currently hydrogen-ready, a lot will need replacing or retrofitting to allow for a shorter changeover and down-time during the swap to a hydrogen fuel supply. If equipment is not replaced with hydrogen ready equipment, it will have to be replaced or retrofitted at the time of the changeover to hydrogen. Retrofitting and replacing equipment will increase down-time during the transition, therefore consumers need confidence that there will be a hydrogen supply in the future so that they can plan a phased replacement of equipment within scheduled plant down time. Consumers also need this confidence in a future hydrogen network to build a business plant around the transition and plan their capital expenditure accordingly.

Retrofitting and replacing equipment during the transition increases the logistics complexity, this will have to happen at the same time as neighbouring industrial sites, when the natural gas network is changed to hydrogen.

Some service pipes (which supply industrial sites) may also require replacing as part of the Iron Mains Risk Reduction Programme, and depending on their location, may have to be replaced gradually in phases. Gas mains often run one meter deep along road networks, so there are restrictions on how much work can be carried out at one time to minimise public disruption. The Repurposing Strategy has more information on the pipeline materials and which pipelines will need replacing and why.

7.2 Specification development

There are limited standards and regulations covering hydrogen infrastructure components, pipelines, and industrial hydrogen fuelled equipment. Similarly, the overarching regulations and safety legislation are limited in their reference to the use of hydrogen.

Some of the major regulations and legislation which are applicable to the proposed network are (but are not limited to):

- Pressure System Safety Regulations (PSSR)
- Pipelines Safety Regulations (PSR)
- Dangerous Substances and Explosive Atmosphere Regulations (DSEAR)
- Gas Safety (Management) Regulations (GSMR)
- Gas Safety (Installation and Use) Regulations (GS(I&U)R)
- Health and Safety at Work Act
- Management of Health and Safety Regulations
- Construction (Design and Management) Regulations
- Planning act
- EU Council Directive 85/337/EEC

PSSR and PSR cover the design, construction, operation and maintenance of pipelines and AGIs. These set out the requirements for each of these project stages and the required information in order to enable safe continued operation. PSR is not specifically based around the use of natural gas, so can be used for hydrogen pipelines.

DSEAR applies to all hazardous substances and as such can be used for hydrogen.

GSMR does not currently allow hydrogen within gas distribution pipelines above 0.1% (molar), and whilst discussions are currently ongoing, there is no fixed date for an update to these regulations. Currently to convey hydrogen in pipelines, a specific exemption needs to be permitted by the HSE with a specific safety case. This will prove costly for projects and will not provide alignment across the industry.

Whilst legislation is generally applicable to the hydrogen network, standards which have been designed to meet the requirements of the legislation are generally more specific to the use case and have been historically developed around the use of natural gas. Many of the standards which are widely accepted and used within the UK gas networks are the IGEM standards. These are currently undergoing systematic review and standards such as IGEM/TD/13 Edition 2 has had a supplement issued which covers pressure regulating installations for hydrogen at pressures exceeding 7 bar. IGEM/SR/25 Edition 2 has had a hydrogen supplement issued which outlines differences in the approach for hazardous area classification of installations handling hydrogen compared to natural gas which the initial standard was developed for.

It is predicted that further specifications and guidance documents for hydrogen equipment will be created as the hydrogen industry develops. There will also be a need for clearer definitions of key terms such as "hydrogen-ready".

The (Health and Safety Executive) HSE has high-level decommissioning regulations. It states that when a pipeline has reached its end of life it should be dismantled, removed or left in a safe condition. The conversion of networks to hydrogen provides a use case for the infrastructure which would otherwise become obsolete with a reduction in natural gas demand.

7.3 Pressure and flow challenges

As stated in the Repurposing Strategy, the energy density per unit mass of NG is 50 MJ/kg compared to hydrogen which is 120 MJ/kg. However, NG is much denser than hydrogen, it has a volumetric density approximately 3.3 times higher that hydrogen. The velocity of a fluid in a pipe is limited by its erosional velocity. This is a velocity threshold where erosion would occur if exceeded over prolonged periods. Hydrogen has an erosional velocity 2.9 times higher than NG, meaning more hydrogen can be transported per unit volume through a pipe per unit time compared to NG without erosion happening. Overall, this means that with hydrogen in the pipelines, approximately 88% of the current NG energy capacity can be reached (Kahn, et al., 2021)

Increasing the network pressure could require some physical interventions including higher pressure steel pipework reinforcement. Pressure and flow control equipment have associated transition challenges. Details on pipework material challenges, and pressure control equipment are detailed in the Repurposing Strategy report.

It should also be noted that the power demand from gas networks (natural gas and hydrogen) is expected to be reduced, as some components are converted to electrical power. There will be areas where this is not possible for example in extreme high temperature processes like cement kilns (up to 1500 °C). Processes that can't be electrified will likely be replaced with a hydrogen fuel supply.

7.4 Safety challenges

The HSE has overseen hydrogen's safe industrial use for nearly 20 years. However, there are safety challenges associated with the transition to hydrogen from NG and the operation of hydrogen infrastructure.

Hydrogen is highly flammable so can cause fires and explosions, the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) must be followed. DSEAR assessments will highlight the required zoning required at AGIs and will likely be different to that of existing NG installations. Hydrogen installations will likely have larger zones and may require additional land to facilitate the control of these zones and also the appropriately ATEX rated equipment may also be different to that of a NG installation.

Hydrogen is a colourless, odourless and tasteless gas that is highly flammable. Natural gas is also odourless but odorants such as Mercaptan (methanethiol) are added to make it easier for people to detect leaks. Adding an odorant to hydrogen will have the same effect of making leaks easier to detect. Odorisation in natural gas systems is required by the Gas Safety (Management) Regulations at pressures below 7barg. Odourant injection rates are typically set to meet a required intensity at users, this can vary from site to site. Based upon initial investigation findings, odourant injection rates for hydrogen are about 20% higher than that of NG in order to meet the same odour intensity on the sales scale.

Once the pipelines are in operation there are additional safety risks to consider. As mentioned in the Repurposing Strategy report, hydrogen is more prone to leaks compared to NG. However, leaks are very unlikely and if they do occur, they are more likely to be in AGIs, for example at flanged equipment or connections. This can be mitigated at AGIs by the use of appropriately specified and designed equipment such as appropriate gaskets and valve stem packing as well as stress analysis of piping which looks at flange leakage.

If hydrogen leaks into the atmosphere, even though it is not a pollutant it is very likely to have small warming effect (BEIS 2018). This is due to the two "dis-benefits": stratosphere moistening causing ozone depletion and increasing methane and tropospheric ozone growth rates. It is difficult to say exactly how this compares with NG's (methane's) global warming and climate change effects because there is only some data on hydrogen's impact on the atmosphere. There is even less accurate data predicting how much hydrogen may leak into the atmosphere as the scale of hydrogen fuel uptake is not known, the land use change of hydrogen sink land is not known and the potential rate of hydrogen leaking from pipework and components is not known (Warwick 2022).

Land use zones are advised by Health and Safety Executive (HSE) to demonstrate varying levels of risks in the vicinity of a NG pipeline or AGI. These zones are determined using the results from a quantified risk assessment (QRA), specifically, the pipe thickness and diameter, maximum operating pressure, material and depth. Then the boundaries of the zones are established at distances where there are 0.3, 1 and 10 chances per million per year (cpm) of receiving a dangerous dose of thermal radiation as classified by the HSE. Guidance will be required from the HSE in the application of this with regards to hydrogen pipelines and AGIs.

There are no additional H&S risks associated with the installation process of hydrogen equipment compared to natural gas fired. All work must follow the ISO 45001 Occupational health and safety management systems.

7.5 Funding challenges

An overarching funding challenge facing the transition to hydrogen is the current climate of economic uncertainty. This creates a higher level of risk for predictions such as return on investment (ROI). Additionally, as mentioned previously, hydrogen infrastructure technology and research are in its infancy which creates uncertainty in what technology or equipment will be used, and therefore how much different aspects of the transition will cost.

As stated in Section 2.1 Consumer transition, complicated logistics will be involved with coordinating he users' and the gas distribution networks' (GDNs') transition. The hydrogen producers and the National Transmission System (NTS) will also have to coordinate their production / transition. There are down-time issues mentioned previously which cause financial challenges, but there are also challenges with starting the large-scale production of hydrogen process. This is because hydrogen producers want the security of knowing there is a strong demand before they commit to building a hydrogen production facility, and consumers want to know there is a strong hydrogen supply before they commit to transitioning their equipment to be hydrogen compatible. Due to these reasons, and the limited consumer awareness mentioned in Section 2.1, the uptake of hydrogen may be slow, this would lead to a longer ROI.

Network companies will also have to weigh-up the balance between installing larger more expensive pipes, which is more efficient and environmentally friendly, or smaller cheaper pipes hat will have a shorter ROI. They will have to find a balance between what is best for their business and what will help Ofgem and the Department for Energy Security and Net Zero (DESNZ) to reach the target of net-zero by 2050 in national infrastructure. For the transition to take place in time to meet the target, gas transmission and distribution companies may need to take on longer ROIs than they would typically accept.

There have been some hydrogen technology development schemes to support the transition including the Hydrogen Production Business Model and Net Zero Hydrogen Fund: Rounds 1 and 2. These schemes grant funding for new hydrogen production facilities. The Industrial Hydrogen Accelerator Programme grants funds to innovation projects which demonstrate industrial fuel switching to hydrogen, including production, network transition and hydrogen burning equipment projects. The Scottish Emerging Energy Technologies Fund - Hydrogen Innovation Scheme funds the same type of projects, but for Scottish companies.

The some of the areas of the transition which are likely to be the most costly are the hydrogen backbone, replacing or retrofitting much of the NG infrastructure and industrial equipment and the loss of money due to down time.

The hydrogen backbone is a collection of high-pressure high-capacity transmission lines which will connect hydrogen manufacturers and hydrogen clusters around the country. Some of the lines will be repurposed NG pipelines and some will be purpose built.

The costs to replace or retrofit almost all consumer NG equipment will likely be very high. Also, much of the hydrogen compatible equipment is likely more expensive than the current NG equipment in the networks and that is consumer-owned. This is because the hydrogen equipment costs must cover new product risks, testing and the scale of production will be initially small but build over time.

It will likely be cheaper, and quicker to convert existing NG equipment to hydrogen compatible (if possible) by swapping out some components, rather than replacing the entire piece of equipment. For example, by replacing just the burners and some associated component in a NG boiler to make it hydrogen compatible. The time to install a piece of hydrogen compatible equipment would likely be comparable to installing a piece of NG compatible equivalent equipment. The costs would vary on the type and size of equipment and on the availability of parts and qualified fitters. (BEIS 2022)

Sensitivity analysis has shown that small changes early on in the transition process for example if there are unexpected findings in a hydrogen pipework behavioural research study this could have significant, large impacts on the costs of the projects.

8. Network interfaces

The development of the ECH network will be phased, it is therefore critical to the project to consider how the ECH network will develop and what requirements are at each stage to facilitate this. There are different interface points on the NGN sections of ECH. These are detailed within the Optioneering and pipeline routing section of this report. These have been generalised within this section and the interface requirements discussed. How this transition is undertaken is detailed in the Transition Process section. The identified interface points are listed below alongside some of the key interface requirements:

- Repurposed NTS to LTS hydrogen connections

• This is where NGT have repurposed an NTS feeder and the NGN LTS is required to connect to this, whether it be new build or repurposed.

• The interface of these connections needs to be managed to ensure that the changeover process can be achieved and that the LTS connections are able to accept hydrogen when the NTS needs to be changed to hydrogen. It is anticipated that this will be through a phased approach of converting existing AGI assets on the LTS to be able to accept hydrogen and connecting the new build assets with sufficient isolation. Connections between the NTS and LTS will largely be similar to existing natural gas AGIs, with minor differences anticipated to equipment spacing and sizing.

• Within the FEED stage of the ECH project, the phasing of the NGT feeder repurposing will need to be better understood. This will include whether the intention is to repurpose the feeders in one outage, or isolate sections and have a phased approach. This will impact upon the construction and transition programme for the LTS.

• The producers of hydrogen will typically input hydrogen to the network at LTS pressures. This will need to be compressed further to be supplied into the NTS. The NTS currently has 24 compressor stations within the system to provide flow and build line pack. NGT are currently investigating how existing compression equipment can be repurposed for use with hydrogen through their HyNTS Compression Beta Project. This will need to be better understood during the FEED stage to inform the NGN LTS interface requirements.

- **Existing NTS natural gas pipeline to Existing LTS connections**

  To facilitate continued natural gas use where the original NTS feeder which supplied the LTS has been repurposed, and a connection needs to be made to a different NTS natural gas pipeline.

  Some connections will not require much modification, for example at Pannal or Cowpen Bewley offtake where Feeders are proposed to be repurposed to hydrogen, but there are already other feeders to that offtake which can feed the LTS network with natural gas where required. There are other offtake sites which are fed by a sole feeder which will be repurposed. In these instances, new LTS infrastructure will be required to connect to an existing natural gas offtake or a new NTS offtake. This will require the alignment of phasing between the ECH partners.

- **Existing LTS natural gas pipeline to Existing LTS natural gas pipeline**

  • Where NGN link their LTS to an alternative section of their LTS to enable the continues flow of natural gas when another section is removed. This may also be required where the network modelling identified that the removal of a connection does not then allow sufficient flow to all of the network. Since this interface is internal within NGN this can be managed easily to achieve the most efficient solution. Instances where new AGIs are required to facilitate this have been detailed in the options section for each area.

- **New LTS hydrogen pipeline connections to private pipelines or producers**

  NGN connections to private pipelines to facilitate the input of hydrogen into the network. This may be a connection to a private pipeline, or a connection to a facility. These will need to be metered and the quality monitored.

Many of the identified producers are currently proposing pipelines to the users they have identified. This is partially because they require a certain method of connecting to users in the absence of certainty around LTS and NTS network conversions. It is thought that once the ECH network is developed, producers may look to the GDNs to provide the infrastructure of pipelines where possible.

There will need to be consultation between NGN and the producers to determine the ownership and operation responsibilities of the entry point equipment. There are examples and precedent for this with the biomethane industry. As with other aspects of the industry, entry point equipment for hydrogen at this scale is in its infancy. There will need to be consultation between equipment producers, hydrogen producers and GDNs to ensure that the equipment is fit for purpose.

Connection agreements will need to be put in place, these will likely be bespoke due to the unique production patterns and properties of each producer.

- **New LTS hydrogen pipeline connections to storage facilities**

NGN connections to storage facilities to enable balancing of the network.

Much of the connection interface to storage facilities will be the same as to producers, from the perspective of a GDN operator. With the difference being that flow will be required both ways and the entry point equipment will be required to facilitate this.

The interfaces within the network will be impacted by the regulatory frameworks which govern them. Currently the GDNs are regulated by Ofgem for the distribution of natural gas. This allows them to charge gas shippers for the use of the network. There is currently no contract or regulatory regime which is designed for the transportation of hydrogen.

The government went out for consultation in 2022 on business model designs, regulatory arrangements, strategic planning and the role of blending in hydrogen transport and storage infrastructure. A summary of responses was published in August 2023. Within those responses there is acknowledgement that industry needs clarity on how they will be able to operate and what regulatory frameworks this will be under. The government are working with Ofgem to enable early projects to operate within existing regulatory regimes. It is an assumption within this project that the regulatory frameworks for hydrogen transport will be similar to those currently in place for the transport of natural gas.

9. Optioneering the pipeline routes

9.1 Strategy and Aims

The overall aim of the pipeline route optioneering is to develop and assess the feasibility of routes to connect the identified producers / network supplier (e.g., NGT), storage and users of hydrogen within the NGN area of ECH. The outputs of this will identify a hierarchy of users and groups of users based on multiple factors such as their demand profile, the capital expenditure required to connect, construction timelines, consenting risks and security of supply. This will enable the phasing plan and transition process to be detailed and develop a proposed network which best meets the needs of all stakeholders.

9.2 Methodology

In section 5, the six areas were explained (Teesside, Bishop Auckland to Pannal, Leeds / Bradford, Towton to Asselby, Humber, Tyneside). Each of the six areas were assessed independently for pipeline routing. The concepts for each area were developed by grouping the producers, storage and users into clusters. Clusters were selected based on the proximity of the stakeholders as well as existing pipelines and proposed private pipelines. For each area or cluster different scenarios were also identified which were based on aspects such as specific existing lines being able to be repurposed or based on private lines which may or may not happen. This approach allowed a flexible set our routes to be developed which could be tailored and selected based on the later stages of the project such as the phasing plan and also when assumptions were firmed up. An outline of the process undertaken is shown in Figure 7.

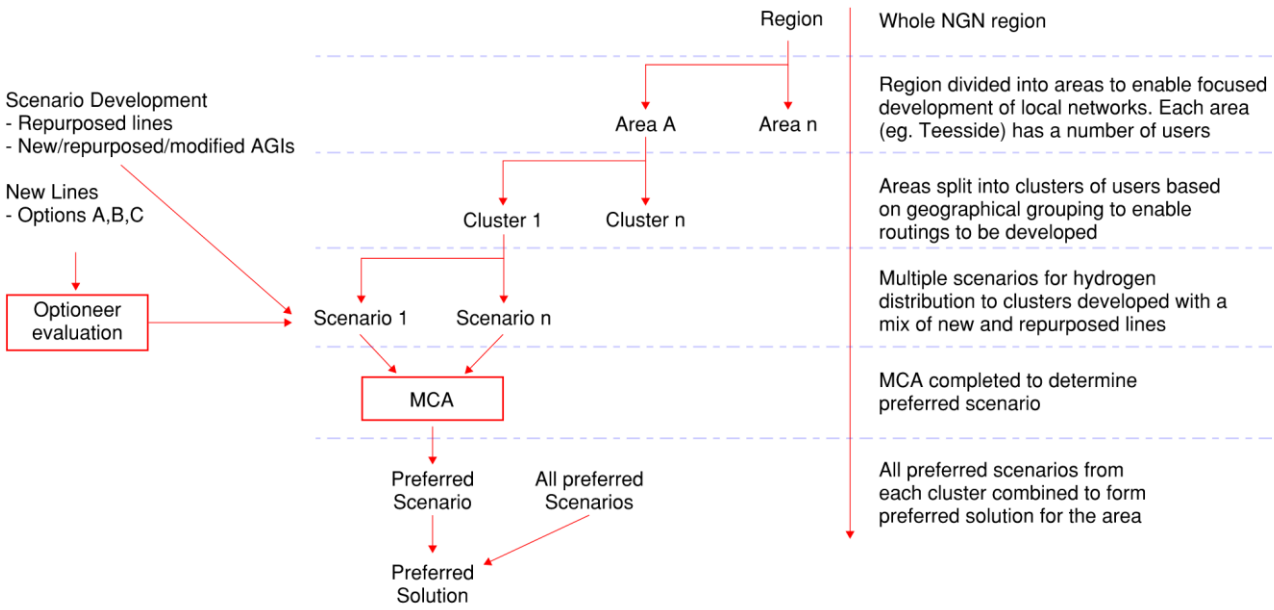


Figure 7: Methodology flowchart for network development

- Geographic assessment of producers, users and storage
- Identification of assessment areas
- Production of industrial clusters for development
- Identification of scenarios based upon key decisions
- Establish and detail constraints to routing
- Iterative routing of networks

Once the clusters had been developed, outline network plans were created for each, linking the stakeholders. These lines were then routed in more detail to enable a better understanding of the viability, cost and construction time of each line so that the network clusters could be evaluated. The routing was undertaken utilising Continuum's Optioneer™ linear infrastructure routing tool. The tool considers route options via a constraint weighting & automated AI routing methodology that holistically considers constructability along with environmental & consenting criteria. This meant that routing options could be rapidly accessed, iterated on and analysed for metrics. Optioneer™ tool was populated with GIS layers which represent the constraints to the routing, an example of this is shown in Figure 8. The data layers consist of 117 separate datasets which cover aspects such as Sites of Special Scientific Interest, buildings, national parks, electrical infrastructure, flood zones etc. The full list of data layers can be seen in Appendix B.

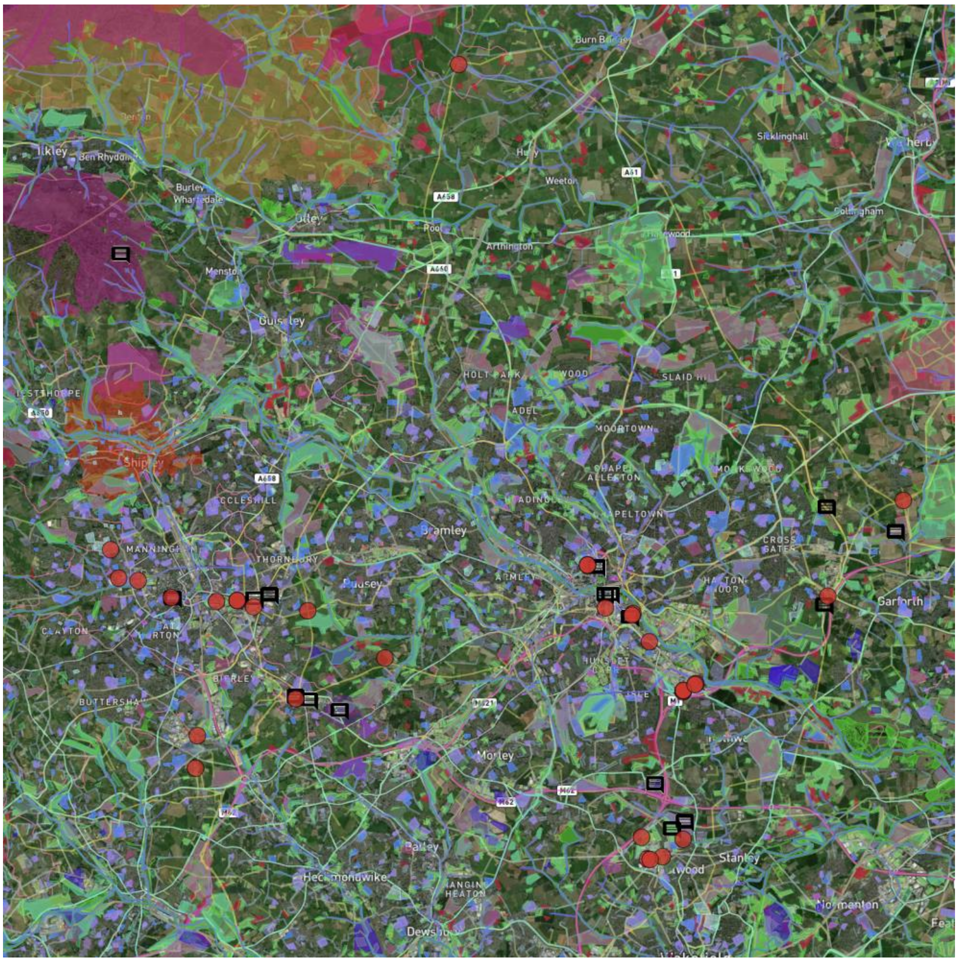


Figure 8: Example of Optioneer data layers

Against each of the data layers, a technical and consenting penalty classification was assigned. This allowed the determination of a technical and consenting penalty for all points of the study area and informed the AI engine which developed the routes. The build-up of the overall penalty for each route option was generated by the tool to establish the most efficient route. The datasets used for the GIS layers and the penalty classifications applied can be seen in Appendix B. The classifications are quantified in the table below.

Table 2 - Classification / ranking of data layers

Classification / ranking	Constraint type	Risk-based	Policy wording	Designation type
Class 5	Hard constraint	Likely to preclude development	No development	Depends on the specific objective
Class 4	Critical importance	Significant risk Significant impact	Avoid as far as reasonably practicable	Internationally and/or nationally designated
Class 3	High importance	Likely risk Significant impact	Avoid where possible	Regionally designated
Class 2	Medium importance	Likely risk Low impact	Reduce effects on	Locally designated
Class 1	Low importance	Insignificant risk Low impact	Avoid where possible whilst avoiding undue diversion	Non-statutory designation
Class 0	None - information only	No risk	Report on	For information only

With the tool populate with the layers and penalties, all of the required routing points were inputted and multiple routes created between each A to B point. There were each assessed individually to ensure the tool was applying the criteria in the correct manner and routing in a realistic way. The route options could be compared against each other, an example below shows how a single route could be evaluated along its length and the build-up of the various penalties can be seen at each point along the route (Figure 9).

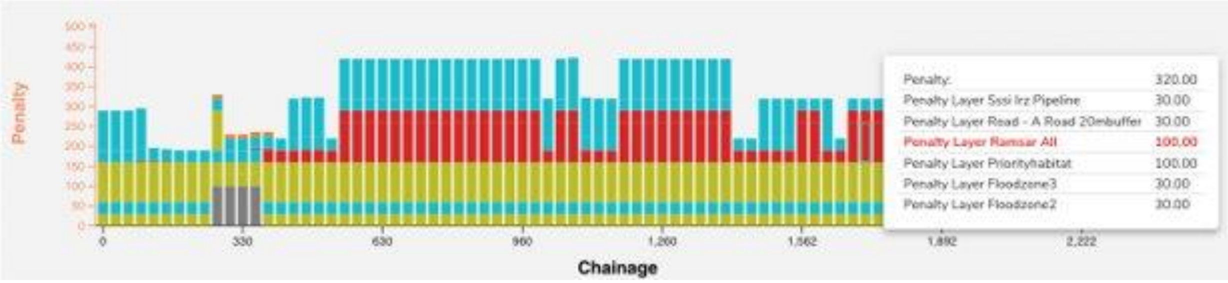


Figure 9: Optioneer route penalty assessment

After the routing was completed, a multi criteria analysis was used to reach the optimal solution for the cluster, evaluating scenarios against each other for each cluster and route as well as being used to assess the repurposed routes which were being proposed. The MCA framework is shown below in Table 3.

