HyDeploy

HyDeploy2 Project

Project Close Down Report // June 2024

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1.0 Project summary

The HyDeploy2 project builds on the foundational work at Keele University to demonstrate on public distribution networks that natural gas containing levels of hydrogen beyond those in the Gas Safety Management Regulations (GSMR) can be distributed and utilised safely. Successful demonstration has the potential to support the growth of the UK hydrogen economy and decarbonise heat.

The HyDeploy2 project was delivered by a consortium of partners, consisting of: Cadent; Northern Gas Networks (NGN); Progressive Energy; Health and Safety Executive – Science Division (HSE-SD); Keele University and ITM Power. Alongside the core consortium were a number of key subcontractors, including Dave Lander Consulting, Blue Flame, DNV UK Limited, Atkins Limited and Rosen.

Under the Climate Change Act, the UK is committed to achieving Net Zero emissions by 2050. Hydrogen blending is a key step in meeting this goal, as it provides a foundation from which the hydrogen industry can develop. This along with the amount of CO^2 that can be displaced provides a momentous step towards reaching Net Zero. Following the UK Energy white paper and 10 Point Plan, the UK government made a strategic policy decision in December of 2023 confirming that hydrogen blending will play a critical role in the UK's Net Zero strategy.

The HyDeploy2 project was split into two key phases: The public network trial, and GB wide evidence base.

The first phase of the project involved building on the evidence and knowledge gained from the previous demonstration at Keele University and applying for a second exemption to GSMR from the Health and Safety Executive (HSE). The village of Winlaton, near Gateshead in the North East of England, on NGNs network was selected as the ideal candidate for the trial due to the representative size and makeup of the network, demographic and assets. The purpose of this phase was to prove that hydrogen blending was safe, practical, and effective using the existing gas network infrastructure and Business As Usual (BAU) processes which unlike Keele University, involved numerous gas shippers and suppliers.

HyDeploy was originally planned to complete a second public network demonstration in the North West of England to further the evidence base. However, due to the greater success of Phase 1 and 2 in furthering the safety evidence than originally planned, and in the context of developing Government policy on Hydrogen Blending, it was decided that the funds for this demonstration should be reallocated to reorient the scope of evidence development to cover underlying evidence applicable for the wider GB gas distribution networks (GDN), and thus support a national safety assessment for hydrogen blending. This was agreed with Ofgem via a Material Change to the HyDeploy2 Project Direction on 27th July 2021.

The result of the last 7 years of testing, investigation, and evaluation is the creation of what can be viewed as a 'world leading' safety evidence base in support of hydrogen blending.

The full safety evidence base is set to be reviewed by the HSE with the intention to provide the Department for Energy Security and Net Zero (DESNZ) with the necessary evidence and confidence to make an amendment to the GSMR.

2.0 Executive summary

2.1 Scope and Objectives

Following the success of HyDeploy1, the natural next step in the HyDeploy project was to build upon the existing evidence to conduct a second demonstration utilising the public gas network. Alongside conducting this second demonstration, an extensive evidence base was created in support of rolling out hydrogen blending up to 20 mol% (hereon referred to as 'blended gas') across the whole of the GB gas distribution system.

The project aims to demonstrate that the use of blended hydrogen gas in the GB gas networks is not only safe, but practicable and feasible using current working practices and materials, and without the need for extensive disruption to the GB gas networks or its stakeholders.

The demonstration in the village of Winlaton has proven that the conveyance of blended gas is possible with limited-to-no interruption to the general public and has a host of benefits that are detailed in this report. This is further expanded upon using the GB evidence base, which has investigated in-depth, the changes, challenges and benefits brought on by conveying hydrogen blended gas through the existing gas networks from the high-pressure local transmission networks through to end user applications.

System Evidence System Boundary

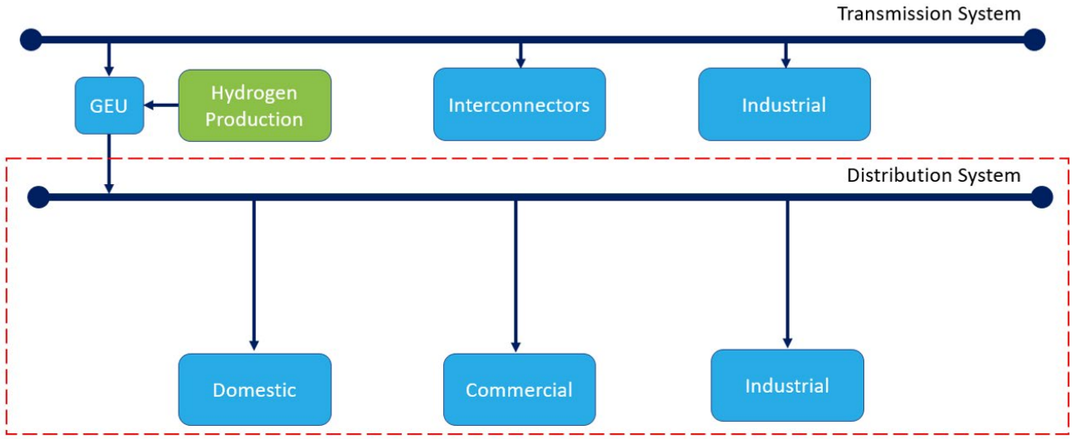


Figure 1: Schematic illustration of the existing Gas System, depicting where hydrogen injection will take place. Sectors in the red-dashed box depicts the scope of the system covered by the HyDeploy2 evidence submission.

2.2 Project Outcomes

A key outcome of the HyDeploy2 project has been the positive policy decision made by the UK government in favour of hydrogen blending. This is a momentous step towards the UK's Net Zero target and included reference to the work conducted by the HyDeploy project.

HyDeploy has successfully demonstrated that it is possible to achieve an Exemption to the hydrogen limit within the GSMR Schedule 3 on both private and public gas networks. In addition to this, a key outcome of HyDeploy2 has been the demonstration that existing appliances, procedures, and network assets can be operated on blended gas with no physical changes being required for safe operation. Further outcomes for HyDeploy2 have been:

1. The building on, and establishing of, a robust evidence base to support the first public blending trial within the UK.
2. Successfully manage an intensive engagement and review process with the HSE, where 229 individual questions were raised against the safety case evidence base for the Winlaton trial, and successfully responded to.
3. The safe delivery of the UK's second hydrogen blend trial to 668 properties, including limited commercial properties, where there was Zero Loss Time Injuries recorded across the trial duration. The trial delivered over 92,613 scm of hydrogen and abated over 50 tCO2.
4. Evidencing of the operational suitability of hydrogen blends during the Winlaton trial with the vast array of domestic appliances expected on the GB gas networks.
5. The two successful trials (Keele and Winlaton) have demonstrated the network's ability to effectively and safely manage a hydrogen blended network, with an emphasis on the Winlaton trial applying BAU techniques.
6. Generating the technical and procedural precedents for evidence generation and review by the HSE, which have informed subsequent safety case submissions through HyDeploy2 and the wider hydrogen safety case industry.
7. Building on the robust social science evidence base to understand real world attitude of consumers using hydrogen blends founded during the Keele trial.
8. To satisfy the HSE that a hydrogen blend is safe, 65 evidence criteria which have been defined by the HSE have been reviewed, adapted and addressed in the HyDeploy2 evidence base.
9. Various industrial & commercial trials have been conducted to demonstrate the safety of transitioning to a hydrogen blend on existing industrial appliances and manufacturing processes without compromising product quality.
10. The generation of a vast, potentially 'world leading' safety evidence base to facilitate a national safety evidence review.

HyDeploy2 has been a very successful project that has delivered on its objectives and enabled the UK to take the first practical steps of demonstrating the safety and operational feasibility of hydrogen blends on a public gas network and has pushed the evidence further to cover the wider GB gas distribution system.

2.3 Successful Delivery Reward Criteria

All Successful Delivery Reward Criteria (SDRCs) were delivered to the satisfaction of Ofgem. The project extended beyond the original timeline, primarily due to resourcing difficulties in the hydrogen testing and expertise area, impacting contractor resource and test facility availability.

Alongside this, further time was required to complete further study and testing into materials & assets. However, the project extension was within the 12 months beyond which a material change would be required to be sanctioned. The submission timings of any affected SDRCs were agreed with Ofgem and all SDRCs were submitted in line with the agreed timings.

Table 1: SDRCs successfully delivered to Ofgem

SDRC	Title	Target Date	Delivered
1	Customer Engagement Plan	31/10/2019	✓
2	Evidence base for first trial	30/06/2020	✓
3	First Exemption submission	31/09/2020	✓
4	First trial commencement	31/01/2021	✓
5	Evidence base for second trial	31/03/2022	✓
6	First trial completion and interim roadmap	31/12/2021	✓
7	Initiation of National Evidence Submission	31/03/2024	✓
8	Evidence dissemination roadmap	31/03/2024	✓
9	National Evidence Submission Overview	31/03/2024	✓
10	Completion of wider network evidence base, roadmap & dissemination	31/03/2024	✓
N/A	Comply with knowledge transfer requirements of the Governance Document	End of Project	✓

2.4 Learning

The HyDeploy2 project has made significant progress in the technical and regulatory requirements to enable the introduction of a hydrogen blend within the GB gas distribution network.

All project partners have benefited from their involvement in the project, where valuable learning has been captured from the delivery of the project. At a project-level, the main learning outcomes are:

- it is possible to provide a robust demonstration of the parity of safety between natural gas and blended gas, undertaken in the context of both a private network trial, and a public network trial.
- Building on the point above, the Winlaton trial coupled with the GB evidence base has demonstrated that the introduction of a hydrogen blend can be achieved with minimal-to-no intervention, whilst continuing to use existing network assets and consumer appliances.
- The HyDeploy project completed its 7th successive year of successful project delivery through to 2024. This achievement was possible due to the continued efforts of a team of highly dedicated and capable individuals and organisations, both project partners and subcontractors. Successful delivery of innovative projects like HyDeploy is contingent upon the right people, with the right experience, knowledge, and focus. The largest areas of potential engineering risk are in the interface between independent systems. All mechanical, electrical and instrumentational interfaces require focus to ensure a seamless delivery of an overall solution is achieved.

- Cross project collaboration has been a particular achievement driven by HyDeploy. The increase in hydrogen research projects generated the risk of duplication and misalignment. HyDeploy was keen to ensure that resources were spent efficiently, particularly in materials testing as it can be a resource heavy field. A cross industry materials working group was established via the Energy Networks Association (ENA), wherein all GDNs shared evidence regarding the suitability of materials and assets to be repurposed for hydrogen, and all GDNs were informed of one another's projects, schedules, results, and conclusions – this has been a key learning outcome.
- Due to the enormous success of the Winlaton trial, the project was re-directed to develop a safety evidence base for GB. This change in direction required the entire HyDeploy consortium and the subsidiary contractors and stakeholders to understand what this step change meant with respect to how the remainder of the evidence needed to be investigated and presented, given the reduced availability of the HSE. A key learning from this change was the importance of ensuring that effective communications were made to all relevant project stakeholders such as contractors involved in developing key safety evidence.
- The importance of stakeholder engagement was personified over the past 12 months as HyDeploy embarked on a tripartite engagement journey with DESNZ and the HSE. Both stakeholders were custodians of the same output from HyDeploy such as the safety evidence, but from different perspectives. The HSE are making the direct safety assessment of the presented evidence, whilst DESNZ are interested in developing the business case for blending and determining the value for money, if investment was required to introduce blended networks. The HyDeploy team took great care to harbour relationships, and it was evident to learn the value of clear concise communications, as well as information sharing.
- An increase in hydrogen related research in the UK led to a small period of scarcity of supply. However, the project maintained resilient hydrogen supplies through carefully negotiated contracts, designed to provide reliable hydrogen availability during the trials.

The key learning which has been demonstrated by the HyDeploy2 project is that blending hydrogen into a live gas network is possible and can be done safely and efficiently. Before HyDeploy2, the introduction of hydrogen within the public gas network was an ambition. This is a critical learning as it provides confidence within the gas industry and with wider stakeholders, both in the UK and across the globe, that hydrogen offers a viable pathway to decarbonise heat and industry.

3.0 Project Description and Outcomes

The HyDeploy2 project was split into two distinct phases: The evidence gathering for, and conducting of, the Winlaton public demonstration; and the generation of a GB wide safety evidence base undertaken by HyDeploy, as discussed further below.

3.1 Winlaton Public Network Trial

Following the delivery of a successful hydrogen blending trial on a private gas network at Keele University, the next natural step was to establish a second trial to expand the evidence utilising the public gas network. This section provides further detail on the key elements of the trial and site selection process.

3.1.1 Site Selection

A key element of the second hydrogen blending demonstration was the selection of an appropriate site that would prove a solid foundation for gathering evidence of operating a public hydrogen blending network. A key aim was to broaden the coverage of assets and users following the Keele trial.

Using the below selection criteria, the village of Winlaton on NGN's network was identified as the most suitable option. The Winlaton infrastructure contained a representative mixture of domestic and commercial properties, along with a good mixture of metallic and plastic supply piping. NGN's InTEGRel site, also known as the Low Thornley gas depot near Gateshead, was identified as an optimum site to host the compound to allow for the trial network to be in the Winlaton geography.

Table 2: Site Selection Criteria

Criteria	Basis of assessment
Ease of isolation from wider network.	Limited isolation points required to isolate trial network from other parts of the NG network.
Downstream of, or including Biomethane injection points in trial area.	Challenging to run test if in close proximity downstream from Biomethane. Would not run with injection points within trial area.
Minimum scale of commercial buildings.	Must have between 500-1,000 dwellings and ideally some commercial buildings.
Statistically representative range of housing stock.	Dwellings should be representative of UK housing stock.
Mix of steel and plastic pipes.	Sites which contain only one type of iron material, and which have only limited steel sections are preferred.
Suitable operating pressures.	Sites which can accommodate the pressure drop inherent in the HBGEU are preferred.
Proximity to sensitive receptors.	Sites which require location of the electrolyser in close proximity to schools or hospitals (etc) are likely to be rules out.
Presence of IGT's.	Less favourable if IGT's present in the area of the distribution of the blend.
Planning position requirements.	Lengthy and costly planning permission could cause significant risks to the project deliverability.
Location of other utilities.	The compound/electrolyser will require a supply of water and natural gas.

