Appendix A15 – Repurposing Strategy

ARUP

Northern Gas Networks

East Coast Hydrogen Pre-FEED

Repurposing strategy

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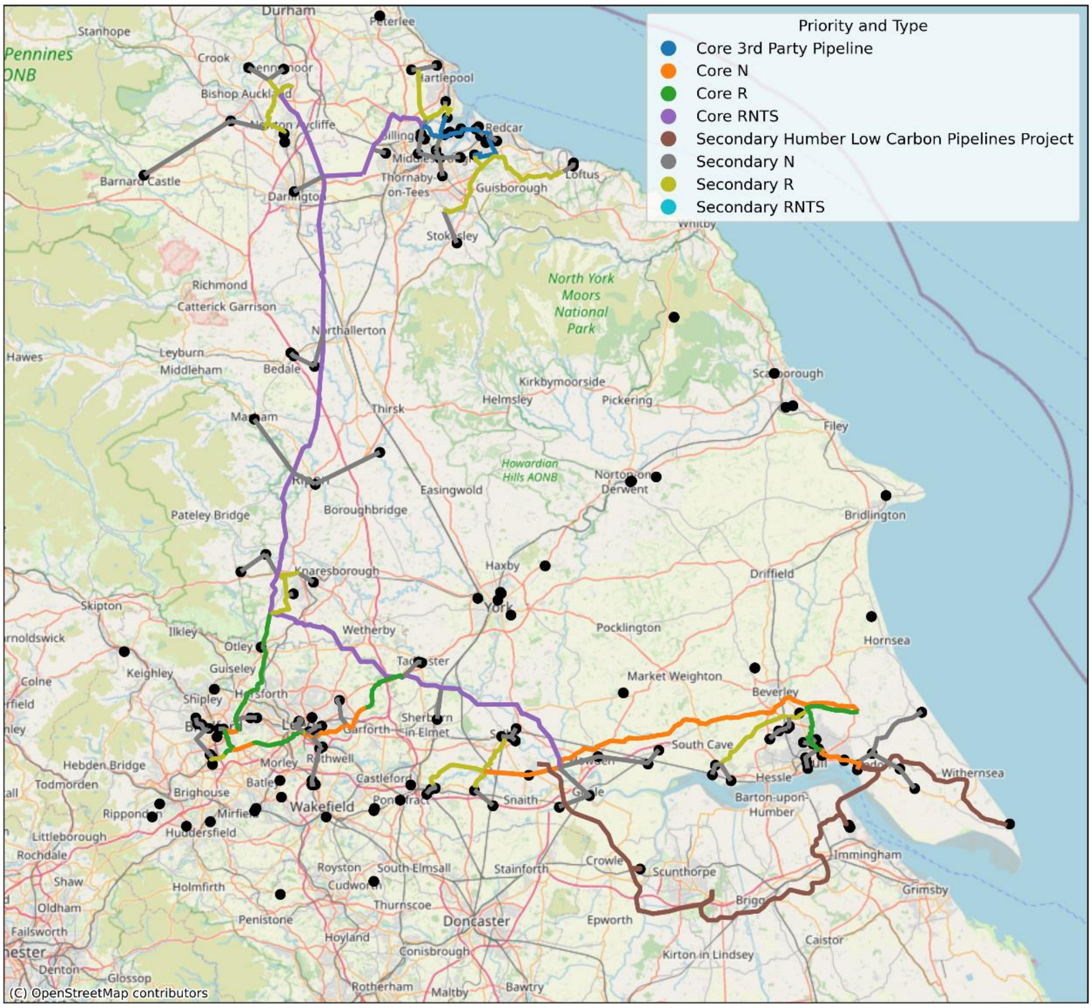

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1. Introduction

Northern Gas Networks (NGN) are the company responsible for distributing natural gas to homes and businesses across the north of England, an area covering West, East & North Yorkshire, the North East and Northern Cumbria.

East Coast Hydrogen (ECH) provides a solution to connect these industrial clusters with other supply points, such as the East Midlands Hydrogen Innovation Zone, and export hydrogen production across the North of England, enabling the seamless conversion of businesses and homes to 100% hydrogen where it is best deployed.

