national gas

July 2023

FutureGrid Testing Guide

Contents

The hydrogen challenge

As we move towards net zero, the interaction between gas and electricity will likely increase, but do you know how they interact now? You may be surprised to learn that 40% of the UK's electricity supply is generated using natural gas.

The amount of renewable energy used across the UK is growing each year, but at times, there isn't enough to meet demand. This is where natural gas steps in. We can't control when renewable energy sources, such as wind and solar, can provide power, but we can control when and where we push gas through our network.

The amount of renewable generation is unlikely to change, so to meet our target of net zero by 2050, we need to find a greener alternative to natural gas. This is where hydrogen can play a part. More than 80% of the UK's 28 million homes are using natural gas for heating and cooking and hydrogen can be used in much the same way. People can use it to cook on their hob and for their central heating, and it provides a plausible way to decarbonise the UK gas industry.

The UK is a world leader in the development of both blue and green hydrogen production, as well as being at the forefront of hydrogen gas boiler development. A hydrogen transition will provide great opportunities for industry growth and the UK economy for years to come. Small-scale transportation of hydrogen is already underway in some countries, suggesting that we could re-purpose our gas network – the National Transmission System (NTS) – to carry hydrogen instead of the natural gas we transport today. Doing so would provide a cost-effective way to transition to net zero, as the need for expensive, new infrastructure would be greatly reduced. Not to mention, utilising current pipelines and equipment would minimise disruption.

The NTS has provided a safe, efficient and resilient supply of natural gas to homes, businesses and industry for over 40 years, and transitioning from natural gas to hydrogen will allow it to continue doing so.

But there is a big jump from talking about using the NTS to carry hydrogen, to actually doing it. So, how do we get there? That's where FutureGrid – our project to build an offline hydrogen test facility – comes in.

FutureGrid

A high-pressure hydrogen test facility using decommissioned transmission assets, to demonstrate the National Transmission System (NTS) can transport hydrogen safely and reliably.

Standalone hydrogen Tests

Standalone hydrogen test modules are operating alongside the main test facility, to provide key data required to feed into the main facility.

Offline hydrogen test facility

A representative range of NTS assets of different types, sizes, and material grades have been supplied from decommissioned assets to build the test facility.

Four key hydrogen concentrations are being tested:

2%	5%	20%	100%
Hydrogen gas	Hydrogen gas	Hydrogen gas	Hydrogen gas

The FutureGrid facility

1 High Pressure Reservoir

60m length of new 1200mm (48") diameter X65 grade carbon steel pipe and wall thickness 22.4 mm sourced directly from manufacturer in 2020.

2 Ball valve

Two 450mm (18") diameter ball valves and 50mm (2") bypass pipework manufactured in 1992 sourced from Billingham, Stockton on Tees.

3 Filter

A 450mm (18") diameter filter manufactured in 1992 sourced from Billingham, Stockton on Tees.

4 Ultrasonic meter

Two 3" ultrasonic meters which have been newly sourced to be suitable for a twin stream system.

5 Flow Control Valve

A 450mm (18") flow control valve manufactured in 1992 sourced from Billingham, Stockton on Tees.

6 Non-Return Valve

A 450mm (18") non -return valve manufactured in 1998 sourced from Sandbach, Cheshire.

7 Filter Skid

A filtering skid manufactured in 1998 consisting of two 3" filters sourced from Sandbach, Cheshire.

8 Orifice Plate Metering Skid

A metering skid manufactured in 1998 consisting of 4" parallel streams with a single orifice plate in each sourced from Sandbach, Cheshire.

9 Boiler House and Heat Exchanger

One boiler house with three boilers and one heat exchanger manufactured in 2010 sourced from Sandbach, Cheshire.

10 Regulator Skid

An 80 mm (3") regulator skid manufactured in 1998 sourced from Sandbach, Cheshire.

11 Pipeline Isolation Valve

A 900mm (36") diameter ball valve with 450mm (18") diameter bypass pipework and plug valves manufactured in 1975 sourced from Lanark, Scotland.