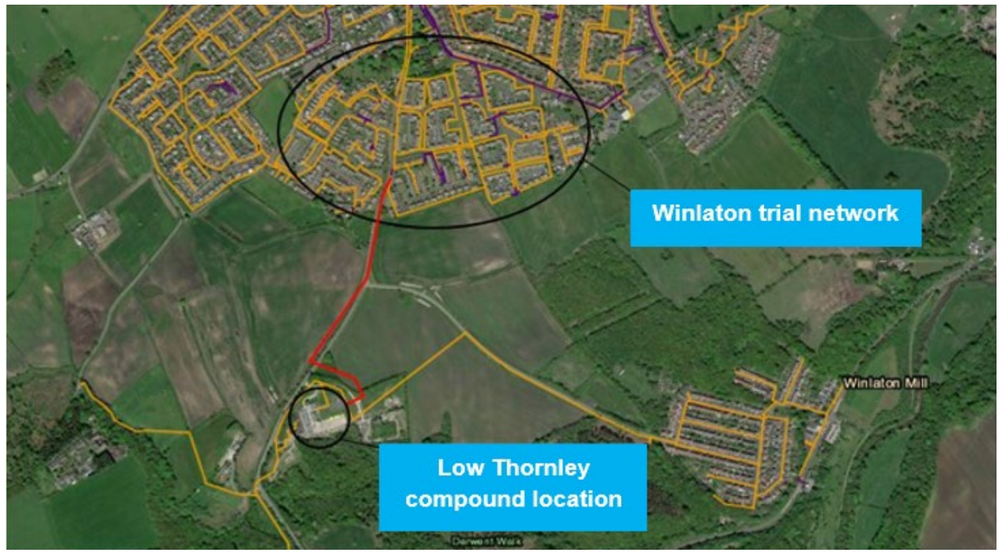


Figure 2: Image showing Low Thornley gas depot (location of compound hosting hydrogen supply and grid entry unit) and the Winlaton trial area. New medium pressure PE pipeline to supply the blended hydrogen is shown in red.

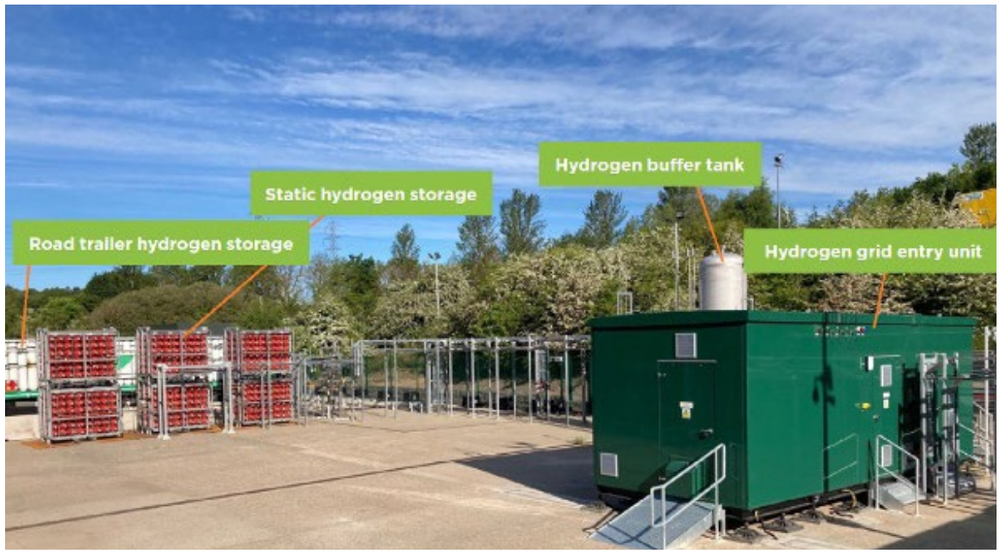


Figure 3: Integrated compound

Figure 4: Aerial Image of Low Thornley Compound

3.1.2 Hydrogen Supply

Hydrogen was taken from a bulk trailer storage facility housed at the InTEGReL site. The hydrogen supply system comprised of a road trailer unloading and static hydrogen storage facility (Figure 3), designed, constructed, and installed in accordance with industry standards. The purpose of the trial was to demonstrate the distribution and utilisation of hydrogen blends, and not the feasibility of generating low carbon hydrogen as this is sufficiently covered by other projects across GB.

3.1.3 Grid Entry Unit

In order to safely and reliably blend hydrogen into the network, a Hydrogen Blending Grid Entry Unit (HBGEU) was designed and installed. This was a bespoke unit based on the successful design and operation of the HBGEU used in HyDeploy1 for the Keele trial. Thyson Technology Ltd was selected as equipment provider and undertook final design and fabrication based on a developed design and specification not too dissimilar to the Keele HBGEU. The equipment completed fabrication and was initially Factory Acceptance Tested (FAT) using inert gases at their facility. This was followed by a Site Acceptance Test (SAT) at NGN's Low Thornley site, the HBGEU can be seen situated in the Low Thornley compound in Figure 4.

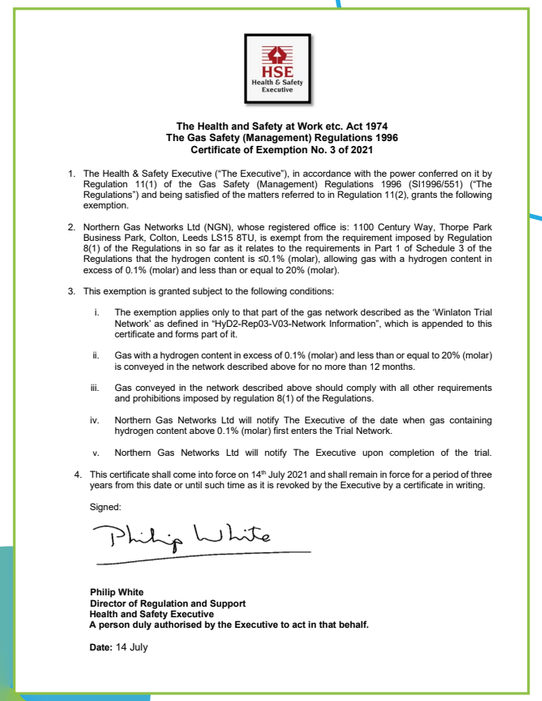
Figure 5: HBGEU Internals (Keele University Trial)

The HBGEU comprised of gas analytical instrumentation and controls to allow the stipulated blend level to be achieved whilst remaining within all other gas quality limits set by GSMR and to any additional process limitations. The unit was specifically designed with instrumentation to ensure that hydrogen blends above 20%vol cannot be blended into the network.

3.1.4 Grant of Exemption

On the 14th of July 2021, the HSE granted a second exemption to GSMR for the blending of up to 20 mol% of hydrogen. This time, the exemption covered injection into a public gas network, and noted the extensively increased area of the trial, both in scope (assets, materials etc.) and in geographics (no. of dwellings, size of network etc.).

This was another milestone achievement of the HyDeploy project, as it was the second time an exemption has been granted for the change of the allowable hydrogen limit in GSMR, only this time it was being applied in a much more realistic BAU manner.



HSE
Health & Safety Executive

The Health and Safety at Work etc. Act 1974
The Gas Safety (Management) Regulations 1996
Certificate of Exemption No. 3 of 2021

1. The Health & Safety Executive ("The Executive"), in accordance with the power conferred on it by Regulation 11(1) of the Gas Safety (Management) Regulations 1996 (SI1996/551) ("The Regulations") and being satisfied of the matters referred to in Regulation 11(2), grants the following exemption.

2. Northern Gas Networks Ltd (NGN), whose registered office is: 1100 Century Way, Thorpe Park Business Park, Colton, Leeds LS15 8TU, is exempt from the requirement imposed by Regulation 8(1) of the Regulations in so far as it relates to the requirements in Part 1 of Schedule 3 of the Regulations that the hydrogen content is ≤0.1% (molar), allowing gas with a hydrogen content in excess of 0.1% (molar) and less than or equal to 20% (molar).

3. This exemption is granted subject to the following conditions:

   i. The exemption applies only to that part of the gas network described as the 'Winlaton Trial Network' as defined in "HyD2-Rep03-V03-Network Information", which is appended to this certificate and forms part of it.

   ii. Gas with a hydrogen content in excess of 0.1% (molar) and less than or equal to 20% (molar) is conveyed in the network described above for no more than 12 months.

   iii. Gas conveyed in the network described above should comply with all other requirements and prohibitions imposed by regulation 8(1) of the Regulations.

   iv. Northern Gas Networks Ltd will notify The Executive of the date when gas containing hydrogen content above 0.1% (molar) first enters the Trial Network.

   v. Northern Gas Networks Ltd will notify The Executive upon completion of the trial.

4. This certificate shall come into force on 14th July 2021 and shall remain in force for a period of three years from this date or until such time as it is revoked by the Executive by a certificate in writing.

Signed:

Philip White

Philip White
Director of Regulation and Support
Health and Safety Executive
A person duly authorised by the Executive to act in that behalf.

Date: 14 July

Figure 6: Winlaton exemption certificate

3.1.5 Safety Evidence Creation Pre-Trial

Prior to the commencement of the Winlaton trial, supplementary evidence proving the safe distribution and use of hydrogen blending was gathered. This evidence built upon the previous data originating from the Keele University trial and its accompanying evidence base.

To support the second exemption to GSMR further evidence was commissioned such as:

Appliance safety testing

To determine the continued safe operation of appliances on a hydrogen blend, extensive laboratory tests were conducted. Building on from the evidence gathered by HyDeploy1, the HyDeploy2 project focused laboratory testing on generic burner types to cover all domestic & commercial configurations across the UK. This was a substantial increase to the data gathered in HyDeploy1 which lead to the confirmation that there were no negative changes to safety performance. A crucial finding on appliances was a significant reduction in CO production, which is the leading course of fatalities with regards to appliances.

Gas characteristics

The gas characteristics of blended gas, in comparison to natural gas, was an important area of understanding to underpin the quantitative risk assessment and support appropriate supplementary guidance for operational procedures to be developed, where needed. A review of natural gas explosion incidents was conducted to ascertain the frequency and severity of incidents; this review granted a detailed insight into the varying nature of gas explosions.

Extensive modelling and experimental work showed that the accumulation of blended gas from leaks is almost identical to that of natural gas, meaning that the likelihood of the blended gas contacting an ignition source remains unchanged and the impulse arising from ignition (overpressure x time) is comparable with natural gas.

In-house inspections

Prior to the trial commencing, house-to-house (H2H) surveys were conducted to both gather data on the appliances present on the Winlaton network, and conduct gas safe checks.

Materials & assets

The materials evidence generated by HyDeploy1 laid the foundation for the assessment of mechanical property data on numerous materials. HyDeploy2 built upon this data by applying various testing methods and work procedures to hydrogen-soaked samples. This resulted in testing electrofusion couple types (socket, cap, saddle etc.), squeezing off, and re-rounding hydrogen-soaked pipes. Following hydrostatic testing, samples were assessed with x-ray and DPI methods, showing that no evidence of stress cracking was present. It is important to note that for the purposes of the tests, the samples were subject to total (100%) hydrogen immersion.

Similar soaking and strength testing was conducted on materials that were not present on HyDeploy1 (brass, cast iron, steel etc.) The materials testing concluded that there was no discernible difference between the soaked samples, and the control samples. Fractographic assessment showed that the presence of hydrogen does not change the failure mechanism of the materials as tested.

Operational procedures

Prior to conducting work on the Winlaton trial, NGN's gas network procedures relating to activities on / expected to be used on the trial network were reviewed. Assessment of the upstream procedures was led by NGN and assessment of the downstream procedures was led by Blue Flame Associates (Blue Flame are an industry expert on downstream gas procedures).

The operational procedures assessment led to a determination as to whether the existing procedure was suitable for hydrogen blend operation, or if an amendment was required.

The downstream procedures review concluded no change to domestic procedures ,and their related competencies, for all IGEM and BSI procedures that underpin Gas Safe natural gas competencies. There are over 100,000 Gas Safe registered engineers in the UK and they will not need retraining or upskilling to work on appliances receiving hydrogen blended gas. This work was peer reviewed by IGEM, BSI and appliance manufacturers before being formally communicated to the Gas Safe community via a Technical Bulletin. The Gas Safe community was further engaged with via a dedicated webinar, where nearly 700 engineers attended to ask questions and engage with the project.

Following the steps taken to achieve the exemption to GSMR for the Winlaton trial, this evidence base was further expanded upon to cover the GB wide gas network. This expansion of the evidence base is covered in S3.2.

3.1.6 Live Trial

On August 4th 2021, Winlaton, Gateshead became the first community to receive hydrogen blended gas via the existing public natural gas network. This was the first time in the UK's history that a publicly operated network transported hydrogen blended gas to customers to use within their existing natural gas appliances.

3.1.7 Network Monitoring

The success demonstrated in the Keele trial led to a reduced need for extensive monitoring of the Winlaton trial gas network. Nevertheless, safety was considered paramount and heightened monitoring was implemented at the Low Thornley site via the HBGEU, along with an increase in leakage sweeps for cast iron pipework as agreed with the HSE. In-field tests were consistently carried out during the trial to align with the leakage sweeps.

A primary objective of the Winlaton trial was to apply BAU practices to substantiate that a network can safely operate on a hydrogen blend while adhering to existing gas network protocols. To ensure a safe and controlled environment for the trial, the injection rate of hydrogen into the gas network was increased incrementally over a period of 6 weeks to a final limit of 20 mol% (minus control tolerances).