This collaborative programme between NGN, Cadent Gas and National Gas (NG) represents an opportunity for the Government and the private sector to work together in delivering on our 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.

ECH can utilise the natural gas assets of the North of England, including existing natural gas storage and potential hydrogen storage facilities, and build on the hydrogen production in two of the UK's largest industrial clusters in the North East and North West 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 domestic heating in the East Coast region. Proposed phases can be seen below:

- Phase 1 - (2022 2026) - Completion of Pre-FEED, FEED Study and development of East Coast Cluster infrastructure
- Phase 2 - (2024 2030) - Connection of Humber and Teesside clusters, and growth into Yorkshire and East Midlands
- Phase 3 - (2028 2037) - Expansion from the industrial Clusters into Northern urban areas and the Midlands
- Phase 4 - (2032+) - Connection of the network into further regions and future growth opportunities

NGN will look to trigger the Net Zero and Small Projects (NZASP) Reopener to undertake the subsequent phase i.e., FEED study

Arup have been commissioned by NGN to undertake a Pre-FEED study to support the Net Zero and Small Projects (NZASP) Reopener and subsequent project phases e.g., FEED study.

2. Purpose of document

The UK gas network has developed over a long period which has seen large geographic changes in natural gas production and industrial consumption. This has resulted in areas with large amounts of redundancy and oversized infrastructure. This offers opportunities in the push for net zero, to repurpose some of this infrastructure to allow the transport of low carbon hydrogen. Typically, repurposing gas transport pipelines for hydrogen use costs less than a third of a dedicated new build pipeline.

The purpose of this document is to outline the repurposing strategy for the East Coast Hydrogen project. The strategy will feed into the optioneering phase of the Pre-FEED stage of the project, enabling the development of the proposed network and the phasing of this. This document also outlines the assumptions which have been made up to the stage of issue, which are also captured in the project assumptions register.

3. Existing infrastructure

The UK gas network is split into different distribution systems. At the highest level, the country is served by the National Transmission System (NTS). This is the backbone of natural gas distribution throughout the country and is owned and operated by National Gas (NG) and is shown in Figure 1. The pipelines which make up the NTS are known as Feeders. This NTS is effectively also a storage asset given the large volumes of gas that are contained within the system.