12 Flow Control Valve

A 200mm (8") flow control valve manufactured in 1992 sourced from Lake District, Cumbria.

13 Low Pressure Reservoir

A 900mm (36") diameter pipe of 19.1mm wall thickness manufactured in 2007 sourced from Ambergate, Derbyshire.

14 Metering & Gas Quality Kiosks

The data centre consisting of telemetry kiosks, metering and gas quality equipment sourced from Sandbach in Cheshire.

15 Re-compression Unit

A re-compression unit manufactured in 2022 with 8" inlet and 8" outlet sourced new.

16 FutureGrid Control Room

A 6m x 10m control room manufactured in 2022 sourced new.

Getting to know our assets

1

High Pressure Reservoir

The high pressure reservoir is constructed from large diameter pipe that acts as a storage reservoir for the test facility. Gas in the form of natural gas or hydrogen, or a specific blend of both, is stored in the high pressure store at 70 bar. This then connects to the facility and provides the gas required to conduct the test programme.

2

Ball valve arrangement

Double block and bleed valve arrangement consisting of two ball valves installed in series. A vent valve is installed on the pipe between the two ball valves. A smaller diameter bypass pipe is installed around the valves. The bypass allows the gas pressure to be equalised each side of the larger valves.

3

Filter

Filtering is used primarily at entry points to the system to capture any particulates which may be present in the gas from any production processes. Over time the filter element will collect dirt and dust and the element can be replaced with a new one. There is a differential pressure gauge on the filter vessel that provides an indication of when the filter element requires replacing.

4

Ultrasonic meter

Twin Stream Ultrasonic Meters are used to calculate flow rates. Based on Gas composition, density, pressure and temperature, flow rate is calculated by the velocity of sound between two probes. One of the meter is rated for 100% Natural gas and the other meter is rated to up to 30% Hydrogen blend.

5

Flow Control Valve

A flow control valve is used in the system to control the flow rate of the gas. The desired flow rate can be set, and the valve will maintain the required flow by constantly adjusting itself, allowing more or less gas through. Flow control valves are often found at multijunction sites on the boundary between different sections of the national transmission system. This is an 18" valve.

6

Non-Return Valve

The non-return valve ensures the flow of gas in one direction. This protects upstream parts of the network where pressure conditions may have otherwise caused reverse flow. These are most often found on compressor outlets.

7

Filter Skid

These smaller filters ensure no particulates enter the pressure reduction station, both to protect the sensitive equipment on site and to maintain gas quality standards for the downstream customer.

8

Orifice Plate Metering Skid

When gas is flowing through the orifice plate meter, the differential pressure is determined to accurately calculate the flow rate of gas. This consists of two parallel streams, with a single Orifice Plate in each which, allows for one to be operational while the other provides redundancy.

9

Boiler House and Heat Exchanger

When natural gas is expanded (i.e. reduced in pressure) it also reduces in temperature. To avoid pipes and valves becoming frozen the gas in the system is heated before its pressure is reduced. The boiler house contains three gas boilers that work in tandem to heat water. The water is passed through the heat exchanger and heats the gas flowing through the system.

10

Regulator Skid

The regulator skid contains two parallel streams each containing a pair of pressure regulators and a slam shut safety valve. The pressure regulators reduce the incoming pressure and the slam shut safety valve monitors the downstream pressure, shutting off flow if it detects a increase in pressure above the set point.

11

Pipeline Isolation Valve

The long distance gas pipelines on the transmission network have isolation valves at regular intervals along their length. This will be used to demonstrate the capability of critical valves which are used to isolate pipelines in event of an emergency or for maintenance.

12

Flow Control Valve

A flow control valve is used in the system to control the flow rate of the gas. The desired flow rate can be set, and the valve will maintain the required flow by constantly adjusting itself, allowing more or less gas through. Flow control valves are often found at multijunction sites on the boundary between different sections of the national transmission system. This is an 8" valve.

13

Low Pressure Reservoir

The low pressure hydrogen reservoir is constructed from large diameter pipe and is located at the end of the flow facility loop. It will ensure there is sufficient volume of gas for the re-compressor unit to run efficiently.