9.2.1 Multi criteria analysis:

Table 3: Multi criteria analysis framework

Criteria	Weighting	Low - 1	Low/Medium - 2	Medium - 3	Medium/High - 4	High - 5
Consenting	15%	No new consenting requirements	TCPA for AGI only - requiring engagement with single land owner.	TCPA for pipeline - requiring engagement with multiple land owners (som e of whom agreements already exist for existing pipelines).	TCPA for AGI and pipeline - requiring engagement with multiple land owners (none of whom have agreements in place for existing pipelines).	Nationally Significant Infrastructure Project. Development consent order required (3-4 years)
Environmental Impact (human health and designated landscape, heritage and nature sites)	20%	No or very low environmental impact, no sensitive area crossings - no environmental impact assessment required (Schedule 2 site not requiring env impact assessment).	Option goes through designated sensitive area(s) of local importance and meets the Schedule 2 thresholds. Limited Environmental impact assessment required.	Option goes through designated sensitive area(s) of regional importance and meets the Schedule 2 thresholds. Environmental impact assessment required.	Option goes through designated sensitive area(s) of national importance and meets the Schedule 2 thresholds. Environmental impact assessment required.	Option goes through designated sensitive area(s) of international importance (e.g. European designated sites or world heritage site and/or meets the Schedule 1 thresholds. Environmental impact assessment required.
Land interests and public perception/ safety considerations (sepa ration distance).	15%	Very low impact on land interests and public perception. Separation distances for safety not constrained.	Low impact on land interests and public perception. Separation distances for safety not constrained.	Medium impact on land interests and public perception. Separation distances for safety minimally constrained.	High impact on land interests and public perception. Separation distances for safety constrained.	Very high impact on land interests and public perception (high pressure pipeline through a town e.g.). Separation distances for safety significantly constrained.
Constructability	15%	Minor refurbishment to AGI, no modifications to pipeline	Replacement of existing AGI, no modification to pipeline.	Replacement of existing AGI, refurbishments required to existing pipeline.	Minor refurbishments to AGI, new pipeline required.	Replacement of existing AGI, new pipeline required.
Total Installed Cost	20%	Total installed cost will be scored based on ranking of options. The utilisation factor of the lines will be factored into the cost and the scoring will be based on the order of magnitude of the cost in terms of £/MWh/annum.				
Security of Supply	15%	Hydrogen supply from repurposed NTS (offtake close to repurposed NTS) and natural gas supply as back up for full capacity. No compromise to other users of natural gas (e.g. domestic or non top 200)	Hydrogen supply from repurposed NTS with no natural gas back up supply (offtake far from repurposed NTS), as well as access to hydrogen production and storage sites allowing for buffer capacity.	Hydrogen supply not directly from repurposed NTS (no natural gas back up supply), with access to hydrogen production and storage allowing for buffer capacity for security of supply.	Hydrogen supply not directly from repurposed NTS but nearby access hydrogen and natural gas storage sites as a buffer.	Hydrogen supply not directly from repurposed NTS, with no buffer capacity from production, linepack, or storage and no natural gas supply as back up supply.

9.3 Capex model

Within Optioneer™ the Capital Expenditure (CAPEX) can also be developed. The tool applies different construction methods to each section of a route, dependent on the terrain or features it is running through and the complexity of these. Costs were assigned to each construction methodology in terms of fixed costs (for start up, equipment etc.) and linear costs (for labour, materials etc) which enabled the build up of CAPEX for each pipeline, which was also used in the route selection process. A diagram of the capex model is shown in Figure 10.

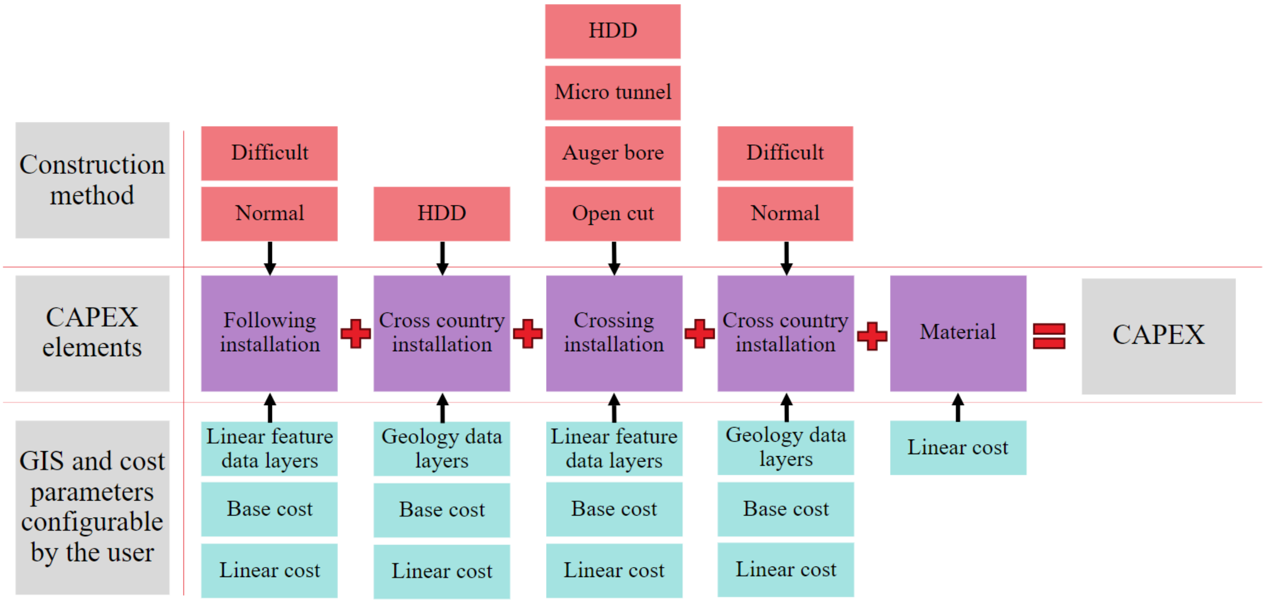


Figure 10: CAPEX model – High level structure of the onshore pipeline costing logic in optioneer

9.4 Teesside

9.4.1 Approach and specific assumptions

The Teesside area includes potential users, hydrogen producers and plans for private hydrogen distribution pipelines as well as the existing natural gas network. To provide a structured approach to routing in the area the hierarchy in Figure 11 has been developed.

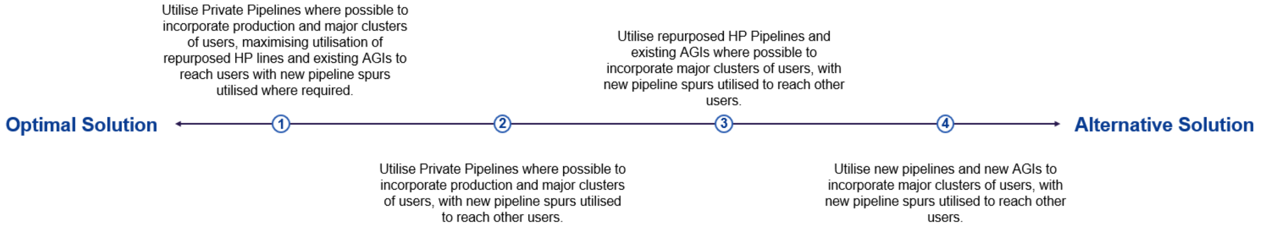


Figure 11: Hierarchy for Teesside area approach

Options

Two options have been considered for the area:

1. [redacted] **NOT Utilised:** Assumes that the [redacted] private pipelines is not constructed as currently planned and is based on high pressure hydrogen being available at both Cowpen Bewley AGI and [redacted] AGI.
2. [redacted] **Utilised:** Assumes that the [redacted] is constructed as currently planned and can be utilised as a backbone for high pressure hydrogen distribution in the Teesside area including direct connection to users and producers.

The following assumptions have been made in the development of the network for this area:

- [redacted] private pipeline assumed to operate at HP
- NTS pipeline between Cowpen Bewley to Haverton Hill area can be re-purposed

9.4.2 Users

There are 17 users which have been identified within the Teesside area from the demand study (293805-ARUP-DMS) for hydrogen connection as shown in Table 4. Some additional potential users who have signed MoUs with producers have also been considered for connection in the area.

These users have been grouped together into "clusters" to enable the development of a basis for the network. These clusters were utilised in the development of option 1 [redacted] pipeline not utilised). The clusters are detailed within Table 4.

Table 4: Summary of clusters and users

[redacted]

Some users were included in multiple clusters to enable all potential options for routing to be considered, in the preferred solution the optimal routings to connect these users are included.

[redacted]

Figure 12: Map of Teesside users

9.4.3 Scenarios

Two scenarios have been developed for connection to each cluster of users. Table 5 covers option 1 where utilisation of private pipelines is not possible, leaving the "optimal solution" as either *new* or *repurposed* pipelines. A summary of the scenarios and potential solutions are described in Table 6, these were assessed and the preferred solution is detailed at the end of this section.

Table 5: Summary of scenarios for option 1 (BP pipeline NOT utilised)

Cluster	Scenario	Description
1	1	Connection to Hartlepool users including repurposed HP line from Greatham to Naisberry with *new* lines to users
	2	Connection to the Hartlepool users using all *new* pipelines
2	1	Connection to the north Tees users using all *new* pipelines
	2	Connection to the north Tees users including *repurposed* NTS pipeline from Cowpen Bewley to Haverton Hill area with new lines to users
3	1	Connection to Seal Sands users including *repurposed* HP line from Cowpen Bewley to Seal Sands Industrial Regs with *new* lines to users
4	1	Connection to south Tees users using all *new* pipelines
5	1	Connection to south Tees users (further afield) including repurposed HP lines from [redacted] to Newby and [redacted] to Brotton with *new* lines to users
	2	Connection to south Tees users (further afield) using all *new* pipelines
6	1	Connection to lower Hartlepool users including *repurposed* HP line from Greatham to [redacted] with *new* lines to users
	2	Connection to lower Hartlepool users using all *new* pipelines

9.4.4 Route evaluation and selection

Options for the each of the new pipeline route corridors have been developed and evaluated using Continuum Optioneer software to determine the optimal routings to include for each scenario. The preferred options were then determined based on lowest penalty and capex. Fully developed scenarios with preferred options were then analysed using multi criteria analysis (MCA) (see 9.2) to determine the preferred scenario for each cluster.

Preferred solutions for option 1 (BP pipeline NOT utilised)

The preferred routings for option 1 are displayed in Figure 13 with further details included in Table 6.

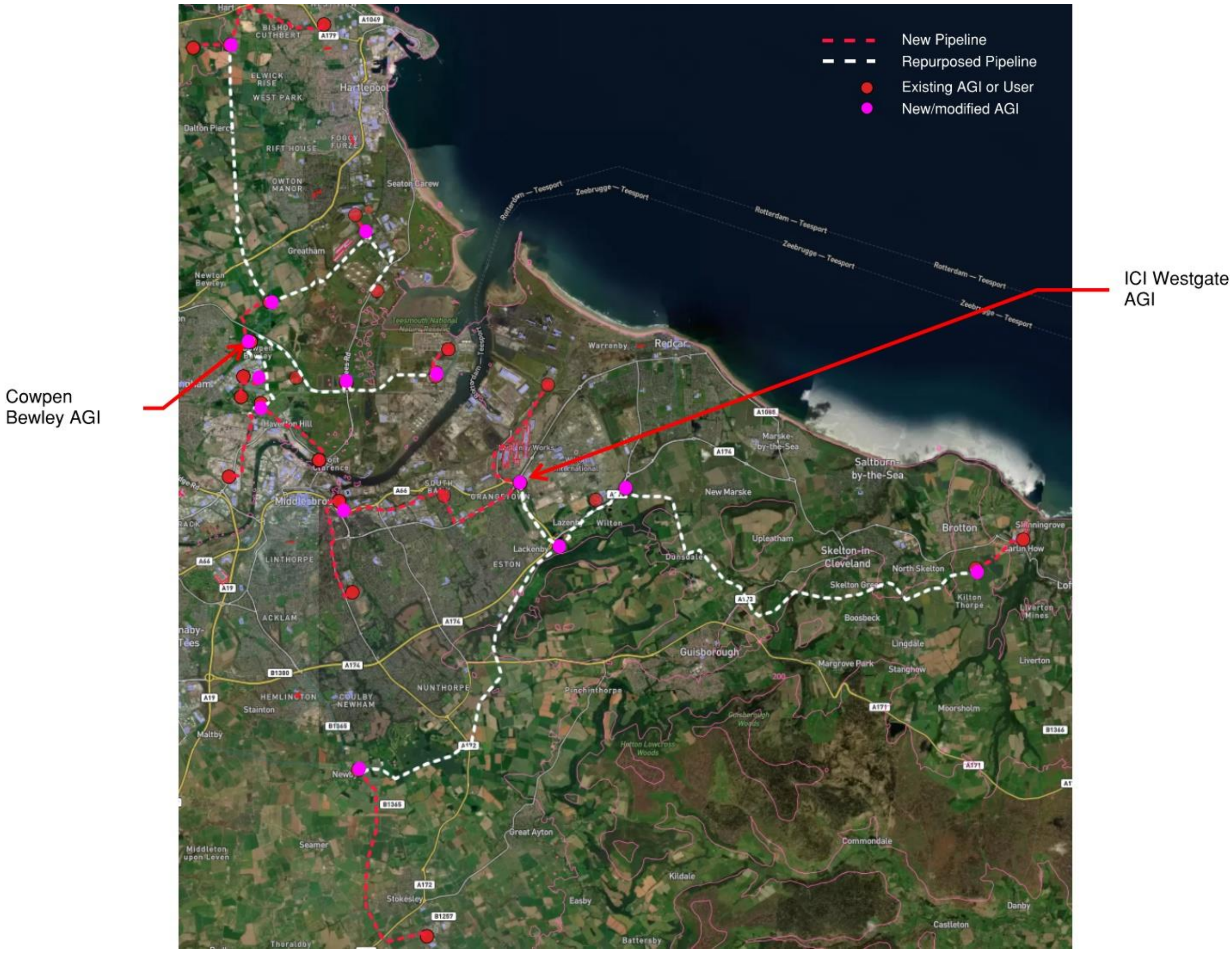


Figure 13: Selected routes and AGI's for option 1 - BP Pipeline NOT utilised

Table 6: Option 1 (BP pipeline NOT utilised) selected scenario summaries with route descriptions

Cluster	Preferred scenario	Description
1	1	**New pipelines** total 6.6km at 300mm NB • Cowpen Bewley AGI to Greatham AGI (1.8km, HP) • Naisberry AGI to [redacted] (1km, MP) • Naisberry AGI to [redacted] (3.8km, MP) **Repurposed HP pipeline** Greatham AGI to Naisberry AGI (7.9km) **Modified AGI** at Naisberry for PRS (HP to MP) **Modified AGI** at Cowpen Bewley for hydrogen distribution **Modified AGI** at Greatham for hydrogen distribution
2	2	**New pipelines** total 6.2km at 300mm NB • Closest point on RP NTS pipeline to [redacted] (0.8km, MP) • [redacted] to [redacted] (0.4km, MP) • Closest point on RP NTS pipeline to [redacted] (2.3km, MP) • [redacted] to [redacted] (2.7km, MP) **Repurposed NTS pipeline** Cowpen Bewley to Haverton Hill area (3km) [Note 1] **New AGI** off the NTS near [redacted] for PRS (HP to MP) **New AGI** off the NTS nearest to [redacted] for PRS (HP to MP)
3	1	**New pipelines** total 1.1km at 300mm NB • Dtba Seal Sands AGI to [redacted] (1.1km, MP) **Repurposed HP pipeline** Cowpen Bewley to Seal Sands Industrial Regs AGI (3.9km) **Repurposed HP pipeline** Seal Sands Industrial Regs AGI to Dtba Seal Sands AGI (2.9km) **Modified AGI** at Dtba Seal Sands for PRS (HP to MP) **Modified AGI** at Seal Sands Industrial Regs for hydrogen distribution
4	1	**New pipelines** total 14km at 300mm NB • [redacted] AGI to [redacted] (4.1km, HP) • [redacted] AGI to [redacted] (3.2km, MP) • [redacted] to [redacted] (3.5km, MP) • [redacted] to [redacted] (3.2km, MP) **Modified AGI** at [redacted] for PRS (HP to MP) **New AGI** at [redacted] for PRS (MP to LP)
5	1	**New pipelines** total 8.3km at 300mm NB • Brotton AGI to [redacted] (1.6km, MP) • Newby AGI to [redacted] (6.7km, MP) **Repurposed HP pipeline** [redacted] AGI to Brotton AGI (18.7km) [Note 2] **Repurposed HP pipeline** [redacted] AGI to Newby AGI (13km) [Note 2]

		Modified AGI at Brotton for PRS (HP to MP) **Modified AGI** at Newby for PRS (HP to MP) **Modified AGI** at Greystones pig trap for hydrogen distribution **Modified AGI** at Kirkleatham PRS for hydrogen distribution
6	1	**New pipeline** total 1.8km at 300mm NB • Cowpen Bewley AGI to Greatham AGI (1.8km, HP) **Repurposed HP pipeline** Greatham AGI to Venator (6.1km) **New AGI** near [redacted] for PRS (IP to MP)

The following notes are associated with further work / assessment required to confirm the selected routes within the FEED stage of the project.

Note 1: Discussion required with National Gas to determine feasibility of repurposing this line.

Note 2: Potential difficulties with repurposing the section of this line from [redacted] to Greystones to be further investigated in FEED.

Preferred solutions for option 2 (BP pipeline utilised)

Utilising the BP private pipeline, option 2, offers the opportunity for a high-pressure hydrogen backbone crossing the river Tees to connect all users and producers. This approach has been developed based on available information from BP and with selected routes from option 1 to connect all users as shown in Figure 14 with further details included in Table 7.

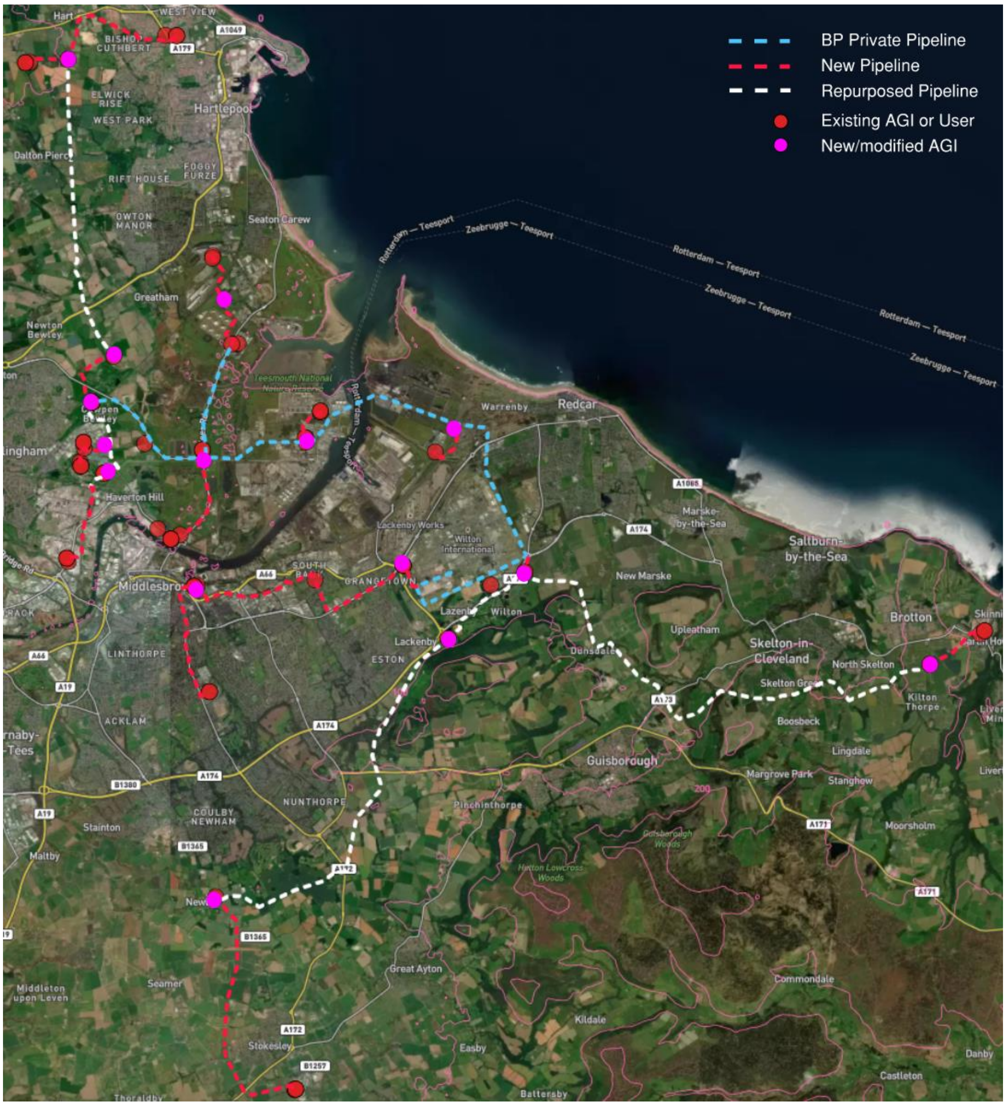


Figure 14: Selected routes for option 2 BP Pipeline utilised

Table 7: Option 2 (BP pipeline utilised) selected scenario summaries with route descriptions

Cluster	Preferred scenario	Description
1	1	**New pipelines** total 6.6km at 300mm NB • Cowpen Bewley AGI to Greatham AGI (1.8km, HP) • Naisberry AGI to [redacted] (1km, MP) • Naisberry AGI to [redacted] (3.8km, MP) **Repurposed HP pipeline** Greatham AGI to Naisberry AGI (7.9km) **Modified AGI** at Naisberry for PRS (HP to MP) **Modified AGI** at Cowpen Bewley for hydrogen distribution **Modified AGI** at Greatham for hydrogen distribution
2	2	**New pipelines** total 3.5km at 300mm NB • Closest point on RP NTS pipeline to [redacted] (0.8km, MP) • [redacted] to [redacted] (0.4km, MP)

		• Closest point on RP NTS pipeline to [redacted] (2.3km, MP) **Repurposed NTS pipeline** Cowpen Bewley to Haverton Hill area (3km) [Note 1] **New AGI** off the NTS near [redacted] for PRS (HP to MP) **New AGI** off the NTS nearest to [redacted] for PRS (HP to MP)
3	1	**New pipelines** total 3.8km at 300mm NB • Dtba Seal Sands AGI to [redacted] (1.1km, MP) • Seal Sands Industrial Regs AGI to [redacted] (2.7km, MP) **Modified AGI** at Dtba Seal Sands for PRS (HP to MP) **Modified AGI** at Seal Sands Industrial Regs for hydrogen distribution
4	1	**New pipelines** total 11.9km at 300mm NB • BP private pipeline to Bran Sands (1.3km, HP) • BP private pipeline to [redacted] AGI (0.7km, HP) • [redacted] AGI to [redacted] (3.2km, MP) • [redacted] to [redacted] (3.5km, MP) • [redacted] to [redacted] (3.2km, MP) **Modified AGI** at ICI Westgate for PRS (HP to MP) **New AGI** near to [redacted] for PRS (HP to MP) **New AGI** at [redacted] for PRS (MP to LP)
5	1	**New pipelines** total 8.7km at 300mm NB • BP private pipeline to Kirkleatham AGI (0.4km, HP) • Brotton AGI to [redacted] (1.6km, MP) • Newby AGI to [redacted] (6.7km, MP) **Repurposed HP pipeline** ICI Westgate AGI to Brotton AGI (16.4km) [Note 2] **Repurposed HP pipeline** ICI Westgate AGI to Newby AGI (10.7km) [Note 2] **Modified AGI** at Brotton for PRS (HP to MP) **Modified AGI** at Newby for PRS (HP to MP) **Modified AGI** at Greystones pig trap for hydrogen distribution **Modified AGI** at Kirkleatham PRS for hydrogen distribution
6	1	**New pipeline** total 2.7km at 300mm NB • BP private pipeline to [redacted] (0km, IP) • [redacted] to [redacted] (2.7km, IP) **New AGI** near [redacted] for PRS (IP to MP)

The following notes are associated with further work / assessment required to confirm the selected routes within the FEED stage of the project.

Note 1: Discussion required with National Gas to determine feasibility of repurposing this line.

Note 2: Potential difficulties with repurposing the section of this line from [redacted] to Greystones to be further investigated in FEED.

