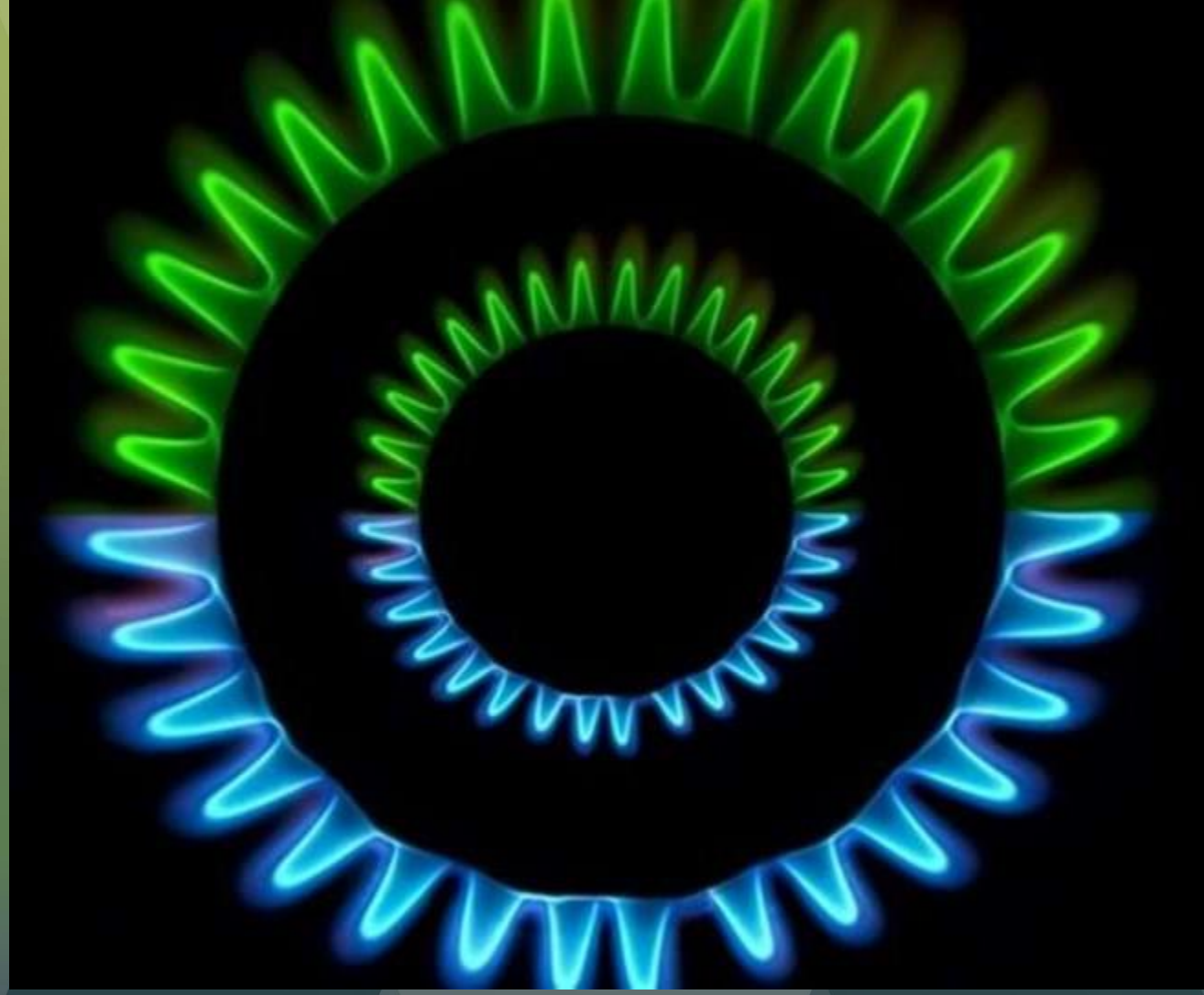
# Hydrogen, Materials and Net Zero



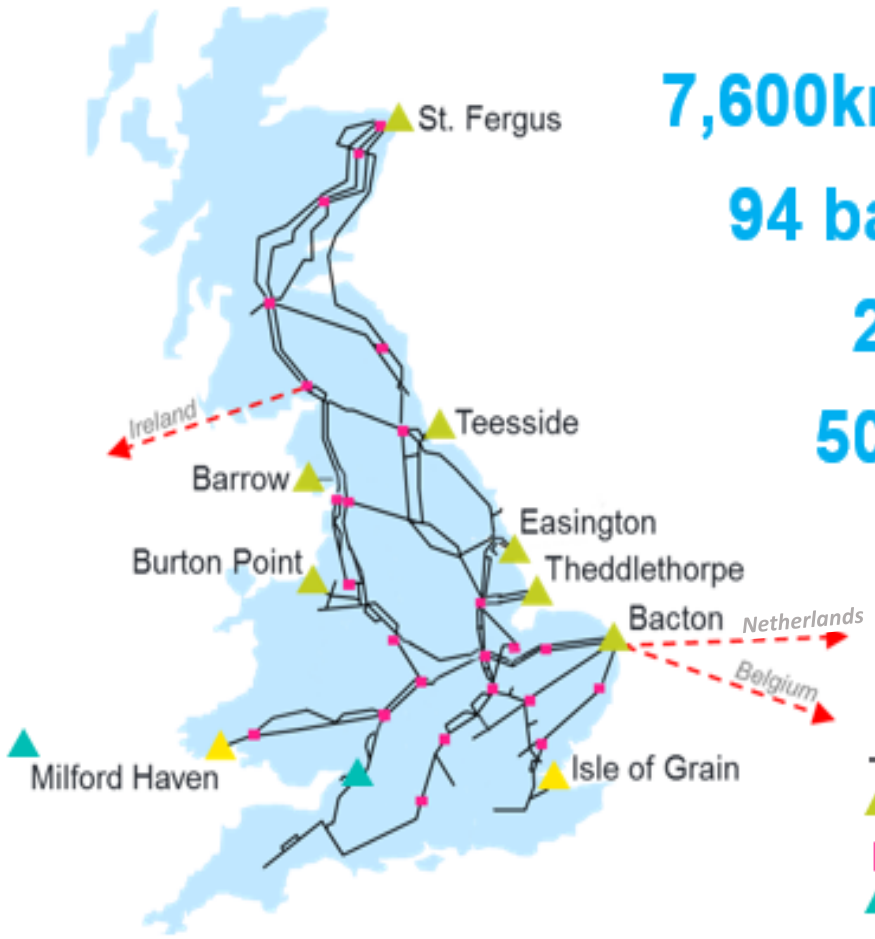

## Robert Best

**Hydrogen Innovation Engineer – Materials & Processing, National Grid Gas Plc**

# The Role of Gas in the UK Today

Gas Transmission and Metering

## The National Transmission System (NTS):




**7,600km** high-pressure pipe

**94 bar** maximum pressure on the network

**24** compressor stations

**504** above-ground installations

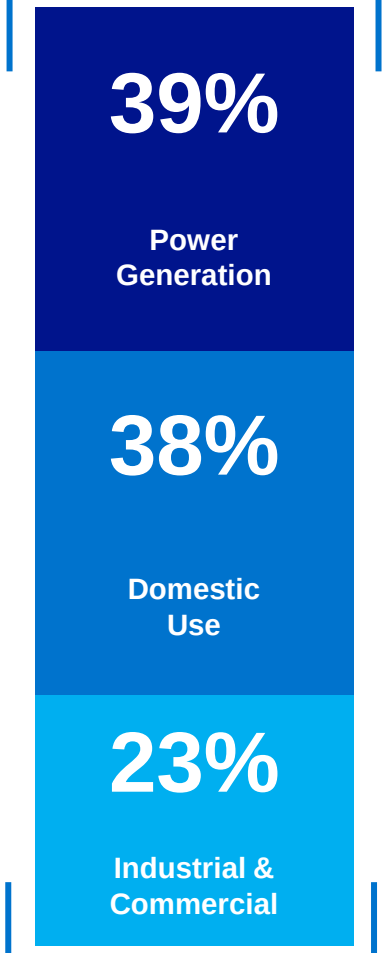
**8** connected distribution networks

## Gas Demand in the UK today:

**22m**
gas customers across the UK

**85%**
households are using gas for heat

**881 TWh**
of energy is delivered by the NTS




**881 TWh** 2020: Total gas demand

**330 TWh** 2020: Total electricity demand

# UK Policy Landscape

Gas Transmission and Metering

2020


TEN POINT PLAN FOR A GREEN INDUSTRIAL REVOLUTION
*November 2020*


ENERGY WHITE PAPER
*December 2020*

CCC 6th CARBON BUDGET
*December 2020*

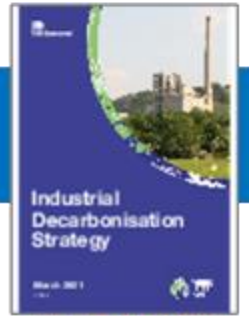

SCOTTISH HYDROGEN: ASSESSMENT REPORT
*December 2020*

2021

CONSULTATIONS: UK LOW CARBON STANDARD
DESIGN OF THE NET ZERO HYDROGEN FUND
HYDROGEN BUSINESS MODEL


UK HYDROGEN STRATEGY
*August 2021*


DECARBONISING TRANSPORT
*July 2021*




INDUSTRIAL DECARBONISATION STRATEGY
*July 2021*

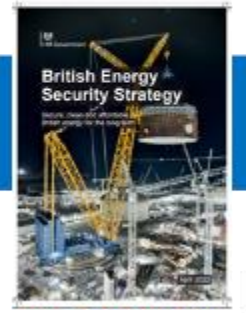
HYDROGEN IN WALES - CONSULTATION
*January 2021*