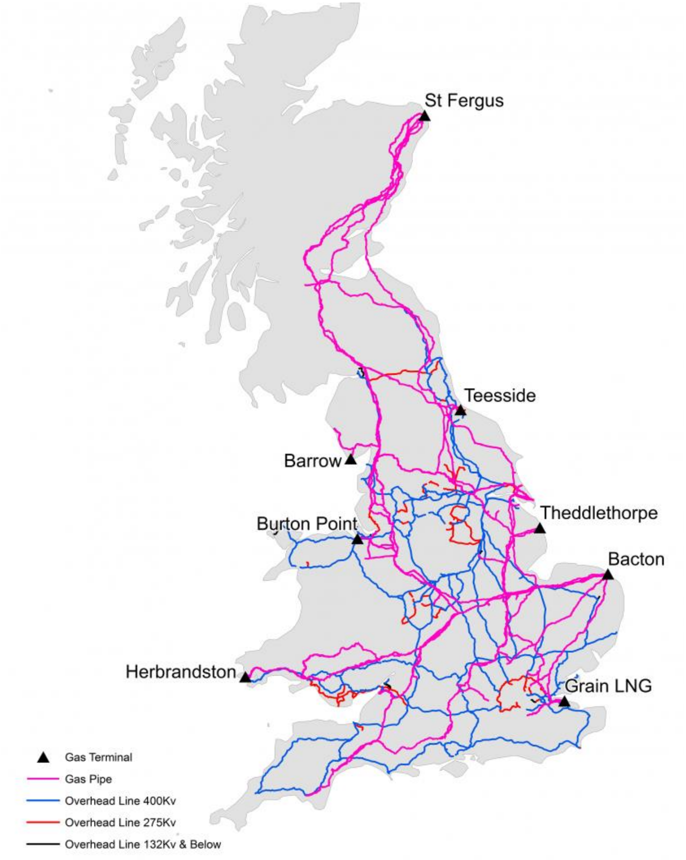


Figure 1: NG NTS map

From the NTS, natural gas is distributed by Gas Distribution Networks (GDNs), such as NGN. NGN manages the development, operation and maintenance of the High Pressure and below 7 bar Distribution Networks. These extend from the inlet valves of the pressure regulating installations at the National Transmission System interface, to the outlet of the consumer's emergency control valve in the North East of England, Northern Cumbria and West, North and East Yorkshire. Within GDNs, there are two main tiers; the Local Transmission System (LTS) a high pressure network responsible for the transport of gas within a region and The Distribution network; a lower pressure system responsible for distributing gas around cities, towns and villages. This is the part of the network that connects the majority of customers. The ECH project will focus on the LTS network to supply the large industrial users and town trials within the timescales of the project. The Distributions Network will be used in certain instances to allow unmeshing of the existing network and allow sections of the LTS to be repurposed.

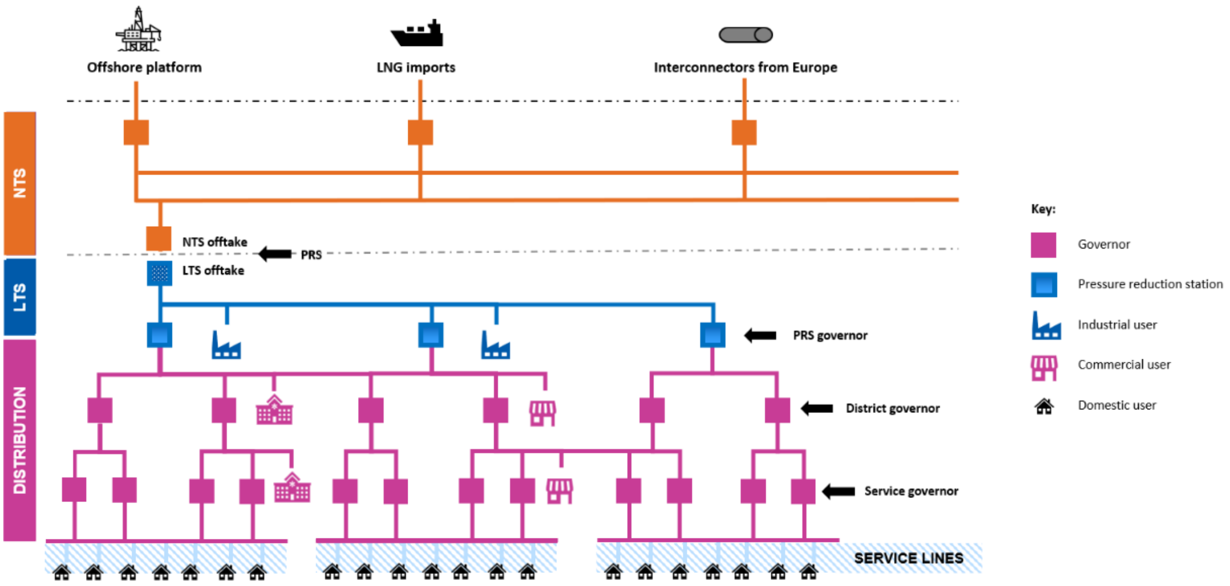


Figure 2: Schematic of the UK gas distribution network

The NGN modelling team have been working collaboratively with Arup to undertake an Existing Network Study. This study identifies sections of the network which could be repurposed due to significantly reduced demand and where there are a small number of natural gas users which will be the best candidates for repurposing sections of the LTS. The study also reviews the capacity of the network in terms of pressures and flows to determine capacity which can be mapped against the demand study which has also been undertaken.

3.1 Proposed NTS modifications

The ECH project is a collaboration between NGN, Cadent and NG. This has enabled joint planning of system repurposing and planning. Understanding the potential hydrogen NTS backbone is critical to inform the development of options for the LTS. NG have proposed that feeder 7 is the main feeder which can be repurposed to provide that back bone, as well as connections to Cowpen Bewley. New build NTS pipeline is also proposed to connect the Huber region. This can be seen in Figure 3.