14

Metering & Gas Quality Kiosks

Compiles data from the FutureGrid facility and sends it to the FutureGrid control room for monitoring and recording purposes. The data includes but is not limited to pressure, temperature, vibration and flow rates with gas composition.

15

Re-compression Unit

The re-compression unit generates gas flows around the facility. This unit has been designed for the FutureGrid facility, to operate with natural gas and hydrogen at a wide range of flow rates and pressures to replicate the national transmission system.

16

FutureGrid Control Room

The Control Room is where all the test data from the different assets can be monitored and recorded via the SCADA system. It is connected to the FutureGrid site via a series of communications links.

Our testing approach

The main test programme focuses on evaluating the performance of the key assets which comprise the NTS such as valves, filters and pipework. The programme will test both the integrity of the assets and their performance in varying network conditions and hydrogen blends.

Each hydrogen concentration will be tested in the facility for 4 weeks, operating at seven different flow rates in order to generate conditions seen on the NTS. Throughout the testing we will be concentrating on vibration, noise, and permeation across the facility. Leak monitoring will be completed across the facility and compared across the blends of gases.

How we operate each test

For 100% natural gas and each of the hydrogen tests we will follow a 4 week testing cycle.

Week 1:
The facility is configured such that the high flow loop is tested. Calibrations are conducted on the facility and testing begins with the lowest flow rate on the high flow loop, Flow 4. Operational data is logged during testing and stored within the data centre.

Week 2:
The flow rates on which the testing is being conducted are increased incrementally until the testing on the maximum flow rate is completed. The block valve arrangement is isolated from the system.

Week 3:
The facility is configured to test the low flow loop by opening valves to the pressure reduction skid and activating the pre-heat system. Testing begins with the lowest flow rate on the low flow loop with additional data points being captured throughout the pressure reduction system.

Week 4:
The flow rates are increased in steps until testing on the maximum flow rate on the low flow loop is completed. Once testing has been completed the data is compiled into a report and the facility is vented as necessary to allow for re-fill for the next the gas composition test.

Results validation:
Each 4 week test cycle is followed by a review of the data to ensure that all data has been captured as necessary and there are no safety concerns in moving to the next blend.

Gas fill:
Prior to testing the facility must be filled with the gas composition being tested. Gas is vented off as necessary and then hydrogen is added to return the facility to its normal operating pressure. The gas quality is then checked before testing begins.

Four key hydrogen concentrations are being tested:

2%
hydrogen in natural gas

The first hydrogen blend that will flow through the FutureGrid facility will be 2% mixed with 98% natural gas. This is due to the market foreseeing the introduction of smaller scale blends while production begins to scale up. This creates demand for hydrogen produced and enables changes to Gas Safety (Management) Regulations, known as GS(M)R, to be made which allows blending on the NTS.

5%
hydrogen in natural gas

A 5% hydrogen blend with 95% natural gas will now be incorporated into the phase 1 FutureGrid test programme The EU has released a decarbonised gas package, which proposes all TSOs (Transmission System Operator) must be able to accommodate up to a 5% blend. It's our ambition to keep aligned with this, as we are interconnected with Europe. The potential for variable hydrogen blends in the early stages of blending makes a safety margin necessary, so in the case of operating with a 2% blend, having tested upto 5% provides that margin.

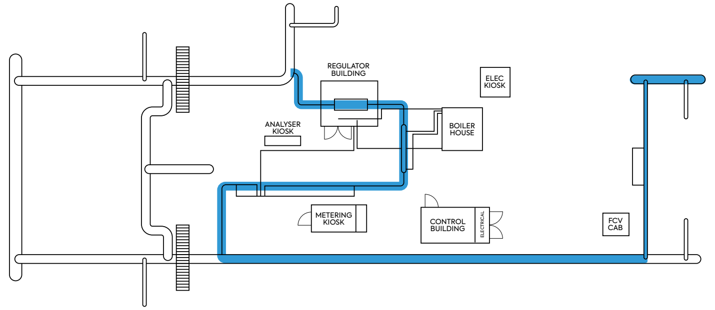
20%
hydrogen in natural gas

The last blend is 20% hydrogen with 80% natural gas. This has been chosen because it represents the highest level of blending that existing consumer appliances can handle without modification. This may dictate the maximum blend compatible with the NTS without needing modification.