HEAT IN BUILDINGS STRATEGY SCOTLAND
*October 2021*


HEAT AND BUILDINGS STRATEGY
*October 2021*


NET ZERO STRATEGY
*October 2021*

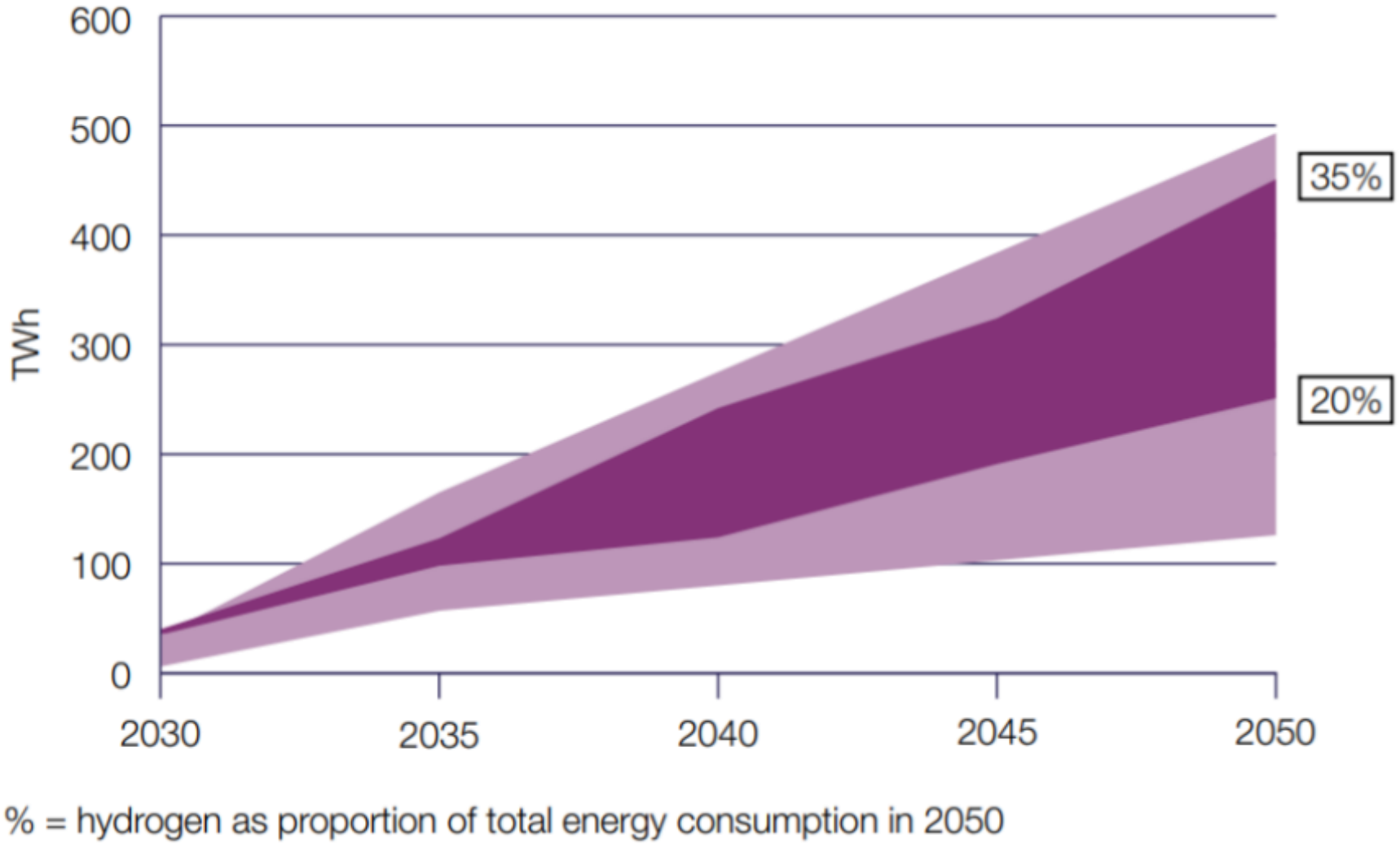
2022




ENERGY SECURITY STRATEGY
*April 2022*

# Up to 35% of UK energy demand could be met by hydrogen

Gas Transmission and Metering




% = hydrogen as proportion of total energy consumption in 2050

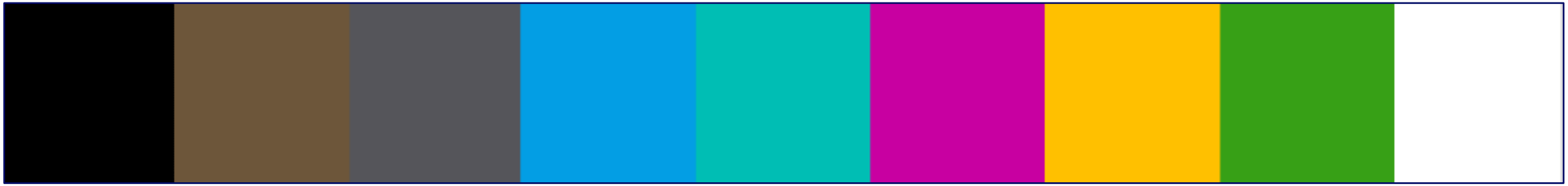
**UK Hydrogen Strategy** – Aug 2021

# What sectors will hydrogen serve?

Gas Transmission and Metering

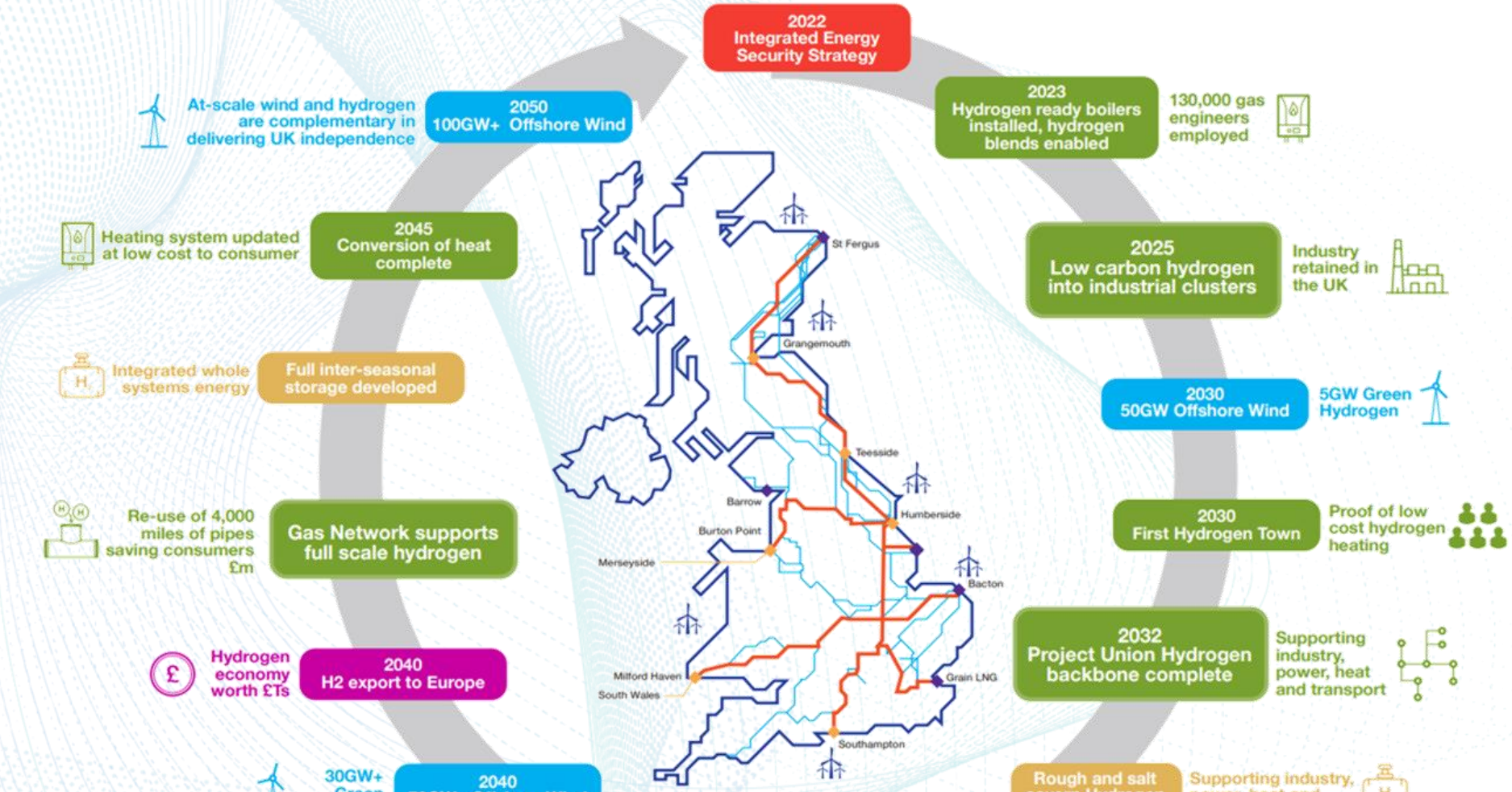
# What colour is the future?

Gas Transmission and Metering




# HyNTS Hydrogen Roadmap : delivering clean energy independence

Gas Transmission and Metering