9.4.5 Challenges

- Crossing the river Tees to connect users and producers and develop a full network
- Interfaces with producers and private pipelines and uncertainty around timelines and full routings
- Highly industrial and densely populated areas to navigate around for new routings
- Flood zone north of Middlesbrough

9.4.6 Opportunities

- [redacted] also have plans for a private pipeline along a similar route to the [redacted] pipeline. Should [redacted] not progress their plans then the [redacted] pipeline offers a secondary option as a hydrogen backbone in the area.
- Connection to additional users in the area outside of the original top 200 list provided
- Operate repurposed lines at MP rather than HP to reduce number of PRSs

9.4.7 Risks

- BP pipeline, if used, will expose NGN to potential lease costs or operational constraints.
- Repurposing from [redacted] to Newby is only possible subject to new methane connection to Teesworks to meet increasing demand

9.4.8 Conclusion and next steps

Pipeline routings for a hydrogen network in the Teesside area have been successfully developed to enable distribution of hydrogen to all users identified in the demand study (293805-ARUP-DMS). Out of the two options explored, Option 2 is the preferred option as this utilises the BP private pipeline, keeps capex costs down and minimises the length of new & repurposed pipeline required.

A summary of the key components is in Table 8, showing the pipeline lengths for each option.

Table 8: Summary of pipeline lengths for both routing options

Area modification	Option 1 (BP pipeline NOT utilised) Line length / number of	Option 2 (BP pipeline utilised) Line length / number of
Length new pipeline (km)	38	37.2
Length of repurposed pipeline (km)	55.5	38
AGIs new/repurposed/modified	4 New 10 Modified	5 New 10 Modified

The next steps for the FEED study of Teesside area routing are included in the list below:

- Further modelling of the repurposed lines required to assess implications of repurposing pipelines on wider network and other industrial and domestic users.
- Liaise with [redacted] regarding new pipeline to understand timelines, targeted users and producers and agreement on interface between the private line and NGN
- Liaise with National Gas Transmission regarding repurposing of NTS line from Cowpen Bewley to Haverton Hill Industrial Cluster and repurposing of NTS line from Feeder 7 to Cowpen Bewley via Elton.

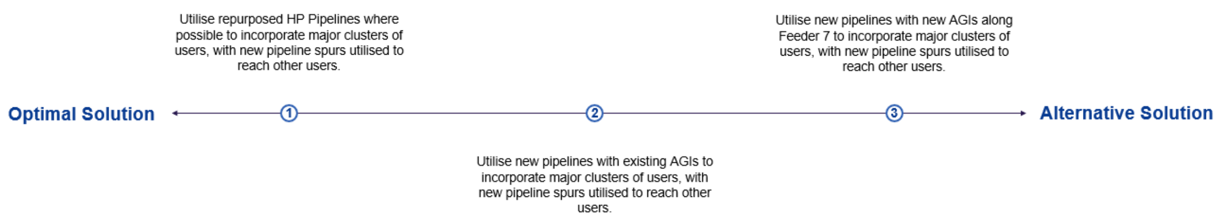
- Liaise with Teesworks and BP to determine plan regarding increased methane routing and new pipeline to Teesworks
- Re-evaluation of capital costs for the Teesside area
- Further route optimisation for all new lines required in FEED
- Develop a connection from Cowpen Bewley AGI to Elton AGI
- Identify further off-takers outside of the Top 200 suitable for the proposed lines
- Further assess AGI requirements based on additional industrial off-takers and other demands
- Investigate connection to trials in the area
- Assess existing AGIs included in preferred routes to understand requirement for new/repurposed/modification
- Consider an overarching strategy for HP/IP/MP for the new network
- Continuum shape files for routes to be exported as google earth files for future presentations
- Consider strategic locations of the pig traps for the new network

9.5 Bishop Auckland to Pannal

9.5.1 Approach and specific assumptions

To provide a structured approach to routing in the area, the hierarchy in illustrated in Figure 15 has been developed.

Figure 15: Hierarchy of solutions for approach



The following assumptions have been made in each scenario in the development of the network for this area:

- Feeder 7 shall be fully repurposed to hydrogen.
- Unmeshing of the IP/MP and LP network will be possible in scenarios where HP network lines are repurposed.
- Existing AGIs can be used for hydrogen distribution network.

9.5.2 Users

There are 17 users which have been identified from the demand study (293805-ARUP-DMS) for hydrogen connection as shown in Figure 16.

[redacted]

Figure 16: Map of users

9.5.3 Clusters

Initially to enable the development of a basis for the network, the users were split into clusters for which various scenarios were developed to enable connection. The clusters are detailed within Table 9.

Table 9: Summary of clusters and users

[redacted]

[redacted]

Some users were included in multiple clusters to enable all potential options for routing to be considered, in the preferred solution the optimal routings to connect these users are included. These are highlighted in blue.

9.5.4 Scenarios

Scenarios have been developed for connection to each of the clusters of users with some including repurposing of existing pipelines where other scenarios have been developed using all new pipelines as detailed in Table 10. Lines to users who have been included in multiple clusters that have not been selected for inclusion due to being included in another cluster are shown in italics. Optimal to alternative solutions are all summarised in the table. For clusters 5 and 6, only 1 scenario is possible.

Table 10: Summary of scenarios

Cluster	Scenario	Description
1	1	• Repurposed HP line connection between Bishop Auckland AGI and Newton Aycliffe/ Darlington Cluster (1). • Repurposed line from Bishop Auckland AGI to Newton Aycliffe exit spur AGIs (Direct Worktops Pig Trap and Hydropolymers offtake) • New line from Direct Worktops Pig Trap to [redacted]. • New line from [redacted] exit HP spur to [redacted]. • New line from [redacted] • New line from [redacted]. • *New line from [redacted] to [redacted]*
	2	• New line connection between Bishop Auckland AGI and Newton Aycliffe/ Darlington Cluster (1) via centrepoint. • New line from Bishop Auckland AGI to centre point between [redacted] and [redacted] (shortest route.) • New line from centre point between [redacted] and [redacted] • New line from centre point between [redacted]. • New line from [redacted] to [redacted]. • New line from [redacted] to [redacted]. • *New line from [redacted] to [redacted]*
	3	• New line connection with new AGI from Feeder 7 to Newton Aycliffe/Darlington Cluster (1) via centrepoint. • New line (shortest distance) between new AGI on Feeder 7 and a centre point between [redacted] and [redacted]. • New line from centre point between [redacted]/[redacted] and [redacted] to [redacted]/[redacted]. • New line from centre point between [redacted]/ [redacted] and [redacted] to[redacted].

		• New line from [redacted] [redacted] to [redacted]. • New line from [redacted] to [redacted]. • *New line from* [redacted] *to* [redacted]
	4	• New line connection with new AGI from Feeder 7 to Newton Aycliffe/ Durham Cluster (1) via [redacted]. • New line (shortest distance) between new AGI on Feeder 7 and [redacted]. • New line from [redacted] to [redacted]. • *New line from* [redacted] *to* [redacted] • New line from [redacted] to [redacted]. • New line from [redacted] to [redacted].
	5	• New line connection with new AGI from Feeder 7 to Newton Aycliffe/Durham Cluster (1) via centrepoint. • New line (shortest distance) between new AGI on Feeder 7 and a centre point between [redacted] and [redacted]. • New line from centre point between [redacted] and [redacted] to [redacted] • New line from centre point between [redacted] and [redacted] to [redacted]. • New line from [redacted] to [redacted]. • New line from [redacted] to [redacted]. • *New line from* [redacted] *to* [redacted]
2	1	• New line connection between Little Burdon AGI and Darlington Cluster (2). • New line between Little Burdon AGI and [redacted].
	2	• New line connection with new AGI from Feeder 7 to Darlington Cluster (2). • New line (shortest distance) between new AGI on Feeder 7 and [redacted].
3	1	• Repurposed HP line connection to Middlestone Moor PRS to feed Spennymoor Cluster (3) • Repurposed HP line from Leasingthorne Pig Trap to Middlestone Moor PRS. • New line from Middlestone Moor PRS to [redacted]. • New line from Middlestone Moor PRS to [redacted].
	2	• New line connection from Bishop Auckland AGI to Spennymoor Cluster (3). • New line from Bishop Auckland AGI to [redacted] • New line from [redacted]. to [redacted].

	3	• New line connection from Leasingthorne Pig Trap to Spennymoor Cluster (3). • New line from Leasingthorne Pig Trap to [redacted]. • New line from Leasingthorne Pig Trap to [redacted].
4	1	• New line connection from Thrintoft AGI to Leeming Cluster (4). • New line from Thrintoft AGI to [redacted]. • New line from [redacted] [redacted]. • New line from [redacted] to Transport (A1). • *New line from* [redacted] *to* [redacted].
	2	• New line connection with new AGI from Feeder 7 to Leeming Cluster (4). • New line (shortest distance) between new AGI on Feeder 7 to [redacted]. • New line from [redacted] to [redacted]. • New line from [redacted] to Transport (A1). • *New line from* [redacted] *to* [redacted].
	3	• Repurposed HP line connection to Catterick PRS feeding Leeming Cluster via Transport (A1). • Repurposed HP line from Thrintoft AGI to Catterick PRS. • New line (shortest distance) from repurposed HP line to Transport (A1). • New line from Transport (A1) to [redacted]. • New line from [redacted] to [redacted]. • *New line from* [redacted] *to* [redacted].
5	1	• New line connection with new AGI from Feeder 7 to [redacted]. • New line (shortest distance) between new AGI on Feeder 7 to [redacted]
6	1	• New line connections with new AGIs from Feeder 7 to Masham/ Ripon/ Dalton Cluster (5). • New line (shortest distance) between new AGI on Feeder 7 to [redacted] • New line from [redacted] to [redacted]. • *New line from new AGI on Feeder 7 (shortest distance to* [redacted]*) to* [redacted].
7	1	• New line connection from Burley Bank AGI to Birstwith Cluster (6). • New line from Burley Bank AGI to [redacted] • New line from [redacted] to [redacted].
	2	• New line connections with new AGIs from Feeder 7 to Birstwith Cluster (6). • New line (shortest distance) between new AGI on Feeder 7 to [redacted].

		• New line from [redacted] to [redacted].
8	1	• Repurposed HP line from Burley Bank AGI to Harrogate PRS. • New line from Harrogate PRS to [redacted]. • New line from Harrogate PRS to [redacted].
	2	• New line connections with new AGIs from Feeder 7 to Harrogate Cluster • New line (shortest distance) between new AGI on Feeder 7 to [redacted] • New line from [redacted]. to [redacted]
	3	• Repurposed HP line connection from Burley Bank AGI to Pannal AGI feeding [redacted]. • New line (shortest distance) from existing HP line with new AGI to [redacted]. • New line from [redacted]. to [redacted].
	4	• New line connection from Burley Bank AGI feeding [redacted]. • New line from Burley Bank AGI to [redacted]. • New line from [redacted]. to [redacted].

9.5.5 Route evaluation and selection

Options for the each of the new pipeline route corridors have been developed and evaluated using Continuum Optioneer software to determine the optimal routings to include for each scenario. The preferred options were then determined based on lowest penalty and capex. Fully developed scenarios with preferred options were then analysed using multi criteria analysis (MCA) (see 9.2) to determine the preferred scenario for each cluster.

Figure 17 below shows the preferred routing scenarios. Feeder 7 is shown in orange, with repurposed lines shown in white and new lines shown in red. More information on each scenario can be found in Table 11.

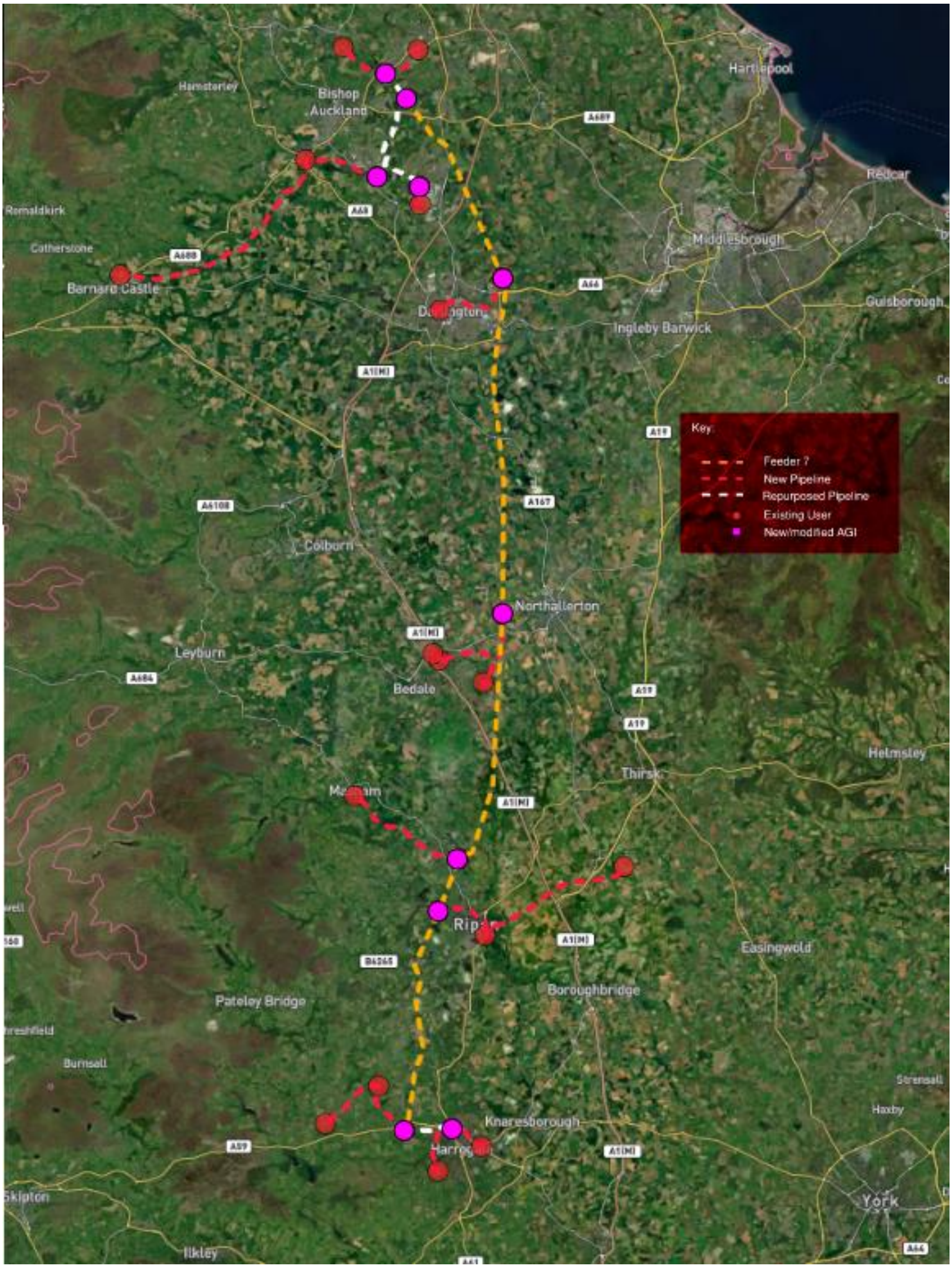


Figure 17: Selected routes

Table 11: Selected scenario summaries with route descriptions

Cluster	Preferred scenario	Description
1	1	**Repurposed Bishop Auckland AGI** **Repurposed HP line** connection between Bishop Auckland AGI and Newton Aycliffe/ Darlington Cluster. (8.6 km repurposed HP line). **Repurposed HP line** from repurposed Bishop Auckland AGI to repurposed Newton Aycliffe exit spur AGIs (Direct Worktops Pig Trap and [redacted] offtake). (1.2 km and 3.0 km repurposed HP lines respectively). **Modified Pig Trap** at Direct Worktops for MP. **New MP line** from Direct Worktops Pig Trap to [redacted]. (5.4 km new 300 mm MP line) **New MP line** from [redacted] to [redacted] (17.3 km new 300 mm MP line). **Modified AGI** at [redacted] Offtake. **New HP line** from [redacted] exit HP spur to [redacted]. (0.1 km new 300 mm HP line). **New PRS** at [redacted] to IP. **New IP line** from [redacted] to [redacted]. (1.8 km new 300 mm IP line).
2	1	**Modified AGI** at Little Burdon. **New MP line** between Little Burdon AGI and [redacted]. (7.1 km new 300 mm MP line).
3	1	**Modified Pig Trap** at Leasingthorne **Repurposed HP line** from Leasingthorne Pig Trap to Middlestone Moor PRS. (2.3 km repurposed HP line) **Modified PRS** at Middlestone Moor **New MP line** from Middlestone Moor PRS to [redacted]. (3.5 km new MP line). **New MP line** from Middlestone Moor PRS to [redacted] (3.1 km new MP line).
4	1	**Modified AGI** at Thrintoft **New HP line** from Thrintoft AGI to [redacted]). (5.7 km new 300 mm HP line). **New HP line** from [redacted] to [redacted]. (5.8 km new 300 mm HP line). **New HP line** from [redacted] to Transport (A1). (1.4 km new 300 mm HP line). **2 new AGI/PRS** to provide MP to [redacted] and [redacted].
5	1	**New AGI** on Feeder 7 at the closest point to [redacted].

		New MP line (shortest distance) between new AGI on Feeder 7 to [redacted]. (9.1 km new 300 mm MP line).
6	1	**New AGI** on Feeder 7 at the closest point to [redacted]. **New MP line** (shortest distance) between new AGI on Feeder 7 to [redacted]. (5.2 km new 300 mm MP pipe). **New MP line** from [redacted] to [redacted]. (11.5 km new 300 mm MP line).
7	1	**Modified AGI** at Burley Bank. **New MP line** from Burley Bank AGI to [redacted]. (4.2 km new 300 mm MP line). **New MP line** from Birstwith Mill to [redacted]. (4.8 km new 300 mm MP line).
8	1	**Repurposed HP line** from Burley Bank AGI to Harrogate PRS. (3.6 km repurposed HP line). **Modified PRS** at Harrogate PRS. **New MP line** from Harrogate PRS to [redacted]. (3.2 km new 300 mm MP line). **New MP line** from Harrogate PRS to [redacted]. (4.5 km new 300 mm MP line).

9.5.6 Challenges

- High number of options and scenarios to evaluate.
- Large distances between industrial users resulting in long pipeline routings.
- Leeming Bar is relatively industrialised, making routing to Transport A1 difficult.
- Routing around/through urban areas such as Ripon, Harrogate, and Darlington.

9.5.7 Opportunities

- Repurposing the existing HP line from Bishop Auckland AGI to Newton Aycliffe exit spur AGIs - Direct Worktops Pig Trap and [redacted] offtake (saves approximately 12 km of new pipeline).
- Repurposing the existing HP line from Leasingthorne Pig Trap to Middlestone Moor PRS (saves approximately 4 km of new pipeline)
- Repurposing the existing HP line from Burley Bank AGI to Pannal AGI (saves approximately 2-4 km of new pipeline)
- Potential for repurposing for IP/MP lines where there are multiple running in parallel.
- Potential for refurbishment of existing AGIs for use in the hydrogen distribution network (Bishop Auckland, Leasingthorne, Direct Workstops, [redacted], Little Burdon, Middlestone Moor, Leasingthorne, Burley Bank, Thrintoft, Harrogate).
- Saves approximately 4-8 km of new pipeline routing directly to [redacted] rather than from Cluster 1.
- Saves approximately 4 km of new pipeline compared to including [redacted] in Cluster 4 and approximately 2-4 km of new pipeline compared to including [redacted] in Cluster 6.
- Developing backbone hydrogen network in Darlington for potential future domestic use.

- Noting the existing twin lines between Bedale and Masham, there is a potential for repurposing the IP/MP network to connect [redacted] to [redacted].
- Developing backbone hydrogen network in Ripon, Harrogate, and Darlington for potential future domestic use.
- The routing for cluster 2 passes a now heavily industrial area on the east of Darlington, that includes new potential users such as [redacted].
- The routing for cluster 4 could be adjusted to connect with recently announced hydrogen village in Askew.
- Transport Hub A1(M) could be connected directly to Thrintoft in cluster 4 to reduce the number of new AGIs required.

9.5.8 Risks

- Some users (e.g. [redacted]) are situated a long way from Feeder 7 and their nearest industrial users, therefore hydrogen supply to these users may not be cost effective.
- Distance from [redacted] to [redacted] is significant (approx. 13 km). Concluded that it should not be included within this cluster based on this information if new lines are being used.

9.5.9 Conclusion and next steps

Pipeline routings for a hydrogen network in the area between Bishop Auckland and Pannal have been successfully developed to enable distribution of hydrogen to all users identified in the demand study (293805-ARUP-DMS).

Table 12: Summary of pipeline lengths

Area modifications	Line Length / number of
Length new pipeline (km)	93.5
Length of repurposed pipeline (km)	18.7
New AGIs	5
Repurposed/Modified AGIs	7

The next steps for the FEED study of area routing are included in the list below:

- Evaluate cost-benefit analysis associated with building line for single user [redacted] given long distance in FEED, to consider any non-top 200 users that may benefit from a hydrogen network within Darlington.
- Further modelling to be carried out in FEED for repurposed HP line between Bishop Auckland AGI to Direct Worktops Pig Trap and [redacted] offtake to assess implications of repurposing pipeline on wider network and other industrial or domestic users.
- Assess options (and implications) for the potential repurposing of the or new IP/MP network in FEED taking into consideration the non-top 200 user requirements and the domestic requirements.
- Evaluate cost-benefit analysis associated with building individual line for single user in FEED, to consider any non-top 200 users that may benefit from a hydrogen network within Darlington.
- Further modelling to be carried out in FEED for repurposed HP line between Leasinghorne Pig Trap and Middlestone Moor PRS in FEED to assess implications of repurposing pipeline on wider network and other industrial or domestic users.

- Further modelling to be carried out in FEED for repurposed HP line between Thrintoft AGI to Catterick PRS in FEED to assess implications of repurposing pipeline on wider network and other industrial or domestic users.
- Assess routing option to [redacted] that does not cross through Ripon.
- Further modelling of the repurposed lines required in FEED to assess implications of repurposing pipeline on wider network and other industrial and domestic users.
- Re-evaluation of capital costs for Area B following completion of capital cost model development
- Further route optimisation for all new lines required in FEED.
- Consider non-top 200 industrial users and domestic users in FEED, particularly in urban areas.

9.6 Leeds / Bradford

9.6.1 Approach and specific assumptions

The area covers Leeds and Bradford which contains large industrial users, one producer and a large population for future domestic demand. Feeder 7 runs from Pannal (approximately 20km North of both city centres) in a South-Easterly direction to the Towton AGI. Many of the large industrial users are located to the South of the cities, with little industrial use between Feeder 7 and the anticipated users. The urban areas mean that repurposing will be the key focus, since routing will be difficult in the built up areas, however the large domestic loads mean that a lot of the HP network is highly utilised. There is planned hydrogen production in this area at Bowling back lane in Bradford. The area is also a gateway to providing hydrogen connections further south to areas such as Huddersfield, Halifax and Wakefield.

To provide a structured approach to routing, the following hierarchy was implemented:

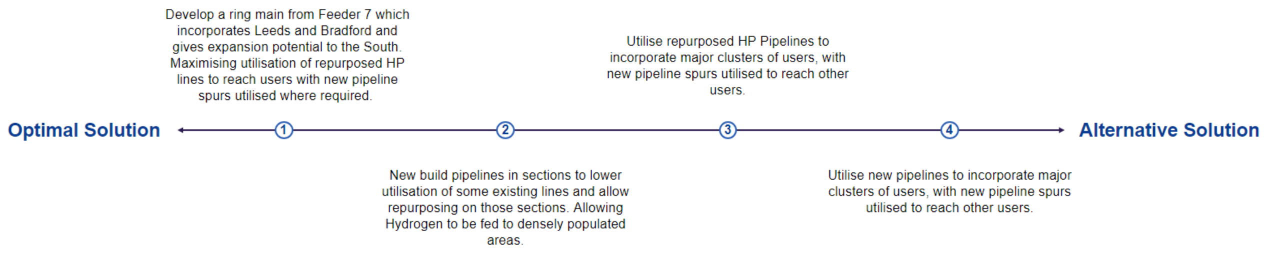


Figure 18: Hierarchy for Leeds / Bradford area approach

The following assumptions were key for the Leeds / Bradford area network development and routing:

- Feeder 7 will be repurposed and hydrogen will be available at Pannal and Towton offtakes.
- The NGN Pannal to Tyresal HP line can be repurposed with the additional methane flow being able to be transported via the HP line to the East with a new offtake North of Crook PRS from Feeder 29.
- There is sufficient space at Meadow Lane PRS to install a new Hydrogen AGI.
- The town trials will be fed from the Towton offtake.

9.6.2 Users

There are 16 industrial users which have been identified within the Leeds / Bradford area from the demand study (293805-ARUP-DMS) and which were deemed feasible for connection within the timescales of the project. The users are shown in Table 13.

These users have been grouped together into “clusters” to enable the development of a basis for the network. These clusters were utilised in the development of the network and are detailed within Table 14.

Table 13: Summary of clusters and users

[redacted]

[redacted]

Figure 19: Users identified in the Leeds/Bradford area

9.6.3 Scenarios

Scenarios have been developed for connection to each of the clusters of users with some including repurposing of existing pipelines where other scenarios have been developed using all new pipelines as detailed in Table 14. Due to the geographic spread of the users and NGT connections, the development of scenarios for this section was apparent from the initial network development, as a result the only cluster with scenario options was cluster 1.

Table 14: Summary of scenarios

Cluster	Scenario	Description
1	1	Establishing a ring main around Leeds and Bradford from Feeder 7 with a mix of *repurposing* and *new* build lines, assuming the line from Pannal to Tyresal can be *repurposed*. This includes connection for town trials.