100%
Hydrogen

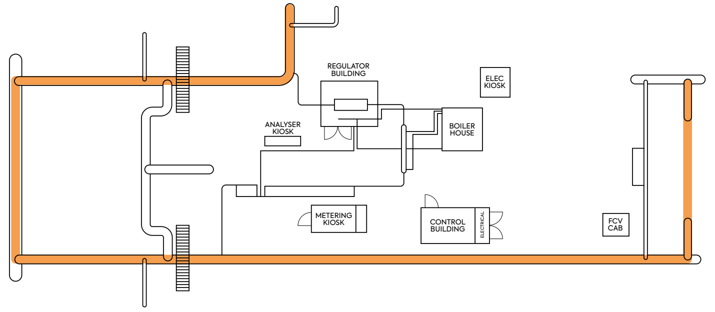
The final test will use flows of 100% hydrogen. When we repurpose our network to 100% hydrogen these results will further our understanding of working with hydrogen and how it interacts with our assets. This will enable the development of appropriate processes, procedures, and safety standards, which are required to operate our network safely.

Low flow rate



Flow 1 – 0.12mSCm/day
Flow 2 – 0.24mSCm/day
Flow 3 – 0.36mSCm/day

High flow rate



Flow 4 – 0.36mSCm/day
Flow 5 – 0.82mSCm/day
Flow 6 – 1.28mSCm/day
Flow 7 – 1.74mSCm/day

Our standalone hydrogen testing

Alongside the main offline hydrogen facility testing, we are conducting a number of standalone hydrogen test modules. These are vital to provide key data to develop the design of the facility and also to answer additional questions.

There are six specific standalone tests, some of which were completed prior to construction of the facility, others are ongoing throughout FutureGrid Phase 1.

These are summarised below:

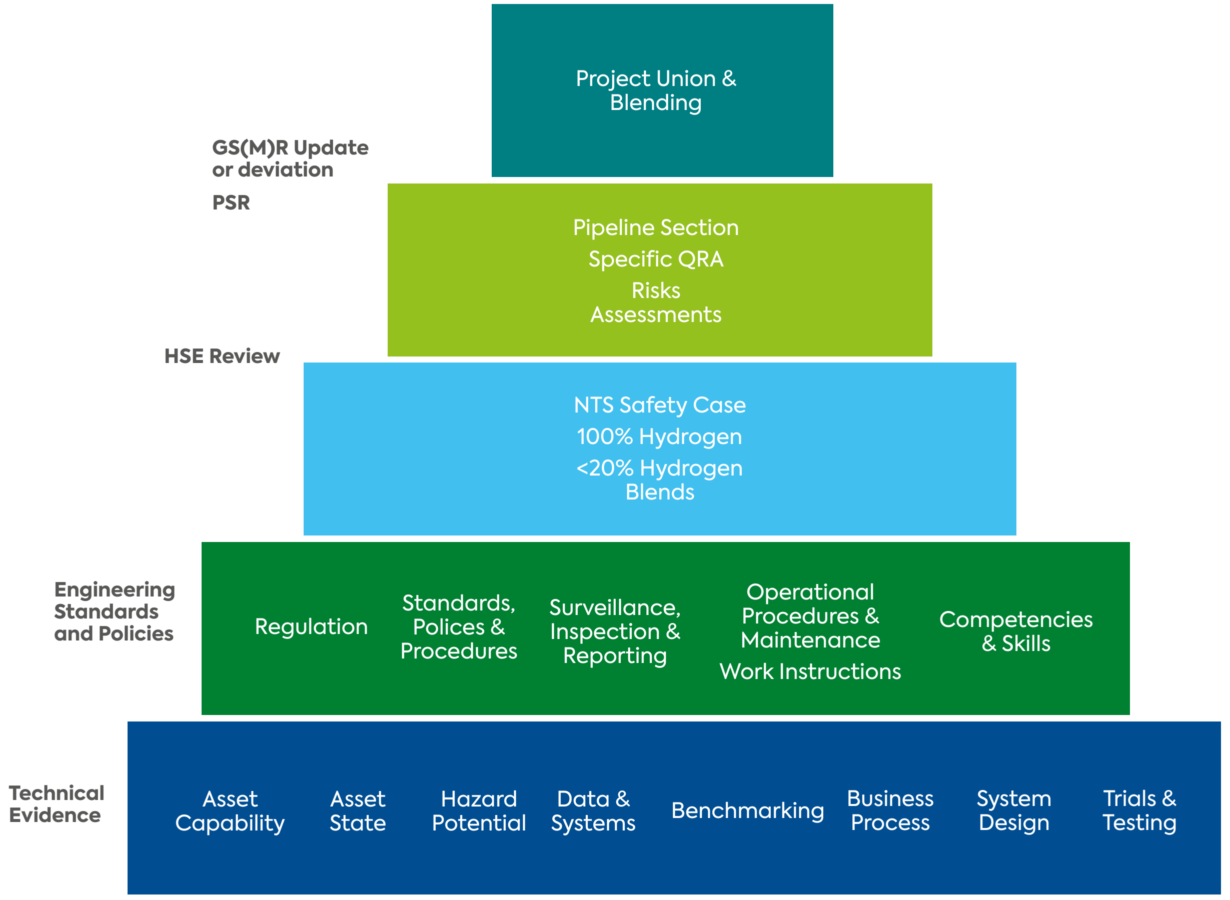
Standalone hydrogen test module	Topic	Key areas
Material permeation testing	Hydrogen has been reported to permeate through solid steel. These tests aim to determine the scale of this and whether it presents a material risk to the transmission system.	Initial testing showed no detectable permeation after holding hydrogen at 70 bar for 40 days. A more intensive test method has been developed to detect smaller quantities of hydrogen.
Pipe coating and Cathodic Protection testing	This is the assessment of hydrogen impact on external pipe coatings as well as the cathodic protection system to identify any issues which could arise from the hydrogen within the pipe wall.	This test is dependant on the outcome of the permeation testing to understand to what extent hydrogen could be present on the external surface of the pipe. The scope of this test may be altered based on the findings of the permeation test.
Flange testing	Flanges are numerous across the transmission system. This test is designed to ensure they will continue to contain gas after transitioning to hydrogen.	The two principle flange types in operation on the NTS were tested; RTJ (ring-type joint) and RF (raised face). Both types fully contained both natural gas and hydrogen, providing evidence that these seals will be suitable for use when transitioning the system to hydrogen.
Asset leak testing	Hydrogen is understood to leak at a greater rate than natural gas under certain scenarios. These tests will determine the relationship between natural gas leaks and hydrogen leaks.	The leak tests covered a wide range of leak rates and showed similar results to previous literature; Well maintained assets will remain leak tight with hydrogen, however hydrogen leak rates can exceed those of natural gas, particularly in assets which have poor gas tightness.
Rupture testing	A pipeline rupture is one of the most significant risks which must be understood when operating a pipeline system. These tests will simulate such a rupture to determine if additional mitigations are necessary for hydrogen transportation.	The first rupture test has been completed which looked to assess the potential for delayed ignition with a hydrogen pipeline rupture. During the test the hydrogen ignited almost instantly which has positive outcomes for the potential risk. Thermal radiation and overpressure measurements were taken which will incorporated into our overall risk model.