# ProjectUnion

Gas Transmission and Metering

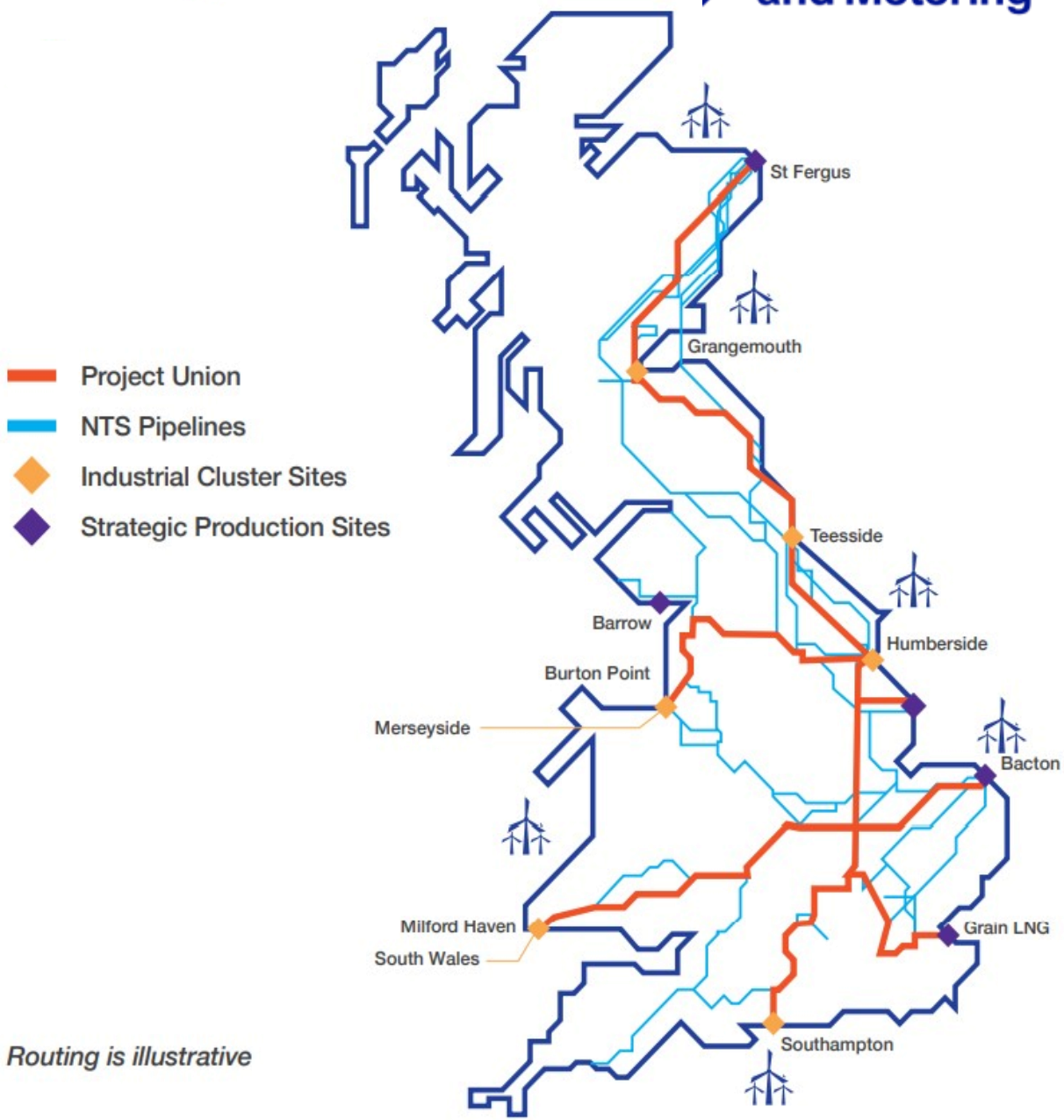
Development of a UK hydrogen “backbone” by repurposing ~2,000 km of existing assets
(~25% of NTS today)

Integral to delivering the UK’s hydrogen strategy

Aligned to green and blue hydrogen developments and CCUS clusters

Decarbonise heavy industry
(e.g. steel, concrete, and glass manufacturers)

Connect hydrogen production, demand, storage, and export centres



# ProjectUnion

Gas Transmission and Metering

## Project Union benefits

### Decarbonisation of industry & power

Fair access to green and blue hydrogen enabling businesses to decarbonise. Access to transmission enables green hydrogen production to scale.