	2	Establishing a ring main around Leeds and Bradford from Feeder 7 with a mix of *repurposing* and *new* lines, requiring a *new* build line from Pannal to Tyresal. This includes connection for town trials.
2	1	Connection to two chemical production sites mainly utilising *repurposed* lines and one *new* line. This also facilitates hydrogen transport further south at a later date.
3	1	Connection to central Bradford large users with *new* pipelines.
4	1	Connection to [redacted] using all *new* pipelines.
5	1	Connection to South East Leeds, connecting into the Cluster 1 ring main and providing *new* lines to users.
6	1	Connection to [redacted] with *new* pipelines.
7	1	Continuation of cluster 5, connecting to users in the Wakefield area.

9.6.4 Route evaluation and selection

Options for the each of the new pipeline route corridors have been developed and evaluated using Continuum Optioneer software to determine the optimal routings to include for each scenario. The preferred options were then determined based on lowest penalty and capex. Fully developed scenarios with preferred options were then analysed using multi criteria analysis (MCA) (see 9.2) to determine the preferred scenario for each cluster.

The selected routes are shown below in Figure 20.

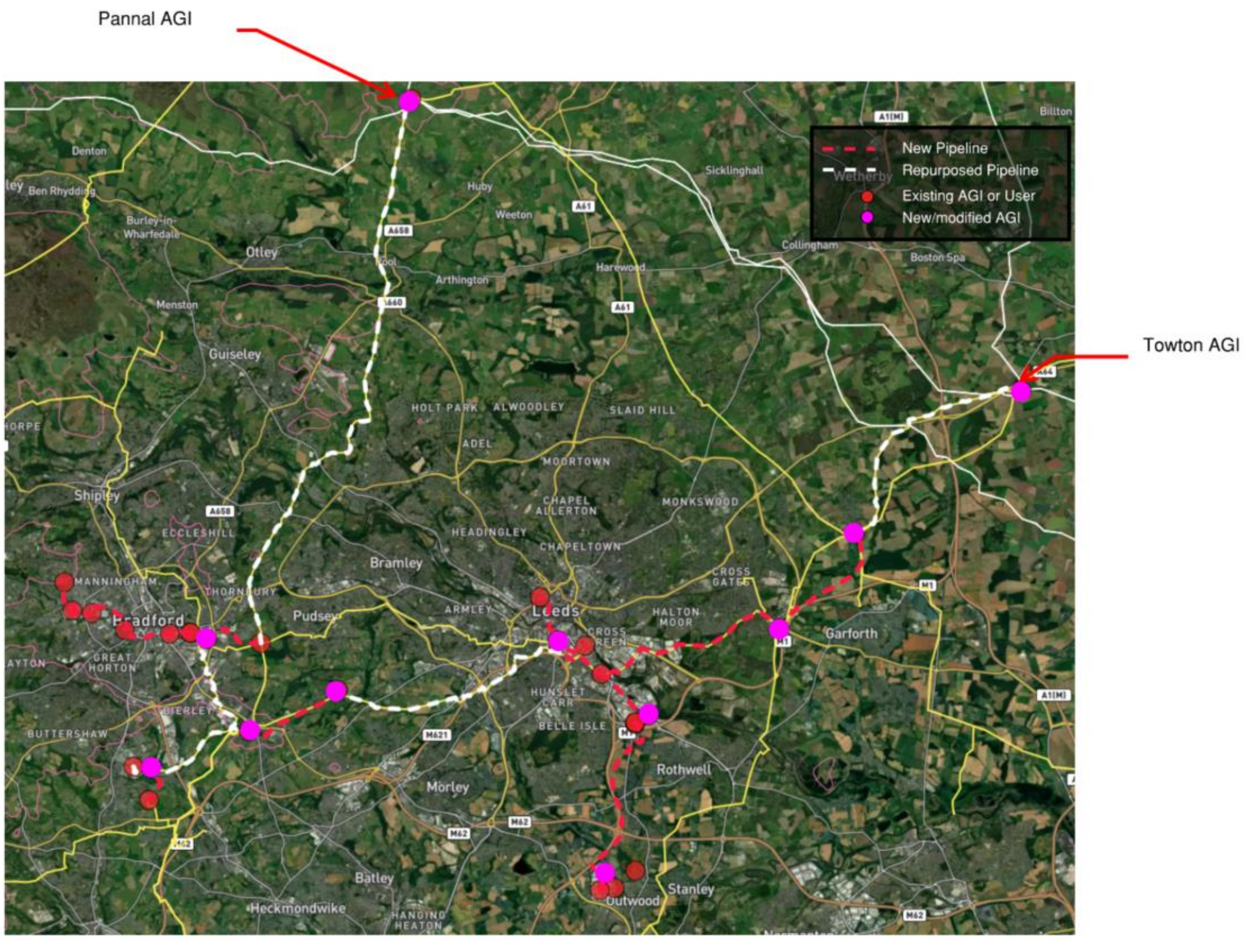


Figure 20: Leeds / Bradford selected routes

The selected routes and required infrastructure is further detailed in the table below.

Table 15: Selected routes

Cluster	Preferred scenario	Description
1	1	**New HP pipelines** 15.3km at 300mm NB • Tyersal to Birkshall (2.4km) • East Bierley to Tong (3.6km) • Meadow lane to Bullerthorpe lane (9.6km) 4.7km at 400mm NB • Barwick to Bullerthorpe lane (4.7km) **Repurposed HP pipelines** • Pannal Offtake to Tyersal PRS (21.0km) • Birkshall to East Bierly (4.2km) • Tong to Meadow Lane (9.7km) • Barwick Pig trap site to Towton (8.9km) **Modified AGI** at Barwick pig trap site to connect existing to new line

		Modified AGI at Bullerthorpe lane to allow future connection to town trials **Modified AGI** at Meadow lane for hydrogen distribution **Modified AGI** at Tong for hydrogen distribution and modification for continued NG distribution **Modified AGI** at East Bierly for hydrogen distribution **Modified AGI** at Birkshall for PRS **Modified AGI** at Tyersal for hydrogen distribution and modification for continued NG distribution
2	1	**New HP pipelines** 1.5km at 300mm NB • Low moor PRS to [redacted] (1.5km) **Repurposed HP pipelines** • East Bierley PRS to Low moor PRS (4.1km) • Low moor PRS to [redacted] (0.8km) **Modified AGI** at Low moor for hydrogen distribution
3	1	**New MP pipelines** 8.6km at 300mm NB • Birkshall to [redacted] (0.9km) • [redacted] to [redacted] (1.1km) • [redacted] to [redacted] (1.9km) • [redacted] to [redacted] (1.9km) • [redacted] to [redacted] (1.4km) • [redacted] to [redacted] (1.4km) AGI modification included in Cluster 1
4	1	**New MP pipelines** 1.3km at 300mm NB • Meadow lane to [redacted] (1.3km) AGI modification included in Cluster 1
5	1	**New HP pipelines** 2.8km at 300mm NB • Tee off Meadow lane to Bullerthorpe lane line to [redacted] (2.2km) • [redacted] to [redacted] (0.6km) **New AGI** PRS allowing MP connection to [redacted] and HP continuation to cluster 7
6	1	**New MP pipelines** 2.1km at 300mm NB • Meadow lane to [redacted] (2.1km) AGI modification included in Cluster 1
7	1	**New HP pipelines** 3.5km at 300mm NB • Arla foods (New AGI) to Wakefield 41 industrial estate (New PRI) **New MP pipelines** 1.4km at 300mm NB Wakefield 41 industrial estate (New PRI) to [redacted] (0.8km)

	[redacted] to [redacted] (0.6km)
	New AGI PRI allowing MP connection to users

9.6.5 Challenges

- Maintaining methane flow to Tong, this has been achieved by a mix of repurposing and new build lines from Birkshall.
- There are large amounts of urban area routing required within this area, easier to route / install medium pressure lines have been used where possible.
- The distance from a hydrogen supply (feeder 7) is relatively large, this has been mitigated through repurposing of existing NG assets where possible, but large capital investment will still be required to develop the ring main from which users can be connected.

9.6.6 Opportunities

- There is an existing pipebridge which crosses the river Aire at Knostrop. This could be utilised to reduce the construction cost of routing under the river.
- The area has large industrial users but particularly high future domestic potential. The selected routes also allow future routing potential to the areas further south such as Huddersfield, Halifax and Wakefield.
- Additional demands of industrial users outside of those assessed, but which are in close proximity to the proposed network.

9.6.7 Risks

- Further repurposing modelling required due to the complexity of the networks where the repurposed lines are being proposed.

9.6.8 Conclusion and next steps

Pipeline routing for a hydrogen network in the Leeds and Bradford area have been successfully developed to enable distribution of hydrogen to all users identified in the demand study (293805-ARUP-DMS). The production of a ring main system was deemed to be preferable and this has been achieved by repurposing as much as technically possible. Large industrial users have been able to be connected to the network and multiple options have been enabled for further distribution to domestic loads and other towns.

Table 16: Summary of pipeline lengths Leeds Bradford

Area modifications	Length / number of
Length new pipeline (km)	88.6
Length of repurposed pipeline (km)	56
New AGIs	3
Repurposed/Modified AGIs	8

The next steps for the FEED study of the Leeds and Bradford area routing are included in the list below:

- Confirmation that the Pipebridge across river Aire can be used.
- Determine required sizing for new pipelines.
- Further modelling of the repurposed lines required in FEED to assess implications of repurposing pipeline on wider network and other industrial and domestic users.

- Further optimisation of when MP network can be utilised and further transport via a HP network is not required.
- Liaise with [redacted] to check on export/import requirements and that space is available for and AGI to connect to the new / repurposed lines.
- Monitor the selection of Feeder 7 vs other Feeders south of Pannal.
- Re-evaluation of capital costs for following completion of capital cost model development.
- Further route optimisation for all new lines required in FEED.
- Investigate connection to trials further when more detail is available.

9.7 Towton to Asselby

9.7.1 Approach and specific assumptions

This area is located along Feeder 7 from Towton AGI to Asselby AGI and includes a number of potential industrial users. There are no planned hydrogen production sites in the area so all potential hydrogen users would be supplied by new or repurposed network fed from Feeder 7.

The solution hierarchy is detailed in Figure 21, with repurposed HP lines being preferred to new pipelines.

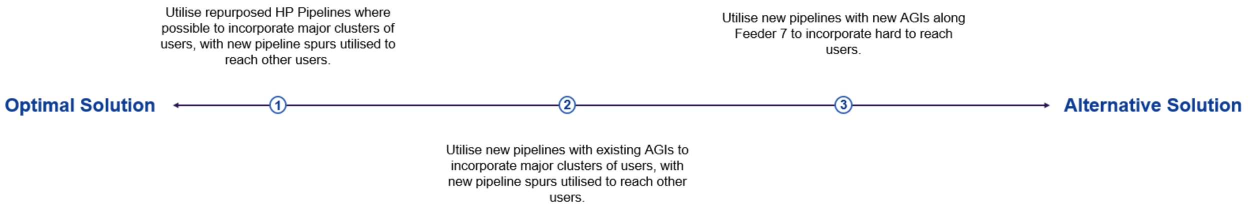


Figure 21: Hierarchy for area solutions

9.7.2 Users

There are 20 users which have been identified within this area from the demand study (293805-ARUP-DMS), as shown in Figure 22.

[redacted]

Figure 22: Map of users

9.7.3 Clusters

To enable the development of a basis for the network, the users were split into clusters for which various scenarios were developed. The clusters and users are detailed within Table 17.

Table 17: Summary of clusters and users

[redacted]

9.7.4 Scenarios

Scenarios have been developed for connection to each of the clusters of users as detailed in Table 18. The scenarios have been developed using new pipelines and repurposing of existing pipelines where possible, per the hierarchy of solutions above. At this stage of the project, repurposing was only considered for HP pipelines; repurposing of IP/MP lines was not considered.

Table 18: Summary of scenarios and solutions

Cluster	Scenario	Description
1	1	Connection to Selby users from repurposed Asselby AGI using all new IP pipelines
2	1	Connection to Goole users from repurposed Asselby AGI using all new MP pipelines

	2	Connection to Goole users from repurposed Asselby AGI using all new MP pipelines via a common centre point
3	1	Connection to Howden users from repurposed Asselby AGI using all new IP pipelines
4	1	Connection to Selby and Knottingley users using: New HP connection from Asselby AGI to Chappel Haddlesey PRS. Repurposed HP pipelines from Chappel Haddlesey PRS to Selby PRS and Knottingley PRS. Repurposed HP line from Chappel Haddlesey PRS to [redacted]. New pipelines from Selby PRS to Selby users and new pipelines from Knottingley PRS to Knottingley users.
5	1	Connection to [redacted] from repurposed Towton AGI using new IP pipeline
	2	Connection to [redacted] from new AGI at closer point on Feeder 7 using new IP pipeline
6	1	Connection to Tadcaster users from repurposed Towton AGI using all new MP pipelines
	2	Connection to Tadcaster using repurposed MP line from Towton with new pipeline between users
7	1	Connection to Knottingley users from repurposed Asselby AGI using all new HP and MP pipelines

9.7.5 Route evaluation and selection

Options for the each of the new pipeline route corridors have been developed and evaluated using Continuum Optioneer software to determine the optimal routings to include for each scenario. The preferred options were then determined based on lowest penalty and capex. Fully developed scenarios with preferred options were then analysed using multi criteria analysis (MCA) (see 9.2) to determine the preferred scenario for each cluster.

The preferred routings are illustrated in Figure 23 with further details included in Table 19.

Figure 23: Selected preferred routes

Table 19: Selected scenario summaries with route descriptions

Cluster	Preferred scenario	Description
1	1	**New pipelines** total 22.5km • **New MP line** Asselby AGI to [redacted] (5.7km new MP line) • **New IP line** Asselby AGI to [redacted] (11.6km new IP line) • **New IP line** [redacted] to [redacted] (1.2km new IP line) • **New IP line** [redacted] to [redacted] (1.8km new IP line) • **New IP line** [redacted] to [redacted] (2.2km new IP line) **Modified AGI** at Asselby for hydrogen distribution
2	2	**New pipelines** total 14.2km • **New MP line** Asselby AGI to [redacted] (8.5km new MP line) • **New MP line** [redacted] to [redacted] (2.4km new MP line) • **New MP line** [redacted] to [redacted] (3.3km new MP line) **Modified AGI** at Asselby for hydrogen distribution
3	1	**New pipelines** total 18.2km • **New IP line** Asselby AGI to [redacted] (7.4km new IP line) • **New IP line** [redacted] to [redacted] (8.0km new IP line) • **New IP line** [redacted] to [redacted] (2.8km new IP line) **Modified AGI** at Asselby for hydrogen distribution
4	n/a	Users connected within Cluster 1 and 7 scenarios

5	1	**New MP pipeline** Towton AGI to [redacted] (10.7km new MP line) **Modified AGI** at Towton for hydrogen distribution
6	1	**New pipelines** total 3.7km • **New MP line** Towton AGI to [redacted] (3.0km new MP line) • **New MP line** [redacted] to [redacted] (0.7km new MP line) **Modified AGI** at Towton for hydrogen distribution
7	1	**New pipelines** total 38.2km • **New HP line** Asselby AGI to [redacted] (19.1km new HP line) • **New MP line** New PRS to [redacted] (4.6km new MP line) • **New MP line** New PRS to [redacted] (7.4km new MP line) • **New MP line** [redacted] to [redacted] (0.8km new MP line) • **New MP line** [redacted] to [redacted] (1.6km new MP line) • **New MP line** [redacted] to [redacted] (4.7km new MP line) **Modified AGI** at Asselby for hydrogen distribution **New PRS** after [redacted] **(**HP to MP)

9.7.6 Challenges

- Limited potential for repurposing HP lines in this area.
- Significant distances from Feeder 7 to some users resulting in long pipeline routings.

9.7.7 Opportunities

- Potential for modification and repurposing of existing AGIs for hydrogen distribution (Asselby and Towton).
- Potential for repurposing the existing IP network, in particular to connect the users at Selby and Howden clusters.
- Potential for repurposing the existing MP network, in particular to connect the users at Tadcaster cluster.
- Potential for repurposing Feeder 29 south of Pannal, instead of Feeder 7 (dependent on NGT decision). This would be closer to some users in the area.

9.7.8 Risks

- Several users (e.g., [redacted]) are situated a long way from Feeder 7, therefore hydrogen supply to these users may not be cost effective.
- Significant lengths of new pipeline required to connect users, due to limited options for repurposing HP lines, may be difficult to construct and may not be cost effective.

9.7.9 Conclusion and next steps

Pipeline routings for a hydrogen network in the area between Towton and Asselby have been successfully developed to enable distribution of hydrogen to all users identified in the demand study (293805-ARUP-DMS).

Table 20: Summary of pipeline lengths for Towton to Asselby

Area modifications	Line Length / number of
Length new pipeline (km)	107.5
Length of repurposed pipeline (km)	0
New AGIs	1
Repurposed/Modified AGIs	2

The next steps for the FEED study of this area routing are included in the list below:

- Assess options (and implications) for the potential repurposing of IP/MP network, taking into consideration the non-top 200 user requirements and any domestic requirements.
- Evaluate cost-benefit analysis associated with building long pipeline lengths to reach users which are sited significant distances from Feeder 7.
- Re-evaluation of capital costs following completion of capital cost model development.
- Further route optimisation for all new lines required.
- Consider non-top 200 industrial users and domestic users, particularly in urban areas.
- Liaise with National Gas Transmission regarding decision on repurposing of Feeder 29 or Feeder 7 south of Pannal.
- Further assess AGI requirements based on additional industrial off-takers and other demands.

9.8 Humber

9.8.1 Approach and specific assumptions

The Humber region, a key industrial cluster, is located east of Asselby with Feeder 29 to the north and Paull, a major feeder intersection location, in the southeast. The area under consideration lies north of the river Humber and goes as far east as Aldbrough – a potential site for both hydrogen storage and production ([redacted]). [redacted] are the other two hydrogen producers considered, and combined they make up a significant proportion of the UK's planned Hydrogen production capacity. The majority of the industry considered surrounds Hull with smaller clusters found distributed throughout the region: the clusters near Brough and Cottingham being the most notable outside-of-hull cluster in terms of assessed future hydrogen demand. From a strategic perspective, the connection of Asselby to Saltend is a priority. Figure 24 below depicts the map of the Humber area, indicating the key NGN assets.

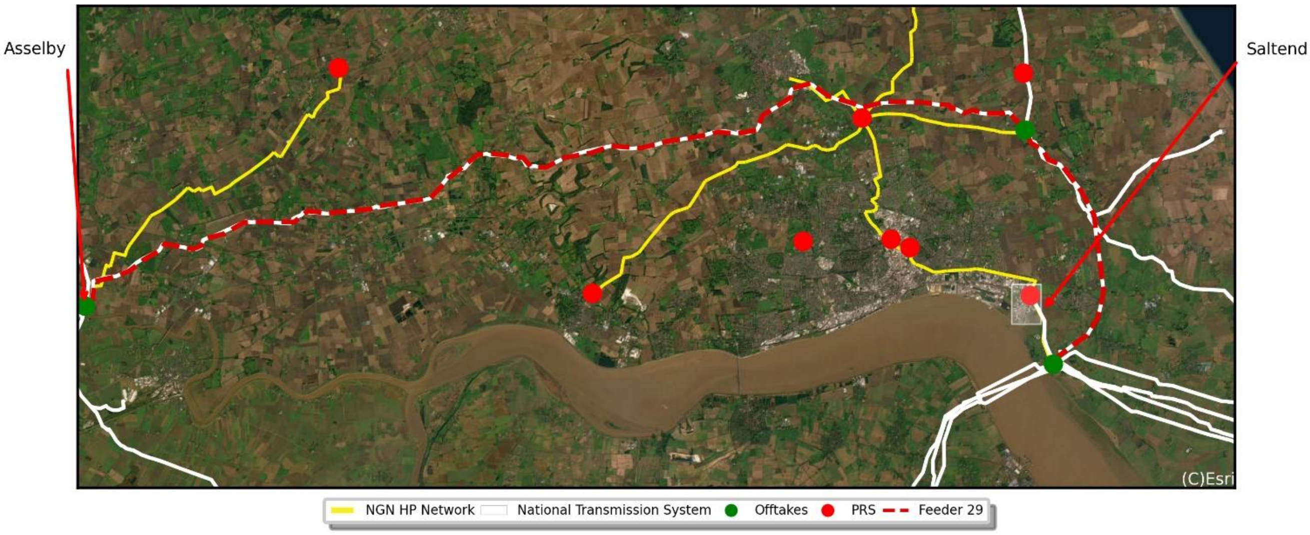


Figure 24: Map of the Humber area, indicating the key NGN assets (pipelines and AGIs) informing hydrogen routing. Asselby and Saltend are highlighted as the main locations to be connected.

The solution hierarchy is detailed in Figure 25, with repurposed HP lines being preferred to new pipelines.

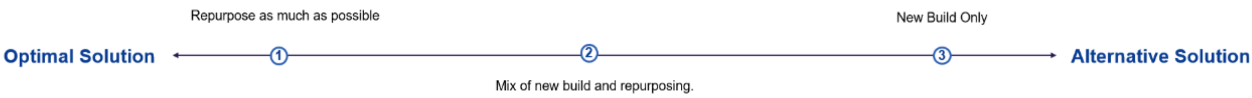


Figure 25: Hierarchy for area solutions for Humberside

The following assumptions have been made in each scenario in the development of the network for this area:

1. That Feeder 29 can not be repurposed for Hydrogen. Hydrogen will be available at Asselby and Saltend.
2. That this area is of strategic importance and will, therefore, require high pressure trunk lines throughout to accommodate future flexibility, and to link suppliers and users inside and outside this area.

9.8.2 Users

There are 28 users identified as key locations to link up with ECH's network in the Humber area. They were identified in the demand study (293805-ARUP-DMS) as requiring significant amounts of Hydrogen in the future and are in close enough proximity to each other. Most of these users are connected to the MP network, however, there are six users requiring an IP connection: [redacted] The users are geospatially shown in Figure 26 and Figure 27.

[redacted]

Figure 26: Users considered in the west of the Humber area

[redacted]

Figure 27: Users considered in the east of the Humber area

9.8.3 Clusters

The Humber was initially split into 14 small clusters by considering the spatial separation of the users, where users shared current natural gas pipelines, and how they would fit within the overall solution scenarios. These clusters were analysed using the Optioneer software tool producing multiple AI-optimised pipeline corridor options, from which we decided on the optimal collection of A-B routes to connect each cluster. These decisions primarily relied upon comparing the total weighted penalties, the estimated CAPEX costs, and the length of the routes. In this cluster analysis we determine routes to rough and Aldborough, however, this is omitted from future analysis under the assumption that they will be provided by other interested parties.

Once we understood these optimal corridors, we then re-scoped our definition of clusters to create combined clusters: these described the configuration of the network following the key scenario-driven options for the main trunk lines: Repurposing or new build. We also now started considering the network pressures and the AGI’s requirements of the new clusters. The users found within these clusters are listed in Table 21, and the solution scenarios for them are described in Table 22.

Table 21: Summary of clusters and users for Humberside

[redacted]

9.8.4 Scenarios

The final (combined) clusters and scenarios are presented in Table 22. These scenarios align with the solution scope defined previously in Figure 25, and combine the optimal corridors from the Optioneer analysis. The process of minimizing the number of new AGIs whilst connecting users at their current pressures also informed the cluster-scenario configurations. The final assessment of these scenarios, and the selection of a new route is performed in the following section.

Table 22: Summary of the Humber cluster scenarios

Cluster	Scenario	Description
1	1	New build main trunk connecting Asselby with Wawne, with four new spur groups: one line from Aseelby to the users near Howden (MP); one near the centre of the trunk, connecting users near Newport (IP) and those in and near Brough (MP); one connecting [redacted] (HP) with users near Cottingham (MP); and a small final spur from Wawne to connect [redacted] (MP).
	2	New build main trunk connecting Asselby with Elloughton, followed by repurposing Elloughton to Wawne, with four new spur groups: one from Aseelby to the users near Howden (MP); one from Elloughton, connecting users near Newport (IP) and those in Brough (MP); one of the repurposed section, connecting [redacted] (HP) with users near Cottingham (MP); and a small final spur from Wawne to connect [redacted] (MP).
2	1	Repurposed main trunk from Wawne to Bankside and Bankside to Chamberlin Road, combined with a new build main trunk from Chamberlin Road to [redacted]. From Bankside new lines will connect all users in the north of hull (IP and MP), and from Chamberlin Road new lines will connect to the rest of the Hull and West Hull users (MP).
	2	New build main trunk from Wawne to [redacted]. From Bankside new lines will connect all users in the north of hull (IP and MP), and from Chamberlin Road new lines will connect to the rest of the Hull and West Hull users (MP).
3	1	The main trunkline is made up from a repurposed HP line between Wawne and Ganstead (requiring a new natural gas offtake from Feeder 29 to Wawne AGI) and a new build line between Ganstead and Saltend. From Saltend new lines will connect to users in South East Hull (MP), and a new build spur connected to the new build trunk section will connect to users to the west (IP and MP).
	2	The main trunkline is made up from a new build HP line between Wawne and Ganstead and a new build line between Ganstead and Saltend. From Saltend new lines will connect to users in South East Hull (MP), and a new build spur connected to the Ganstead-Saltend trunk section will connect to users to the west (IP and MP).
	3	The new build main trunkline connects [redacted] in Hull to Saltend. From Saltend new lines will connect to users in Southeast Hull (MP), and another new build line from Saltend will connect to users to the west (IP and MP).