Fatigue testing

FutureGrid safety outputs

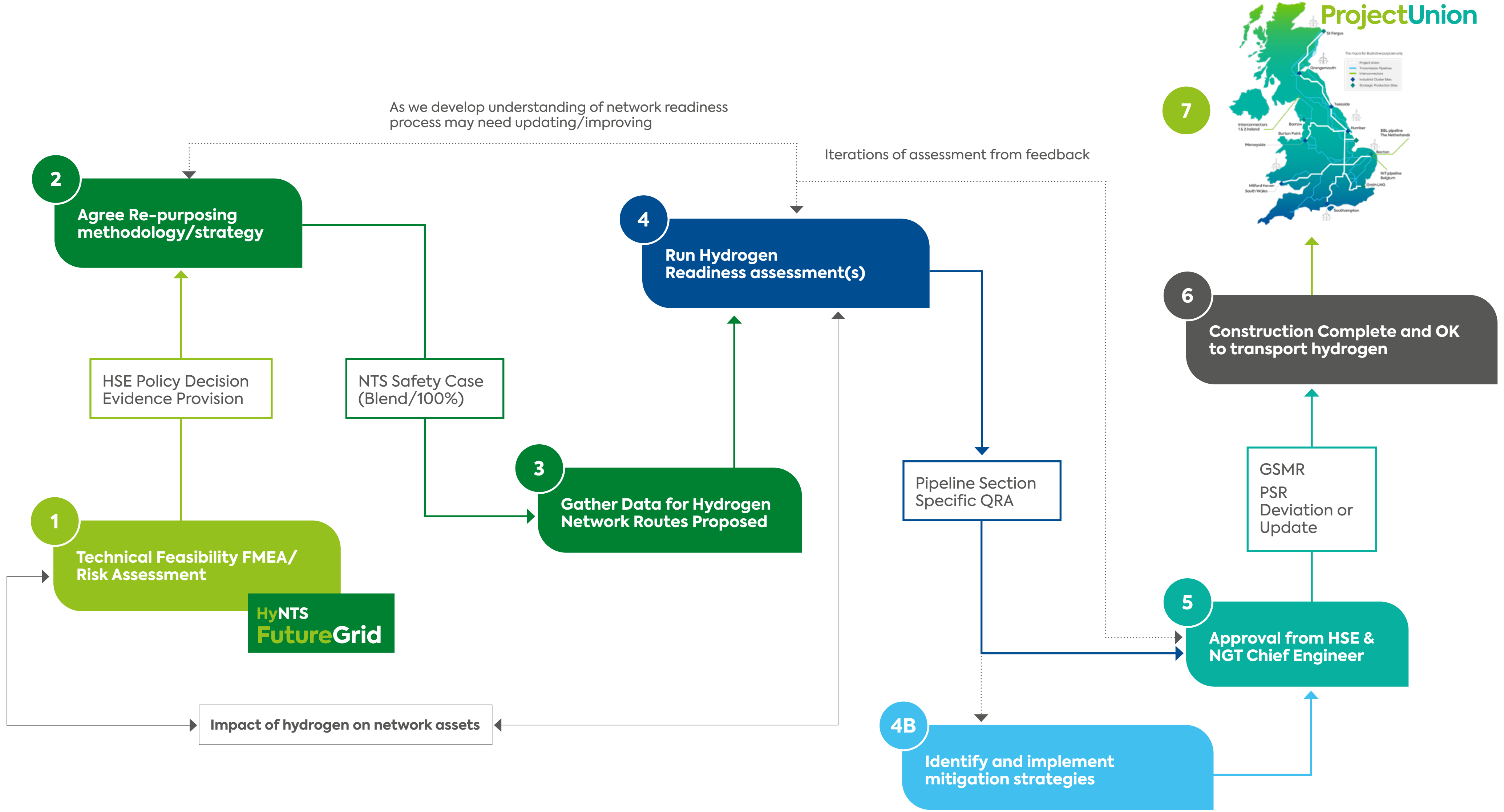
There are many similarities in how hydrogen behaves compared to natural gas, but there are also differences for some key safety parameters. We must be able to understand these in more detail and how the varying concentrations of hydrogen could have an impact. This will allow us to develop our safety standards. FutureGrid supports this with the key outputs from the Phase 1 testing:

	Procedure Review	Categorisation of NG procedures as high, medium, low impact with a report detailing the methodology findings and next steps for each.
	Hazard Assessment of the Transmission System (HATS)	Assess impact of hydrogen on (MAPD) Major Accident Prevention Document. Provide an updated HATS for the NTS pipelines, based on the network transporting hydrogen instead of Natural Gas.
	Quantitative Risk Assessment (QRA)	Record and update the Hazard Assessment Methodology Manual (HAMM) where deviations are required for assets transporting Hydrogen.
	Hazardous Area Impact	Hazardous Area Drawings will be produced for each asset type at 20% & 100% hydrogen and compared to existing Natural Gas drawings. IGEM also working on SR/25 update for hydrogen.
	Overpressure Risk (OR)	Identify whether the existing methodology can be adapted for 100% hydrogen. If needed, develop an appropriate methodology for risk analysis and emergency planning purposes.
	National Gas Transmission (NGT) Safety Case	Review the NG safety case (policies, procedures and work instructions) and provide recommendations for updates depending on the impact of hydrogen. Review will involve SMEs.



Our approach to delivering the NTS Safety case

From testing to implementation



FutureGrid Phase 2 – Compression

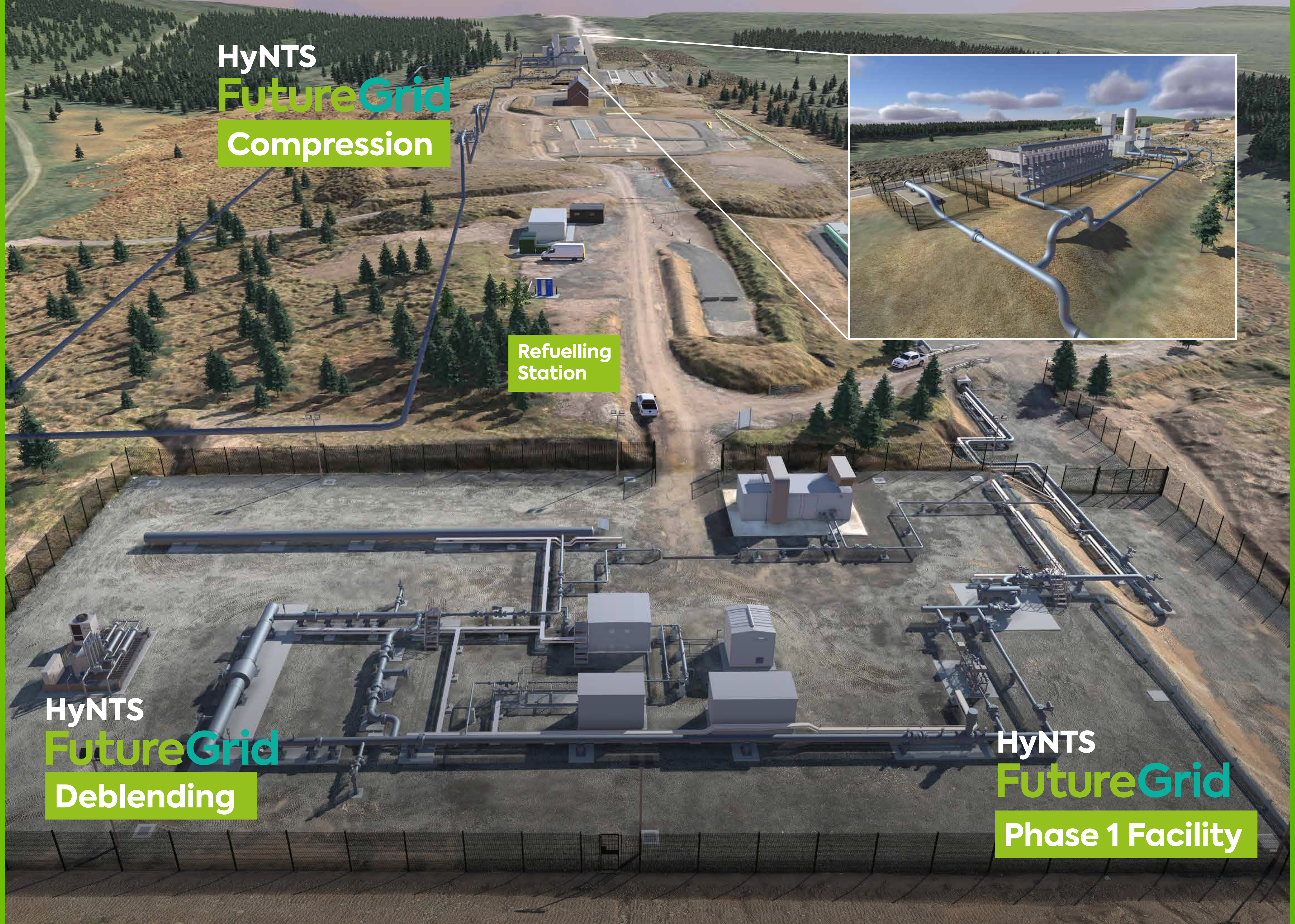
The National Transmission System (NTS) currently provides a resilient supply of natural gas to homes, businesses, and industry across the UK. The gas is moved by a complex compression system comprised of 24 compressor stations and 74 individual compressor units. To transport and store hydrogen across the UK, compression is required to provide flow, and deliver hydrogen when and where it's needed.