### Energy storage & resilience

System resilience to move and store sufficient volumes across the country

### Connectivity & efficiency

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

### Market coupling

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

### Levelling up & job creation

Potential for >100,000 jobs by 2050, and contribution of £13billion to GVA

### Global leader in green innovation

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

### Flexibility & optionality

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

### Consumer-centric

Innovative, cost-effective consumer focused energy solutions, e.g., the pilot hydrogen town brings scalability & phasing.

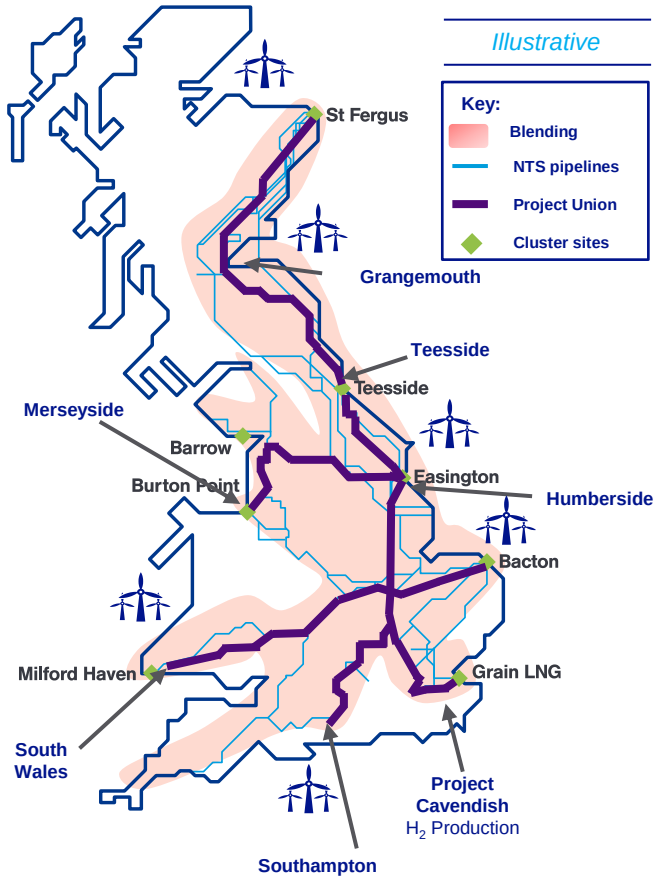
**Project Union will contribute to Energy Security**

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

# Dual Pathway to a hydrogen NTS: hydrogen blending and rollout of 100% hydrogen pipeline connections

Gas Transmission and Metering

Delivering a blend of hydrogen across the NTS in parallel to a strategic rollout of 100% transmission pipeline sections




**Rollout of blending across the NTS**

**Strategic rollout of 100% pipeline connections**

## Delivering a Dual Pathway to transitioning the NTS to hydrogen:

- In 2024/5 low level hydrogen blending on will be facilitated on the transmission network
- From 2025 onwards blending could extend and increase up to 20% - more if deblending technology can be proven.
- In 2028/9 Project Union will deliver the first phases of 100% hydrogen transmission pipeline between the northern clusters
- By 2033 Project Union will have delivered a circa 2000 km hydrogen backbone joining key production and use clusters
- Asset conversion continues to 2045 to deliver a complete 100% hydrogen network.

## Net Zero 2050

**Levelling up, Job Creation**

**Global Leader in Green Innovation**

**Providing flexibility and optionality**

**A dual pathway approach will ensure the most efficient and timely transition to hydrogen whilst ensuring those connected to the network are not left behind**

# European Hydrogen Backbone

**31** Gas infrastructure companies covering **28** countries

**53,000 km** by **2040**

**60%**
conversion

**40%**
new pipelines

**€80-143 billion,** for the 2040 infrastructure

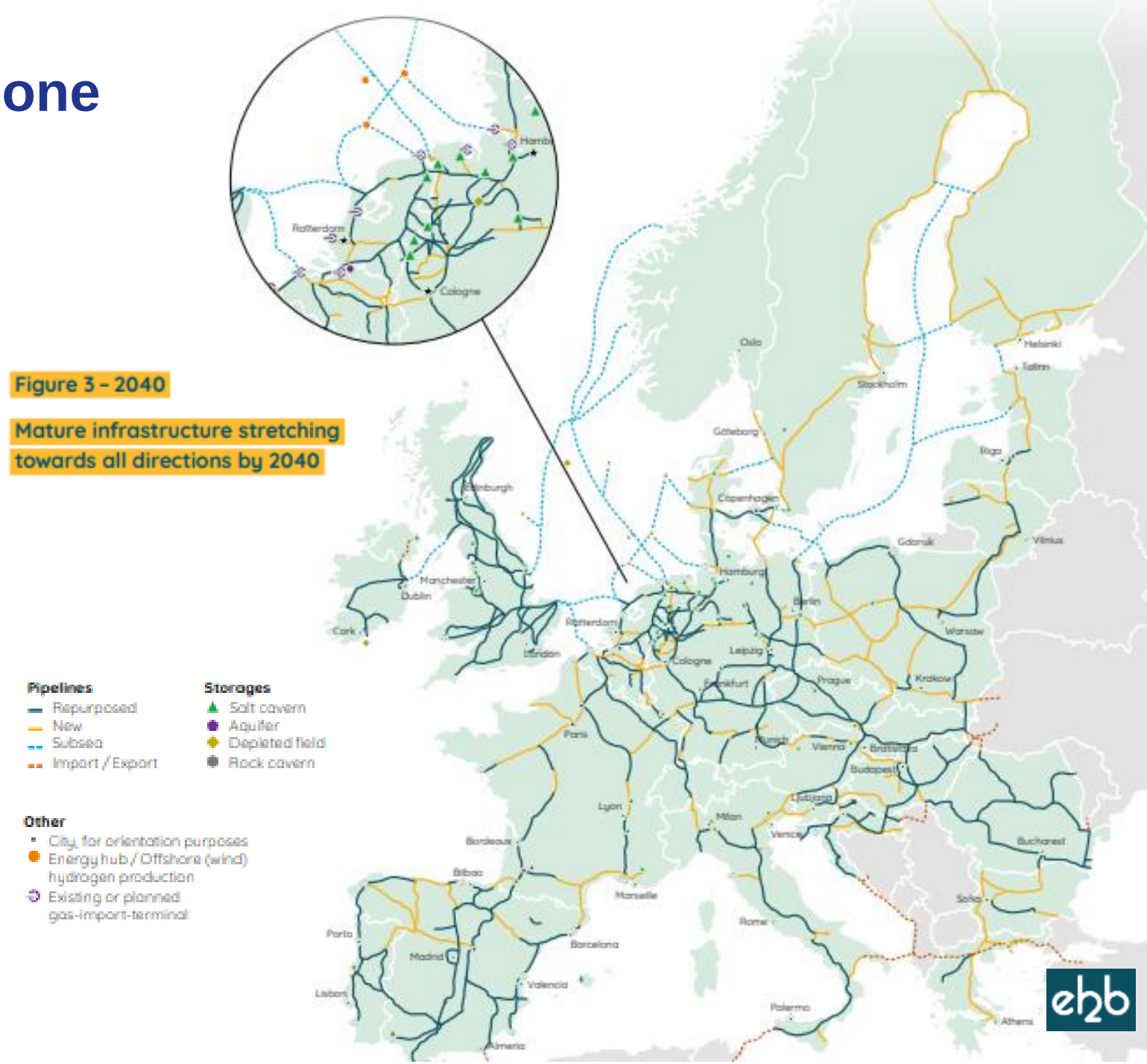
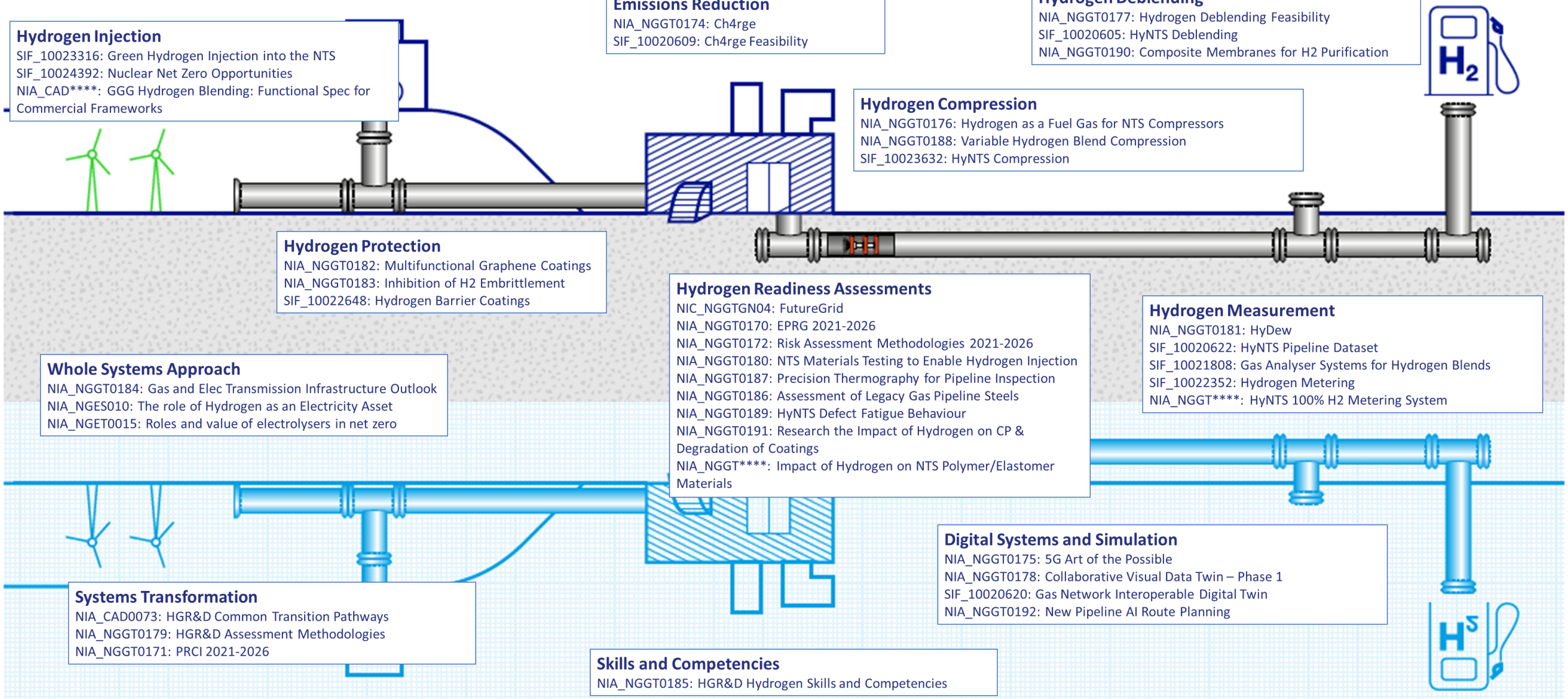