During the trial, no specific increase in Rhinology checks were conducted, other than a monthly check at the governor kiosk which resulted in satisfactory levels. This decreased level of Rhinology observations was determined due to the success of the Keele University trial, demonstrating that there was no observable dilution of gas odourant across all injection set points.

Finally, no additional gas appliance checks were employed based on the extensive evidence developed for domestic appliances and checks conducted prior to and during the Keele University trial. All appliances operated on the Winlaton trial network performed adequately with no appliance failures caused by the blended gas at any of the hydrogen blending set points.

3.1.8 Network Performance

During the trial extensive work was conducted to ensure safety of the general public was maintained. This included a thorough approach to leakage identification across the Winlaton network. Upon analysis of the leakage data, it was concluded that there was no increase in leaks identified under blended gas operation when compared to gas escape data from previous years.

The makeup and construction of pipelines in the Winlaton network were a combination of Polyethylene, Cast Iron, and Steel. It was noted with the HSE that Cast Iron pipework was of the highest concern for compatibility with hydrogen, and this was monitored with increase leakage sweeps as described in S3.1.7 above. During the trial, a single 4" spun cast iron main fractured in October of 2021. Failures of this nature are not uncommon at this time of year due to ground temperature variations. The fracture occurred on the longest section of the 600 m of cast iron present on the network. Crucially, the fracture was repaired using existing BAU repair methods, demonstrating that these practices remain practical with a hydrogen blended gas.

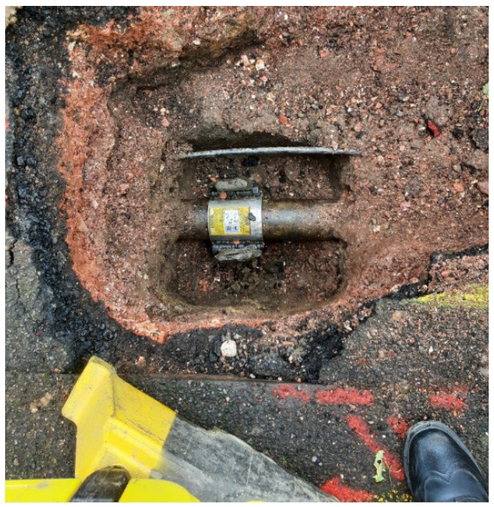


Figure 7: Image of 4" cast iron main with a successful repair clamp

3.1.9 Customer Engagement

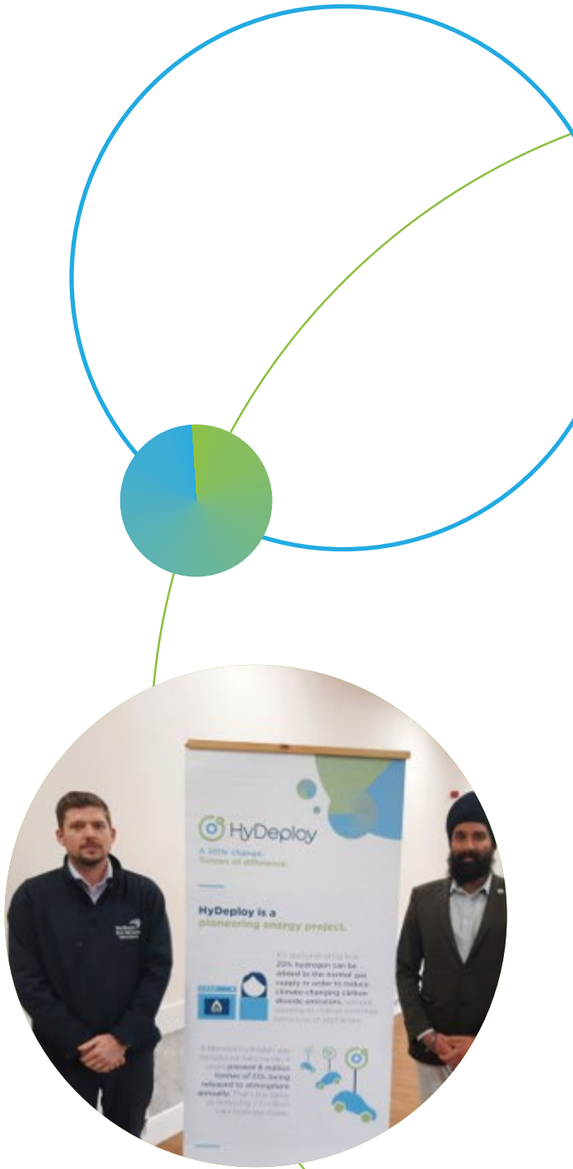
Consumer feedback has proven crucial to the HyDeploy project, enabling the project team to gauge not only the reactions to the trials taking place, but to the concept of, and reception to, hydrogen blending as a whole.

For the Winlaton demonstration, a total of 130 customer survey responses were received and 11 interviews conducted prior to the trial's commencement; with a further 50 surveys and 9 interviews post-trial. The vast majority of surveys were conducted door-to-door, with the interviews being conducted either by telephone or online.

The findings of the consumer research highlighted a trend of increased satisfaction over the course of the trial with over half (66%) of respondents in favour of hydrogen blending pre-trial, rising to 78% post-trial.

It is acknowledged that there are expected to be concerns around hydrogen, and the research confirmed this. The main factors being the overall safety of blending, the effect on existing appliances, cost implications, and the effectiveness of hydrogen as a solution to climate change. Prior to the trial commencing, the data suggests that the engagement work had largely reassured residents of the safety, effectiveness, and ease of the trial, highlighting the importance of consumer engagement with regards to hydrogen blending. By the end of the trial, the feedback suggested that a high level of trust had been built with the residents of Winlaton.

The major findings of the consumer engagement were that at the end of the trial, both survey respondents and interviewees noted that they experienced no difference in their gas supplies. Alongside this, 70% of respondents would have liked to continue to have received blended hydrogen.



Below are some extracts from the consumer engagement research:

Interviewer:
"How do you feel about Winlaton being chosen as the trial area for the UK for this project?

Interviewee:
"This might sound corny, but privileged." (Pre-trial)

"To be honest I thought, I'm so pleased that you're doing something to help the environment. That was the main thing." (End-of-trial)

"Just as long as it doesn't actually affect my bill in any shape or form [...] As long as that is not affected at all, I really don't [have] any issue whatsoever. I think it's a good experiment." (Pre-trial)

"It's an easy way to do your little bit without noticing any difference, basically" (End-of-trial)

Concerns, Reassurance, and Trust
"I think the fact that they've done safety checks, I think that reassures an awful lot of people ... Because it just shows that safety was the number one step before anything else happened." (Pre-trial)

"I think it's fine. I've got no complaints at all. They've kept us informed. I've said, they've sent us letters and we went up to the club, saw the layout of the plans and everything." (Pre-trial)

Experience Post-Trial & Desire to Continue
"But everyone I've spoken to; it's made no difference to their usage of gas. It's nothing wrong at all with it. Everything's just the same" (End of trial)

"I mean there's been absolutely no changes for us. Everything's been run smoothly. There's not been any issues or anything. So, it's been fine, yes." (End-of-trial)

"To be honest with you, I barely even know the project's taking place. There's been no disruption at all" (End-of-trial)

"I think it's sad that it is coming to an end because if you've got something that works why aren't you just continuing it?" (End-of-trial)

"Well, I'm saddened, because I would like to continue with hydrogen" (end-of-trial)

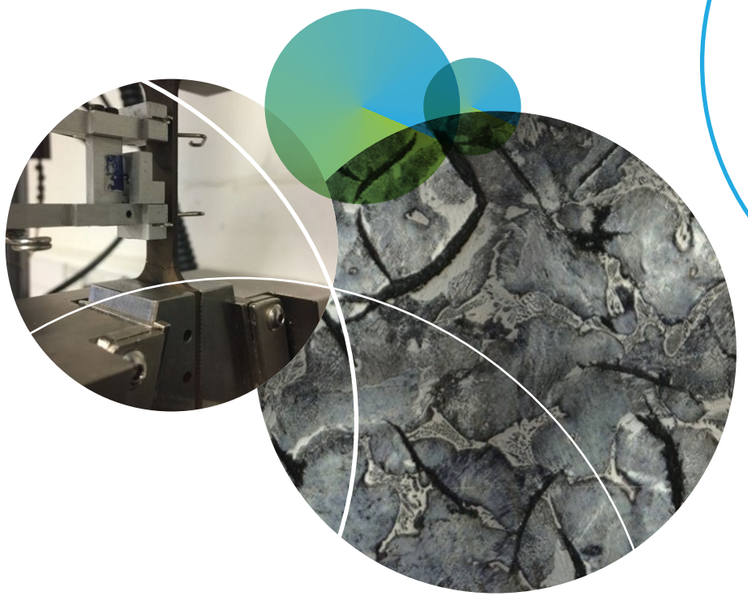


Figure 8: Resident engagement

3.2 Extension of Existing Evidence Base for GB-Wide Application

The second phase of the HyDeploy2 project was centred around building on the trial specific evidence base to extend to full GB gas networks particularly assets which operate at higher pressure tiers than the low/medium pressure trial networks and extending the end user applications to include industrial and commercial users.

The HSE was instructed by DESNZ to identify the safety assurance requirements for the use of hydrogen for heating. In 2020 the HSE issued a report to describe the 65-safety considerations that were identified during the review process. The considerations were discussed with the HSE by the HyDeploy project team, and it was agreed that they would be equally applicable with some minor adaptions in the evaluation of safety evidence for a transition to hydrogen blending. These considerations set out the minimum requirements for safety to be demonstrated and were adopted by the HyDeploy project in its evidence generation and reporting, to facilitate a robust review of the safety evidence. HyDeploy has addressed these evidence considerations and provided them with a logical structure as described in figure 9 below.

Figure 9: Illustration of the 4 "Steps" which form the logical, sequential approach to the HyDeploy submission.

This evidence base takes the form of 8 Main Reports, in which the feasibility, practicality, and safety of introducing a hydrogen blend into the GB gas networks is laid out. In these reports, a multitude of technical reports, published studies, and research papers are referenced, many of which have been conducted as part of the HyDeploy project. The following sections cover how this evidence is structured to enable a comprehensive safety review.

It is important to note that the conclusions drawn and referenced in the evidence base submitted to the HSE are HyDeploy's own and are based on expert technical evidence developed and gathered throughout the project and are subject to the HSE evidence review.

3.2.1 System Architecture

To demonstrate the feasibility, applicability and safety of a hydrogen blend, the effects of a hydrogen blend on the existing gas system architecture required reviewing. This included covering aspects such as the system capacity, establishing/confirming the system boundaries, mapping dutyholders, and confirming technical requirements such as pipeline proximity distances.

The purpose of this section of the evidence base is to define how hydrogen blending will interact with the existing gas infrastructure, along with how responsibilities of dutyholders are impacted.

The evidence base has defined the scope of the existing gas network that is covered by the HyDeploy2 project, this has been outlined in Figure 1. Note when referring to the transmission system this is in relation to the National Transmission System (NTS) only. The Local Transmission System (LTS) operated by GDNs is considered a part of the distribution system.

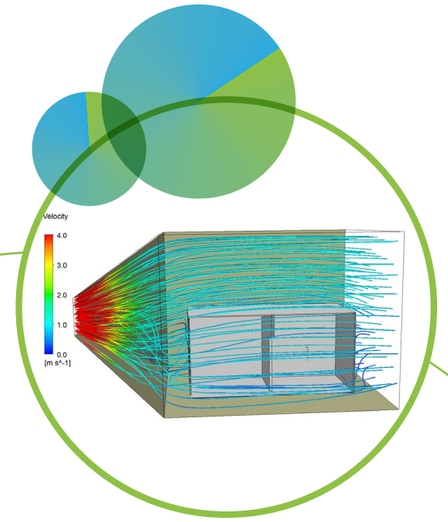
3.2.2 Gas Characteristics

To demonstrate the feasibility, applicability and safety of a hydrogen blend, the changes to gas characteristics has been reviewed. This involved reviewing leak scenarios and release rates, gas dispersion and accumulation, ignition sources, and release consequences. Testing and modelling have determined that there are no new leakage scenarios for a hydrogen blend when compared to natural gas.

The gas characteristics workstream has investigated the changes in behaviour that will occur with the introduction of a hydrogen blend, focusing on how the changes in behaviour effect the existing risks compared to natural gas. Extensive modelling and experimental work has shown that gas accumulation resulting from leaks of blended gas within buildings will be almost identical to that of natural gas. Therefore, the likelihood of accumulated blended gas coming into contact with an ignition source is unchanged compared to natural gas.

Overall, the 'Gas Characteristics' evidence has shown that blended gas is suitable and safe for use within the GB gas networks. due to the increase in hydrogen content. As part of the 'Gas Characteristics' work, evidence has shown that the majority of identified credible ignition sources were within the minimum ignition energy of natural gas.

Overall, the 'Gas Characteristics' evidence has shown that blended gas is suitable and safe for use within the GB gas networks.



3.2.3 Gas Network

The Gas Network report of the HyDeploy2 evidence base covers the critical aspects of the compatibility and safety of network assets, equipment, and materials. This forms a core part of the case for the safe use of hydrogen blended gas; designed to ensure that materials, components, and assets pre-existing on the network will remain safe and functional in the presence of a hydrogen blended gas.

To successfully demonstrate the compatibility and feasibility of the existing gas network for use with hydrogen blends, HyDeploy2 created an extensive evidence workstream capturing the following elements described in the illustration below.