The HyNTS FutureGrid Compression project will develop evidence that our existing compressor fleet can be modified for hydrogen use in a cost-effective manner, by providing a technical demonstration at DNV's Spadeadam facility.

A decommissioned gas turbine representative of the current fleet will be fuelled by different blends of hydrogen up to 25%, then following modifications, 100% hydrogen. This will provide technical and safety evidence for the repurposing of our current gas turbine fleet. Following this, the full compression system including the power turbine, gas compressor and the cab and ancillary equipment will undergo offline testing at the Future Grid hydrogen test facility, to demonstrate that the assets can be repurposed for hydrogen blends and 100% hydrogen. A compression test loop will be constructed out of decommissioned NTS assets to test the compressor systems in a range of hydrogen scenarios.

This will demonstrate the capability of both the rotating machinery package and the full system and will give an understanding of how these would operate on a hydrogen network.

This will support the creation of a wider strategy for the NTS compression system and how it will adapt to hydrogen in the network.



FutureGrid Phase 2 – Deblending

National Gas have been considering the role of the gas networks in the energy transition, and the associated potential use cases. Hydrogen has been identified as one of the solutions to help achieve net zero by 2050 and in the transitional period, is likely to be blended with natural gas to provide energy.

The HyNTS FutureGrid Deblending project focuses on the deblending of gases within the high-pressure National Transmission System (NTS) to enable delivery to transport applications. Without this technology, refuelling of transportation assets will be limited to the use of locally produced hydrogen, until the gas networks can transport 100% hydrogen. This will limit large scale hydrogen infrastructure availability and therefore the speed of transition for the transport industry.

The project will showcase the full process, starting with taking blended transmission gas through the Electrochemical separation system which purifies and compresses the gases, culminating in refuelling hydrogen vehicles of a variety of sizes. The project will also develop low-cost mobile solutions for deblending and purification that can be migrated around the UK networks as we transition to 100% Hydrogen. Gas separation technology has historically only been used in specific chemical industrial processes and has never been trialled on a variable gas network. We need to demonstrate that the technology can operate with fluctuations in the gas inlet of temperature, low, pressure and composition.

Alongside the transport application, this technology can also be used to remove hydrogen from a blend with natural gas, which will help to meet the varying customer requirements expected during the transition period.

Our vision is that in the future, businesses could apply to connect to the NTS with the sole purpose of extracting hydrogen for a refuelling station connected to a large-scale road, rail, bus depot, or for use in the marine and aviation sectors.

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You can find out more and get in touch:

FutureGrid@nationalgas.com
nationalgas.com/FutureGrid
National Gas Transmission

Warwick Technology Park
Gallows Hill, Warwick, CV34 6DA
nationalgas.com