Figure 3 – 2040

Mature infrastructure stretching towards all directions by 2040

# Hydrogen Innovation Technology Projects

Gas Transmission and Metering




## Hydrogen Injection
SIF_10023316: Green Hydrogen Injection into the NTS
SIF_10024392: Nuclear Net Zero Opportunities
NIA_CAD****: GGG Hydrogen Blending: Functional Spec for Commercial Frameworks

## Emissions Reduction
NIA_NGGT0174: Ch4rge
SIF_10020609: Ch4rge Feasibility

## Hydrogen Deblending
NIA_NGGT0177: Hydrogen Deblending Feasibility
SIF_10020605: HyNTS Deblending
NIA_NGGT0190: Composite Membranes for H2 Purification

## Hydrogen Compression
NIA_NGGT0176: Hydrogen as a Fuel Gas for NTS Compressors
NIA_NGGT0188: Variable Hydrogen Blend Compression
SIF_10023632: HyNTS Compression

## Hydrogen Protection
NIA_NGGT0182: Multifunctional Graphene Coatings
NIA_NGGT0183: Inhibition of H2 Embrittlement
SIF_10022648: Hydrogen Barrier Coatings

## Hydrogen Readiness Assessments
NIC_NGGTGN04: FutureGrid
NIA_NGGT0170: EPRG 2021-2026
NIA_NGGT0172: Risk Assessment Methodologies 2021-2026
NIA_NGGT0180: NTS Materials Testing to Enable Hydrogen Injection
NIA_NGGT0187: Precision Thermography for Pipeline Inspection
NIA_NGGT0186: Assessment of Legacy Gas Pipeline Steels
NIA_NGGT0189: HyNTS Defect Fatigue Behaviour
NIA_NGGT0191: Research the Impact of Hydrogen on CP & Degradation of Coatings
NIA_NGGT****: Impact of Hydrogen on NTS Polymer/Elastomer Materials

## Hydrogen Measurement
NIA_NGGT0181: HyDew
SIF_10020622: HyNTS Pipeline Dataset
SIF_10021808: Gas Analyser Systems for Hydrogen Blends
SIF_10022352: Hydrogen Metering
NIA_NGGT****: HyNTS 100% H2 Metering System

## Whole Systems Approach
NIA_NGGT0184: Gas and Elec Transmission Infrastructure Outlook
NIA_NGES010: The role of Hydrogen as an Electricity Asset
NIA_NGET0015: Roles and value of electrolysers in net zero

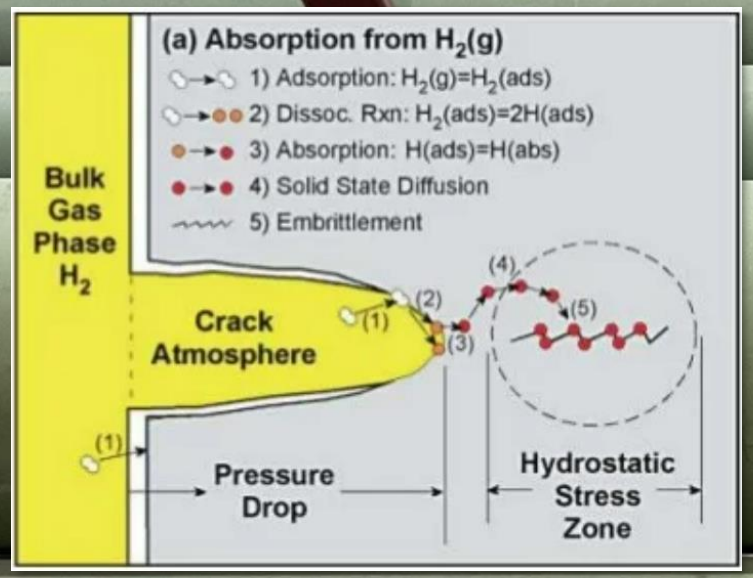
## Digital Systems and Simulation
NIA_NGGT0175: 5G Art of the Possible
NIA_NGGT0178: Collaborative Visual Data Twin – Phase 1
SIF_10020620: Gas Network Interoperable Digital Twin
NIA_NGGT0192: New Pipeline AI Route Planning

## Systems Transformation
NIA_CAD0073: HGR&D Common Transition Pathways
NIA_NGGT0179: HGR&D Assessment Methodologies
NIA_NGGT0171: PRCI 2021-2026

## Skills and Competencies
NIA_NGGT0185: HGR&D Hydrogen Skills and Competencies

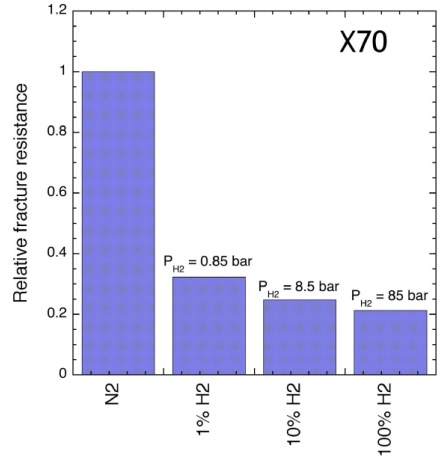
# What's the Problem?