4	The new build main trunkline connects [redacted] in Hull to Saltend. There is then an additional trunk line made up from a repurposed HP line between Wawne and Ganstead (requiring a new natural gas offtake from Feeder 29 to Wawne AGI) and a new build line between Ganstead and Saltend. From Saltend new lines will connect to users in Southeast Hull (MP), and another new build line from Saltend will connect to users to the west (IP and MP).

9.8.5 Route evaluation and selection

Options for the each of the new pipeline route corridors have been developed and evaluated using Continuum Optioneer software to determine the optimal routings to include for each scenario. The preferred options were then determined based on lowest penalty and capex. Fully developed scenarios with preferred options were then analysed using multi criteria analysis (MCA) (see 9.2) to determine the preferred scenario for each cluster.

The preferred routings are illustrated in Figure 28 with further details included in Table 23.

Figure 28: The selected route for the Humber

Table 23: Preferred cluster summaries with route descriptions Humberside

Combined Cluster	Preferred Option	Description
1	2	**Repurposed HP pipeline** Elloughton AGI to Wawne AGI (17.8km) **Modified AGI** at Asselby for PRS (HP to MP) **Modified AGI** at Wawne for PRS (HP to MP) **Modified AGI** at Elloughton for PRS (HP to IP) **New PRS** west of Elloughton (IP-MP) **New PRS** by [redacted] (HP-MP) **New pipelines total 68.7 km** (All 300mm NB) • 25.8km of MP pipeline ○ Asselby AGI to [redacted] and [redacted] (9.7km) ○ New PRS to [redacted], [redacted], and [redacted] (6.8km) ○ New [redacted] PRS to Castle Road , [redacted] Glenavon, [redacted], [redacted] (6.9km) ○ Wawne AGI to [redacted] (2.4)

		• 14.1km of IP pipeline
		  ○ Elloughton to [redacted] and [redacted] (14.1km)
		• 28.8km of HP pipeline
		  ○ Asselby to Elloughton (26.4km)
		  ○ Repurposed HP to [redacted] (2.4km)

2	1	**Repurposed HP pipeline** Wawne AGI to Bankside AGI (8.0km)
		Repurposed HP pipeline Bankside AGI to Chamberlin Road (1.3km)
		Modified AGI at Bankside for PRS (HP to IP)
		Modified AGI at Chamberlin Road for PRS (HP to MP)
		New PRS west of [redacted] (IP-MP)
		New pipelines total 14.6km (All 300mm NB)
		• 10.4km of MP pipeline
		  ○ New PRS west of [redacted] to [redacted] and [redacted] (3.5km)
		  ○ Chamberlin Road AGI to [redacted] (6.8km)
		• 2.5km of IP pipeline
		  ○ Bankside AGI to [redacted] and [redacted] (2.5km)
		• 1.6km of HP pipeline
		  ○ Chamberlin Road AGI to [redacted] (1.6km)

3	3	**Modified AGI** at Saltend for PRS (HP to MP and HP to IP)
		New PRS just East of [redacted] (IP-MP)
		New pipelines total 22.1km (19.47km at 300mm NB and 2.67km at 550mm NB)
		• 7.5km of MP pipeline
		  ○ Saltend AGI to [redacted] and [redacted] (2.7km at 550mm NB)
		  ○ New PRS to [redacted] (4.9km at 300mm NB)
		• 8.0km of IP pipeline
		  ○ Saltend AGI to [redacted] and [redacted] (8.0km at 300mm NB)
		• 6.6km of HP pipeline
		  ○ [redacted] to Saltend (6.6km at 300mm NB)

The following routes assessed, being nationally significant and/or connecting a single party's site, considered as part of the initial or combined clustering have been initially proposed as part of ECH. However, due to the significance of these routes or reliance of a single offtaker e.g., Easington / Rough storage, it would be beneficial to NGN that these assets are developed by other third parties. The list below provides as summary of these potential routes and thirds parties who may be best placed to develop these.

- Saltend to Aldborough (Assumed [redacted])
- Saltend to Easington / Rough (Assumed NGT)

- Main trunk Asselby to Wawne (Potentially NGT)
- Main trunk Asselby to Hull (Potentially NGT)
- Main trunk Hull to Saltend (Potentially NGT)
- HP to [redacted] (Potentially Equinor)

These are highlighted in Figure 29.

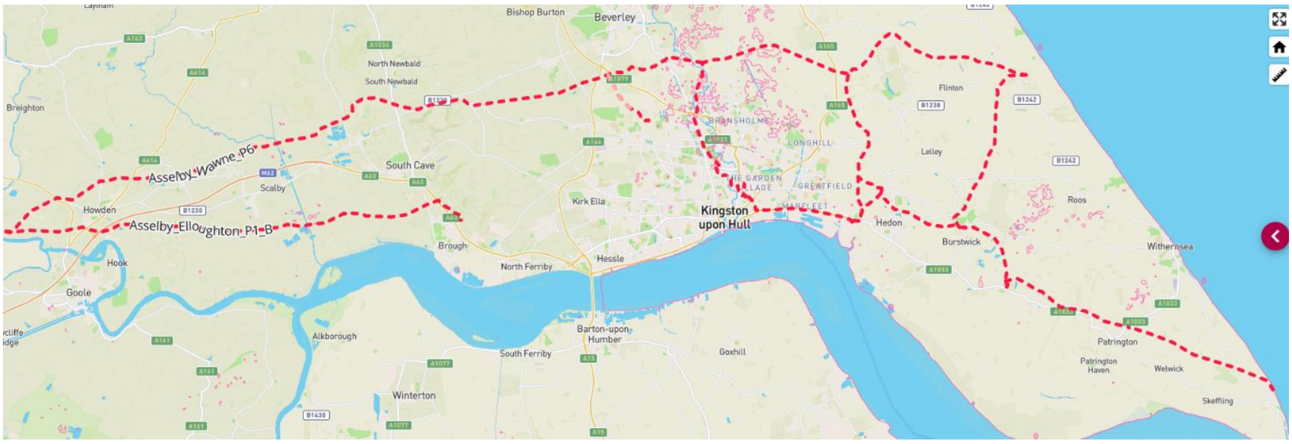


Figure 29: Pipelines within Humberside that may not be NGN's Responsibility

9.8.6 Challenges

- Lots of interested parties from a pipeline perspective.
- New build pipeline through Hull will be disruptive and difficult.
- Not possible to assume a feeder within the area is repurposed, so all scenarios require a significant amount of new build.
- The storage within the Humber area could result in large amounts of hydrogen being transported through the designed network.

9.8.7 Opportunities

- Lots of opportunity to collaborate to reduce repeated work and to reduce the amount of infrastructure required.
- Connecting the Humber to the Hydrogen network will bring large amounts of production and storage capacity.
- Repurposing the Elloughton to Wawne HP pipeline saves a significant amount of new build requirements. Due to its large diameter, it also may be suitable as a feeder (if further investigations prove it able to work with NTS pressures).

9.8.8 Risks

- If collaboration does not happen, delays, more disruption, and extra costs may be incurred.
- That if a significant amount of additional hydrogen demand, production, and storage sites are proposed, the network may not have the capacity for their connection into the network.

9.8.9 Conclusion and next steps

The Humber region is large and there are many potential users, suppliers, and storage sites to connect to the wider future hydrogen network. In this project we have proposed a distribution network, designed in collaboration and with the latest tools, that strengthens the Humber's position as a key Hydrogen cluster.

Table 24: Summary of pipeline lengths and AGI requirements Humberside

Area modifications	Line Length / number of
Length new pipeline (km)	105.4 (2.7km at 550 mm NB and 102.7km at 300mm NB)
Length of repurposed pipeline (km)	27
New AGIs	4
Repurposed/Modified AGIs	6

Next steps are:

- Further modelling of the repurposed lines required to assess implications of repurposing pipelines on wider network and other industrial and domestic users.
- Liaise with Equinor regarding new Aldborough pipeline to understand timelines and agreement on interface between the line and NGN.
- Liaise with National Gas Transmission regarding their plans to connect Asselby and Saltend, and Saltend to Easington.
- Re-evaluation of capital costs for the Humber area
- Further route optimisation for all new lines required in FEED
- Identify further off-takers outside of the Top 200 suitable for the proposed lines
- Further assess AGI requirements based on additional industrial off-takers and other demands
- Investigate connection to trials in the area
- Assess existing AGIs included in preferred routes to understand requirement for new/repurposed/modification
- Consider strategic locations of the pig traps for the new network

9.9 Tyneside

9.9.1 Approach and specific assumptions

The area covers Newcastle upon Tyne and surrounding areas, it contains large industrial users and a large population for future domestic demand. The two closest points of hydrogen connection from project union are at Cowpen Bewley and Bishop Auckland. The large industrial users are wide spread around the area, with no definitive industrial clusters. The high proportion of urban areas mean that repurposing will be the key focus, since routing will be difficult, however the large domestic loads mean that a lot of the HP/IP network is highly utilised. Due to the distances from the initial connection points on the NTS from project union and the absence of town trial locations, the area was not deemed to be high scoring within the ECH timeframes. As such, the options routed were minimal, looking at repurposing and connecting the largest users, which would form the basis of a potential future network post 2037.

To provide a structured approach to routing, the following hierarchy was implemented:

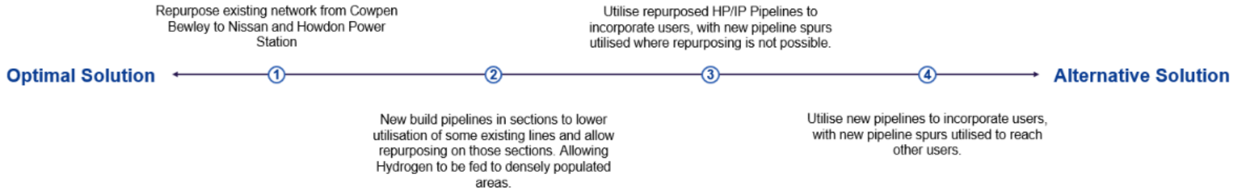


Figure 30: Hierarchy for Tyneside area approach

When assessing the options to connect the Tyneside users to either Cowpen Bewley or Bishop Auckland, the repurposing of the HP network to Warden Law AGI was assessed from each. Both sites connect to Warden Law and then onto Hendon AGI, which supplies the Sunderland area. The HP line from Bishop Auckland is the most critical to the continued NG supply to Hendon and it was determined that this could not be repurposed with the anticipated levels of NG reduction. Therefore, the routing for this area was based upon the repurposing of the Cowpen Bewley to Warden Law line.

The following assumptions have been made in the development of the network for this area:

The IP line to [redacted] can be repurposed and the AGI at Warden Law can be modified to accommodate this.

9.9.2 Users

There are 2 users which have been identified within the Tyneside area from the demand study (293805-ARUP-DMS) for hydrogen connection as shown in Figure 31.

[redacted]

Figure 31: Users identified in the Tyneside Area

9.9.3 Clusters

Due to only two suitable offtakers identified for this area, only one cluster is proposed.

Table 25: Summary of clusters and users for Tyneside

Cluster	Users
1	[redacted]

9.9.4 Scenarios

Only one scenario has been developed for Tynside area as detailed in Figure 26.

Table 26: Summary of scenarios for Tyneside

Cluster	Scenario	Description
1	1	Connecting Cowpen Bewley to Warden Law by *repurposing* the existing HP line. Modifications to the existing AGI at [redacted] to facilitate the removal of this HP line from the other NG line and connection to a new HP hydrogen line. Connection of [redacted] to [redacted] and onto [redacted] with a *new* HP hydrogen line, with a *new* HP to IP PRI at each user.

9.9.5 Route evaluation and selection

Options for the each of the new pipeline route corridors have been developed and evaluated using Continuum Optioneer software to determine the optimal routings to include for each scenario. The preferred options were then determined based on lowest penalty and capex. Fully developed scenarios with preferred options were then analysed using multi criteria analysis (MCA) (see 9.2) to determine the preferred scenario for each cluster.

The selected routes are shown below in Figure 32. More information on the scenario can be found in Table 27.

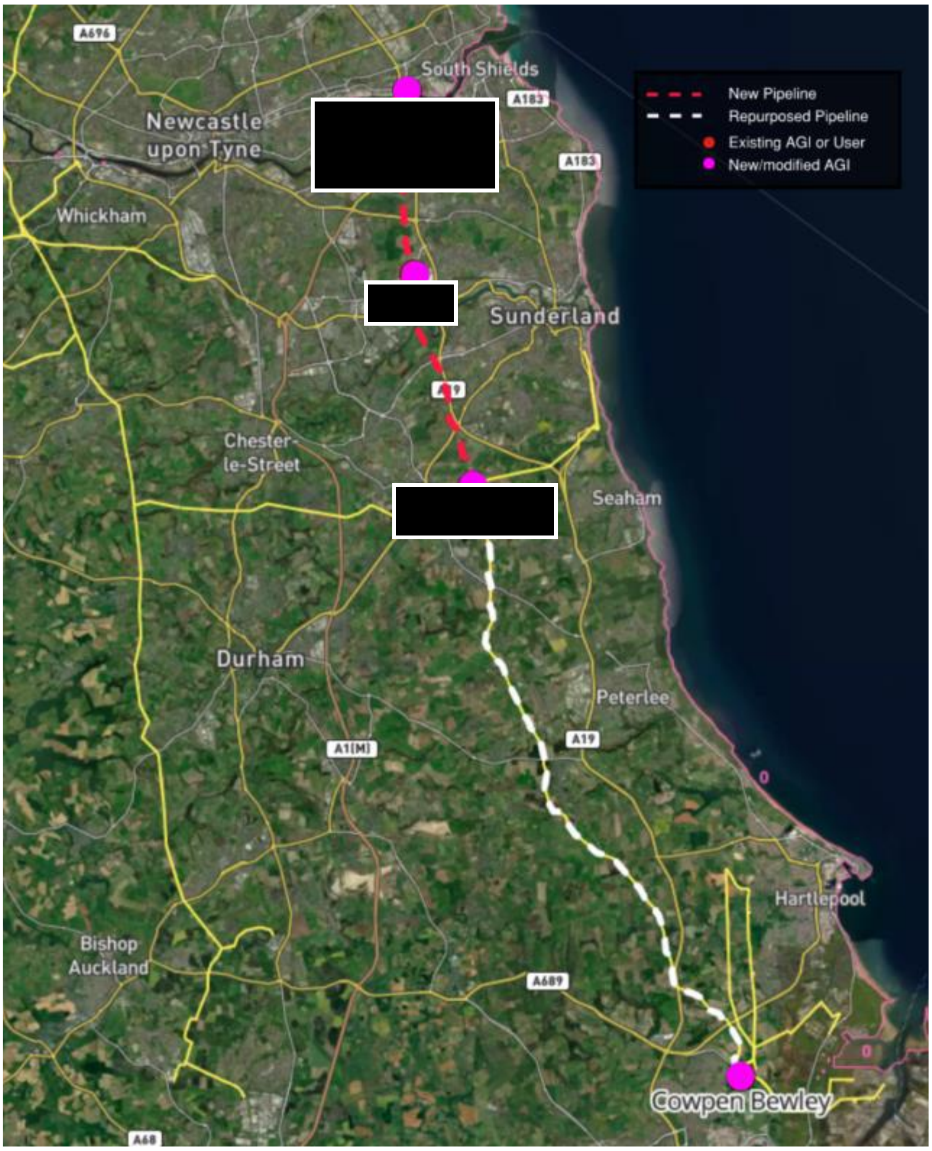


Figure 32: Tyneside selected routes

Table 27: Selected scenario summary with route descriptions Tyneside

Cluster	Preferred scenario	Description
1	1	Repurposed IP line to [redacted]. New IP to MP AGI at [redacted] New MP line [redacted] AGI to [redacted]

9.9.6 Challenges

- Crossing of the Tyne to reach [redacted]
- Long distances from NTS hydrogen supply within project union ECH phase

9.9.7 Opportunities

- Possibility of utilising existing crossings on the Tyne including one owned by [redacted]
- Additional users around [redacted]
- Maritime and shipping demand around [redacted]

- Closer NTS connections from other project union phases

9.9.8 Risks

- Repurposing of the Cowpen Bewley to [redacted]. This has been assessed through modelling but further assessment may be required to confirm the feasibility of technical constraints.

9.9.9 Conclusion and next steps

Pipeline routing for a hydrogen network in the Tyneside area have been successfully developed to enable distribution of hydrogen to users identified in the demand study (293805-ARUP-DMS). Despite the large distances from project union NTS supply points, new build has been limited by the repurposing of the Cowpen Bewley to Warden Law HP line.

Table 28: Summary of pipeline lengths and AGI requirements Tyneside

Area modifications	Line Length / number of
Length new pipeline (km)	10
Length of repurposed pipeline (km)	40.2
New AGIs	2
Repurposed/Modified AGIs	1

The next steps for the FEED study of the Tyneside area routing are included in the list below:

- Confirmation of any existing crossings of the River Tyne which can be used
- Determine required sizing for new pipelines.
- Further modelling of the repurposed line required in FEED to assess implications of repurposing pipeline on wider network and other industrial and domestic users.
- Further discussions with NGT on the potential other options for connection to Tyneside
- Re-evaluation of capital costs following completion of capital cost model development.
- Further route optimisation for all new lines required in FEED.
- Investigate connection to trials further when more detail is available
- Investigate potential for additional demand close to identified users

9.10 Additional optioneering

Post completion of the above assessments for each area, further iterations of the network were undertaken in key areas. This was due to the evolving information in the hydrogen space, such as new producers and storage providers. It also followed further stakeholder engagement and refinement of user demand, which added credibility to some users and identified issues with others. This development was undertaken due to the time available, to ensure that a smooth transition could be made to the FEED stage of the project. Some of the main developments are discussed below.

9.10.1 East Riding

The east riding of Yorkshire has significant storage potential in salt cavern and porous geological storage which was identified in the storage study report. NGN has been liaising with stakeholders who are investigating opportunities in this area. Due to this, the network was investigated for the feasibility of providing network connections within this area.

The new route aimed to repurpose as much as possible of the NGN high pressure pipeline from Wawne AGI North of Hull to Cayton PRI South of Scarborough, which is approximately 51km of pipeline, this can be seen in Figure 33.

Figure 33: East riding network development area

To achieve the repurposing of this HP pipeline, network modelling was undertaken by NGN to confirm the ability to continue natural gas supply to existing users. Where this was not possible, the network was reinforced by adding offtakes from Feeder 6, which is currently remaining as natural gas. These offtakes were then connected to the existing distribution network and connections from the HP pipeline disconnected.

To achieve this repurposing, two PRIs on the route require modification to disconnect the NG network (Catwick and Frodingham). Two new offtakes would also be required to provide natural gas from Feeder 6, these are at Sigglesthorne and Rudston. This is in addition to the modifications required at the Wawne and Cayton AGIs. New pipeline is also required in order to enable this, the study has identified 2.9km of HP, 5.9km IP and 9.5km of MP pipeline would be required.

Connections to storage have not been considered at this stage since these projects are in their infancy and the locations of sites under consideration remains confidential. It is assumed that storage providers would undertake the pipeline infrastructure to connect to the HP network and any compression requirements would be manged by storage providers, which would be typical or by NGT if it is required in the transmission network.

9.10.2 Asselby to Hull

During the initial optioneering phase, Asselby offtake was connected through the NGN network through to Hull. Further confirmation of connection to Hull by NGT and the transmission network of project union has meant that this reinforcement in the distribution network is not required and can be rationalised. The developed solution enables more repurposing and less overall pipeline length to still reach the same users.

From Asselby to Newport, existing dual IP lines can be utilised for much of the route, with occasional new build and connections being required where there is currently single IP lines. The Elloughton to Wawne HP line will still be repurposed to bring hydrogen West from Wawne, with connections being made along the way and distribution network being constructed in short sections from the Elloughton AGI to reach users here.

This has reduced the new build pipeline requirements for the Hull area from 105km to 64km and increased the repurposing of pipelines from 27km to 41km.

9.10.3 Tyneside

One of the risks identified in the Tyneside area was the crossing of the river Tyne. During initial optioneering there was evidence that an existing crossing could be utilised to reach the [redacted] site on the North of the Tyne. This was subsequently found to be unfeasible. As a result, the cost of developing a new crossing of the Tyne would make the connection of [redacted] cost prohibitive at this stage. The pipeline from [redacted] to [redacted] has been removed for this stage of the ECH project and further expansion into Tyneside should be considered in further stages, once more information is know about the Project Union routing within the area.

9.10.4 Project Union enabling

A further review was undertaken to ensure that there was continuity of natural gas supply where required for the network when Project Union is delivered. An example of this is shown in Figure 34 below, feeder 7 currently supplies natural gas to the NGN HP network from the Thrintoft offtake. The NGN HP line needs to be retained as a natural gas asset in the ECH phases being considered, to maintain supply the Thrintoft Offtake needs to be modified to isolate the line. A new Offtake at Yafforth will be required to connect the NGN Feeder 13 to the HP pipeline.

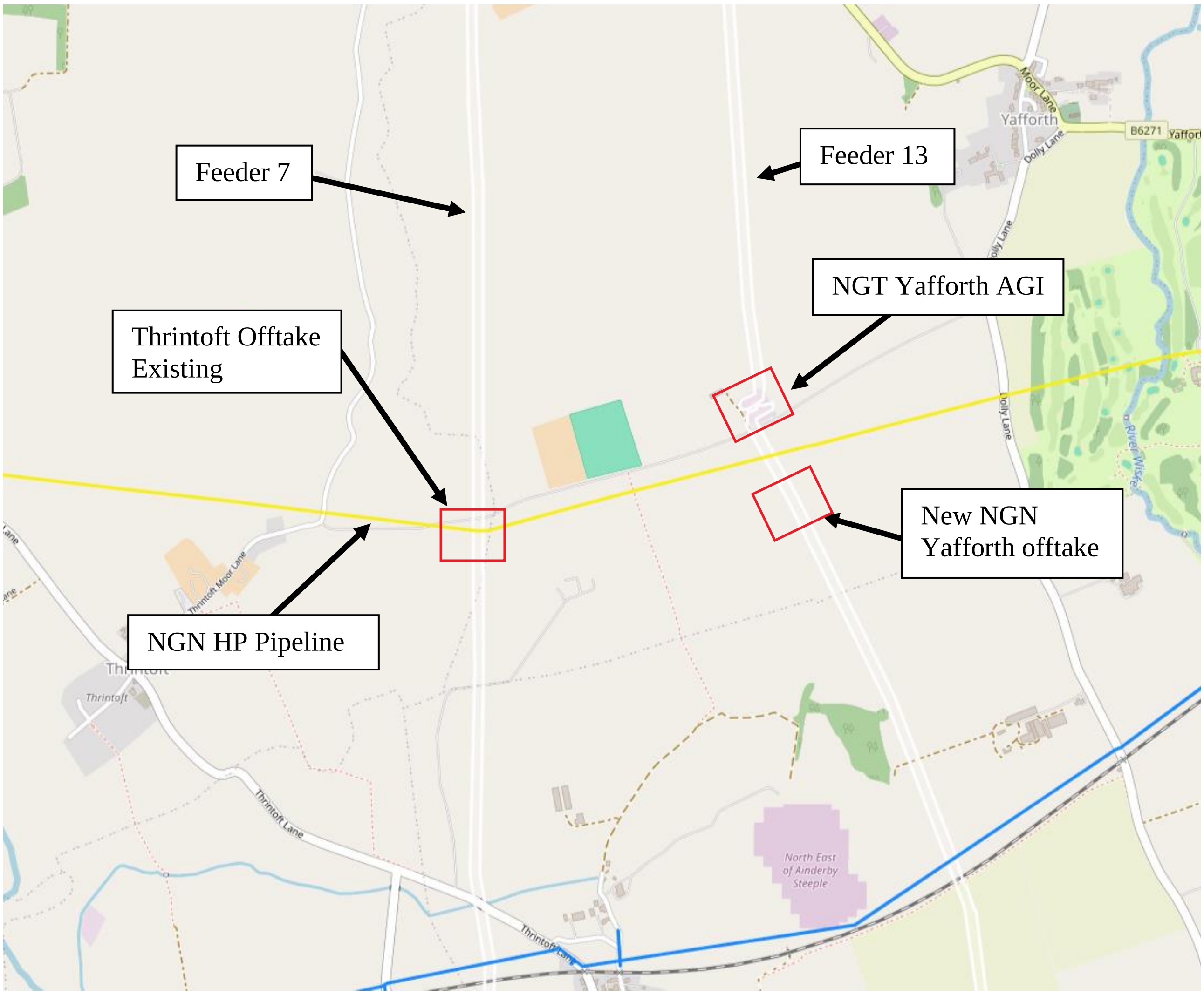


Figure 34: Example disconnection of Feeder 7

Other similar scenarios were considered along the repurposed Feeders to ensure natural gas supply could be maintained.

9.11 Conclusion of optioneering

The routing has been conducted to further detail and assess the network developed in the network concept stage. By routing the lines, unfeasible routes have been discounted and data such as cost, length and feasibility of routes has been obtained. This provides a greater level of detail for the later stages of the project, such as the phasing plan, to make informed decisions about the development of the ECH network.

Throughout this process the focus on users has been based on the assessment of the large industrial users connected to NGNs network. It is more feasible to switch the supply for single users due to the required modifications required to their plant and equipment. However, there are instances where the routeing has been done to a single user which is in an area with multiple other industrial users close by, for example technology parks and industrial areas, but the demand of the other users has not been included. There is therefore an opportunity to further assess the potential demand in the clusters based on the additional users in close proximity.