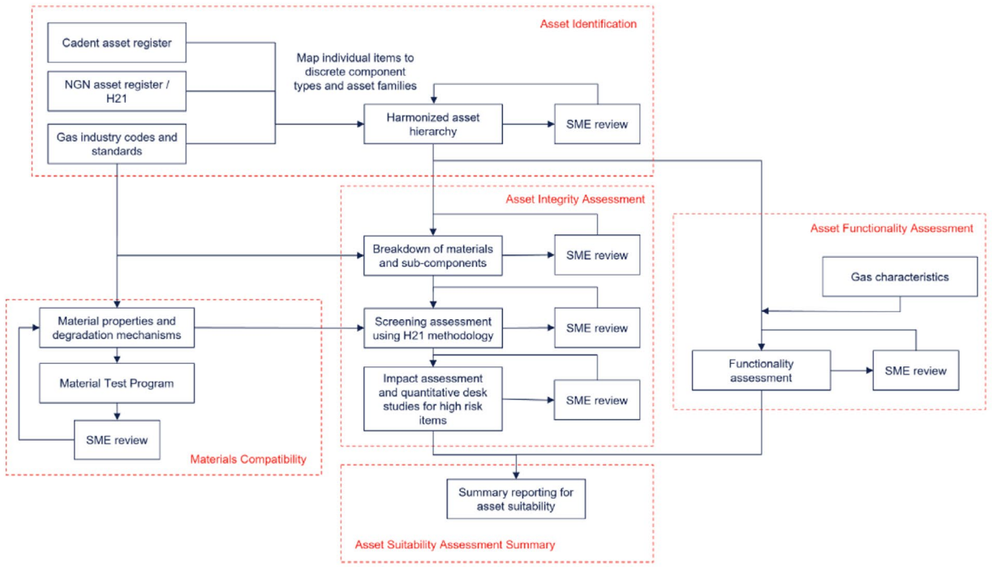


Figure 10: Workflow illustration of the gas network assessment methodology

Asset Identification

This initial activity focused on ensuring that the project was working with a representative example of gas network assets. This was achieved through the review of current and legacy industry standards as well as GDN asset registers. Following this, these assets were grouped and catalogued into classes and families based on materials of construction and functionality.

Materials Suitability

Materials suitability assessments investigated the existing materials present in the gas distribution network based on the groupings identified in the initial Asset Identification activity. Testing of various network materials was conducted here to form a core part of the HyDeploy2 evidence base, gathering physical test data on materials which have been extracted from the existing gas network, exposing them to hydrogen through in-situ (testing in the presence of hydrogen) and ex-situ (testing immediately after exposure to hydrogen) testing methods. A variety of tests were conducted to understand how materials perform in hydrogen environments. The results of this workstream demonstrated that the vast majority of materials used in the existing infrastructure are suitable for use with hydrogen blends with some specific assets requiring limited mitigations. Example mitigations include reviewing existing inspection intervals and for certain assets, reviewing existing stress analysis data on high stress components.

Asset Functionality

The role of the Asset Functionality Assessment was to confirm that an asset will continue to perform its function(s) in the presence of hydrogen.

The assessment process was split into 4 steps described below and illustrated in figure 10.

- Step 1 – Identification of assets requiring a functionality assessment. 165 asset classes were identified.
- Step 2 – Workshops with subject matter experts were held to review the impact from the change in gas characteristics when considering a hydrogen blend and to define the functionality of each shortlisted asset.
- Step 3 – A detailed assessment of shortlisted assets was conducted, reviewing relevant data sources (published literature, ongoing research projects or previous HyDeploy findings) proposing modifications or recommending no changes. Assets were then categorised based on the workshop outcomes.
- Step 4 – Risk scores were assigned to prioritise recommended actions. The assessment concluded with the feasibility of using hydrogen blends with the assessed assets.

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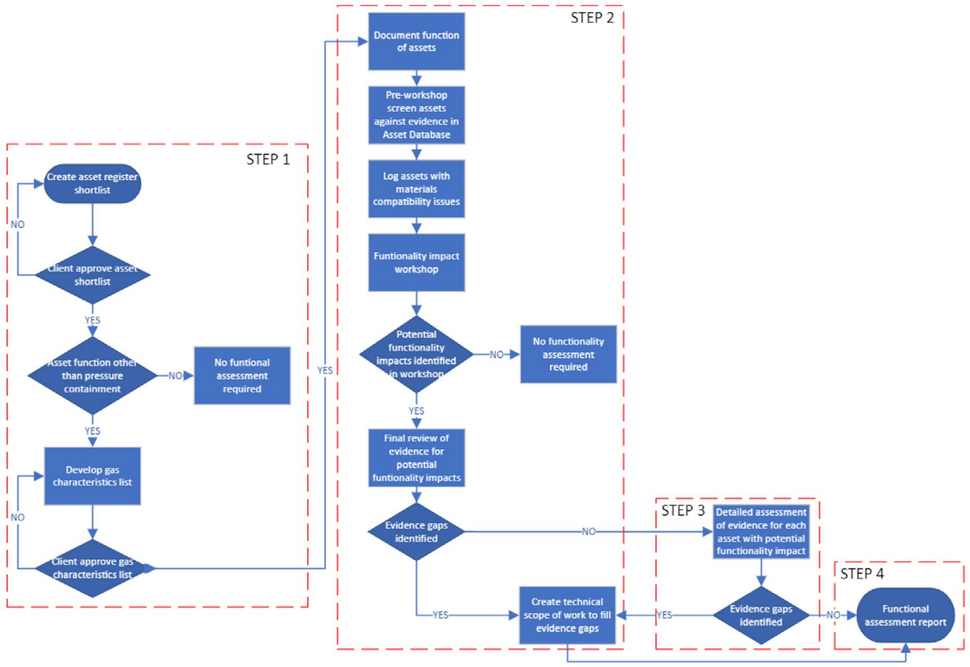

Figure 11: Functionality Assessment Process Flow Chart

Asset Integrity

- The Asset Integrity Assessment considers the ability for an asset to contain gas and thereby retain an adequate level of integrity whilst operating in hydrogen environments.

A natural gas and hydrogen gas risk screening methodology was established to process an assessment for each asset family. The result of the assessment identified which assets required further detailed assessments. Further assessment concluded the assets suitability to operate with hydrogen blends and whether any mitigations were necessary or not.

3.2.4 Appliances & Installations

Existing literature and evidence from both previous domestic trials, and new industrial and commercial (I&C) trials commissioned as part of HyDeploy2 has been compiled to investigate the effects of a hydrogen blend on appliances and installations, with an emphasis of expanding the pre-existing evidence base to gather more data on I&C facilities. The workstream focuses primarily on appliance performance and safety, with insights into changes in flame visibility and its effect, along with the benefits of Carbon Monoxide reduction for a hydrogen blend.

Previous evidence and existing literature, along with the success of the Keele and Winlaton trials have demonstrated that hydrogen blended gas is safe for use in domestic appliances. The evidence base has been expanded to provide extensive evidence that hydrogen blended gas is safe for use in domestic, commercial, and industrial appliances. The following gives a breakdown of how the evidence base covers these sectors:

Domestic

The existing Gas Appliance Directive, and subsequent Gas Appliance Regulations, actively test using a blend of hydrogen and methane. Extensive testing was conducted as part of HyDeploy prior to the Keele University trial, which demonstrated that hydrogen blends can be used safely. The Winlaton demonstration has effectively proven that hydrogen blends can be used safely on the public network and is compatible with the vast array of appliance types and ages to be expected on the public gas network.

Commercial

Commercial installations vary in size, some can be like that of a domestic installation while others can be on the scale of an industrial installation. The suitability of installation components or operation of appliances, for use with a blend, has been indicated by identification and use of appropriate findings from the domestic or industrial sectors.

Industrial

Evidence from the 'Gas Network' workstream referenced in S3.2.3 on network compatibility is considered applicable to the majority of industrial pipework and equipment suitability. For compressors, boosters and pre-mix machines installed on industrial installations, some recommendations have been provided for end users in the HyDeploy evidence base.

Similar to the approach taken for domestic appliances, industrial appliances were categorised based on how air/fuel mixtures are controlled to allow for a broader, more realistic assessment of appliances. The vast majority of appliances reviewed were categorised and defined as per Figure 12.

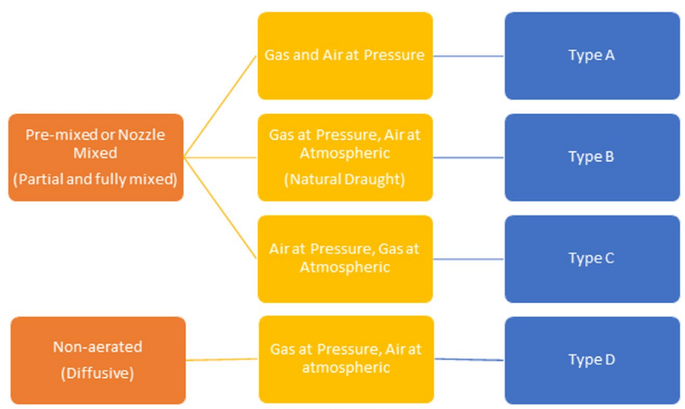

Figure 12: Gas Burner Configurations

A total of 5 appliance types did not fit into the above categories and therefore were assessed in their own right.

For industrial heating appliances, no safety impacts were identified for the normal operation of appliances.

For technologically distinct end users, a number of recommendations have been provided to ensure continued safe operation of gas engines, gas turbines, catalytic burners. No safety impacts were identified for the use of blended gas in oxy-fuel burners, desulphurisation processes, methane reforming, methane pyrolysis, solid oxide fuel cells, metal treating and natural gas dryers.

A review of 49 industrial appliance safety devices has been conducted, and it was found that 47 remain safe for use with a blended gas. Where this was not the case, mitigations have been suggested.

In support of the industrial and commercial sector, various trials were conducted to investigate the effects of hydrogen on processes such as manufacturing, heat generation and product quality. These are described below:

Campden BRI Limited

A trial was conducted at Campden BRI, a food and drink research facility, to test the effect that hydrogen blending has on the quality of food products, namely baked goods. The tests conducted involved comparisons of specific volume, texture, and cell count across various baked goods across natural gas and a 77/23% Methane/Hydrogen blend. Alongside the quantitative tests, a blind tase trial was conducted utilising an expert panel of Campden BRI food scientists. The trial concluded that the use of a hydrogen blend produced a product indistinguishable from one produced using methane.

Figure 13: Campden BRI Baking Trials

Lucideon UK

A thorough trial was conducted with Lucideon UK, a ceramic testing organisation (formerly known as the British Ceramics Research Association), to test the effect that hydrogen blended gas has on the operation of gas fired kilns and the quality of the products they produce. The trial compared products manufactured in a conventionally fuelled kiln, and a bespoke hydrogen blend fuelled kiln. Key safety aspects reviewed included, strength & durability, slip resistance, reaction to fire, and resistance to chemicals. Alongside these safety critical aspects, aesthetic properties such as shape, colour, and texture were also compared.

Unlike the trial conducted at Campden BRI, the products tested by Lucideon are required to comply with stringent product safety standards in line with the Construction Products Regulations. The trial concluded that all products, from clay pipes, sanitaryware, and wall/floor/roof tiles etc. produced using the hydrogen blend kiln were indistinguishable from those produced in the standard kilns. Crucially, the products produced during the trial also complied with all of the relevant safety standards and regulations.

Unilever

In addition to the product quality and manufacturing trials, Dunphy Combustion were able to set up a bespoke burner for an existing Danstoker Opti boiler for Unilever's Port Sunlight factory. The purpose of the demonstration was to test the efficacy of hydrogen blended gas compared to natural gas when firing the boiler at Unilever's factory. During the trial, all of the operational and regulatory requirements were met without issue. The trial concluded that the boiler met all operational requirements when operating on a hydrogen blend, with no discernible differences to flame picture, flame lift, or ignition timings.

Figure 14: Images of various industrial trials & tests completed under HyDeploy2

Pilkington Glass

Another trial was conducted to verify the safety and efficiency of certain industrial appliances and processes, along with verification of product quality using hydrogen blends. Pilkington glass operated a glass furnace on 100% hydrogen to assess the affects and burner performance, followed by a full 5-day continuous automated trial operating on 15% hydrogen. The trial showed that the effects of hydrogen on product quality and equipment operation are limited and proved that Pilkington Glass were able to manage the existing manufacturing process safely and to the desired product quality.

Overall, the evidence base has proven that the GB gas networks will not require extensive appliance modifications or similar to ensure compatibility with a hydrogen blend.

3.2.5 Public Behaviour

A qualitative review of the Public Behaviour concerns has been undertaken to investigate and understand the changes to public behaviour that may affect, or be affected by, the introduction of a hydrogen blend to the GB gas networks.

The technical and social evidence pertaining to blending hydrogen with natural gas demonstrates that domestic users experience no perceptible difference from a blend when compared to natural gas. Technical performance and subjective interfaces e.g., flame visibility, remain unchanged to the user. This is evidenced by laboratory and desk-based analysis and confirmed by the social science research undertaken for the Keele and Winlaton demonstrations.

Evidence gathered throughout the case studies/ workshops has shown that the theft of blended gas is no more likely than currently exists for natural gas.

3.2.6 Controls

Controls in the gas system are used to reduce or eliminate risks arising from hazards posed by distributing, storing, and using natural gas. These control mechanisms span across multiple areas, which have been grouped and described below. To facilitate a transition from natural gas to hydrogen blended gas it is important to review existing controls for suitability or determine how they would need to be modified to remain suitable.

A logical approach to explain the impacts of blended gas on controls and proposed mitigations is followed in the report through specific sections that sequentially consider:

- Passive system design controls
- Engineering controls of gas parameters
- Human controls for operating and maintaining the system

In order to demonstrate the safety and applicability of the gas network controls, an extensive review of existing literature, standards, and procedures was conducted, along with case studies and workshops.

It was noted that for the future roll out of hydrogen blending across the GB gas networks, GDN procedures will require amending and/or creating. To tackle this, ROSEN, an expert third party contractor was employed to undertake a full review and assessment of an example GDN's processes & procedures. For the purposes of HyDeploy2, NGN's full document suite was assessed.

To achieve this, a Procedures Peer Review Group (PPRG) was established, consisting of representatives from Cadent, NGN, HSE – Science Division, Dave Lander Consulting, DNV UK, and Progressive Energy. This group was specially selected to provide expert opinion and coverage of procedures, from safety and materials to maintenance and training.