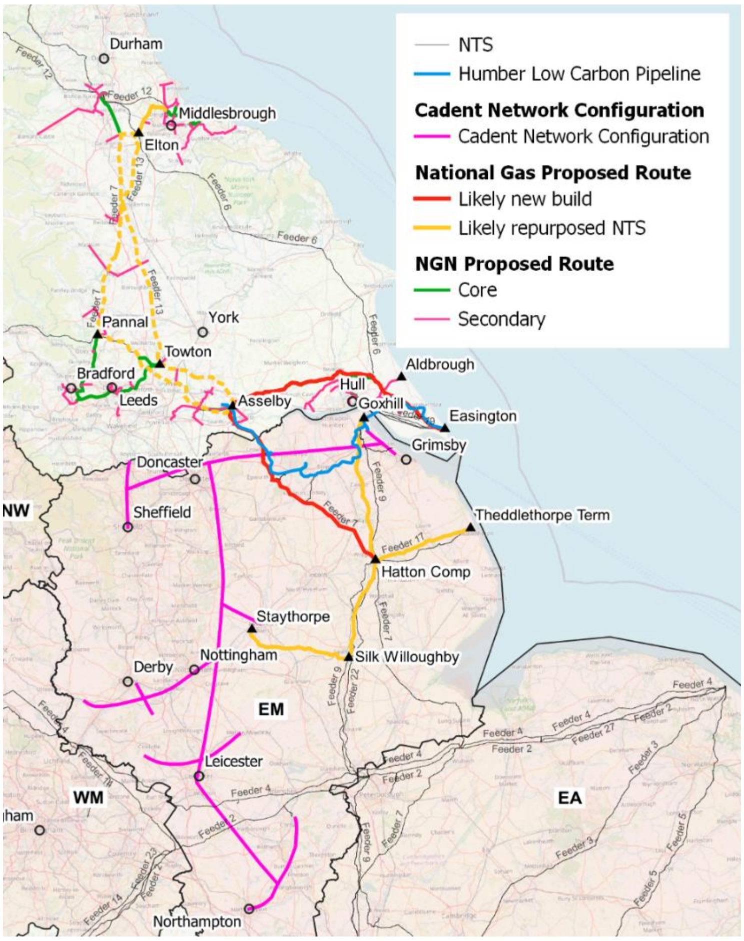


Figure 3: ECH initial network planning

4. Suitability of existing assets

4.1 Legislation

The UK gas network is required to comply with the Gas Safety (Management) Regulations 1996 (GS(M)R) when conveying natural gas (methane). An amendment to these regulations was issued in 2023 which included bringing piping from biomethane and liquified natural gas facilities into the regulations and some adjustments to the items of the regulations relating to these fuels. There has been no amendment to these regulations to include for the conveyance of hydrogen. Currently NGN would be required to develop a specific safety case and operational procedures to cover the conveyance of hydrogen on their network and submit these to the Health and Safety Executive (HSE).

There are various industry guidance documents which are adopted for the design, construction and operation of gas conveying assets. Common ones include those from the Institution of Gas Engineers and Managers (IGEM). Some of these guidance documents have been updated to include for the conveyance of hydrogen, for example a supplement to IGEM/TD/13 edition 2 was released in 2021 to cover pressure regulating installations for hydrogen at pressures exceeding 7 bar.

4.2 Measuring equipment

Metering systems which measure the pressure, temperature and nature of fuel gas are standard as these parameters affect the price of the gas supplied. Natural gas, LPG and LNG measuring devices in the UK must comply with the Measuring Instruments Regulations 2016. This was a European Commission Regulation that was preserved in the EU Withdrawal Act 2018 so is still applicable. These regulations refer to “gas meters” referencing natural gas and do not cover hydrogen meters. Compliance with these regulations is approved by OFGEM.

The standards and codes of practice which currently apply to natural gas meters are:

- BS 6400 – domestic sized gas meters up to 6 m3 h-1
- BS EN 1359 – diaphragm meters
- Product design specification as set out by the meter asset manager
- BS EN 14236 – Ultrasonic meters
- IGEM/GM/6 Edition 3 or IGEM/GM/8 - For meters exceeding 6 m3 h-1
- BS 7671 – IEE wiring regulations

It is hoped that there will be regulatory frameworks developed for hydrogen as a domestic fuel (including metering regulations and codes of practice), which this project would be able to adopt in future stages, the absence of these remains a current project risk.