All routes have been assessed against the technical and consenting criteria and penalties related to the areas which they pass through. This gives the most technically feasibly route for all scenarios. Whilst some routes were discounted throughout this process based on them being unfeasible from a technical or consenting perspective, there may still be routes which are undesirable. This will partially be assessed later in the capital cost build up, since the technically difficult routes will incur a higher cost and therefore be required to have a larger needs case to progress.

A map of preferred solutions from all scenarios is shown below in Figure 35. A table of proposed routes and AGIs can be seen in Appendix A.

Figure 35: Map of the preferred network routes

10. Phasing plan

To facilitate the transition to hydrogen fuel, pipelines will need to be constructed or repurposed in phases which allows natural gas supply to remain where required and reduce disruption to the existing network as much as possible. This section of the report will provide initial detail on what will be included in each phase of the project.

Summarised in Figure 36 are the expected milestones for the East Coast Hydrogen project.

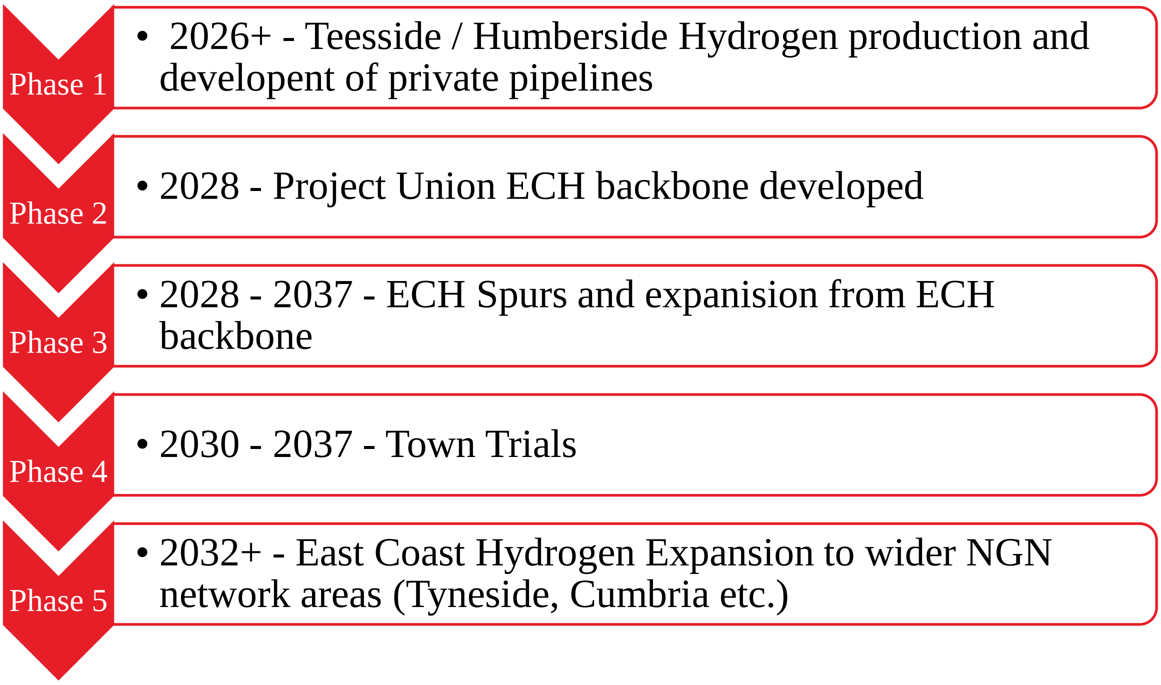


Figure 36: Phasing Plan Overview

10.1 Private Pipelines

The first phase of the ECH project, starting in 2026, shall see the establishment of small hydrogen networks by third parties in key industrial locations, such as in Teesside and Humberside. As discussed in section 5.3, a number of blue and green hydrogen, such as BP, Kellas and Equinor are proposing to build their own local distribution networks to users within the vicinity of their plants.

10.2 Project Union

The network will be developed in conjunction with a section of pipework from Project Union, due to start in 2028, that runs through the area. This will provide a key backbone to the ECH project. It will be critical to deliver some of the NGN infrastructure to enable project union, which will allow continued natural gas supply to users who require it.

10.3 Pipeline Development

ECH will develop new and repurposed distribution pipelines from 2028 to connect the transmission line established in Project Union to clusters of industrial and commercial users.

As outlined in section 5, the primary aim of the project phase was to repurpose as much of the existing network, and associated existing infrastructure, as possible since this has a lower CAPEX compared to newbuild pipelines. Where existing pipelines could not be repurposed or utilised, then new build piping has been assessed.

10.4 Town Trials

Phase 4 of the ECH project shall see the conversion of gas distribution systems to support NGN in the Town Trials, starting in Hull, Leeds, and Teesside. The first of these are due to start in 2030, with further expansions to the trials in 2032 and 2037. These trials are essential to demonstrate to DESNZ and Ofgem the feasibility of utilising hydrogen for heating, allowing the decarbonisation of the industry. Whilst the town trial demand has been considered in the flexible routing of the network, with cognisance taken of a possible move to hydrogen for heating, these demands and town specific routing has not been included in the final solutions.

10.5 East Coast Hydrogen Expansion

Phase 5 of the East Coast Hydrogen project aims to connect the hydrogen network beyond the east coast region, into the remaining parts of the NGN area from, for example into Cumbria and East Yorkshire, starting from 2032.

11. Transition process

To facilitate the transition to hydrogen, pipelines will need to be constructed or repurposed in phases which allows the continuation of NG flow where required and causes minimal disruption to the existing network. The methodology of transition will vary dependant on each specific scenario, general transition processes for new pipelines, repurposed pipelines and AGIs are discussed below.

11.1 New pipelines

Where existing natural gas pipelines are not appropriate for hydrogen transportation due to their size, material or condition. These will be replaced with new steel or PE pipelines. Additionally, some hydrogen pipelines will be built in new locations to improve network routing. The process for building new pipelines is outlined below:

1. Determine requirement for new pipeline rather than repurposing of existing.

   - The requirements for new pipelines are determined by their technical and network suitability. For pipework to be technically suitable it must be made of a hydrogen compatible material and it must be a suitable size and strength.

   - The required pressure in a specific pipeline may have to increase due to the energy requirement and the density of hydrogen when compared to natural gas. The required pressure in a pipe will determine the necessary strength of the pipe and therefore its material (steel/PE) and wall thickness. Additionally, as mentioned in the repurposing Strategy (293805-ARUP-RPS), some of the existing MP and LP pipework are iron. These pipes are not suitable for hydrogen and require replacing. Most of these lines are being replaced as part of the Iron Mains Replacement Programme (IMRP). Any remaining iron pipe would have to be replaced with PE pipes before transitioning to hydrogen.

   - Some pipework will likely need replacing due to its condition as some lines are over 50 years old. There are higher stresses in corroded areas of pipes and these areas are more likely to be affected by hydrogen embrittlement. There has also been little research into how hydrogen behaves in deteriorated mains which is an additional risk. Work has been undertaken to develop understanding of this in the H21 project, the initial findings state that most of the existing natural gas pipelines are compatible with hydrogen and changing existing assets to supply hydrogen has no adverse effects on leakage.

- During and after the transition to hydrogen, the demand from a specific pipeline may change compared to its typical natural gas use. The gas infrastructure modelling software, Synergi can be used to help determine the required size pipelines that are in the networks that are below seven bar.

- New pipelines may also need to be built if there aren't any natural gas pipelines along the desired route that are available for repurposing. Those identified for ECH have been routed and discussed in section 9.

2. Determine required capacity and operating pressure in order to complete line sizing

- This determination of hydrogen requirements is described in the demand study (293805-ARUP-DMS) and the Production Study (293805-ARUP-PRS). The capacity of the line will be determined based on the flow required for all downstream users identified in this study, with an additional allowance for future demand increases.

3. Design a suitable routing corridor for the new pipeline

- Routing corridors will need to be identified for new lines, during this study the new lines have been routed using the Optioneer™ routing tool. This is shown in section 9.2.

4. Determine planning and consenting requirements

- If a new pipeline is over 800 millimetres in diameter and more than 40 kilometres in length, or if itss construction is likely to is likely to have a significant effect on the environment, it is classed by the Planning Act 2008 Part 14(1)(f) as a "nationally significant infrastructure project" (NSIP). If a new pipeline construction is classified as a NISP, it will require development consent as stated in Section 37 of the Planning Act. The Development Consent Order (DCO) must be submitted to the Planning Inspectorate. All works must be within the planning application's redline boundary or "order limits". An Environmental Statement (ES) must also be submitted alongside the DCO. An ES outlines the assessment of likely environmental effects of the project. The ES may require an Environmental Impact Assessment by law if a development is classified a Schedule 1 project or a Schedule 2 project that is likely to have a significant impact on the environment due to its nature, size or location. The legal basis for the EIA Schedule 1 and 2 classifications are in the European Community Directive 85/337/EEC36 (the 'EIA Directive') (as amended by Directive 2014/52/EU7). The four stages of the DCO EIA are screening, scoping, preparation of preliminary environmental information, and preparation of an ES. EIAs are to be completed by "competent experts" as stated in Regulation 14(4) of the EIA Directive, and a statement should be submitted alongside the ES to outline the relevant qualifications or expertise of the experts.

- Other planning applications may also be required for example a flood risk assessment and/or various habitat assessments depending on the development's nature, size and location. The requirements for these will be identified in an Environmental Impact Assessment (EIA)

5. Construct new pipeline

- New pipelines construction will be phased so as to not strain construction resources.

- If a new line is to be constructed on a site that hasn't previously been used for gas pipelines, the area will have to be cleared, a trench built, the pipework laid and assembled. Various construction methods are used for pipelines dependant on the conditions of the site. During this study the required construction methods throughout the length of each pipeline were evaluated, this fed into the CAPEX build up.

- If an existing line is being replaced, there will be two options to achieve this. If supply to existing users can be maintained without the section of existing line the old section of pipeline will be isolated from the network, bled and removed. The new pipeline will be built on the same route as the previous line. As mentioned previously, some pipework replacement is already underway as part of the IMRP replacing MP and LP iron mains with PE pipes.

- If the supply to the existing users cannot be maintained without the existing pipeline section, this will have to remain in place and the new pipeline constructed alongside at a safe distance, or in an alternative routing corridor. Once the new line ins constructed and the connections made to the users, the existing line can then be decommissioned.

6. Connect and commission pipeline with hydrogen
   - The pipelines will be connected either to existing repurposed AGIs or to purpose built AGIs. These have been identified in section 9.
7. Hydrogen pipeline now in operation as part of the new network

11.2 Repurposing pipelines

Many of the preferred solutions determined during the options study require the unmeshing and repurposing of existing natural gas pipelines for use as part of the new hydrogen network. This is expected to follow the sequence outlined below:

1. Determine existing network capacity to transport displaced natural gas demand
2. Ensure connection of natural gas lines required to transport displaced natural gas demand or build new if required
3. Disconnect pipeline for repurposing from the natural gas network and purge
   - This may be performed using the double block and bleed method
   - Purging using pigs may be performed to remove the natural gas from the pipelines. Gas pipeline pigs are pieces of equipment that are used to seal, clean or help purge a pipeline. Purging is when a pipeline is pumped with an inert gas to help force out remaining natural gas in a system after bleeding
4. Complete inspections to ensure the pipeline is suitable for hydrogen transfer at desired pressure
5. Connect and commission pipeline with hydrogen
6. Hydrogen pipeline now in operation as part of the new network

Figure 37Figure 37 and Figure 38 below show a simplified version of how the transition would take place for repurposed lines.

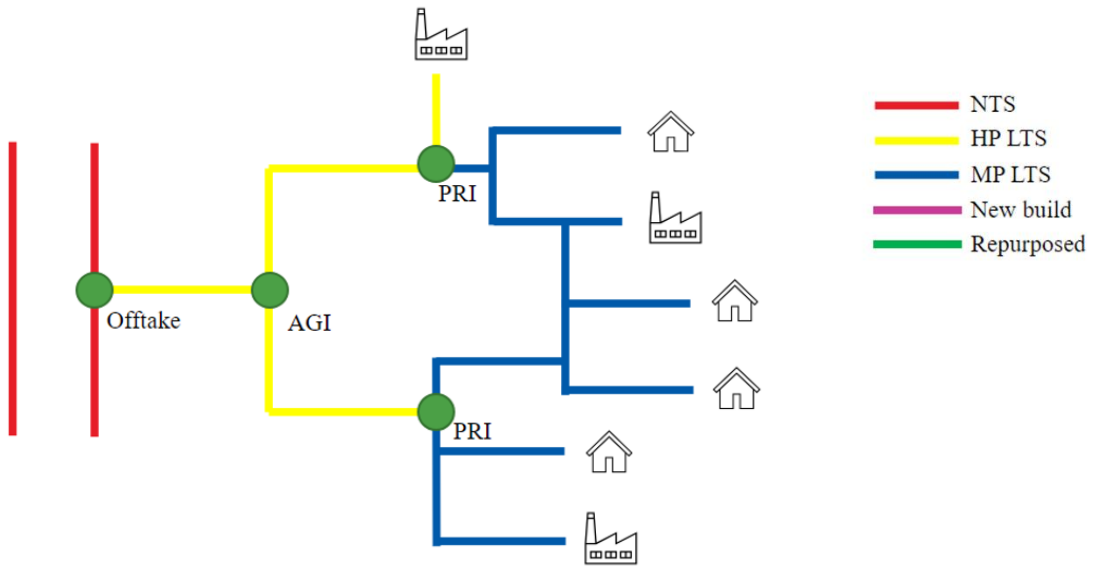


Figure 37: Example network: Mixture of HP and MP industrial usage and domestic areas fed from the MP network

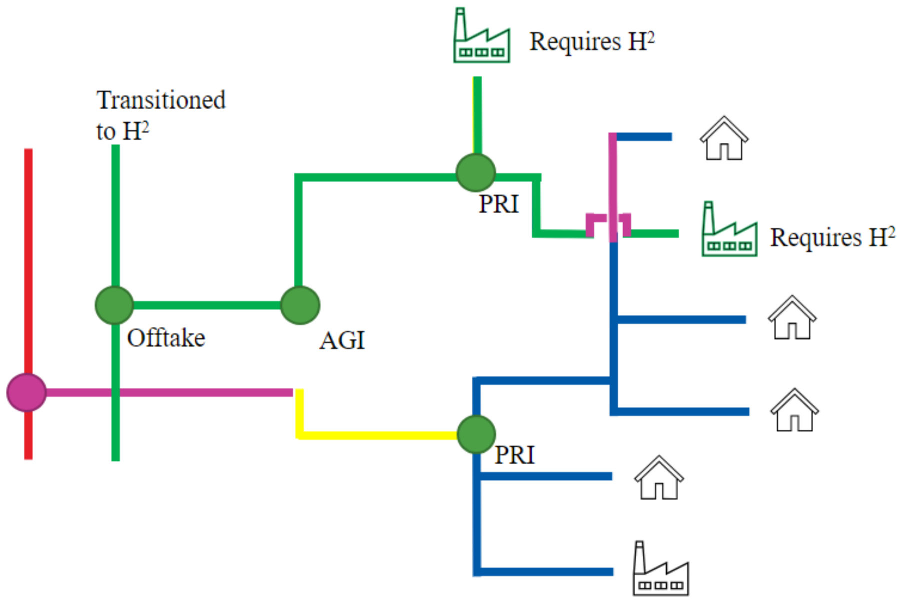


Figure 38: Example network: Final connections are made and blocked valves installed on existing network

11.3 Hydrogen AGIs

The preferred solutions for the new network will require AGIs to deliver hydrogen at the required pressure to users. AGIs included in the routings have been assigned 3 classifications in this study:

- New: if there is no existing AGI on the plot,
- Modified: if some existing assets are retained for use in natural gas network and,
- Repurposed: if existing assets are to be fully converted for hydrogen use.

For new AGIs, they shall be design to either IGEM TD/13 Edition 2 Supplement 1 (Pressure regulating installations for hydrogen at pressures exceeding 7 bar) or IGEM TD/23 (IGEM/TD/23 - Reference standard Hydrogen pressure regulating installations not exceeding 7 bar) dependant on their pressure.

Modified AGIs will have both operational natural gas and hydrogen assets on the site. The process for transitioning these AGIs to prepare for the new network will depend on the purpose of the new AGI and may require land purchase around the existing AGI site to provide space for new assets.

Repurposed AGIs will only be required where there are no remaining natural gas assets in operation on the site.

• Some pipework will likely need replacing due to its condition as some lines are over 50 years old. There are higher stresses in corroded areas of pipes and these areas are more likely to be affected by hydrogen embrittlement. There has also been little research into how hydrogen behaves in deteriorated mains which is a project risk. Work has been undertaken to develop understanding of this in the H21 project.

• This determination of hydrogen requirements is described in the demand study (293805-ARUP-DMS) and the Production Study (293805-ARUP-PRS). The capacity of the line will be determined based on the flow required for all downstream users identified in this study, with an additional allowance for future demand increases.

• Routing corridors will need to be identified for new lines, during this study the new lines have been routed using the Optioneer™ routing tool. This is shown in Section 9.2.

12. Storage and network balancing

Storage will be required to ensure the system always has supply for when demand occurs. This is particularly important in low carbon hydrogen systems due to the production profile of green hydrogen produced from renewable energy. Without sufficient storage, the network would not be balanced during peaks, leading to outages. Production plants typically operate at a steady state output, but demand fluctuates on hourly, daily and seasonal cycles, these also differ between industrial and domestic users. Storage is required to buffer the different profiles. The potential storage within the ECH area was assessed in the storage Study (293805-ARUP-STS). As part of this Options Study, the connection to the storage sites was assessed.

12.1 Storage

Storage of hydrogen can be provided in multiple ways and technologies vary dependant on the scale of storage required. This project is primarily concerned with large scale storage, this is typically geological storage such as salt caverns. Furthermore, the NTS pipelines also act as storage, with an operating range of pressures, there is headroom built into the operating philosophy which enables the network to be drawn down in times of peak demand and pressurised further in times of low demand, this is know as linepacking.

It is thought that the production sites which are currently in development will have local storge, typically in pressure vessels, which will manage the intraday storage of the supply to their current identified users. This should be sufficient to manage their balancing since they are supplying industrial users which typically have little inter-seasonal storage requirements, since their gas use is not used for space heating.

To determine the required inter-seasonal and intraday storage, the production and demand profiles of the network are assessed.

The ECH region has a wealth of geological storage facilities which are currently being explored for repurposing to hydrogen, as identified in the Storage Study.

12.2 Network Balancing

Network balancing for natural gas is normally managed through a mixture of NTS line packing and geological storage. There is less capacity for linepacking with hydrogen network due to the lower volumetric energy density of hydrogen when compared to NG. To balance a hydrogen network, a greater proportion of geological storage is likely to be required. Geological storage is typically at higher pressures than the NTS (150-200barg) and therefore requires compression. Compressing a gas for storage and then reducing the pressure for usage has inherent losses, reducing the overall efficiency of the network and ultimately increasing costs.

Within the Teesside and Humber areas network balancing is of little concern due to close proximity of users to major producers such as BP, Kellas Midstream and Equinor. For other areas, further away from producers, Feeder 7 will provide network balancing due to its large capacity relative to the off take demand requirements.

13. Pressure and compression

An important part of this study is understanding the compression or pressure reduction requirements of the users, producers, storage providers and NGT. It is therefore relevant to understand the distribution network pressures, optimal routing and then assess whether any system pressure changes are required. Increase in system pressure due to distribution system pressure drop will require suitable compression facilities and where pressure is required to be reduced e.g., from HP to IP systems, pressure reduction stations are required, both of which add cost to the system. By understanding the requirements at the outset of the routeing, efficiencies have been made by optimising the network to reduce the number of AGIs and therefore the cost associated with those.

The ECH distribution system consists of the following networks:

Table 29: ECH distribution network summary pressures

Distribution Network	System typical operating pressure range (barg)
National Gas NTS (project union)	50 – 70
Private distribution	Varies depending on producer, expected to be greater than 38barg typically
NGN high pressure	>7 – 38
NGN intermediate pressure	<7 – 2
NGN medium pressure	<2 – 0.075

The required operating pressure of the ECH distribution system is a function of the hydrogen producers supply pressure, NGT off-take pressures (e.g., project Union feeder), storage pressure and final off-take required supply pressure. Due to the low gas density of hydrogen, it is preferred to operate the ECH distribution system at high pressure via distribution through high pressure trunk mains (to circa 38 barg) and subsequently let-down at strategic AGIs to supply spurs that distribute the lower pressure hydrogen to the off-takers supply pressure. There is a driver to use lower pressure pipelines where possible due to the reduced costs of these pipelines, however, their energy transport capacity is much less. Further development of the extent of IP / MP system utilisation within the ECH network will be undertaken in FEED to reduce the number of potential AGIs, whilst assessing further required off-takers and pipeline installation costs.

Management of the ECH distribution network pressure and subsequent flow will be via the National Gas offtake AGIs, Hydrogen producer distribution pipework offtake AGIs and various pressure reduction stations and governors located on the ECH distribution network. Gas flow direction will be a function of the off-taker demand profile and system operating pressure. For example, the proposed hydrogen distribution ring main around Bradford and Leeds (as per Figure 24) may flow in various directions dependent on off-taker demand and National Gas Feeder 7 offtake flow requirements.

Due to the strategic location of the National Gas Feeder 7 re-purposed line as part of Project Union and hydrogen production at Teesside and Humberside forming a spine for the initial ECH network, no additional hydrogen compression is required up to Phase 4 as part of the NGN ECH scope. Further assessment of potential system compression is required for phase 4 when ECH distribution system is extending to Cumbria. However, it is envisaged that local hydrogen production in Cumbria will be available at this time, so the requirement will need to be assessed with the knowledge of that production. Additionally, from circa 2035 additional National Gas Hydrogen Transmission assets at the east coast towards Barrow are thought to become available.

14. Key findings

The NGN ECH area has significant potential hydrogen production and consumption. Through collaboration with the producers, storage providers, users and NGT, a network of repurposed and new assets has been developed which can connect the stakeholders from the hydrogen backbone, utilising largely repurposed assets.

NGN has a highly resilient network with significant redundancy in some areas due to the historical production and consumption of NG within the UK. Through the assessment of the network this study has identified multiple clusters of hydrogen production and demand potential which can utilise this existing network, providing opportunities for large scale industrial decarbonisation.

The production vs demand during the initial stages is weighted towards production. Through discussions with consumers, it was understood that this is because many of them aren't aware of the possibility of connection to a hydrogen network and have therefore not considered this as an option. Production development has also been constrained, by only taking forward projects with demand in the immediate vicinity. The development of the ECH hydrogen network would allow the connection of production and consumption across much greater geographic areas, also connecting to the vital storage sites which will support the inter-seasonal and intraday storage.

Throughout the new pipeline routing assessment undertaken during this study, the selection of routes has been optimised by the use of the Optioneer™ routing tool. This assessed the technical and consenting feasibility of each route. Throughout this process some potential hydrogen users were discounted due to the poor feasibility of the routes required to connect them, typically due to the high pipeline cost for offtake demand for these users. This process has given confidence in the ability to connect to the remaining hydrogen users which have been finally identified.

This study has focused specifically on the largest industrial users and routed the network to them in clusters or in isolation where applicable. This was done to provide a higher level of confidence in the developed networks feasibility by understanding the potential demand of user in greater depth. There is therefore the potential to connect to industrial users who are in close proximity to the defined routes but have not been assessed as part of this study, due to their smaller demand requirements. The aggregation of these smaller users is thought to offer a considerable amount of additional demand in industrialised locations.

The network developed in this options study report relies heavily on the assumptions which have been detailed. It has been possible to make the best-informed assumptions in many cases due to the collaboration within the ECH consortium and the willingness of stakeholders to collaborate to achieve this network. Further collaboration will be key to ensuring these assumptions are constantly reviewed throughout the project to ensure the project remains as effective as possible in the dynamic industry.

The project Union NTS hydrogen backbone is critical to this project. Whilst best collaboration with NGT has meant that this study has been based on the latest thinking, there is a risk that alterations to NGTs decisions on which feeders make up this backbone alter the network developed. Where this risk is greatest, this network has been developed to take the more conservative approach, which means there are also opportunities going forward to reduce the amount of new build pipelines in the NGN network by optimisation of NGT feeder selection.

15. Considerations for FEED

Further engagement with NGT will be critical to confirm assumptions regarding the project union hydrogen backbone route. The greatest unknown currently for the project union hydrogen backbone is the NTS link in the Humber between Asselby and Saltend. NGT will need to provide a connection to Humber to enable Saltend and storage at Easington to be connected to the rest of the NTS. This could potentially be partially achieved by repurposing the NGN Elloughton to Wawne HP line, this is pending assessment of this lines feasibility to take the higher pressures of the NTS system.

Routes which have been identified as part of this study will need to be further assessed for their planning requirements, this will include environmental impact assessments and planning reviews for the routes. This will also be required for repurposed lines to assess if the change of use has any impacts.

As part of later phases of ECH, Cumbria, The East Yorkshire coast and Wolds and North Tyneside were largely discounted due to the significant new build infrastructure which would be required on the NGN network at this stage, when further repurposing of the NTS in the future would achieve much of this. During the FEED stage of this project there will be better understanding of the future UK hydrogen backbone from the Project Union Pre-FEED study. This can then be used to assess the areas which were discounted in this project, undertaking a similar Pre-FEED study of these areas.