The evidence used to answer the proformas fell into two distinct categories; Evidence Based, or SME Expert Opinion. The former category utilised established, or new, published evidence to directly resolve the question(s) being asked. The latter category was employed when either the evidence was incomplete, or not able to directly resolve the question. In this case, workshops were held in which experts from the PPRG would convene to resolve the query.

The assessment was split into 4 stages. The first stage being the identification of 'Gas Facing' procedures, and the detailed page-by-page review of said procedures. This first stage produced a list of approximately 5,000 technical questions across all applicable NGN procedures. Following this, the technical questions were grouped into topics, and then further grouped into specific proformas. This resulted in a number of technical proformas, each with an overarching question and accompanying technical questions for added context. The final act of stage 2 was to allocate these proformas to the correct technical resource.

Stage 3 involved the review of the proforma responses. This included, where necessary, additional workshops to discuss technical evidence and agree on a common outcome. Once all proformas had been completed, Stage 4 involved the creation, reviewing, and issuing of a final Impact Assessment Report.

The resulting Impact Assessment Report has been developed for use across the gas industry upon the implementation of a hydrogen blend, with the aim to provide guidance on where the largest impacts of introducing a blend are likely to occur. The Impact Assessment report has highlighted that there are very few procedures where further work is required, helping provide yet more evidence in favour of adopting a hydrogen blend for the GB gas networks.

3.2.7 Risk Assessment

To effectively demonstrate the effect that hydrogen blended gas has on the safety of the gas networks, both extensive quantitative and qualitative risk assessments have been undertaken.

The risk assessments are a core element of the HyDeploy evidence that forms part of the national safety evidence review, and focuses on three main settings:

- **Domestic settings**

These are essentially residential dwellings occupied by members of the public who are not duty holders in the context of legislation pertaining to the conveyance and utilisation of natural gas.

- **Industrial and Commercial settings**

These are non-residential settings, typically Industrial and Commercial (I&C) users of gas. These settings do have duty holders in the context of legislation pertaining to the conveyance and utilisation of natural gas. In addition, duty holders have responsibility for managing not just health and safety risks, but also other risks, e.g., environmental risk.

- **Network settings**

These settings are located on or near the gas network and are associated with high-pressure pipelines and Above Ground Installations (AGIs) owned and operated by the Gas Distribution Networks (GDNs).

Before conducting the risk assessments, a review of the historical risk of conveyance and utilisation of gas was conducted. This review looked into all of the aforementioned areas and concluded that the domestic setting dominates the overall health and safety risk with approximately 95% of GB annual fatalities. Industrial and Commercial settings make up the remaining 5%, with Network settings equating to approximately 0.1% of annual fatalities.

Using this data, risk assessments were conducted to ascertain the impact to health and safety that the introduction of a hydrogen blended gas may have. The quantitative approach was used where either; the historical risk has been identified as high, the setting is straightforward to define and model, or the dutyholder responsibilities require a quantitative result. Where none of these are the case, the qualitative approach was applied.

For the Domestic setting, a fault tree analysis model was created and verified against the historical data. This model has presented evidence that the overall risk for the Domestic setting is expected to decrease, remaining within the HSE's framework as "Broadly Acceptable", which is the same as natural gas. This is primarily due to the large, expected reduction in fatalities due to CO poisoning.

For the Network settings, a quantitative approach was applied, investigating the expected risks from High Pressure Pipelines. The work revealed that around 99% of the overall risk was due to thermal energy as opposed to the remaining 1% being related to over pressure risk. The thermal energy risk from a high pressure pipeline dissipates much quicker with a blend than with natural gas with increasing distance from the pipeline. Three case studies were conducted, in which the results concluded that the individual risk level remains within the limits of "Broadly Acceptable" as defined in the HSE framework.

For Industrial and Commercial settings, a qualitative approach was employed. This measure was chosen as, due to the large variety of potential Industrial and Commercial layouts, it was not practical to create individual models. Instead, extensive case studies were completed, in which a realistic selection of Industrial and Commercial users was established. As per the DUKES industry sector descriptors , the five case studies cover over 57% of the UK industrial sectors as a % of total UK gas use. These case studies demonstrated that mitigation measures are readily available for sites to implement to ensure that risk is managed to acceptable levels.

3.2.8 Implementation Strategy

The Implementation Strategy report is designed to describe proposals for an approach to the activities required to ensure the safe implementation of a hydrogen blend into the GB natural gas network.

The implementation workstream has considered a logical approach to the proposed steps of implementing and operating a hydrogen blended network. A key piece of work undertaken in this area was the identification of, and proposed engagement levels with, the relevant stakeholders throughout the gas industry. This included highlighting the 'journey' of gas through the gas networks from beach to meter and considering how the identified stakeholders may be affected by the introduction of blended gas, and how they should be engaged with prior to, and during the implementation of hydrogen blended gas. Whilst the identification of physical stakeholders is important, it was also critical to identify the overarching stakeholders, such as legislative and standards bodies, gas shippers/traders, and consumer advice organisations etc.

This mapping exercise resulted in an overarching picture of the gas industry landscape and enabled HyDeploy to propose methods of engagement for these stakeholders (I.e. Local planning engagement, industry events, workshops, localised media engagements etc.). The aim of this workstream is to provide a good understanding of how the implementation of hydrogen blended gas may impact the overall nature of the gas industry landscape, from government legislation and regulation, through to the end users.

The blending roadmap described in figure 15 for the integration of hydrogen blending into the gas distribution networks is a multifaceted process that involves various stages of safety assessment, regulatory review, operational readiness, and market framework adjustments.

The roadmap highlights the need for further work to be undertaken to create a 'Blending Delivery Model' with Government and industry, with the aim of Network-wide roll-out of the model for Networks being "blend ready" by the end of Q4 2026.

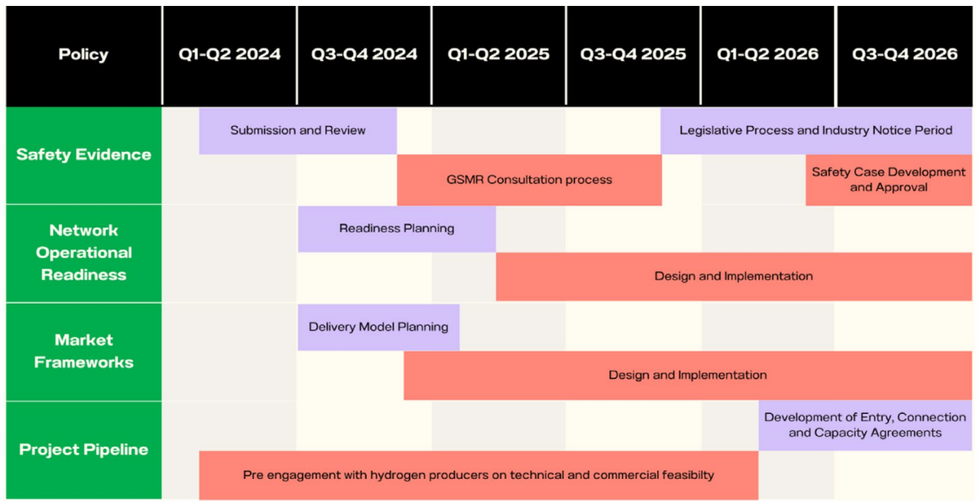

Figure 15: High level delivery roadmap

3.3 Communication & Dissemination

HyDeploy has been consistently engaging with key officials in DESNZ regarding the evidence and benefits of hydrogen blending. In December 2023, DESNZ delivered a strategic decision on blending, following a public consultation with industry.

Hydrogen was at the forefront of discussions across the industry in 2023, due to the vast amount of innovation projects being developed across the full value chain. With discussions focussing on 100% hydrogen and its production, storage and use, blending was able to take a period of consolidation and consideration with regards to the ongoing communications. Nevertheless, HyDeploy continued to engage with stakeholders on its outputs and roadmap through a variety of communication methods. In September 2023, HyDeploy in collaboration with Xoserve, released a podcast which discussed the customer experience of using a hydrogen blend amongst other technical aspects of the project. The podcast episode can be found here: https://podcast.xoserve.com/2047715/13677894.

HyDeploy has effectively communicated and disseminated its key outputs through strategic participation in a variety of conferences tailored to diverse audiences. Notable speaking engagement events include Utility Week Live, The Energy Innovation Summit, IMechE hydrogen conference and the supply chain school virtual conference, where the project described the work done to date to advance hydrogen blending. The project has also been proactively maintaining its online presence by regularly updating the official project website with important information on hydrogen blending. A project summary video was uploaded to the site to highlight the significant milestones achieved to date.

Following the Winlaton exemption, HyDeploy technical reports were uploaded to the Institute of Gas Engineers and Managers (IGEM) online hydrogen knowledge centre to facilitate open collaboration. Feedback from IGEM has shown that some of the most viewed content on the knowledge centre is the HyDeploy reports, not just here in the UK but also across the world. For example, the outputs and learning from the successful domestic demonstrations have also been shared internationally with a presentation delivered to FortisBC, which is British Columbia's gas distribution network and ITALGAS (Italian distribution network) as they prepare to conduct their own blending trials.

Going into 2024, the top priority of HyDeploy was the completion and submission of the projects technical evidence base which can subsequently be disseminated with relevant stakeholders. HyDeploy will once again make all evidence reports available to the public which can then be used to benefit industry projects in the UK and across the globe.

4.0 Policy Engagement

Throughout the project, HyDeploy has been actively engaged in providing support to DESNZ by providing detailed insight into the blending evidence base and offering valuable inputs into the value for money assessment and strategic policy decisions. HyDeploy maintains regular engagements with DESNZ, the Health and Safety Executive (HSE), and Ofgem, facilitating discussions on the hydrogen blending national evidence submission and review process, aimed at enabling regulatory amendments for widespread blending rollout.

The significance of HyDeploy's engagements is highlighted in various government documents, including the recent strategic policy decision, which explicitly references HyDeploy's industry trials, demonstrations, and tests as pivotal components in gathering evidence for safe blending implementation.

The collaboration between HyDeploy and DESNZ represents a crucial element in driving national change towards Net Zero emissions, laying the groundwork for the integration of hydrogen blending into the gas distribution networks and contributing significantly to the development of the hydrogen economy.

5.0 Performance

The HyDeploy2 project has effectively delivered against its deliverables, resulting in the successful completion of the Winlaton demonstration on a public gas network and the generation of a GB wide evidence base in support of hydrogen blending.

5.1 Overall Performance

The HyDeploy2 project sought to prove the technical and regulatory viability of providing a hydrogen blend to a live public gas network. Alongside this, HyDeploy2 also generated an evidence base for hydrogen blending on behalf of the entire GB gas distribution industry. This has been clearly demonstrated in sections 3.1 through 3.3.

The technical evidence base generated to support the safety case application to the HSE, in pursuit of an Exemption to the 0.1 mol% hydrogen limit within Schedule 3 of GSMR (for the purposes of the Winlaton Trial), was successful in:

- Identifying the key technical contributors of risk as a consequence of the conveyance and use of natural gas in Winlaton.
- Developing, adapting, and validating risk assessment tools for use on a public gas network to convey blended gas.
- Generating rigorous comparative safety analysis which covers the Winlaton trial network.
- Managing the ongoing engagement process with the HSE throughout the evidence creation stages and the resulting safety case submission to allow the evidence base to be appropriately reviewed and ultimately accepted by the HSE, as the basis of an Exemption to GSMR Schedule 3 for the purposes of the Winlaton trial.

The wider GB evidence base generated to benefit the gas distribution industry and demonstrate the safety of blended gas for use in the GB gas networks was successful in:

- Employing efficient assessment methodologies to make broad assessments for wider coverage.
- Generating significant data from long-term and intricate materials testing which has provided valuable insight into the durability and performance of various materials under diverse conditions.
- Offering a comprehensive insight into the impact on existing network assets and their operations and understanding how their integrity and functionality is affected by hydrogen blends.
- Implementing cost effective strategies to group, prioritise, and archetype subjects to cover a broader spectrum of the GB network.
- Conducting and expanding on an extensive social science research on public perception and engagement with blended gas. This research spans the public engagement with hydrogen blending and decarbonisation, to investigating and modelling the likelihood of theft of gas.

Research into the risks and benefits of hydrogen blending on a nationwide scale has yielded a substantial evidence base, underscoring both the opportunities and challenges associated with this energy transition strategy. Hydrogen blending, the process of mixing hydrogen with natural gas, has been shown to reduce greenhouse gas emissions, contributing to cleaner energy production and a reduction in carbon footprint. HyDeploy2 has shown that blending hydrogen up to 20 mol% can be safely integrated into existing natural gas infrastructure with minimal modifications, providing a cost-effective pathway toward decarbonisation.

By establishing the technical and safety evidence to demonstrate the feasibility of providing a hydrogen blend for distribution and utilisation, the project has significantly increased the potential for deployment of hydrogen blends within the gas distribution network, further proven by the strategic policy decision made by the UK Government in December 2023. This meaningful progression has demonstrated the viability of hydrogen in playing a critical role in achieving the UK Government's environmental ambitions of Net Zero by 2050 and has shown a pathway to develop a Net Zero compliance gas distribution network.