4.3 Gas quality

The GS(M)R govern the natural gas quality on network entry - NEA (Network Entry Agreement) and network exit -NExA (Network Exit Agreements), but there is no inclusion for hydrogen. As stated in Section 4.2, it is hoped that there will be regulatory frameworks developed for hydrogen which this project would be able to adopt in future stages, the absence of these remains a project risk.

4.4 Pipeline capacity

Various differences between natural gas and hydrogen affect the energy flow capacity of a given pipeline size. Methane is the main component of natural gas and is therefore used as the basis for comparison. Hydrogen has an energy density per unit mass of 120 MJ/kg, compared to methane which is 50 MJ/kg. However, hydrogen is much less dense and has a volumetric energy density 3.14 times lower than methane (Bossel & Eliasson 2020). Pipeline velocities are limited to an erosional velocity, above which, there would be pipeline erosion over a long period. The erosional velocity of Hydrogen is approximately 3 times higher than methane, so although there is less energy within each unit of volume, 3 times as much volume can be transported in the same period of time. This means than the energy capacity of a pipeline with hydrogen is approximately 88% of that of natural gas (Kahn 2021).

To assess feasibility of repurposing existing pipeline, assessments have been undertaken on both the energy capacity of the repurposed line as well as an assessment of any existing lines which will be required to uptake additional natural gas flow.

Gas quality measurements are at NTS offtakes and are owned by the GDNs. As mentioned in Section 4.2, the measurement equipment is approved by OFGEM. Hydrogen is not currently covered by OFGEM and this will need upgrading and re-approved where applicable.

4.5 Materials

The gas network pipelines are typically constructed of steel pipes for high pressure, and cast iron or polyethylene (PE) for medium and low pressure. Hydrogen can cause integrity issues to metallic pipelines, known as hydrogen embrittlement (HE). HE is a reduction in the ductility of the metal due to absorbed hydrogen; once absorbed, hydrogen lowers the stress required for cracks in the metal to initiate and propagate.

Steel and pipelines are affected by hydrogen embrittlement in different ways:

- High strength steel pipelines, typically found in newer lengths of the NTS, are not considered suitable for hydrogen given the operating pressure, molecular structure of the material and the relatively small thickness of the pipeline walls. NG have identified that this comprises c.11% of its network. Through the engagement with NG on this project, we have been able to identify suitable sections of the NTS which can be repurposed.

- Lower strength steel pipelines, comprising the majority of the steel portions of the networks at NTS, LTS and distribution levels, is considered suitable for hydrogen as a result of a slightly different molecular structure and much thicker pipeline walls.

Carbon steel is available in a wide variety of grades. Common piping grades such as API 5L X52 have been demonstrated to give acceptable longevity in hydrogen service at the correct conditions. Hydrogen specific piping standards such as ASME B31.12 allow the use of grades such as these. One of the main factors which gives resistance to hydrogen embrittlement is the relatively low strength of these grades due to the reduction in brittle fracture propagation. Existing piping grades can be reviewed against standards such as B31.12 to access their suitability for repurposing.

In addition to pipeline material, pipeline condition must also be considered for the steel pipelines that are technically able to accept hydrogen. Whilst all networks operate appropriate integrity management systems, the age profile of these assets (some of these pipes are >50 years old) means some are unlikely to be suitable for hydrogen due to condition.

Cast iron pipework is in the process of being converted to PE.

As PE pipe is non-metallic, it is not susceptible to hydrogen embrittlement. Grades PE80 and PE100 are used in the pipeline network. The PE100+ Association states that using PE80 and PE100 for hydrogen transport appears viable.

Metallic and non-metallic seals and components are also affected by the hydrogen exposure in various ways. The combination of the materials used in the seals and the fluid being transported affects the quality of the seal. As mentioned previously, HE is a risk in metallic components. Also, hydrogen has a much lower viscosity and smaller molecular size compared to natural gas, so is more prone to leaks (Pacific Northwest National Laboratory 2022). These factors will affect the requirements of seal and component designs.