To achieve a feasible network, clusters were developed in isolation from others in most cases. This allows flexibility of the network whilst the demand and consumption remain dynamic. When production and demand is firmed up, there is the opportunity to optimise the clusters and the AGIs to share some of the infrastructure.

Pigging stations and pig traps are an integral component of gas transport networks. The locations of these have not been assessed in detail during the Pre-FEED stage and should be assessed during the FEED stage.

The demand and production figures on which this project is based remain ever changing. These will need to be reassessed during the FEED stage. There are additional producers whose project plans were deemed to be too much in their infancy to be included in this Pre-FEED study. These should also be reassessed at FEED stage.

A summary of the actions identified for the FEED stage within each area of this study is shown below:

General:

- Re-evaluation of capital costs
- Further route optimisation for all new lines required in FEED
- Confirmation of demand and production from assumed connections
- Assess any new requirements for domestic connections including trials
- Identify further off-takers outside of the Top industrial and commercial users which are suitable connections for the proposed lines

Teesside:

- Further modelling of the repurposed lines required to assess implications of repurposing pipelines on wider network and other industrial and domestic users
- Liaise with BP and Kellas regarding new pipeline to understand timelines, targeted users and producers and agreement on interface between the private line and NGN
- Liaise with National Gas Transmission regarding repurposing of NTS line from Cowpen Bewley to Haverton Hill Industrial Cluster and repurposing of NTS line from Feeder 7 to Cowpen Bewley via Elton
- Liaise with Teesworks and BP to determine plan regarding increased methane routing and new pipeline to Teesworks
- Develop a connection from Cowpen Bewley AGI to Elton AGI
- Further assess AGI requirements based on additional industrial off-takers and other demands
- Assess existing AGIs included in preferred routes to understand requirement for new/repurposed/modification
- Consider strategic locations of the pig traps for the new network

Bishop Auckland - Pannal

- Evaluate cost-benefit analysis associated with building line for single user Glaxo GSK given long distance in FEED, to consider any non-top 200 users that may benefit from a hydrogen network within Darlington
- Evaluate cost-benefit analysis associated with building individual line for single user in FEED, to consider any non-top 200 users that may benefit from a hydrogen network within Darlington

Leeds / Bradford

- Confirmation that the Pipebridge across river Aire can be used
- Further modelling of the repurposed lines required in FEED to assess implications of repurposing pipeline on wider network and other industrial and domestic users
- Further optimisation of when MP network can be utilised and further transport via a HP network is not required
- Liaise with Bradford Low Carbon Hydrogen to check on export/import requirements and that space is available for and AGI to connect to the new / repurposed lines
- Monitor the selection of Feeder 7 vs other Feeders south of Pannal

Towton – Asselby

- Evaluate cost-benefit analysis associated with building long pipeline lengths to reach users which are sited significant distances from Feeder 7
- Liaise with National Gas Transmission regarding decision on repurposing of Feeder 29 or Feeder 7 south of Pannal
- Further assess AGI requirements based on additional industrial off-takers and other demands

Humber

- Further modelling of the repurposed lines required to assess implications of repurposing pipelines on wider network and other industrial and domestic users
- Liaise with Equinor regarding new Aldborough pipeline to understand timelines and agreement on interface between the line and NGN
- Liaise with National Gas Transmission regarding their plans to connect Asselby and Saltend, and Saltend to Easington
- Further assess AGI requirements based on additional industrial off-takers and other demands

Tyneside

- Further modelling of the repurposed line required in FEED to assess implications of repurposing pipeline on wider network and other industrial and domestic users.
- Further discussions with NGT on the potential other options for connection to Tyneside

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Appendix A

Routes

Area	Start	End	Type	Pipeline Length (km)	Diameter (mm NB)	Pressure
Hartlepool						
Teesside	Greatham AGI	Naisberry	Pipeline - Repurposed	7.9	300	HP
Teesside	Cowpen Bewley AGI	Greatham AGI	Pipeline - New	1.8	300	HP
Teesside	Naisberry AGI	[redacted]	Pipeline - New	1.4	300	MP
Teesside	Naisberry AGI	[redacted]	Pipeline - New	3.8	300	MP
Haverton Hill						
Teesside	Cowpen Bewley	Belasis Avenue	Pipeline - Repurposed	3.0	300	HP
Teesside	Cowpen Bewley AGI	[redacted]	Pipeline - New	1.3	300	MP
Teesside	Cowpen Bewley AGI to [redacted] line	[redacted]	Pipeline - New	0.7	300	MP
Teesside	Belasis Avenue	[redacted]	Pipeline - New	1.5	300	MP
Teesside	Belasis Avenue	[redacted]	Pipeline - New	2.3	300	MP
Teesside	Belasis Avenue	[redacted]	Pipeline - New	1.3	300	MP
Port Clarence						
Teesside	[redacted] repurposed line	[redacted]	Pipeline - Repurposed	1.2	300	MP
Teesside	Seal Sands	[redacted] repurposed line	Pipeline - New	2.7	300	MP
Seal Sands						
Teesside	Dtba Seal Sands PRS	[redacted]	Pipeline - New	0.0	300	MP
BP						
Teesside		Bran Sands	Pipeline - New	1.3		HP
Teesside	[redacted] pipeline	[redacted] AGI	Pipeline - New	0.7		HP
Teesside		Kirkleatham AGI	Pipeline - New	0.4	300	HP
Teesside South						
Teesside	Kirkleatham AGI	Brotton AGI	Pipeline - Repurposed	13.6	600	HP
Teesside	[redacted] AGI	[redacted]	Pipeline - Repurposed	0.5	500	MP
Teesside	[redacted] AGI	[redacted]	Pipeline - New	3.8	300	HP
Teesside	[redacted]	[redacted]	Pipeline - New	6.0	300	MP
Teesside	[redacted]	[redacted]	Pipeline - New	3.2	300	MP
Skinningrove						

Area	Start	End	Type	Pipeline Length (km)	Diameter (mm NB)	Pressure
Teesside	Brotton PRS	[redacted]	Pipeline - New	1.6	300	MP
Hartlepool South						
Teesside	[redacted]	[redacted]	Pipeline - New	2.7	300	IP
Barnard Aycliffe						
Bishop Auckland to Pannal	Leasingthorne	Newton Aycliffe / Darlington (Thic)	Pipeline - Repurposed	8.6	300	HP
Bishop Auckland to Pannal	Newton Aycliffe / Darlington (Thic)	Newton Aycliffe exit spur AGIs	Pipeline - Repurposed	4.2	300	HP
Bishop Auckland to Pannal	Direct Worktops Pig Trap	[redacted]	Pipeline - New	5.4	300	MP
Bishop Auckland to Pannal	[redacted]	[redacted]	Pipeline - New	17.3	300	MP
Bishop Auckland to Pannal	[redacted] exit HP spur	[redacted]	Pipeline - New	0.1	300	HP
Bishop Auckland to Pannal	[redacted]	[redacted]	Pipeline - New	1.8	300	IP
Darlington						
Bishop Auckland to Pannal	Little Burdon AGI	[redacted]	Pipeline - New	6.6	300	MP
Bishop Auckland North						
Bishop Auckland to Pannal	Bishop Aukland AGI	Leasingthorne	Pipeline - New	2.8	300	HP
Bishop Auckland to Pannal	Leasingthorne Pig Trap	Middlestone Moor PRS	Pipeline - New	2.3	600	HP
Bishop Auckland to Pannal	Middlestone Moor AGI	[redacted]	Pipeline - New	3.5	300	MP
Bishop Auckland to Pannal	Middlestone Moor AGI	[redacted]	Pipeline - New	2.2	300	MP
Thrintoft						
Bishop Auckland to Pannal	Thrintoft AGI	[redacted]	Pipeline - New	5.6	300	HP
Bishop Auckland to Pannal	[redacted]	[redacted]	Pipeline - New	4.6	300	HP
Bishop Auckland to Pannal	[redacted]	[redacted]	Pipeline - New	1.3	300	HP
Bishop Auckland to Pannal	Leeming	Bedale	Pipeline - New	3.7	300	MP
Bishop Auckland to Pannal	Bedale	[redacted]	Pipeline - Repurposed	9.1	180	MP
Ripon						
Bishop Auckland to Pannal	Feeder 7 / [redacted] AGI	[redacted]	Pipeline - New	5.1	300	MP

Area	Start	End	Type	Pipeline Length (km)	Diameter (mm NB)	Pressure
Bishop Auckland to Pannal	[redacted]	[redacted]	Pipeline - New	11.5	300	MP
Harrogate						
Bishop Auckland to Pannal	Burley Bank	Harrogate	Pipeline - Repurposed	3.6	450	HP
Bishop Auckland to Pannal	Burley Bank AGI	[redacted]	Pipeline - New	4.2	300	MP
Bishop Auckland to Pannal	[redacted]	[redacted]	Pipeline - New	4.7	300	MP
Bishop Auckland to Pannal	Harrogate PRS	[redacted]	Pipeline - New	3.2	300	MP
Bishop Auckland to Pannal	Harrogate PRS	[redacted]	Pipeline - New	4.5	300	MP
Bradford Leeds						
Leeds / Bradford	Tong	Meadow Lane	Pipeline - Repurposed	9.7	300	HP
Leeds / Bradford	Tyersal	Birkshall	Pipeline - New	2.4	300	HP
Leeds / Bradford	East Bierly PRS	Tong	Pipeline - New	3.6	300	HP
Leeds East						
Leeds / Bradford	Meadow Lane	Bullerthorpe Lane	Pipeline - New	9.6	300	HP
Leeds / Bradford	Barwick	Bullerthorpe Lane	Pipeline - New	4.7	400	HP
Leeds / Bradford	Barwick Pig trap site	Towton	Pipeline - Repurposed	9.0	600	HP
Leeds / Bradford	Meadow lane Barwick	[redacted]	Pipeline - New	1.3	300	MP
Bradford						
Leeds / Bradford	Birkshall	East Bierly	Pipeline - Repurposed	4.2	450	HP
Leeds / Bradford	East Bierley PRS	Low moor PRS	Pipeline - Repurposed	4.1	450	HP
Leeds / Bradford	Low moor PRS	[redacted]	Pipeline - Repurposed	0.8	300	HP
Leeds / Bradford	Low Moor PRS	[redacted]	Pipeline - New	1.5	300	HP
Leeds / Bradford	Birkshall	[redacted]	Pipeline - New	0.9	300	MP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	1.1	300	MP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	1.9	300	MP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	1.9	300	MP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	1.4	300	MP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	1.4	300	MP

Area	Start	End	Type	Pipeline Length (km)	Diameter (mm NB)	Pressure
Leeds South						
Leeds / Bradford	Tee off Meadow lane	Bullerthorpe lane line to [redacted]	Pipeline - New	2.2	300	HP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	0.6	300	HP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	3.5	300	MP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	0.8	300	MP
Leeds / Bradford	[redacted]	[redacted]	Pipeline - New	0.6	300	MP
Pannal Pudsey						
Leeds / Bradford	Pannal Offtake	Tyersal PRS	Pipeline - Repurposed	21.0	600	HP
Selby						
Towton to Asselby	Asselby AGI	[redacted]	Pipeline - New	5.7	300	HP
Towton to Asselby	[redacted]	[redacted]	Pipeline - New	11.6	300	IP
Towton to Asselby	[redacted]	[redacted]	Pipeline - New	0.7	300	IP
Towton to Asselby	[redacted]	[redacted]	Pipeline - New	1.8	300	IP
Towton to Asselby	[redacted]	[redacted]	Pipeline - New	2.2	300	IP
Goole						
Towton to Asselby	Asselby AGI	Centre Point between [redacted]	Pipeline - New	8.5	300	MP
Towton to Asselby	Centre Point between [redacted]	[redacted]	Pipeline - New	2.4	300	IP
Towton to Asselby	Centre Point between [redacted]	[redacted]	Pipeline - New	3.3	300	IP
Tadcaster Sherburn						
Towton to Asselby	Towton AGI	[redacted]	Pipeline - New	10.7	300	MP
Towton to Asselby	Towton AGI	[redacted]	Pipeline - New	3.5	300	MP
Towton to Asselby	[redacted]	[redacted]	Pipeline - New	0.9	300	MP
Knottingley						
Towton to Asselby	[redacted]	[redacted]	Pipeline - New	8.9	400	HP
Towton to Asselby	[redacted]	[redacted]	Pipeline - New	4.6	400	HP

Area	Start	End	Type	Pipeline Length (km)	Diameter (mm NB)	Pressure
Towton to Asselby	[redacted]		Pipeline - New	7.4	350	MP
Towton to Asselby	[redacted]		Pipeline - New	0.8	300	MP
Towton to Asselby	[redacted]		Pipeline - New	1.6	300	MP
Towton to Asselby	[redacted]		Pipeline - New	3.6	300	MP
West Hull						
Humber	Elloughton	Wawne	Pipeline - Repurposed	17.8	600	HP
Humber	Eloughton AGI	[redacted]	Pipeline - New	2.3	300	MP
Humber	Eloughton AGI	[redacted]	Pipeline - New	3.0	300	MP
Humber	Repurposed HP Elloughton - Wawne	[redacted]	Pipeline - New	0.9	300	HP
Humber	[redacted]	[redacted]	Pipeline - New	1.5	300	HP
Humber	[redacted]	[redacted]	Pipeline - New	0.4	300	MP
Humber	GLENAVON	[redacted]	Pipeline - New	2.9	300	MP
Humber	GLENAVON	[redacted]	Pipeline - New	0.3	300	MP
Humber	[redacted]	[redacted]	Pipeline - New	0.7	300	MP
Humber	Wawne	[redacted]	Pipeline - New	2.4	300	MP
Howden						
Humber	Howdon connection to repurposed line	[redacted]	Pipeline - Repurposed	6.0	250	IP
Humber	Gilberdyke	[redacted]	Pipeline - Repurposed	3.5	125	IP
Humber	Gilberdyke	[redacted]	Pipeline - Repurposed	3.6	180	IP
Humber	[redacted]	[redacted]	Pipeline - Repurposed	1.6	125	IP
Humber	Asselby AGI	Howdon connection to repurposed line	Pipeline - New	6.2	300	IP
Humber	[redacted]	[redacted]	Pipeline - New	3.3	250	IP
Humber	Howden AGI	[redacted]	Pipeline - New	0.8	300	MP
Humber	Howden AGI	[redacted]	Pipeline - New	2.4	300	MP
Hull						
Humber	Wawne	Bankside	Pipeline - Repurposed	8.0	300	HP
Humber	Bankside	Chamberlin Road	Pipeline - Repurposed	1.3	450	HP

Area	Start	End	Type	Pipeline Length (km)	Diameter (mm NB)	Pressure
Humber	[redacted] AGI	Connection Point C	Pipeline - New	2.1	300	MP
Humber	Connection Point C	[redacted]	Pipeline - New	0.8	300	MP
Humber	[redacted]	[redacted]	Pipeline - New	0.6	300	MP
Humber	Chamberlin Road	[redacted]	Pipeline - New	1.1	300	MP
Humber	[redacted]	Connection Point D	Pipeline - New	0.5	300	MP
Humber	Connection Point D	[redacted]	Pipeline - New	3.9	300	MP
Humber	[redacted]	[redacted]	Pipeline - New	0.3	300	MP
Humber	[redacted]	[redacted]	Pipeline - New	1.0	300	MP
Humber	Bankside	Connection Point B	Pipeline - New	0.7	300	IP
Humber	Connection Point B	[redacted]	Pipeline - New	1.7	300	IP
Humber	Connection Point B	[redacted]	Pipeline - New	0.1	300	IP
Humber	Chamberlin Road	[redacted]	Pipeline - New	1.6	300	HP
Humber	Saltend	[redacted]	Pipeline - New	2.7	550	MP
Humber	[redacted]	[redacted]	Pipeline - New	0.1	550	MP
Humber	Saltend	[redacted]	Pipeline - New	4.9	300	MP
Humber	Saltend	[redacted]	Pipeline - New	5.6	300	IP
Humber	[redacted]	[redacted]	Pipeline - New	2.4	300	IP
Humber	[redacted]	Saltend	Pipeline - New	6.6	300	HP
East Riding						
Humber	Wawne	Cayton		51.3	300	HP
Humber	Rudston NG Offtake	Burton Agnes PRI	Pipeline - New	2.9	100	HP
Humber	Cayton PRI	Hunmanby PRI	Pipeline - New	9.5	200	MP
Humber	Brandesburton	Frodingham	Pipeline - New	5.9	100	IP
Tyneside						
Teesside	Cowpen Bewley	Warden Law	Pipeline - Repurposed	35.0	300	HP
Tyneside	Warden Law	[redacted]	Pipeline - Repurposed	10.0	300	IP

AGIs

Area	Name	Type	Pressure
Teesside	Naisberry AGI	PRI - Repurposed	HP to MP
Teesside	Cowpen Bewley AGI	Offtake - Modified	HP
Teesside	Greatham AGI	Offtake - Modified	HP
Teesside	Dtba Seal Sands PRS	PRI - Repurposed	HP to MP
Teesside	[redacted] AGI	PRI - Repurposed	HP to MP
Teesside	Bran Sands	PRI - New	HP to MP
Teesside	[redacted]	PRI - New	MP to LP
Teesside	Brotton PRS	PRI - Repurposed	HP to MP
Teesside	Kirkleatham AGI	Offtake - Modified	HP
Teesside	[redacted]	PRI - New	IP to MP
Teesside	Belasis Avenue	Offtake - New	MP
Bishop Auckland to Pannal	Bishop Auckland AGI	Offtake - Modified	HP
Bishop Auckland to Pannal	Direct Worktops	Pig Trap - Repurposed	MP
Bishop Auckland to Pannal	[redacted] Offtake	Offtake - Modified	HP
Bishop Auckland to Pannal	[redacted] PRI	PRI - New	HP to IP
Bishop Auckland to Pannal	Little Burdon AGI	Offtake - Modified	MP
Bishop Auckland to Pannal	Leasingthorne	Pig Trap - Repurposed	HP
Bishop Auckland to Pannal	Middlestone Moor AGI	PRI - Repurposed	HP to MP
Bishop Auckland to Pannal	Thrintoft AGI	Offtake - Modified	HP
Bishop Auckland to Pannal	Feeder 7 / [redacted] AGI	Offtake - New	MP
Bishop Auckland to Pannal	Burley Bank AGI	Offtake - Modified	MP
Bishop Auckland to Pannal	Harrogate PRS	PRI - Repurposed	HP to MP
Bishop Auckland to Pannal	Yafforth Offtake	Offtake - New	HP
Bishop Auckland to Pannal	Bishopton Offtake	Offtake - New	IP
Leeds / Bradford	Barwick Pig trap site	Pig Trap - Repurposed	HP
Leeds / Bradford	Bullerthorpe lane	PRI - Repurposed	HP

Area	Name	Type	Pressure
Leeds / Bradford	Meadow lane	PRI - Repurposed	HP
Leeds / Bradford	Tong	PRI - Repurposed	HP
Leeds / Bradford	East Bierley	PRI - Repurposed	HP
Leeds / Bradford	Birkshall	PRI - Repurposed	HP
Leeds / Bradford	Tyersal	PRI - Repurposed	HP
Leeds / Bradford	Low moor PRS	PRI - Repurposed	HP
Leeds / Bradford	[redacted] AGI	PRI - New	HP to MP
Leeds / Bradford	[redacted]	PRI - New	HP to MP
Leeds / Bradford	Askwith	Offtake - New	HP
Leeds / Bradford	Pannal	Offtake - Modified	HP
Towton to Asselby	Asselby AGI	PRI - Extension	HP to IP
Towton to Asselby	Asselby AGI	PRI - Repurposed	IP to MP
Towton to Asselby	Towton	Offtake - Modified	MP
Towton to Asselby	Little Heck AGI	PRI - New	HP to MP
Towton to Asselby	Eggborough AGI	PRI - New	HP to MP
Humber	Wawne	PRI - Repurposed	HP to MP
Humber	Elloughton	PRI - Repurposed	HP to IP
Humber	[redacted]	PRI - New	HP to MP
Humber	Bankside	PRI - Repurposed	HP to IP
Humber	Chamberlin Road	PRI - Repurposed	HP to MP
Humber	[redacted] AGI	PRI - New	IP to MP
Humber	Saltened	PRI - Repurposed	HP to IP
Humber	Saltened	PRI - Repurposed	HP to MP
Humber	[redacted] East	PRI - New	IP to MP
Humber	Howden	PRI - New	IP to MP
Humber	Sigglesthorne	Offtake - New	HP
Humber	Catwick	PRI - Repurposed	HP to IP

Area	Name	Type	Pressure
Humber	Frodingham	PRI - Repurposed	IP to MP
Humber	Rudston	Offtake - New	HP
Humber	Cayton	PRI - Repurposed	HP to MP
Tyneside	Warden Law	Offtake - Modified	HP
Tyneside	[redacted]	Offtake - New	HP

Appendix B

Continuum data register

Optioneer Layer Name	Source ID	Dataset Name	Data Type	Descriptive Layer Name	Buffer (m)	Consent Penalty Classification	Technical Penalty Classification	Dataset URL	Used in GIS Pipeline	Comment (Consent)	Comment (Technical)
National_Cycle_Network	ST	Linear Features	Polygon	National Cycle Network	0	1	1	https://data-sustrans-uk.opendata.arcgis.com/	1	Provide necessary diversions where required	Assumed to be other than 'road'
RSPB_-_Reserves	RSPB	Multi_Source	Polygon	Reserves - RSPB	0	4	0	https://opendata-rspb.opendata.arcgis.com/datasets/RSPB::ibas-uk/	1	Assume they form part of a National Nature Reserve/other ecological designation. Paragraph 180 of the NPPF '180. When determining planning applications, local planning authorities should apply the following principles: a) if significant harm to biodiversity resulting from a development cannot be avoided (through locating on an alternative site with less harmful impacts), adequately mitigated, or, as a last resort, compensated for, then planning permission should be refused;'	From a technical perspective, many of the protected zones do not pose any challenges in construction. Routing to avoid these areas should be captured within the consent penalty
Buildings_All_Local	OS	Ordnance Survey	Polygon	Buildings - All - Local	3	0	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	This assumes buildings are not listed	Assumed to be Type T
Buildings_All_Local	OS	Ordnance Survey	Polygon	Buildings - All - Local	3	0	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	This assumes buildings are not listed	
Elevation	OS	Ordnance Survey	Raster	Elevation	0	0	3	https://www.ordnancesurvey.co.uk/business-government/products/terrain-50	1	For consenting, the elevation of the area is not relevant	Assumed to include geotechnical challenges, difficult terrain
Functional_Sites_-_All	OS	Ordnance Survey	Polygon	Functional Sites - All	3	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	0	Ensure the necessary mitigation is in place during times of construction	
Functional_Sites_-_Education	OS	Ordnance Survey	Polygon	Functional Sites - Education	35	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	Sensitive location
Functional_Sites_-_Education_MedicalCare	OS	Ordnance Survey	Polygon	Functional Sites - Education MedicalCare	35	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	0	As above	Sensitive location
Functional_Sites_-_MedicalCare	OS	Ordnance Survey	Polygon	Functional Sites - MedicalCare	35	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	Sensitive location
Functional_Sites_-_Transport	OS	Ordnance Survey	Polygon	Functional Sites - Transport	3	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	0	As above	
Functional_Sites_-_Transport_Air	OS	Ordnance Survey	Polygon	Functional Sites - Transport Air	3	2	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	The Town and Country Planning (safeguarded aerodromes, technical sites and military explosives storage areas) direction 2002 - consideration if areas is safeguarded for aviation (civil, military etc)	
Functional_Sites_-_Transport_Road	OS	Ordnance Survey	Polygon	Functional Sites - Transport Road	3	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	No clear policy reasons - other than to incorporate into design as appropriat/ Asssume it would not impact on any areas for future road building	
Functional_Sites_-_Transport_Water	OS	Ordnance Survey	Polygon	Functional Sites - Transport Water	3	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	No clear policy reasons - other than to incorporate into design as appropriate	
Greenspace_-_All	OS	Ordnance Survey	Polygon	Greenspace - All	0	1	0	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	0	This assumes 'open land' and not considered to be designated open space in any local plan allocations, or any other policy designation	
Greenspace_-_Allotments	OS	Ordnance Survey	Polygon	Greenspace - Allotments	0	3	0	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Paragraph 99 of the NPPF - Assumes sites would be formally designated as open space within the local plan. 'Existing open space should not be built on unless: a) an assessment has been undertaken which has clearly shown the open space, buildings or land to be surplus to requirements; or b) the loss resulting from the proposed development would be replaced by equivalent or better provision in terms of quantity and quality in a suitable location; or c) the development is for alternative sports and recreational provision, the benefits of which clearly outweigh the loss of the current or former use.	
Greenspace_-_Cemeteries	OS	Ordnance Survey	Polygon	Greenspace - Cemeteries	0	3	0	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Paragraph 99 of the NPPF - As above	
Greenspace_-_GolfCourses	OS	Ordnance Survey	Polygon	Greenspace - GolfCourses	0	3	0	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Paragraph 99 of the NPPF - As above	
Greenspace_-_Public_Parks_and_Gardens	OS	Ordnance Survey	Polygon	Greenspace - Public Parks and Gardens	0	3	0	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Paragraph 99 of the NPPF - As above	
Greenspace_-_Religious_Grounds	OS	Ordnance Survey	Polygon	Greenspace - Religious Grounds	0	3	0	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Paragraph 99 of the NPPF - As above	
Greenspace_-_Sports_Grounds	OS	Ordnance Survey	Polygon	Greenspace - Sports Grounds	0	3	0	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Paragraph 99 of the NPPF - As above	
National_Parks	OS	OrdnanceSurvey	Polygon	National Parks	35	4	1	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Paragraph 175- 177 of the NPPF. Major development will only be accepted in exceptional circumstances, where it can be demonstrated there is overriding public benefit	