5.2 Progress Against Bid Plan

The progress of the project against the outlined plan within the bid is set out in the following table:

Table 3: Progress against bid plan

Project Element	Progress
1. Evidence for Wider Roll-out – Materials & Assets	As described in section 3.2 of this report, the materials and assets effort has proven a huge success. Extensive evidence was gathered for the safety case evidence for the trial in Winlaton, building on the data gathered for HyDeploy1, resulting in a successful exemption to the GSMR. Extensive further work was then conducted, covering long term tests, assets on higher pressure networks and wider end user applications beyond the domestic setting. This has established the safe use of existing assets and materials of the existing gas networks and end user applications for use with blended hydrogen.
2. Evidence for Wider Roll Out - Domestic Appliances	Building on the HyDeploy1 project, HyDeploy2 has gathered significant evidence for the safe use of domestic appliance with blended gas. Thorough assessments and laboratory tests were conducted on varying appliance types, resulting in the classification of burner types for domestic appliances. This classification allowed the testing to focus on core burner types, leading to evidence that is applicable to the whole of GB. This evidence has been put into practice during the Winlaton trial, which showed no appliance faults or failures due to blended gas.
3. Evidence for Wider Roll-Out - Gas Characteristics	Extensive work has been conducted throughout the HyDeploy2 project to define and determine the changes introduced to gas characteristics by the addition of hydrogen and the impact of any changes on existing controls such as operational procedures. Physical testing, case studies, workshops and data models have all been conducted and demonstrated that the alterations to gas characteristics introduced with a hydrogen blend are manageable within the existing safety mechanisms.
4. Evidence for Wider Roll-Out - Industrial & Commercial Gas Users	The HyDeploy2 project has put great emphasis on the generation of evidence for I&C users. The work has evolved from physical trials to fundamental analysis of the hazards associated with distributing and utilising a hydrogen blend within the divers I&C settings across GB. Key physical trials included: • Unilever – 7 MW Steam Boiler • Pilkington Glass – 55MW Furnace • Lucideon – Manufacturing of Ceramics • Campden BRI – Food Research The trials proved to be a huge success, with no concerns raised around end product quality or operation of the assets with a hydrogen blend. In addition to this, desktop studies have been conducted to assess the impact of hydrogen blends on industrial and commercial end users such as gas turbines, gas compressors, and reciprocating gas engines. Similarly providing confidence in the ability to transition safely to hydrogen blends. A wider review of applicable regulations, codes and standards was conducted to determine the impact from hydrogen blending and understand common hazard assessment areas. This culminated into a overarching hazards matrix which allows a visualisation of the impacts following a transition to hydrogen blends. To accompany the identification assessments and provide a clear and robust method to review real life impacts, a set of case studies were commissioned in partnership with large industrial sites. The host sites were selected to maximise coverage of different equipment types found across the I&C sector.
5. Evidence for Wider Roll-Out - Procedures	To understand the impact that introducing a hydrogen blend will have on a GDN's procedures, ROSEN conducted a full page-by-page review of a presentative suite of GDN procedures. This process was designed to highlight where changes to procedures, training, equipment, and typographic/ terminologies would be required. The aim of this process is to provide the reader with an understanding of how a hydrogen blend may impact their procedures (Maintenance, welding, training etc.). Following the page-by-page review, numerous technical questions were raised. These questions were grouped into categories based on their technical area (I.e. maintenance, welding etc.) and an overarching question applied in the form of a pro forma. The PPRG was formed, consisting of technical experts from HyDeploy2, to review and answer these pro formas using either technical evidence, or expert engineering judgement. Where engineering judgement was used, a peer review was conducted to ensure alignment. The pro formas were scored based on the likely impact that hydrogen blending may have on the procedures in question and written up in animpact assessment report.

5.2 Progress Against Bid Plan (continued)

Project Element	Progress
6. Extension of Evidence Base Required for Wider Deployment	The culmination of elements 1-5 above have resulted in an extensive evidence base that has proven the safety, feasibility and practicability of hydrogen blending. This evidence base has been submitted to the HSE for review and further consideration by DESNZ.
7. Generic Site Activities	Following the accepted material change request, only one exemption-based network trial was undertaken as part of the HyDeploy2 project. Therefore, please see section 9 and 10 of this table.
8. Local Engagement & Evidence Gathering	HyDeploy2 has once again proven the importance of consumer engagement, especially engagement pre-implementation of a blend. Whilst the reception of hydrogen was mostly positive, some residents had concerns and queries that were addressed through local engagement. An extensive social science programme was conducted as part of the HyDeploy2 project, to understand the public perception of, and reaction to, hydrogen blending. Prior to the Winlaton trial, door-to-door surveys and interviews were conducted to gauge residents prior understanding and reception to hydrogen blending. This method resulted in a good rate of response, and a positive outlook from 66% of residents. During and after the trial, the same door-to-door survey and interview approach was employed and revealed that residents had an increased positive approach to HyDeploy and hydrogen blending, with many specifically stating that they noticed no difference to their gas supply. This coupled with the laboratory testing demonstrating that there is no perceivable change to flame visibility for appliances operating on blended gas, shows that there are numerous advantageous points to highlight when communicating the benefits of blending to the public. This approach has helped highlight the importance of prior public engagement for future blending activities.
9. Develop & Submit Site Specific Exemption	A decision was made in 2021 to the change the project direction for HyDeploy2 from development of a second trial to creation of a GB wide evidence base. There have been ongoing discussions between HyDeploy, DESNZ and the HSE to understand the process by which blending at scale can be implemented e.g., by an exemption process or a more fundamental change to regulations. This project will not be applying for another exemption, the process to allow blending at scale following any review of evidence provided by HyDeploy for the GB gas distribution system will be determined by the HSE and DESNZ following submission of the final evidence base.
10. Site Preparation, Installation & Commissioning	The Winlaton Trial site was successfully prepared, installed, and commissioned in August 2021. The hydrogen supply system comprised of a road trailer unloading and static hydrogen storage facility designed, constructed, and installed in accordance with industry standards. To ensure safe mixing of the natural gas and hydrogen, a HBGEU was installed. The equipment completed fabrication and was initially factory acceptance tested using inert gases at a Thyson Ltd facility. This was followed by a site acceptance test at NGN's Low Thornley site, the HBGEU was situated in the Low Thornley compound
11. Live Trial	On August 4th 2021, Winlaton, Gateshead became the first community to receive hydrogen blended gas via the existing natural gas network. This was the first time in the UK's history that a publicly operated network transported hydrogen blended gas to customers to use within their existing natural gas appliances. This trial was completed in 2022, with any evidence generated to be used in support of the national safety evidence submission to the HSE.
12. Site Reinstatement and Engagement Close Out	This was completed in 2022, with any evidence generated to be used in support of the national safety evidence submission to the HSE.
13. Network Models for Deployment	The evidence gathered on networks within HyDeploy spans the entirety of the GB gas distribution supply and therefore this is now considered the model for deployment. Following a comprehensive review of the HyDeploy evidence, the HSE will communicate their findings to DESNZ to inform the next decision stage. DESNZ, based on the safety review outputs and economic impact assessments, will decide on wide scale roll-out of hydrogen blends. Models for deployment extend beyond the evidence base and will involve engagement with hydrogen producers to evaluate connection requirements, geographical locations, and their associated timelines for integration into the gas distribution system. HyDeploy has maintained communication with relevant bodies to inform implementation planning.
14. Regulatory & Commercial Basis for Deployment	The strategic decision for blending made in December 2023, alluded to the need for a review of safety evidence prior to any change in regulation. It stated, "Government intends to review this evidence before any steps to implement blending, such as amendments to the Gas Safety (Management) Regulations 1996 (GS(M)R), are made". The project aims to submit all safety evidence concerning the proposed change in gas for the existing gas distribution system. Any proposed change to the current limit of 0.1%Vol Hydrogen will need to be reviewed by the HSE. To ensure blending at scale can be rolled out efficiently and swiftly, the government has indicated in the same document that "blending should be implemented in a way that is of least cost and change to current gas system arrangements". The HyDeploy project has been working closely with government and industry to provide input into the review of the commercial regulation, codes, agreements, and licences. The design of any formal changes will be done outside of the HyDeploy project.

5.2 Progress Against Bid Plan (continued)

Project Element	Progress
15. Skills & Training	Initial work was done during the preparation for the Winlaton trial to understand the changes to the skills and competence required to manage a blended gas network and subsequently the impact to training. This was successfully implemented, and operatives were trained to manage the Winlaton trial through updated procedures, equipment and training plans. Building on this work, HyDeploy2 as reviewed all relevant network procedures and associated work activities to understand the required changes to current practices. Across the various system participants which include gas networks, domestic, and I&C there is unique operational nuances in each of the lifecycle stages, however the fundamental principles remain consistent. By leveraging established frameworks which have been designed for natural gas, organisations can start to effectively gauge the sufficiency of current competencies based on existing work activities, in addressing the hydrogen specific changes
16. Communication & Dissemination	In 2021, the UK government published its first Hydrogen Strategy and 2023 was identified as when a key decision on hydrogen blending would be made. HyDeploy has been consistently engaging with key officials in DESNZ regarding the evidence and benefits of hydrogen blending. In December 2023, DESNZ delivered a strategic decision on blending, following a public consultation with industry. Hydrogen was at the forefront of discussions across the industry in 2023, due to the vast amount of innovation projects being developed across the full value chain. With discussions focussing on 100% hydrogen and its production, storage and use, blending was able to take a period of consolidation and consideration with regards to the ongoing communications. Nevertheless, HyDeploy continued to engage with stakeholders on its outputs and roadmap through a variety of communication methods. In September 2023, HyDeploy in collaboration with Xoserve, released a podcast which discussed the customer experience of using a hydrogen blend amongst other technical aspects of the project. The podcast episode can be found here: https://podcast.xoserve.com/2047715/13677894 HyDeploy has effectively communicated and disseminated its key outputs through strategic participation in a variety of conferences tailored to diverse audiences. Notable speaking engagement events include Utility Week Live. The Energy Innovation Summit, IMechE hydrogen conference and the supply chain school virtual conference, where the project described the work done to date to advance hydrogen blending. The project has also been proactively maintaining its online presence by regularly updating the official project website with important information on hydrogen blending. A project summary video was uploaded to the site to highlight the significant milestones achieved to date.
17. Project Management	Effective project management is necessary to deliver a project with six partners and multiple work streams. The governance structure is provided by the steering group which meets quarterly. A well-managed system of monthly project meetings with associated project and budget reporting has been in place, and a comprehensive project risk register being used to manage the project. Subsidiary working groups monitor and progress individual work streams. Overall, effective project management has led to the successfully delivery of the HyDeploy2 project.

5.3 Performance Against SDRCs

The performance of the project partners against each of the Successful Delivery Reward Criteria (SDRCs) is set out in the following table:

Table 4: Progress against SDRCs

SDRC	Title	Target Date	Description & Evidence
1	Customer Engagement Plan	31/10/2019	A full and comprehensive customer engagement plan was developed and submitted for HyDeploy2. This plan took key learning from the plan developed for HyDeploy1 at Keele University. The plan focussed on engagement with stakeholders and customers. A number of key resources informed the development including market research work by Cadent relating to energy and the role of gas, academic work undertaken at Newcastle University, relating to hydrogen perceptions as well as the trial demographics and social science work by Keele University. The plan was successfully delivered on time and met the required scope.
2	Evidence base for first trial	30/06/2020	A scientific project provided the technical foundation of the evidence presented to the HSE in support of the Exemption application. The evidence base to support an application for an Exemption to GS(M)R consisted of nine topic areas. These were required to support the arguments to suffice the hypothesis that blending 20 % H2 into the Winlaton trial network is as safe as the current operations of natural gas transportation and utilisation. Some of the key areas were; Quantitative Risk Assessment, Appliances, Gas Characteristics, Materials and procedures and trial management and installation. The evidence was successfully delivered through a series of technical reports (which are now publicly available) provided to the HSE and were on time and met the required scope.

5.3 Performance Against SDRCs (continued)

SDRC	Title	Target Date	Description & Evidence
3	First Exemption submission	31/09/2020	The first pack of reports was sent to the HSE on 1st June 2020, including the Main Exemption document. The final set of reports was submitted to the HM Inspector of the Health and Safety for the project on 10th August 2020, thus completing the full submission. This evidence was validated through the receipt of an exemption certificate to GSMR, issued to HyDeploy. All evidence was deemed to provide sufficient justification to prove the safe use and distribution of blended gas within the trial area. Additional complexities during the time of the exemption were experienced due to COVID-19 however the project managed to successfully navigate through, and the exemption deliverable was completed on time and met the required scope.
4	First trial commencement	31/01/2021	The consortium successfully secured an exemption from the HSE to inject up to 20mol% hydrogen into the Winlaton trial network for a duration of 11 months. The Winlaton hydrogen blending compound site activity was performed in parallel to generating the scientific evidence to secure the exemption. Therefore, once the exemption was granted by the HSE, the team were able to inform all the appropriate stakeholders (residents, local authority and the HSE) and commence injection on 4th August 2021. The HSE were informed of the commencement and although it was delivered later than anticipated (primarily due to COVID-19) the project met the required scope of the deliverable.
5	Evidence base for second trial	31/03/2022	The HyDeploy demonstrations at Keele and Winlaton focussed on the low and medium pressure tiers of the gas distribution network and predominantly served domestic appliances. The remainder of the HyDeploy 2 project shifted focus to generate evidence to demonstrate the suitability of using hydrogen blended gas in the fields of industrial and commercial users and the performance of materials, assets and procedures on the higher pressure tiers. The generated evidence has been used to support an overarching risk assessment of rolling out hydrogen blended gas networks across the GB gas distribution network. This will be achieved by submitting the evidence to the UK Health and Safety Executive for the national safety evidence review, which if successful should enable the DESNZ to kickstart the regulatory process of embodying hydrogen blending into GSMR. This evidence is provided in more detail within section 3.2 of this report and the deliverable was provided on time and within scope.
6	First trial completion and interim roadmap	31/12/2021	The 11-month trial in Winlaton showed that pipework and component materials performed well throughout the demonstration, with no increase in component failure frequencies when compared to the historical performance of the Winlaton network on natural gas. Operational issues were dealt with by NGN using, mostly, business-as-usual operations and in some cases appropriately amended hydrogen blend procedures, predominantly the use of a new gas detector (available within the current market). Through extensive research into customer perceptions, pre, during and post-trial, HyDeploy found that overall residents were found to be positively engaged and receptive to the trial, with a high degree of local support. Overall the trial was completed successfully and further detail of this is provided within section 3.1 of this report. The interim roadmap investigated four key areas to build the understanding of wide scale roll out. These areas were: • Network model for deployment • Regulatory basis for deployment & commercial requirements • Engagement with DESNZ • Skills/training experience gained during the trials A report detailing the trial completion and roadmap were successfully issued on time and within scope.