4.6 Above ground installations

4.6.1 Compressor stations

Compressors are designed to operate under specific conditions, termed an ‘operational envelope’. Given the difference in properties and resulting fluid dynamics, a natural gas compressor has a different specification to a hydrogen compressor. For low percentage hydrogen blends, some compressors can be repurposed. 100% hydrogen will require new compressors due to the change of the compression curve. Before using any existing compressor, manufacturers must be consulted. However, it is unlikely there will be compressor stations required for Local Transmission Systems within the scope of this project.

It is assumed that the existing compressors would not be suitable for hydrogen conversion and would require replacement.

4.6.2 Pressure reducing installations.

Pressure reduction installations (PRIs) are widely used across the network. These typically consist of an arrangement of pressure control valves, associated isolation valves and metering equipment. Materials of the PRS are subject to the same concerns as pipelines and individual assessments would be required on each PRS to assess the presence of high-grade steels or other unsuitable materials. Components of valves and piping installations such as stem packing, valve seats and gaskets might also not be suitable for hydrogen.

Instrumentation will typically need to be replaced due to the current technologies used to measure natural gas flow being unsuitable for the characteristics of hydrogen. At the least, existing equipment would require recalibration.

Many PRIs will have preheating equipment, this is used to mitigate against the Joules-Thompson effect, in which a loss of temperature is experienced when the pressure of a gas is reduced. This is used to ensure the outlet temperature remains within acceptable limits. Hydrogen is one of a few gasses which does not experience the Joules-Thompson effect and actually experiences a slight heating effect which can normally be neglected. Therefore, existing heating systems would require bypassing / removing.

Based on the above considerations, it is considered for this purposes of this study that existing PRS installations would not be suitable for hydrogen without major modification.

4.6.3 E&I measuring components

It is assumed that all E&I measuring equipment will require replacement due to the difference in physical properties of hydrogen compared to natural gas.

4.6.4 Filters and components

The current standards for pipeline components do not cover the transition to hydrogen. However, some natural gas pipeline components are now designed to be used in pure natural gas, hydrogen blended natural gas and pure hydrogen applications. These components are often designed to meet ISO 15156, which is related to metallic oil and gas components in hydrogen sulphide (H_2S) containing environments (Emerson 2023). The material requirements of pipework components are discussed in Section 4.5. It is assumed that existing filters and similar components will be changed during the transition process.

4.6.5 Heat exchangers

Due to the Joule-Thomson (JT) effect, when natural gas is depressurised at PRIs, it reduces in temperature. Heat exchangers are used to increase the temperature of the natural gas back to an acceptable level. Hydrogen is not affected by the JT effect. This removes the need for heat exchangers on pure hydrogen lines. The JT coefficient of natural gas is significantly affected when blended with hydrogen (Jingfa 2021), so the use of heat exchangers will be affected on blended and pure hydrogen lines.

4.6.6 Overall footprint

The AGIs used for hydrogen may need to be larger than those for natural gas since the hazardous area zones will be larger, due to hydrogen's increased flammability range (McKnight 2022). The suitability of each existing site will need to be assessed further at FEED stage.