5 Low pressure $H_2$ has substantial effect on fracture resistance of pipeline steels

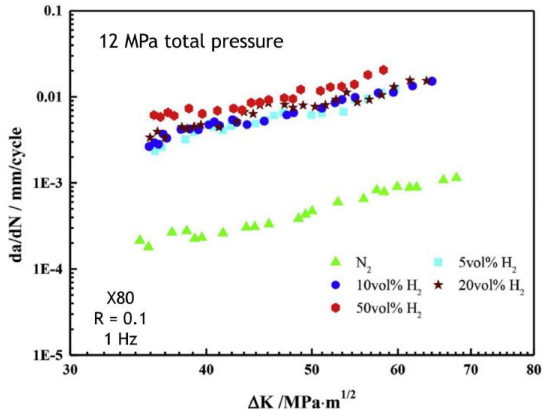



From: Briottet et al, ASME PVP-2018 conf.

- **Measurements of fracture resistance in gaseous mixtures of H2 and N2 show substantial effects of H2**
- **1% H2 is only modestly different than 100% H2**
- **Total pressure = 85 bar**

**<1 bar of H2 reduces fracture resistance**

6 Low pressure $H_2$ has substantial effect on fatigue crack growth of pipeline steels



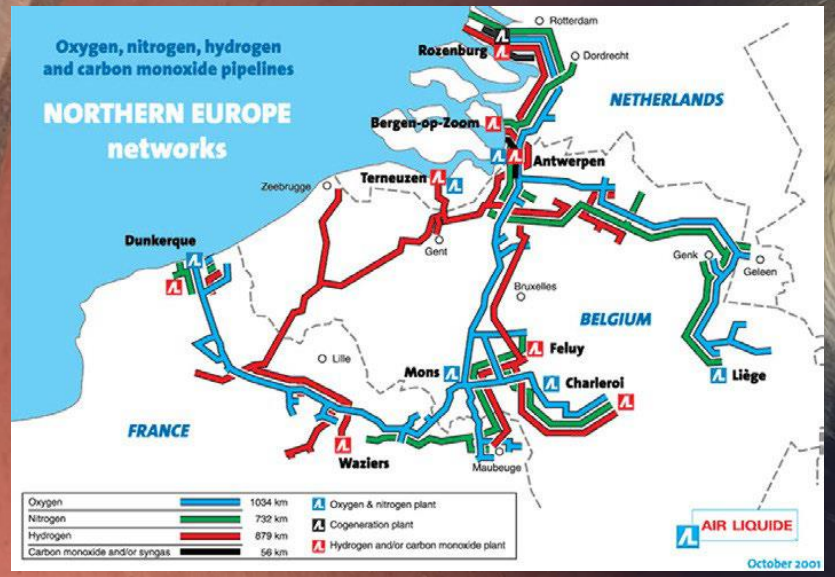

From: Meng et al, *IJ Hydrogen Energy* **42** (2017) 7404.

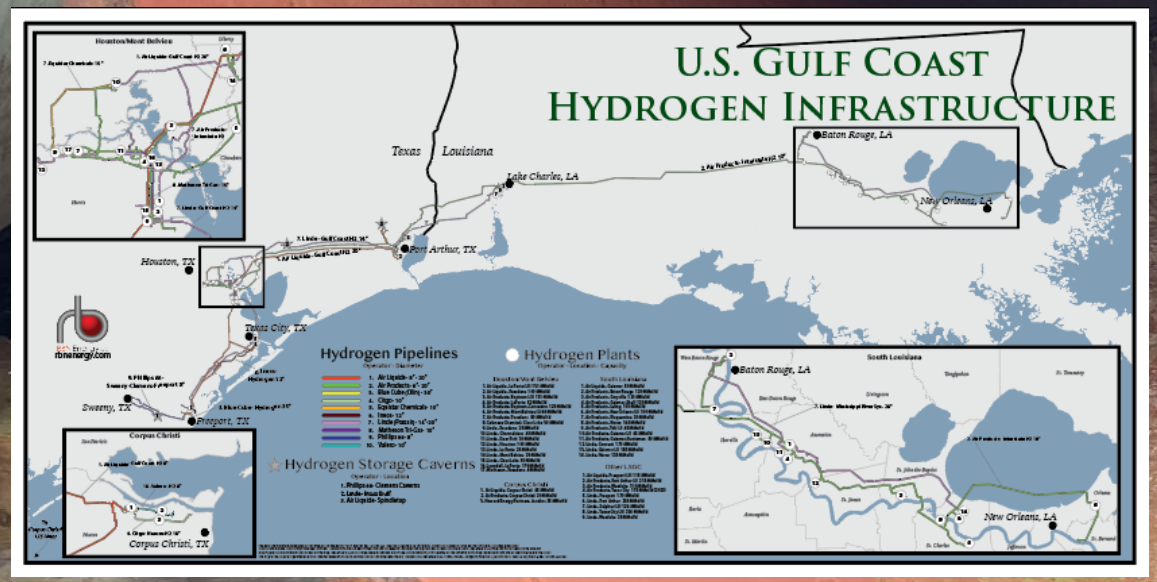
- **Measurements in gaseous mixtures of H2 and N2 show acceleration of fatigue crack growth rate with 5% H2**
  - **But little additional acceleration with higher H2 content**

**Small amounts of hydrogen can have substantial effect on fatigue and fracture**

# Is it *Really* a Problem?

Gas Transmission and Metering




| Parameters | | Fracture Toughness, $K_{IC}$ (MPa.m$^{1/2}$) (pre-1975) | Fracture Toughness, $K_{IC}$ (MPa.m$^{1/2}$) (post-1975) |
|---|---|---|---|
| 60-80 bar | 100% NG | 70 | 200 |
| | 25% $H_2$ | 61 | 175 |
| | 50% $H_2$ | 53 | 150 |
| | 75% $H_2$ | 44 | 125 |
| | 100% $H_2$ | 35 | 100 |
| 80-120 bar | 100% NG | 70 | 200 |
| | 25% $H_2$ | 60 | 170 |
| | 50% $H_2$ | 49 | 140 |
| | 75% $H_2$ | 39 | 110 |
| | 100% $H_2$ | 28 | 80 |