Optioneer Layer Name	Source ID	Dataset Name	Data Type	Descriptive Layer Name	Buffer (m)	Consent Penalty Classification	Technical Penalty Classification	Dataset URL	Used in GIS Pipeline	Comment (Consent)	Comment (Technical)
Rail_-_Multi_Track	OS	Ordnance Survey Line	Line	Rail - Multi Track	20	1	3	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Consideration of Chapter 9 of the NPPF relating to transport - including safety	Assume linear features have Type S buffer when running parallel
Rail_-_Narrow_Gauge	OS	Ordnance Survey Line	Line	Rail - Narrow Gauge	20	1	3	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	
Rail_-_Single_Track	OS	Ordnance Survey Line	Line	Rail - Single Track	20	1	3	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	
Rail_-_Stations	OS	Ordnance Survey	Polygon	Rail - Stations	3	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	
Rail_-_Tunnel	OS	Ordnance Survey Line	Line	Rail - Tunnel	20	1	5	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	Difficult construction technique
Rivers	OS	Ordnance Survey Line	Line	Rivers	20	1	4	https://osdatahub.os.uk/downloads/open/OpenRivers	1	No clear policy reasons but likely to be designated for other reasons (biodiversity, reserves, protected species etc.	
Rivers	OS	Ordnance Survey Line	Line	Rivers	20	1	4	https://osdatahub.os.uk/downloads/open/OpenRivers	1	As above	
Road_-_A_Road	OS	Ordnance Survey Line	Line	Road - A Road	20	1	3	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	No clear policy reasons - other than to incorporate into design as appropriate/ Asssume it would not impact on any areas for future road building. Wider consideration of Chapter 9 of the NPPF	
Road_-_B_Road	OS	Ordnance Survey Line	Line	Road - B Road	20	1	2	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	
Road_-_Classified_Unnumbered_Road	OS	Ordnance Survey Line	Line	Road - Classified Unnumbered Road	20	1	1	https://osdatahub.os.uk/downloads/open/OpenRoads	1	As above	
Road_-_Local_Road	OS	Ordnance Survey Line	Line	Road - Local Road	20	1	1	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	
Road_-_Minor_Road	OS	Ordnance Survey Line	Line	Road - Minor Road	20	1	1	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	
Road_-_Motorway	OS	Ordnance Survey Line	Line	Road - Motorway	20	1	3	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	
Road_-_Other_Roads	OS	Ordnance Survey Line	Line	Road - Other Roads	20	1	1	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	0	As above	
Road_-_Restricted_Local_Access_Road	OS	Ordnance Survey Line	Line	Road - Restricted Local Access Road	20	1	1	https://osdatahub.os.uk/downloads/open/OpenRoads	1	As above	
Road_-_Secondary_Access_Road	OS	Ordnance Survey Line	Line	Road - Secondary Access Road	20	1	1	https://osdatahub.os.uk/downloads/open/OpenRoads	1	As above	
Road_-_Unclassified_Road	OS	Ordnance Survey Line	Line	Road - Unclassified Road	20	1	1	https://osdatahub.os.uk/downloads/open/OpenRoads	1	As above	
Slope	OS	Ordnance Survey	Raster	Slope	0	0	3	https://www.ordnancesurvey.co.uk/business-government/products/terrain-56	1	For consenting, the elevation of the area is not relevant	
Surface_Water	OS	Ordnance Survey	Polygon	Surface Water	20	2	4	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	Paragraphs 161-165 to the NPPF. A check of the extent of surface water would be required. Likely to be classed as 'essential infrastructure' or 'highly vulnerable' (if Hazardous Substance consent is required) in Flood Zones 2 or 3. A sequential and exceptions test would be required.	
Surface_Water	OS	OrdnanceSurvey	Polygon	Surface Water	20	2	4	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	As above	
Urban_Areas	OS	Ordnance Survey	Polygon	Urban Areas	0	0	0	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	1	No defined policy reason, it would be subject to individual allocations and designations within a local plan	Assumed to be captured with Type T area classification (line 121)
Woodland_Miscellaneous_OS	OS	OrdnanceSurvey	Polygon	Woodland Miscellaneous OS	35	2	1	https://www.ordnancesurvey.co.uk/business-government/products/open-zoomstack	0	If not ancient woodland, likely to have local significance in local plan/biodiversity benefit	Type R classification
275kV_OverheadLines	NG	NationalGrid_Line	Line	0	0	0	0	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps	1	Assume no impact due to nature of overhead line	
400kV_OverheadLines	NG	NationalGrid_Line	Line	0	0	0	0	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps	1	Assume no impact due to nature of overhead line	
Gas_Pipeline	NG	National Grid - Line	Line	Gas Pipeline	7	1	5	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps	1	The necessary migitation would be required to be incorporated. Consideration of potential 'no build zones' in proximity to some of these assets	
Gas_Pipeline	NG	National Grid	Line	Gas Pipeline	7	1	5	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps	1	As above	Based on TD1 Minimum pipeline separation distances
Gas_Sites	NG	National Grid	Polygon	Gas Sites	35	1	5	https://www.nationalgrid.com/gas-transmission/land-and-assets/network-route-maps	1	As above	Based on TD1 Minimum pipeline separation distances

Optioneer Layer Name	Source ID	Dataset Name	Data Type	Descriptive Layer Name	Buffer (m)	Consent Penalty Classification	Technical Penalty Classification	Dataset URL	Used in GIS Pipeline	Comment (Consent)	Comment (Technical)
SubstationSites	NG	National Grid	Polygon	0	35	0	5	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps	1	No defined policy reason, it would be subject to individual allocations and designations within a local plan	Assuming Type R classification
Transmission_Tower	NG	National Grid	Polygon	Major utilities and other installations	10	0	5	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps	1	As above	
Underground_Cable	NG	National Grid	Line	Major utilities and other installations	7	0	5	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps	1	As above	Assuming minimum separation distance for pipelines
AncientWoodland	NE	Natural England	Polygon	Ancient Woodland	35	4	1	https://naturalengland-defra.opendata.arcgis.com/datasets/Defra::ancient-woodland-england/explore?location=52.723506,-0.863912,9.39	1	Paragraph 180 (NPPF 2021) part c) development resulting in the loss or deterioration of irreplaceable habitats (such as ancient woodland and ancient or veteran trees) should be refused, unless there are wholly exceptional reasons and a suitable compensation strategy exists; - exceptional circumstances includes NSIP projects.	
Biosphere	NE	Natural England	Polygon	Biosphere Reserve	35	4	1	https://naturalengland-defra.opendata.arcgis.com/datasets/biosphere-reserves-england/explore?location=52.605800,-0.343813,6.17	1	These would likely have other designations within them (i.e international nature designations)	
ALC Grade 1	NE	Natural England	Polygon	Provisional Agricultural Land Classification	35	2	0	https://naturalengland-defra.opendata.arcgis.com/datasets/provisional-agricultural-land-classification-alc-england/	1	Footnote 58 NPPF (2021) '*Where significant development of agricultural land is demonstrated to be necessary, areas of poorer quality land should be preferred to those of a higher quality.'*	
ALC Grade 2	NE	Natural England	Polygon	Provisional Agricultural Land Classification	0	2	0	https://naturalengland-defra.opendata.arcgis.com/datasets/provisional-agricultural-land-classification-alc-england/	1	Footnote 55 NPPF - As above	
CountryParks	NE	Natural England	Polygon	Country Parks	0	3	0	https://naturalengland-defra.opendata.arcgis.com/datasets/country-parks-england/explore?location=52.652719,-0.322441,9.72	1	Potential for country parks to be designated as 'open space' in the NPPF (Paragraph 99 of the NPPF'	
CRoW	NE	Natural England	Polygon	Countryside and Rights of Way (CRoW) Act 2000 - Open Access Land	0	2	0	https://naturalengland-defra.opendata.arcgis.com/datasets/crow-act-2000-access-layer/explore?location=52.590436,-0.298879,9.28	1	Likely to be also designated for other reasons (nature reserves, biodiversity, etc)	
Heritage Coast	NE	Natural England	Polygon	Heritage Coast	0	4	0	https://naturalengland-defra.opendata.arcgis.com/datasets/d9557885721d483dac138bdd0ab08c3e_0/explore?location=52.703648,-2.195731,6.81	1	Paragraph 178 of the NPPF (2021) *'Major development within a Heritage Coast is unlikely to be appropriate, unless it is compatible with its special character'*.	
NationalParks	NE	Natural England	Polygon	National Parks	35	4	1	https://naturalengland-defra.opendata.arcgis.com/datasets/national-parks-england/explore?location=52.528407,0.115097,7.76	1	Paragraph 175- 177 of the NPPF. *'When considering applications for development within National Parks, the Broads and Areas of Outstanding Natural Beauty, permission should be refused for major development other than in exceptional circumstances, and where it can be demonstrated that the development is in the public interest.'*	
NationalTrail	NE	Natural England Line	Line	National Trail	0	2	0	https://naturalengland-defra.opendata.arcgis.com/datasets/national-trails-england/explore?location=52.437852,-1.066360,7.71	1	Paragraph 100 of the NPPF (2021) - Planning decisions should protect and enhance public rights of way and access, including taking opportunities to provide better facilities for users, for example by adding links to existing rights of way networks including National Trails.	
NNR	NE	Natural England	Polygon	National Nature Reserve	35	4	1	https://naturalengland-defra.opendata.arcgis.com/datasets/national-nature-reserves-england/explore?location=52.564937,-1.336029,8.00	1	NPPF Paragraph 180. '*When determining planning applications, local planning authorities should apply the following principles: a) if significant harm to biodiversity resulting from a development cannot be avoided (through locating on an alternative site with less harmful impacts), adequately mitigated, or, as a last resort, compensated for, then planning permission should be refused'*	
PriorityHabitat	NE	Natural England	Polygon	Priority Habitat	0	4	0	https://environment.data.gov.uk/DefraDataDownload/?mapService=NE/PriorityHabitatInventoryNorth&Mode=spatial	1	Paragraph 180 - As above	
RAMSAR_All	NE	Natural England	Polygon	RAMSAR Site	0	4	0	https://naturalengland-defra.opendata.arcgis.com/datasets/ramsar-england/explore?location=52.634048,-2.520138,7.81	1	Paragraph 180 - As above	

Optioneer Layer Name	Source ID	Dataset Name	Data Type	Descriptive Layer Name	Buffer (m)	Consent Penalty Classification	Technical Penalty Classification	Dataset URL	Used in GIS Pipeline	Comment (Consent)	Comment (Technical)
SAC_All	NE	Natural England	Polygon	Special Area of Conservation	0	4	0	https://environment.data.gov.uk/DefraDataDownload/?mapService=NE/SpecialAreasOfConservationEngland&Mode=spatial	1	Paragraph 180 - As above	
SPA_All	NE	Natural England	Polygon	Special Protection Area	0	4	0	https://naturalengland-defra.opendata.arcgis.com/datasets/special-protection-areas-england/explore?location=52.613507,-2.229306,7.73	1	Paragraph 180 - As above	
SSSI	NE	Natural England	Polygon	Site of Special Scientific Interest	0	4	0	https://naturalengland-defra.opendata.arcgis.com/datasets/Defra::sites-of-special-scientific-interest-england/explore?location=52.799987,-2.496337,7.47	1	NPPF Paragraph 180 - b) development on land within or outside a Site of Special Scientific Interest, and which is likely to have an adverse effect on it (either individually or in combination with other developments), should not normally be permitted. The only exception is where the benefits of the development in the location proposed clearly outweigh both its likely impact on the features of the site that make it of special scientific interest, and any broader impacts on the national network of Sites of Special Scientific Interest;	
SSSI_IRZ_Pipeline	NE	Natural England	Polygon	SSSI Impact Risk Zones	0	3	0	https://data.gov.uk/dataset/5ae2af0c-1363-4d40-9d1a-e5a1381449f8/sssi-impact-risk-zones-england	1	As above- noting its proximty to rather than being directly located within it.	
Great_Crested_Newt_-_Observations_-_NBN	NBN	Multi_Source	Polygon	Great Crested Newt - Observations - NBN	35	3	0	https://records.nbnatlas.org/occurrences/search?q=lsid:NHMSYS0000080156&fq=occurrence_status:present&fq=-license:CC-BY-NC&fq=-(identification_verification_status:%22Unconfirmed%22%20OR%20identification_verification_status:%22Unconfirmed%20-%20not%20reviewed%22%20OR%20identification_verification_status:%22Unconfirmed%20-%20plausible%22)&nbn_loading=true	1	Paragraph 180 of the NPPF - noting that they could be in proximity to designated nature sites	
NATS_Danger_Area_AIP	NATS	Multi_Source	Polygon	NATS Danger Area AIP	0	0	0	https://nats-uk.ead-it.com/cms-nats/opencms/en/uas-restriction-zones/#UAS_Airspace_Restrictions_Digital_Datasets	1	Not thought to be required	
NATS_Prohibited_Area_AIP	NATS	Multi_Source	Polygon	NATS Prohibited Area AIP	0	0	0	https://nats-uk.ead-it.com/cms-nats/opencms/en/uas-restriction-zones/#UAS_Airspace_Restrictions_Digital_Datasets	1	Not thought to be required	
NATS_Restricted_Area_AIP	NATS	Multi_Source	Polygon	NATS Restricted Area AIP	0	0	0	https://nats-uk.ead-it.com/cms-nats/opencms/en/uas-restriction-zones/#UAS_Airspace_Restrictions_Digital_Datasets	1	Not thought to be required	
Battlefield	HE	Historic England	Polygon	Registered Battlefields	0	4	0	https://historicengland.org.uk/listing/the-list/data-downloads/	1	Paragraph 199 (NPPF 2021) - *'When considering the impact of a proposed development on the significance of a designated heritage asset, great weight should be given to the asset's conservation (and the more important the asset, the greater the weight should be). This is irrespective of whether any potential harm amounts to substantial harm, total loss or less than substantial harm to its significance.'*	
Conservation Areas	HE	Historic England	Polygon	Conservation Areas	0	4	0	https://historicengland.org.uk/listing/the-list/data-downloads/	1	As above - Paragraph 199 (NPPF 2021)	
ListedBuildings_Grade2	HE	Historic England	Polygon	Listed Buildings	3	4	5	https://historicengland.org.uk/listing/the-list/data-downloads/	1	As above - Parapraph 199 (NPPF 2021)	
ListedBuildings_TopGrade	HE	Historic England	Polygon	Listed Buildings	3	4	5	https://historicengland.org.uk/listing/the-list/data-downloads/	1	As above - Paragraph 199 (NPPF 2021)	
ParksAndGardens	HE	Historic England	Polygon	Registered Parks and Gardens	0	4	0	https://historicengland.org.uk/listing/the-list/data-downloads/	1	As above - Paragraph 199 (NPPF 2021)	
ScheduledMonuments	HE	Historic England	Polygon	Scheduled Monuments	0	4	0	https://historicengland.org.uk/listing/the-list/data-downloads/	1	As above - Paragraph 199 (NPPF 2021)	
WorldHeritage	HE	Historic England	Polygon	World Heritage Site	0	4	0	https://historicengland.org.uk/listing/the-list/data-downloads/	1	As above - Paragraph 199 (NPPF 2021)	
NFI_Woodland_-_Broadleaved_-_Forestry_Comr	FC	Forestry_and_Woodland	Polygon	Woodland NFI Broadleaved	0	2	1	https://services2.arcgis.com/mHXjwgl3OARRqqD4/ArcGIS/rest/services	1	If not ancient woodland, likely to have local significance in local plan/biodiversity benefit	
NFI_Woodland_-_Broadleaved_-_Forestry_Comr	FC	Forestry_and_Woodland	Polygon	Woodland NFI Broadleaved	45	2	1	https://services2.arcgis.com/mHXjwgl3OARRqqD4/ArcGIS/rest/services	1	As above	
NFI_Woodland_-_Coniferous_-_Forestry_Commi	FC	Forestry_and_Woodland	Polygon	Woodland NFI Coniferous	0	2	1	https://services2.arcgis.com/mHXjwgl3OARRqqD4/ArcGIS/rest/services	1	As above	

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NFI_Woodland_-_Coniferous_-_Forestry_Commi	FC	Forestry_and_Woodland	Polygon	Woodland NFI Coniferous	45	2	1	https://services2.arcgis.com/mHXjwgl3OARRqqD4/ArcGIS/rest/services	1	As above	
NFI_Woodland_-_Not_Woodland_-_Forestry_Co	FC	Forestry_and_Woodland	Polygon	Woodland NFI Not Woodland	0	0	0	https://services2.arcgis.com/mHXjwgl3OARRqqD4/ArcGIS/rest/services	0	Assume non-woodland area	
FloodDefences	EA	Environment Agency	Line	National Flood Zones/Areas Benefiting from Defences	0	1	3	https://environment.data.gov.uk/DefraDataDownload/?mapService=EA/FloodMapForPlanningRiversAndSeaFloodStorageAreas&Mode=spatial	1	Diversions would be required where necessary, and it is assumed that any development would not heavily impact upon existing flood defences.	Would require a weight coat
FloodStorage	EA	Environment Agency	Polygon	National Flood Zones/Areas Benefiting from Defences	0	3	3	https://environment.data.gov.uk/DefraDataDownload/?mapService=EA/FloodMapForPlanningRiversAndSeaFloodStorageAreas&Mode=spatial	1	Paragraphs 161-165 to the NPPF. Likely to be classed as 'essential infrastructure' or 'highly vulnerable' (if Hazardous Substance consent is required) in Flood Zones 2 or 3. A sequential and exceptions test would be required.	Would require a weight coat
FloodZone2	EA	Environment Agency	Polygon	National Flood Zones/Areas Benefiting from Defences	0	3	3	https://environment.data.gov.uk/DefraDataDownload/?mapService=EA/FloodMapForPlanningRiversAndSeaFloodZone2&Mode=spatial	1	Paragraphs 161-165 to the NPPF. Likely to be classed as 'essential infrastructure' or 'highly vulnerable' (if Hazardous Substance consent is required) in Flood Zones 2 or 3. A sequential and exceptions test would be required.	Would require a weight coat
FloodZone3	EA	Environment Agency	Polygon	National Flood Zones/Areas Benefiting from Defences	0	3	3	https://environment.data.gov.uk/DefraDataDownload/?mapService=EA/FloodMapForPlanningRiversAndSeaFloodZone3&Mode=spatial	1	Paragraphs 161-165 to the NPPF. Likely to be classed as 'essential infrastructure' or 'highly vulnerable' (if Hazardous Substance consent is required) in Flood Zones 2 or 3. A sequential and exceptions test would be required.	Would require a weight coat
Historic_Landfills	EA	Environment Agency	Polygon	Historic Landfills	0	1	4	https://environment.data.gov.uk/DefraDataDownload/?mapService=EA/HistoricLandfill&Mode=spatial	1	Paragraph 184 of the NPPF - *'Where a site is affected by contamination or land stability issues, responsibility for securing a safe development rests with the developer and/or landowner'.*	Would require a weight coat
Permitted_Waste_Sites	EA	Environment Agency	Polygon	Permitted Waste Sites	0	3	4	https://environment.data.gov.uk/DefraDataDownload/?mapService=EA/PermittedWasteSitesAuthorisedLandfillSiteBoundaries&Mode=spatial	1	Part 8- National Planning Policy for Waste *'When determining planning applications for non-waste development, local planning authorities should, to the extent appropriate to their responsibilities, ensure that: the likely impact of proposed, non-waste related development on existing waste management facilities, and on sites and areas allocated for waste management, is acceptable and does not prejudice the implementation of the waste hierarchy and/or the efficient operation of such facilities*	
SPZ	EA	Environment Agency	Polygon	Source Protection Zone	0	2	0	https://environment.data.gov.uk/DefraDataDownload/?mapService=EA/SourceProtectionZonesMerged&Mode=spatial	1	Envrionment Agency's approach to groundwater protection ' C2 - Non-nationally significant infrastructure schemes 'In SPZ1 and SPZ2, the Environment Agency will only agree to proposals for infrastructure developments of non-national significance where they do not have the potential to cause pollution or harmful disturbance to groundwater flow or where these risks can be reduced to an acceptable level via EPR if applicable.'	
NIA	DEFRA	DEFRA	Polygon	Noise Important Areas	0	1	0	https://environment.data.gov.uk/DefraDataDownload/?mapService=DEFRA/NoiseActionPlanningImportantAreasRound2&Mode=spatial	1	Consideration of DEFRA's approach to Noise mapping necessary	
Aeroways	OSM	OpenStreetMap	Polygon	Aeroways	3	2	2	https://overpass-turbo.eu/	1	The Town and Country planning (safeguarded aerodromes, technical sites and military explosives storage areas) direction 2002 - Consideration if the area is safeguarded by a civil aerodrome	
Bars	OSM	OpenStreetMap	Polygon	Bars	35	0	5	https://overpass-turbo.eu/	1	No defined policy reason, it would be subject to individual allocations and designations within a local plan	Sensitive location
Cafes	OSM	OpenStreetMap	Polygon	Cafes	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
Campsites	OSM	OpenStreetMap	Polygon	Campsites	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
Fuel_stations	OSM	OpenStreetMap	Polygon	Fuel stations	3	0	5	https://overpass-turbo.eu/	1	As above	
Hotels_and_Guest_houses	OSM	OpenStreetMap	Polygon	Guest houses	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
Industrial_sites	OSM	OpenStreetMap	Polygon	Industrial sites	3	0	5	https://overpass-turbo.eu/	1	As above	
Kindergartens	OSM	OpenStreetMap	Polygon	Kindergartens	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
Marketplaces	OSM	OpenStreetMap	Polygon	Marketplaces	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location

Optioneer Layer Name	Source ID	Dataset Name	Data Type	Descriptive Layer Name	Buffer (m)	Consent Penalty Classification	Technical Penalty Classification	Dataset URL	Used in GIS Pipeline	Comment (Consent)	Comment (Technical)
Military_sites	OSM	OpenStreetMap	Point	Military Sites	3	2	5	https://overpass-turbo.eu/	1	The Town and Country planning (safeguarded aerodromes, technical sites and military explosives storage areas) direction 2002 - Consideration if the area is safeguarded for either its aerodrome purposes or military storage purposes	
Military_sites	OSM	OpenStreetMap	Point	Military Sites	3	2	5	https://overpass-turbo.eu/	1	As above - The Town and Country planning (safeguarded aerodromes, technical sites and military explosives storage areas) direction 2002	
Military_Sites	OSM	OpenStreetMap	Point	Military Sites	3	2	5	https://overpass-turbo.eu/	1	As above - The Town and Country Planning (safeguarded aerodromes, technical sites and military explosives storage areas) direction 2002	
Nursing_homes	OSM	OpenStreetMap	Polygon	Nursing homes	35	0	5	https://overpass-turbo.eu/	1	No defined policy reason, it would be subject to individual allocations and designations within a local plan	Sensitive location
Prisons	OSM	OpenStreetMap	Polygon	Prisons	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
Public_Rights_of_Way	OSM	OpenStreetMap	Polygon	Public Rights of Way	0	2	0	https://overpass-turbo.eu/	1	Paragraph 100 (NPPF 2021)' *Planning policies and decisions should protect and enhance public rights of way and access, including taking opportunities to provide better facilities for users, for example by adding links to existing rights of way networks including National Trails* '.	
Pubs	OSM	OpenStreetMap	Polygon	Pubs	35	0	5	https://overpass-turbo.eu/	1	No defined policy reason, it would be subject to individual allocations and designations within a local plan.	Sensitive location
ResourceAreas_100mBufferNonPoly	OSM	OpenStreetMap	Polygon	ResourceAreas 100mBufferNonPoly	0	0	0	https://overpass-turbo.eu/	1		
Restaurants	OSM	OpenStreetMap	Polygon	Restaurants	35	0	5	https://overpass-turbo.eu/	1	No defined policy reason, it would be subject to individual allocations and designations within a local plan.	Sensitive location
Schools	OSM	OpenStreetMap	Polygon	Schools	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
SolarPlant	OSM	OpenStreetMap	Polygon	SolarPlant	3	0	5	https://overpass-turbo.eu/	1	As above	
Stadiums	OSM	OpenStreetMap	Polygon	Stadiums	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
Substations	OSM	OpenStreetMap	Polygon	Substations	3	0	5	https://overpass-turbo.eu/	1	As above	
Theme_parks	OSM	OpenStreetMap	Polygon	Theme parks	35	0	5	https://overpass-turbo.eu/	1	No defined policy reason, it would be subject to individual allocations and designations within a local plan.	Sensitive location
Tourist_Attractions	OSM	OpenStreetMap	Polygon	Tourist Attractions	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
Tourist_Attractions	OSM	OpenStreetMap	Polygon	Tourist Attractions	35	0	5	https://overpass-turbo.eu/	1	As above	Sensitive location
Wind_Plant	OSM	OpenStreetMap	Polygon	Wind Plant	150	1	5	https://overpass-turbo.eu/	1	Ensure the necessary mitigation is in place during times of construction /design	Buffer distance from TD1 for wind farm (see constraint classification tab for more details)

Appendix C

Optioneering presentations