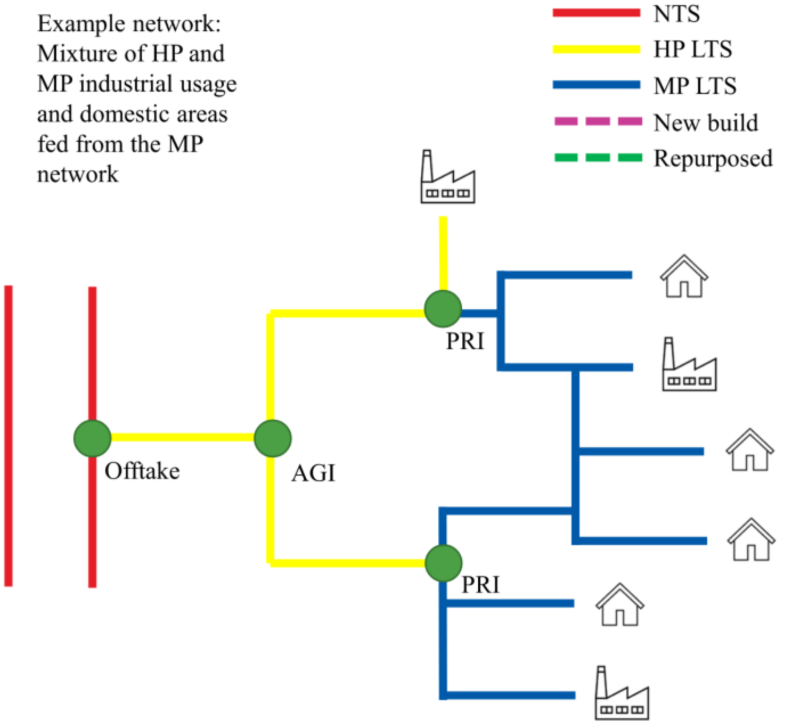
5. Outline conversion strategy

The conversion strategy aims to repurpose pipeline where possible, due to the much lower capital expenditure. This will be assessed alongside the cost of unmeshing and remeshing the natural gas network to allow this repurposing. Multiple scenarios will be considered in the first instance which will contain sections of repurposed and new build pipeline. Continuums Optioneer software will be used to determine optimal routing of the newbuild sections and allow cost estimates to be developed, alongside a Multi Criteria Analysis (MCA) this will help to inform where repurposing will be required.

The initial basis for the route scenarios will be based off the NG hydrogen backbone, incorporating feeder 7, Copwen Bewley, the Humber and also the required pipeline infrastructure to connect the producers and the town and village trials. The strategy will then utilise the results from the demand study to identify repurposed or newbuild infrastructure to large users or industrial areas. This needs to be assessed on an individual but also long term basis with a view to creating a network which can encourage further growth rather than a large number of individual legs.

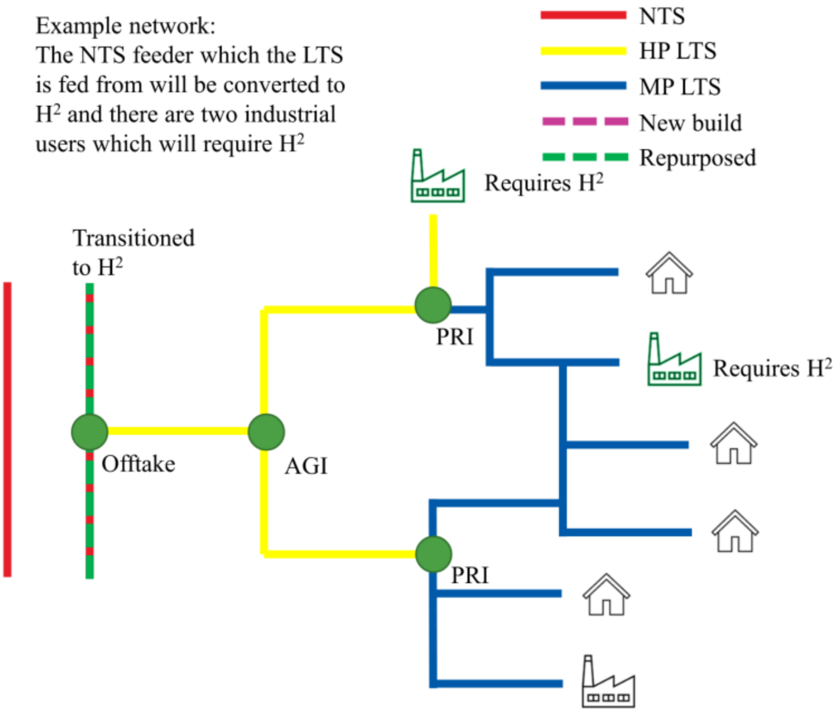
The below figures demonstrate a simplified schematic of a typical repurposing scenario and how it is evaluated and progressed.

1.



Example network:
Mixture of HP and MP industrial usage and domestic areas fed from the MP network
NTS
HP LTS
MP LTS
New build
Repurposed
PRI
Offtake
AGI
PRI

2.