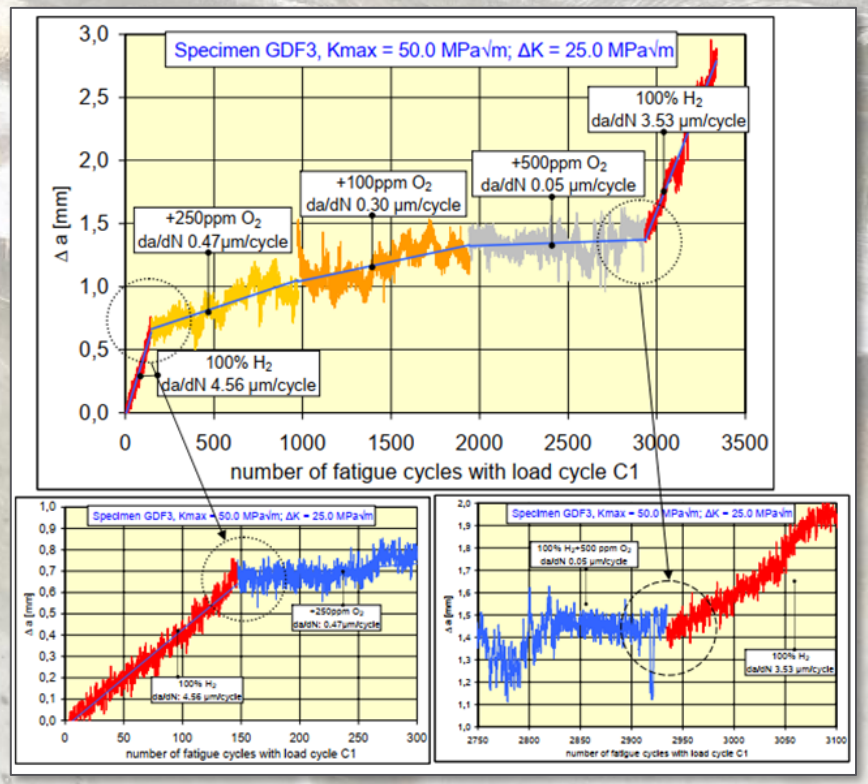
From *van Wortel, H., Gomes, M., Delafonti, G., Capelle, J., Alliat, I. and Chatzidouros, E.* NATURALHY Report No. R0096-WP3-C-0 *Durability of Steels for Transmission Pipes with Hydrogen*. 2009.

# Can we Mitigate the Effects of Hydrogen?

Gas Transmission and Metering

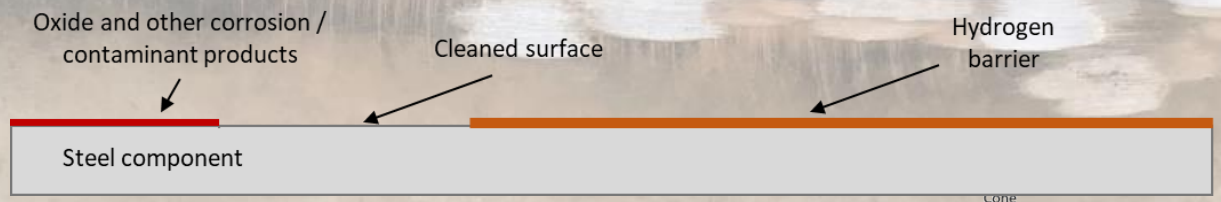
## Oxygen Inhibition

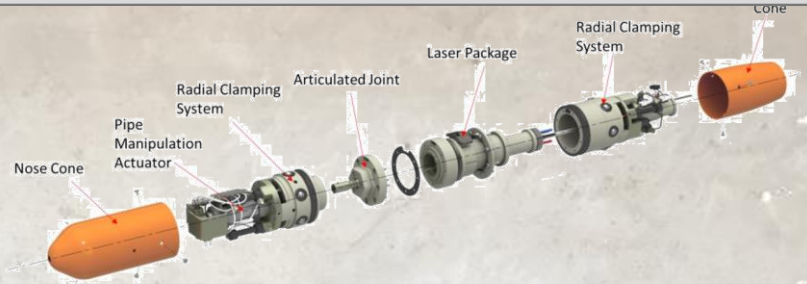
- 50-500 ppm $O_2$ additions into gas flow




## Barrier Coatings

- Continuous coatings of copper, nickel or graphene



# Phase 1 Overview

**Lead:** nationalgrid

**Project Partners:** DNV, HSE, Northern Gas Networks, fluxys, Durham University, The University of Edinburgh

## Objective

**FutureGrid** is an ambitious programme to build a hydrogen test facility from decommissioned assets at DNV's facility in Cumbria to demonstrate the National Transmission System (NTS) can transport hydrogen.

| | |
|---|---|
| **Duration** | April 2021 – November 2023 |
| **Status** | Live |
| **Funding** | NIC Project |
| **Value** | £12.7m |

## Offline hydrogen test facility

NTS assets of different types, sizes & material grades will be tested with 2, 5, 20 & 100% hydrogen

**Testing 4 concentrations of hydrogen:**

- 2%
- 5%
- 20%
- 100%

**Understanding the impact on a range of key NTS assets including:**

- Steel Pipeline & Bends
- Welds
- Valves
- Flow Control Valves
- Pre-Heater and Regulators
- Filters & Meter Streams

## Standalone hydrogen tests

Standalone hydrogen tests will provide key data required to feed into the main facility

**Conducting a range of standalone hydrogen tests to feed into the main facility:**

- Materials testing
- Pipe coating testing
- Fatigue testing
- Flange testing
- Asset leak testing
- Rupture testing

## NTS hydrogen safety case review

**Understanding the impacts of difference concentrations of hydrogen and develop our safety standards:**

- Procedure Review
- Hazard Assessment of Transmission System (HATS)
- Quantitative Risk Assessment (QRA)
- Hazardous Area Impact
- Overpressure Risk (OR)
- NGGT Safety Case