5.3 Performance Against SDRCs (continued)

SDRC	Title	Target Date	Description & Evidence
7	Initiation of National Evidence Submission	31/03/2024	Following extensive engagement with the HSE, the initiation of the evidence submission process commenced on the 29th of February 2024. Receipt of this was provided to Ofgem. The deliverable was delivered on time and within scope.
8	Evidence dissemination roadmap	31/03/2024	As part of HyDeploy's review into the safe use and conveyance of hydrogen blended gas, it is critical that it is understood how the introduction of hydrogen blended gas could affect the populus, industry and regulation of GB. HyDeploy produced a report to detail the actions to identify key stakeholders and describe the depth to which they may be impacted by the introduction of hydrogen blended gas in the GB gas networks. The key aim of the report was to identify the various stakeholder groups affected by the introduction of blended gas and outline how they will be engaged and informed. To ensure effective dissemination of hydrogen blending evidence and foster stakeholder engagement, a structured and actionable strategy was developed. This strategy outlined specific engagement activities and events aimed at reaching diverse stakeholders and facilitating knowledge exchange. The strategy incorporated a variety of dissemination methods tailored to address the needs and interests of key stakeholders. This deliverable was successfully issued to Ofgem on time and within scope.
9	National Evidence Submission Overview	31/03/2024	The evidence for this deliverable takes the form of a project report outlining the scope of submission, evidence criteria, and submission structure for the full output of HyDeploy2 to facilitate a Hydrogen Blending, National Safety Evidence Review by the HSE. Firstly, the report provided detail on the background to the Evidence Submission in the context of UK Government Policy on Hydrogen Blending, resulting in the necessary specific objectives for the submission, and the required scope for it to cover. Building on that context, it outlined the Evidence Criteria for HSE assessment of the HyDeploy evidence (see Section 3.2), based on those originally developed for 100% Hydrogen policy projects and re-interpreted by HyDeploy for Hydrogen Blending. The report then described the two-layered structure of the Evidence Submission, comprising Main Reports and Technical Reports (see Section 12.1), to help the reader navigate the evidence. This report was delivered on time and within scope.
10	Completion of wider network evidence base, roadmap & dissemination	31/03/2024	This deliverable was completed through the submission of a report which provided insight into the evidence base for industrial users transitioning over to a hydrogen blend. Additionally, it outlined a high-level roadmap for wide scale roll out Evidence was compiled to demonstrate the safe impacts on existing end users' installations and appliances. When considering adding hydrogen to natural gas it is necessary to assess the potential safety implications of operating appliances on hydrogen blend. However, due to the large number of different applications it is impossible to assess each application individually. Therefore, the HyDeploy2 project has conducted a gas user identification and categorisation exercise to categorise I&C appliances into technologically distinct and representative equipment groups. This has allowed general assessments and trials to be conducted for the groups and the findings applied more widely. In addition to the I&C evidence, the report provided further insight into the four areas discussed within the interim roadmap. The are described below. **Network model for deployment** DESNZ have described the technical delivery model by which blending should be enabled and this is labelled as the free market approach. This reflects the existing connection model into the gas networks and under this approach, blending would occur where hydrogen producers apply to connect at any location and pressure tier. This does however remain subject to network capacity. **Regulatory basis for deployment & commercial requirements** There are two secondary pieces of legislation that require consideration for deployment of hydrogen blending. The first is the Gas Safety (Management) Regulations, which is safety legislation containing allowable gas quality parameters. The second is the Gas Calculation of Thermal Energy Regulations, which governs the commercial basis of how consumers are billed. **Engagement with DESNZ** e significance of HyDeploy's engagements is highlighted in various government documents, including the recent strategic policy decision, which explicitly references HyDeploy's industry trials, demonstrations, and tests as pivotal components in gathering evidence for safe blending implementation.

5.3 Performance Against SDRCs (continued)

SDRC	Title	Target Date	Description & Evidence
10	Completion of wider network evidence base, roadmap & dissemination	31/03/2024	**Skills/training experience gained during the trials** Drawing from the HyDeploy experience gained through the Keele and Winlaton trials, it has become evident that while the fundamental competencies held by gas engineers remain unchanged, there is a pressing need to focus on upskilling and providing training for new tools, equipment, and processes associated with blending. Finally, the report shed light on the extensive communications work conducted by HyDeploy to disseminate the evidence and key project activities. HyDeploy has taken a multifaceted, layered communications and engagement approach since project inception. HyDeploy 2 project was incepted in 2019, during this time a vast evidence base has been built comprising of a series of successful trials in which communication and engagement has played a central role. This deliverable was completed on time and within scope.

6.0 Modifications to the Planned Approach to the Project

The project has delivered against the original planned approach, however inevitable modifications took place over the course of the project in response to external events, new information and evidence generated.

The depth of evidence required for the initial exemption obtained for HyDeploy1 required expanding on for application on a public gas network. This has never been done before and no precedents existed for the depth and breadth of evidence that was required.

A key modification to the HyDeploy2 approach was the decision to keep the hydrogen electrolyser installed at the Keele University site. This decision was made to not risk damaging the electrolyser and delaying the project. Rather than building a new electrolyser for the Winlaton demonstration, the decision was made to use carbon dioxide emissions off-set bottled hydrogen as the source for blending.

This decision, whilst a deviation from the original plan, did not impact the outcome or desired intentions of the HyDeploy2 project. The second trial was designed to demonstrate the implementation of hydrogen blending on a larger scale as opposed to proving the concept, which was achieved at Keele. The source of the hydrogen was not a primary objective. This modification also provided a key benefit of not relying on a single source of hydrogen from an electrolyser, however it was susceptible to market demand.

One of the other key modifications which took place on the HyDeploy2 project was the shift from conducting a second public demonstration to focussing time, resource and budget on developing the evidence for GB roll out. The reason for the change was due to the accelerated progress made to date during the HyDeploy1 Keele trial and HyDeploy2 Winlaton trial regarding the evidence base to justify the use of hydrogen blends within domestic homes. The position which was submitted to the HSE to support the Winlaton safety case provided a generic case for deployment for domestic use that is not contingent upon appliance checks or prior knowledge of the appliance population. This was a significant achievement and one which was originally envisaged to have only been achieved following the second Exemption process within HyDeploy2. This was agreed with Ofgem via a Material Change to the HyDeploy2 Project Direction on 27th July 2021.

Hydrogen is becoming more widely recognised as a credible solution to help decarbonise the energy sector in domestic, commercial, and industrial settings. This has led to an increase in hydrogen energy related projects across the supply chain from production and transportation, through to storage and end-use. This increase of research and innovation in the field, although positive for the hydrogen economy, had resulted in resourcing challenges.

The use of hydrogen as a credible low carbon alternative to natural gas is still in its infancy from an operational perspective, and therefore there is a scarcity of subject matter experts in this field, this is further compounded by the rise in demand for these scarce resources. This has led some of the HyDeploy research to be conducted overseas by making use of the consortium's international networks and contacts. This has also meant that a larger number of contractor organisations were procured to be able to 'divide and conquer' the breadth of investigations that was necessary, and although this introduced project management risk, quite helpfully, it provided broader peer review of the evidence generated and hence increasing the credibility of the conclusions that are being reached. Simultaneously, there has been a large draw on the HSE's time and resource, given the rise in hydrogen research projects developing safety evidence. This has seen a step change in how the HSE have organised themselves to receive evidence for review, this has differed to previous experiences for HyDeploy when applying for exemptions to GS(M)R via safety case submissions. This has meant the project has had to adapt to the way evidence is reported, submitted, and reviewed.

7.0 Financial Performance

The complex and extensive scientific project associated with both the exemption submission and the creation of the GB safety evidence base required a greater level of effort than originally anticipated. Some rebalancing of the scientific effort across the project enabled this to be addressed. Despite some elements of the project costing more than originally anticipated, HyDeploy has worked collaboratively with other hydrogen projects, ensuring that the project has been operated within budget whilst also producing the highest quality outputs.

The total budget of HyDeploy2 was £14,969,000, consisting of £13,472,000 grant funding via the Ofgem Network Innovation Competition (NIC), and £1,497,000 collective contributions from both NGN and Cadent. The project has been delivered within the allowable time limits and budget constraints. Table 5 below illustrates the planned spend vs the actual spend %.

Table 5: Financial performance

Project Element	Total Spend (%)	Total Budget (%)
Evidence for Wider Roll-Out - Materials	12.0	6.2
Evidence for Wider Roll-Out – Appliances	6.6	3.3
Evidence for Wider Roll-Out – Gas Characteristics	14.5	10.0
Evidence for Wider Roll-Out – Gas Detection	0.4	1.4
Evidence for Wider Roll-Out – Procedures	3.5	1.9
Extension of the evidence base for GB	20.0	15.0
General activities applicable to all sites	7.6	6.7
Local engagement & evidence gathering	2.0	9.5
Develop & submit site exemption	4.2	5.0
Site preparation, installation & commissioning	14.4	15.2
Live trial	1.5	12.0
Site reinstatement & engagement close out	0.2	1.1
Network models for deployment	0.1	0.2
Regulatory and commercial basis for deployment	0.3	1.3
Skills & training	0.1	0.5
Communication & dissemination	0.5	2.0
Project management	12.0	8.6
Total	**100%**	**100%**

8.0 Business Case

Under the Climate Change Act, as modified in 2019, the UK is committed to achieving Net Zero emissions by 2050. This requires decarbonisation of all aspects of the energy sector. The 2021 Hydrogen Strategy built upon the recommendations from the Committee on Climate Change (CCC) in its Net Zero report.

The UK Hydrogen Strategy is clear that 'developing a thriving low carbon hydrogen sector in the UK is a key plank of the government's plan to build back better with a cleaner, greener energy system'. It also notes that 'low carbon hydrogen has a critical role to play in our transition to net zero.' The strategy sets out the roadmap to deliver the ambition of 5 GW of production capacity by 2030, which was subsequently increased by the UK Energy Security Bill to 10 GW.

In December 2023, Government issued its Hydrogen Strategy Update to the Market . This outlined the progress that has been made across the entire hydrogen sector since 2021. It noted Chris Skidmore's Independent Review of Net Zero and the crucial role hydrogen will play in terms of energy security, economic growth, and net zero, as did the UK's Hydrogen Champion report. The 2023 Committee on Climate Change report, delivering a reliable decarbonised Power System is clear that hydrogen has an important role in balancing a low carbon electricity grid, providing a fuel for low carbon dispatchable power generation.

The Energy Act 2023 provides the basis for a cleaner, more affordable, and more secure energy system, with key legislative powers to unlock hydrogen production and infrastructure. In September 2023 the UK and Germany signed an agreement to accelerate the development of an international hydrogen industry. The Update to the Market provided a revised Hydrogen Economy Roadmap underpinning developments and laid out the substantial progress that has been made in announcing the support of 11 electrolytic hydrogen projects. Meanwhile two large scale CCUS-enabled projects are progressing through to financial investment decisions in 2024 under the Track 1 Cluster Sequencing process.

The business case for blending itself has taken a significant step forward over this period, predominantly as part of the process Government committed to in its Hydrogen strategy, which was a strategic decision on blending 2023. The team has been closely engaged with Government, the HSE, Ofgem as well as wider stakeholders over the last year, supporting this process. Through the Blending Strategic Decision , released on 14th December 2023, Government determined that it saw strategic and economic value in blending up to 20% hydrogen by volume into the GB network. This is rightly subject to the review of the evidence developed regarding the safe use of hydrogen as a blend in the GB network, explicitly highlighting the work being undertaken by HyDeploy, as discussed further below.

[3]www.assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf
[2]Net Zero - The UK's contribution to stopping global warming, CCC May 2019
[3]https://assets.publishing.service.gov.uk/media/65841578ed3c3400133bfcf7/hydrogen-strategy-update-to-market-december-2023.pdf
[4]https://assets.publishing.service.gov.uk/media/63c0299ee90e0771c128965b/mission-zero-independent-review.pdf
[5]https://www.theccc.org.uk/publication/delivering-a-reliable-decarbonised-power-system/

The key strategic benefits for hydrogen blending identified include:

Unlocking early rapid build out of hydrogen production by providing offtake resilience. Developing a nascent market for hydrogen production is challenging. Blending provides an opportunity for investors in production to underpin offtake, particularly in the early stages of the market. This is strongly recognised as a benefit in the strategic decision.

In the absence of early large scale hydrogen transport and storage infrastructure, blending acts as a strategic enabler, particularly for electrolytic producers. The CCC has been clear about the role it sees for hydrogen in supporting the electricity network, and this early enabling step expedites this process, noting the 2035 target for a decarbonised electricity grid.

It is recognised that this is a transitional, but important role. Each MWh of natural gas that is displaced today avoids emissions of around 200kg of carbon dioxide at the point of use, with the New Low Carbon Hydrogen Standard ensuring that only low carbon hydrogen is supported and delivered. Ultimately it is important that the sectors of the energy system where hydrogen offers greatest strategic benefits are prioritised. Therefore, Government is keen that blending does not crowd these out, but it has recognised that blending plays an important role on that journey. This is reflected by the appetite of hydrogen producers to engage with blending as part of their development plans. It is also worth noting that in other countries, there is a view that blending hydrogen into the gas grid is simply the equivalent of putting renewable electricity into the electricity grid, so that buyers should be able to contract across the grid with appropriate certificates.

Next steps toward commercialisation

As part of the Strategic Policy Decision, Government announced that it would review the safety evidence, working closely with the Health and Safety Executive to ensure that it is assessed independently and robustly. This is aligned with the expectation of the HyDeploy team, noting this is a wider process than originally anticipated at the start of the HyDeploy project which was focused on local Exemptions rather than building and reviewing a national evidence base. This is helpful in accelerating the journey to implementation and provides a framework for review which combines both the Government and the HSE.