Example network:
The NTS feeder which the LTS is fed from will be converted to H^2 and there are two industrial users which will require H^2
NTS
HP LTS
MP LTS
New build
Repurposed
Requires H^2
Transitioned to H^2
PRI
Requires H^2
Offtake
AGI
PRI

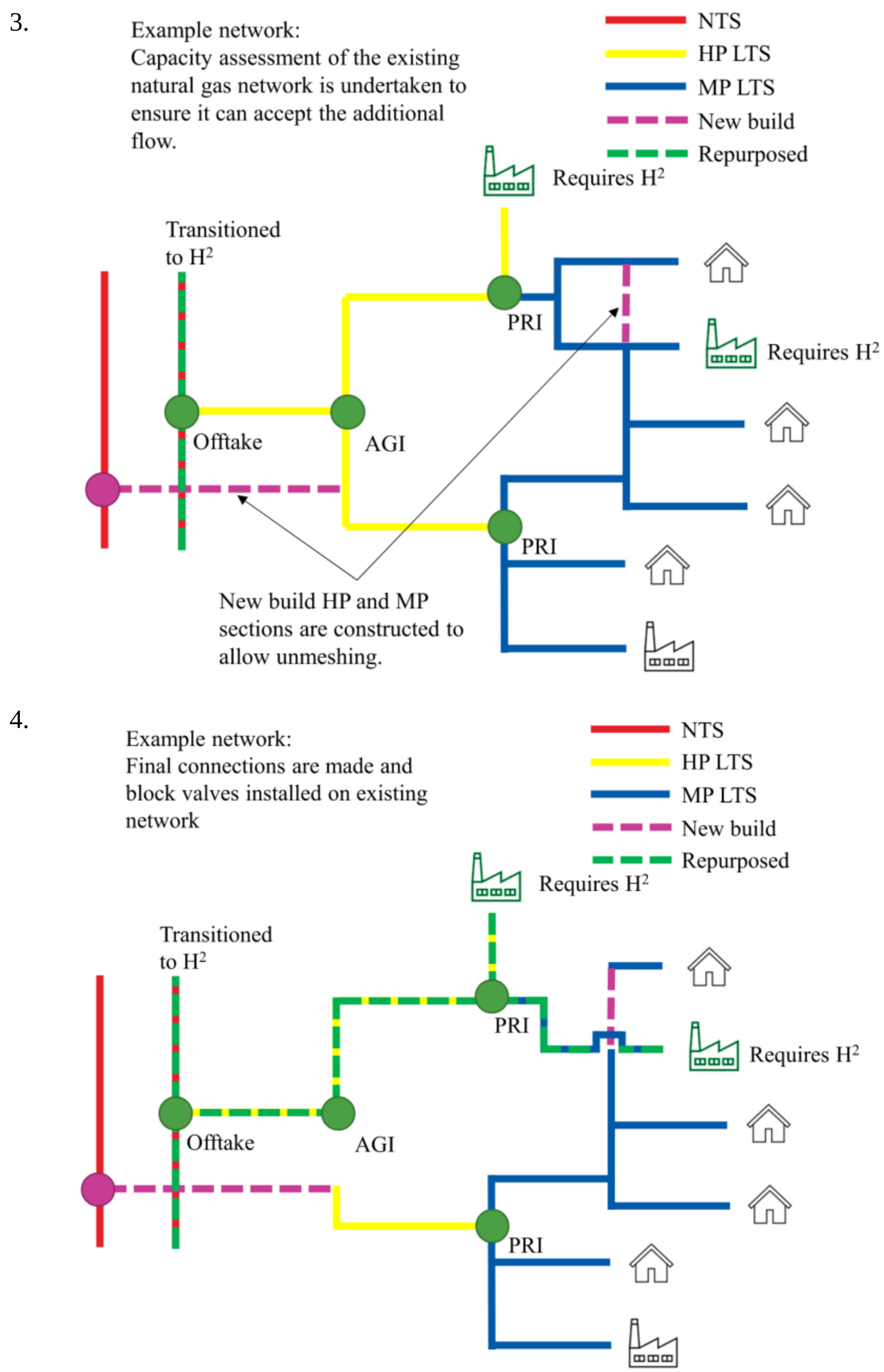


Figure 4: Repurposing strategy scematics

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