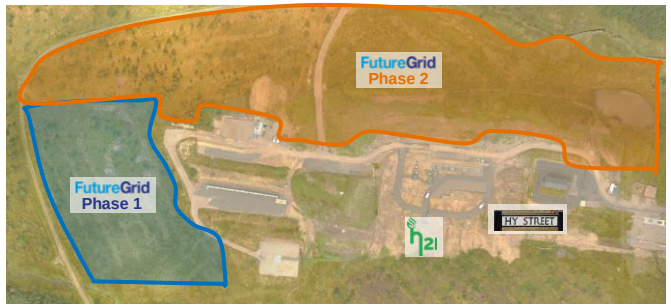
## Get in Touch

FutureGrid@nationalgrid.com

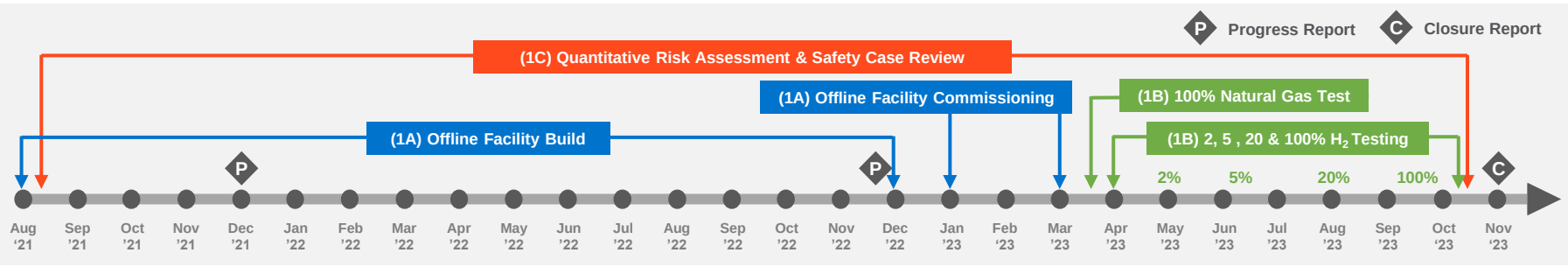
nationalgrid.com/FutureGrid

Innovation at National Grid

## Location on site



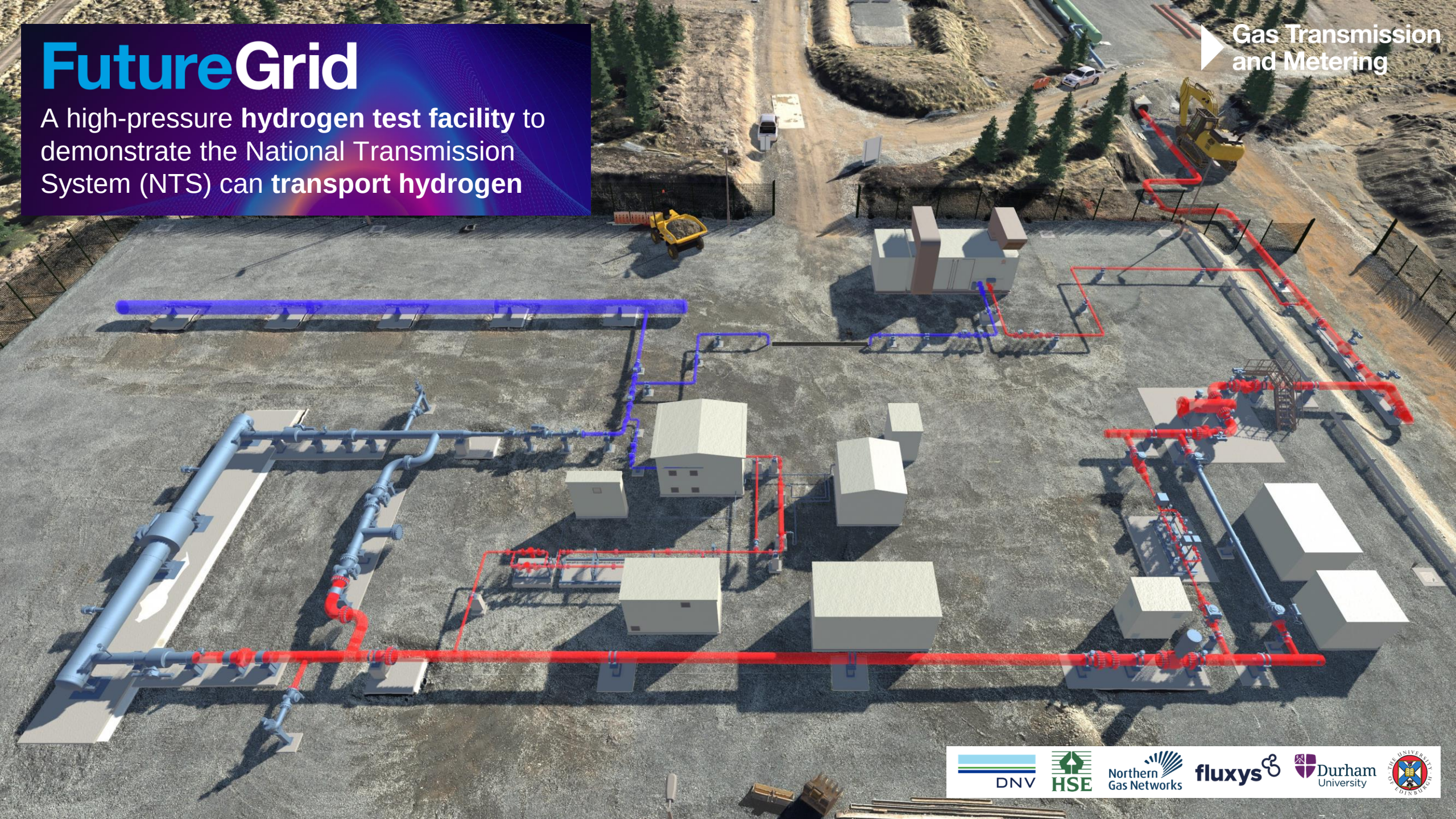

## FutureGrid Phase 1 Timeline



# FutureGrid

A high-pressure **hydrogen test facility** to demonstrate the National Transmission System (NTS) can **transport hydrogen**

Gas Transmission and Metering



DNV HSE Northern Gas Networks fluxys Durham University The University of Edinburgh

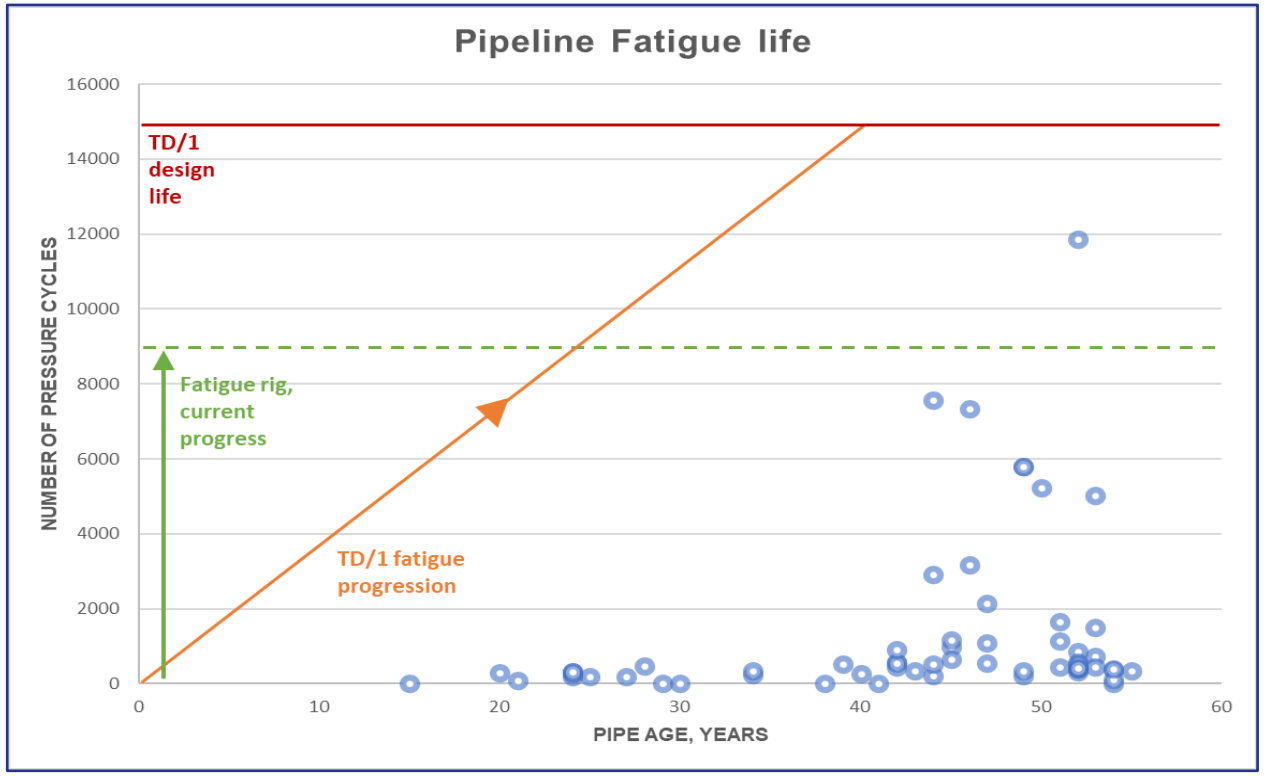

FutureGrid
Construction is nearing completion – this image was taken in October 2022 just before the recompression unit groundworks
Gas Transmission and Metering

# FutureGrid

Asset fatigue testing underway
September 2022

# Fatigue Rig Test Preparation






# Critical Path to Evidence Development



**There is a critical pathway of evidence development that feeds into the development and deployment of 100% hydrogen in our high pressure gas pipelines. Time is a critical factor to deliver a hydrogen transition at pace to meet net zero targets.**

| 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|

## FutureGrid

- Build & Commission
- 2, 20 & 100% $H_2$ Testing
- QRA & Safety Case
- Compression
- Deblending
- Skills + Competencies
- Third Party Development
- Training

- Evidence: % of network that can be repurposed
- Approve: New systems for a resilient HyNTS
- Evidence: Compressor capability
- Approve: Workforce capability for safe operations
- Evidence: Hydrogen Safety Case
- Approve: Hydrogen deployment onto the NTS

## ProjectUnion

- Strategy Phase
- Feasibility
- FEED
- Construction

Future backbone development

- Feasibility
- FEED
- Construction

# Hydrogen, Materials and Net Zero


## Robert Best

**Hydrogen Innovation Engineer – Materials & Processing, National Grid Gas Plc**