Subject to the outcome of this review alongside finalising the economic assessment, then Government would look to undertake a legislative process. Its view is that enabling blending at scale requires amendments to legislation, including GSMR. Note that in the event that the evidence was not to support a wider change to the Regulations, then projects may still be able to apply for regulatory Exemptions.

The primary mechanism to support blending is anticipated to be using the Hydrogen Production Business Model. This does require modifications to that Model, but these were contemplated at the point of its development, and so the framework should be able to accommodate it.

The anticipated technical delivery model is to mimic the existing arrangements for connections to the gas network, letting the market decide where to inject the hydrogen, with the GDNs managing connections and network entry to monitor blend levels to ensure limits are not breached. In terms of billing, Government intends to work within existing gas billing framework as laid out by the Future Billing Methodology Project. Significant amounts of hydrogen blending could be achieved under this approach, and this is viewed as the lowest cost and quickest to implement option for hydrogen blending.

The very substantial progress that has been made in the UK with regard to delivery of the wider Hydrogen Economy, combined with the specific interventions and policy decisions with regard to blending, provides a sound basis for the outcomes of the HyDeploy project to be implemented commercially. The extensive technical work undertaken by HyDeploy has allowed government to focus on the strategic and economic case, knowing that the project will provide the safety evidence for it to review alongside the HSE, on a national basis.

[6]https://assets.publishing.service.gov.uk/media/657a0a82254aaa0010050cde/hydrogen-blending-strategic-policy-decision.pdf

9.0 Lessons Learnt for Future Innovation Projects

Consumer engagement is key. The social science work conducted throughout the Winlaton trial highlighted that whilst the majority of consumers were positive at the news of the blending trial, some had queries and concerns that required addressing. Addressing these concerns helped the consumers feel more at ease with the trial and they welcomed their participation. Keeping the trial participants updated with the progress of the trial, and crucially conducting pre, during and post-trial interviews and surveys helped the HyDeploy project understand the social impact of hydrogen blending on the public.

Planning and awareness of the global hydrogen landscape. The vast and thorough scope of the testing conducted during the creation of the hydrogen blending evidence base required a huge amount of the existing hydrogen testing resources available in the UK. Following on from the continued decarbonisation agenda put forward by many governments across the globe, such test facilities and experts were in high demand. This resulted in the project liaising with companies and laboratories overseas to meet project targets. This demonstrates the importance of understanding the changing landscape, and keeping afront of these changes so the project can continue to quickly adapt to any shortcomings.

Expect the unexpected. No one was expecting a global pandemic of COVID-19. The project team tackled resource constraints during the Winlaton evidence review process and the site installation process. Having a team which can adapt to the changing environmental is critical to the success of such projects like this. Ensuring contingency plans and risk registers are in place allow significant and often unexpected changes to be faced head on.

Effective cost & budget management. The extensive depth and breadth of the evidence required for the GB wide safety evidence base, whilst not underestimated, has proven a substantial challenge. With the interest of hydrogen projects increasing over the lifespan of HyDeploy, resourcing and costings have proven increasingly difficult to manage. It was only because the project was extremely carefully managed, with a clear forward project and budget forecasting process, that this could be effectively managed and addressed.

10.0 Project Replication

HyDeploy2 has built upon the work conducted at Keele University to successfully demonstrate that hydrogen blends can be safely distributed and utilised within existing gas networks. The strategic objective of the project was to establish this principle to facilitate the national roll out of hydrogen blends, in aid of kick starting the hydrogen economy. Key evidence reports which contributed to the successful safety demonstration to achieve the HSE exemptions across the Keele and Winlaton trials were submitted to IGEM for uploading within their Hydrogen Knowledge Centre library. This evidence has become a resource which has been drawn on by the wider industry, leading to hundreds of views to date.

The HyDeploy2 public demonstration in Winlaton was enabled directly by the success of the HyDeploy1 demonstration at Keele University. This public trial was the natural next step in the blending journey. Following on from the public demonstration, the blending evidence base has been designed to apply all of the evidence, practices, and lessons learned to the whole of the gas distribution system in GB, thereby unlocking hydrogen blending, and paving the road for future hydrogen projects.

Ultimately if a blended gas was replicated across the distribution network a total of 29 TWh pa of low carbon gas would be unlocked without disruptive changes for consumers. This represents a material contribution to the Net Zero journey and would abate 6 MtCO2 pa, which is the equivalent of removing 2.5 million cars from the roads. It is the strategic intent of the project that the national safety evidence and successful demonstration of live hydrogen blending at Keele and Winlaton acts as a launchpad for wide scale blending to achieve these meaningful carbon savings whilst unlocking a pathway to deeper hydrogen adoption.

The HyDeploy evidence base has been generated on behalf of the whole of the GB gas distribution industry and is therefore currently the largest and most developed source of evidence on safety impacts from blending. This evidence will go through a rigorous review process with the HSE to inform a decision on changing the current hydrogen content limit in GSMR.

Impacted stakeholders will be able to take benefit from the evidence created by this project via access to its reports and planned dissemination events.

11.0 Planned Implementation

The adoption of hydrogen blends across the GB gas distribution network has been shown to be feasible and safe through the evidence gathered, and demonstrations performed via the HyDeploy project. Workshops have been undertaken to understand what the roll out of a hydrogen blend would look like, how it would affect UK consumers, and wider stakeholders involved in the regulation, distribution, and consumption of gas.

Huge process has been made since the previous HyDeploy project with the government's strategic policy decision on hydrogen blending in December of 2023 acknowledging that hydrogen blending will play a key role in decarbonising GB and reaching the Net Zero target of 2050.

Figure 15 of section 3.2.8 describes the proposed further work required for the GB gas networks to be 'Blend Ready' by the end of Q4 2026.

[6]https://assets.publishing.service.gov.uk/media/657a0a82254aaa0010050cde/hydrogen-blending-strategic-policy-decision.pdf

12.0 Dissemination

12.1 Technical Dissemination

The HyDeploy2 project is the final step in providing the HSE and DESNZ with a GB wide evidence base in support of hydrogen blending. Throughout the project, reports and information have been shared across likeminded projects (e.g. H21 & FutureGrid) in cross-collaboration efforts to work as efficiently as possible, primarily due to overlapping work scopes and global hydrogen resourcing issues.

As was the case with the previous HyDeploy reports, all information will be shared using the IGEM Hydrogen Knowledge Centre and continue to be at the forefront of industry conventions and workshops. For the dissemination of the reports themselves, the HyDeploy evidence base takes the form of 8 main evidence reports, and a host of technical reports (Evidence, case studies etc.), which in turn forms the overall evidence submission to the HSE.

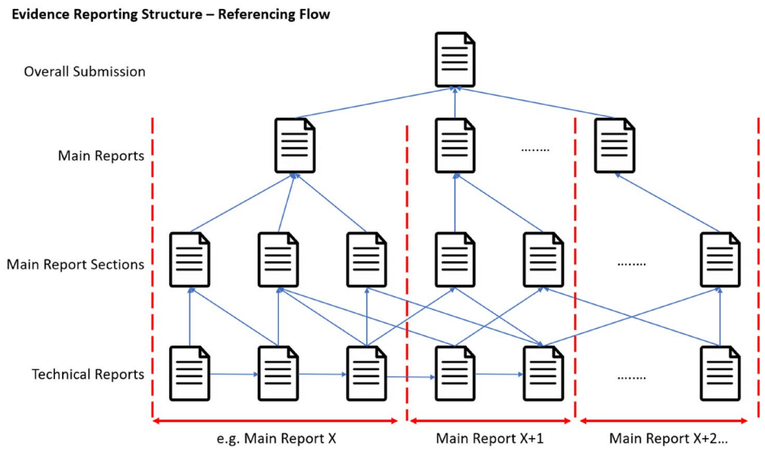

Figure 16: HyDeploy2 evidence reporting structure

12.2 Stakeholders & Dissemination

The HyDeploy2 project has engaged extensively with a wide variety of stakeholders throughout the project. This engagement took the form of one-to-one meetings, conference presentations, webinars, workshops, committee meetings, journal articles, industry articles, interviews, social media, leaflets, letters, and progress reports.

Importantly, the HyDeploy2 project has taken a forward-looking approach with regards to evidence dissemination and communication with stakeholders for the implementation of hydrogen blending. The table below describes the identified stakeholder groups, the extent to which they will be impacted by a hydrogen blend, and the method of which HyDeploy proposes is the best method of communication and dissemination.

Stakeholder Group	Potential Impact Summary	Final Grading	Proposed Engagement Method
1 – Regulation, Certification & Standards Development	Changes to standards/regulations etc. requiring industry-wide collaboration.	Directly Impacted	Presentations via webinars and/or industry events.
2 – Shipping & Trading of Gas	Knowledge/awareness of blending. Potential to trade and transport blended gas.	Directly Impacted	Presentations via webinars and/or industry events.
3 – Gas Supply & Transportation	Group responsible for enacting blending, including managing, and maintaining GB gas network infrastructure.	Directly Impacted	Industry events & 2-day workshop to showcase changes.
4 – Manufacturers & Research	Successful trials have demonstrated safety for appliances; however manufacturers should have key awareness and knowledge of changes to gas characteristics etc. Potential efficiency changes, need to alter future designs to achieve claims etc.	Directly Impacted	Presentations via webinars and/or industry events.
5 – Industrial & Commercial	Current trials have demonstrated no change to product quality; however, industries may want to monitor gas quality to ensure consistency of supply.	Directly Impacted	Presentations via webinars and/or industry events.
6 – Downstream Engineers	Potential change to working practices and limited changes to equipment/ methods applied. Engineers will require knowledge and understanding of blended gas along with awareness of any potential regulations/guideline changes.	Directly Impacted	Presentations via webinars and/or industry events.
7 – Working Indirectly with Gas	No change to operation of work. Some awareness of blended gas should be considered, but no fundamental changes.	Indirectly Impacted	Sharing of evidence & reports via the HyDeploy & IGEM websites.
8 – Domestic End Users /Other	The end user, general public, or other services should notice no changes to their interactions with gas. Appliances and emergency procedures will remain unchanged from this aspect.	No Impact	Sharing of evidence & reports via the HyDeploy & IGEM websites.

Table 6 – Stakeholder Conclusion & Grading

12.3 Example List of Articles & Papers

1. https://academic.oup.com/ce/article/3/2/114/5487479
2. Gas Safe Magazine, May 2019
3. Gas Safe Magazine, July 2020
4. https://www.thechemicalengineer.com/features/heating-with-hydrogen/
5. https://www.bbc.co.uk/news/science-environment-50873047
6. https://markets.ft.com/data/announce/detail?dockey=1323-13855923-0HEV6CMSMJA02OB6UEJBNK3L4G
7. https://www.telegraph.co.uk/business/2018/01/06/hydrogen/
8. https://www.theguardian.com/environment/2020/jan/24/hydrogen-uk-gas-grid-keele-university
9. https://lite.cnn.com/en/article/h_3347a7649050ff96d886c6114ad0cf50
10. https://www.dailymail.co.uk/sciencetech/article-8757923/Cadent-calls-Government-allow-200-times-hydrogen-household-gas.html
11. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/010920-HyDeploy 2-project-could-open-door-to-larger-scale-hydrogen-projects-sources
12. https://registeredgasengineer.co.uk/technical/technical-bulletin-157-co-co2-and-combustion-ratio-checks-using-an-electronic-combustion-gas-analyser-ecga-when-carrying-out-works-on-a-natural-gas-appliance-being-supplied-with-natural-gas-conta/
13. https://www.hvpmag.co.uk/Checking-in-on-the-progress-of-the-HyDeploy 2-project/11819
14. https://www.theengineer.co.uk/HyDeploy 2-keele-hydrogen/
15. https://www.edie.net/news/8/UK-s-first-grid-injected-hydrogen-trials-begin-in-Staffordshire/
16. https://www.energylivenews.com/2020/01/06/uk-first-hydrogen-injected-into-gas-grid-as-landmark-trial-gets-underway/
17. https://fuelcellsworks.com/news/successful-completion-of-the-HyDeploy 2-hydrogen-blend-trial-at-keele-university/
18. https://www.thechemicalengineer.com/news/uk-s-landmark-trial-to-heat-buildings-with-hydrogen-is-fully-operational/
19. https://www.stokesentinel.co.uk/news/local-news/could-future-heating-homes-keele-3700810
20. https://environmentjournal.online/articles/a-green-energy-trial-will-use-hydrogen-to-heat-100-homes-in-staffordshire/
21. https://environment-analyst.com/uk/106389/uk-hydrogen-trials-enter-a-bold-new-era
22. https://renewablesnow.com/news/uk-hydrogen-blended-gas-project-starts-operation-682129/
23. https://www.powerengineeringint.com/world-regions/europe/ground-breaking-7m-hydrogen-project-goes-live-in-uk/
24. https://www.chemistryworld.com/news/uk-project-aims-to-cut-the-cost-of-producing-clean-green-hydrogen/4011788.article
25. https://registeredgasengineer.co.uk/invitation-to-join-hydrogen-webinar/
26. https://www.climateaction.org/news/uks-first-grid-injected-hydrogen-pilot-gets-underway
27. https://www.bloomberg.com/news/articles/2019-04-25/hydrogen-as-a-heating-source-gets-a-boost-in-u-k-from-lawmakers

13.0 Key Documentation

The following project documents are publicly available.

Document	Date of Publication	Description
Full submission	November 2018	Final Network Innovation Competition full submission to Ofgem.
First project progress report	December 2019	First project progress report.
Second project progress report	December 2020	Second project progress report.
Third project progress report	December 2021	Third project progress report.
Winlaton Trial Report	September 2022	Trial completion report
Fourth project progress report	January 2023	Fourth project progress report.
Fifth project progress report	January 2024	Fifth project progress report.

Table 7 – Key documentation

14.0 Contact Details

If you have any questions on the project or would like access to any project documents, please contact:

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HyDeploy

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