HyDeploy2 Project

Gas Network Innovation Competition // Cadent
4th Project Progress Report (PPR) // January 2023

The HyDeploy2 project seeks to address a key issue for UK customers: how to reduce the carbon they emit in heating their homes. The UK has a world class gas grid delivering heat conveniently and safely to over 83% of homes. Emissions can be reduced by lowering the carbon content of gas through blending with hydrogen. This delivers carbon savings, without customers requiring disruptive and expensive changes in their homes. It also provides the platform for deeper carbon savings by enabling wider adoption of hydrogen across the energy system.

This Network Innovation Competition (NIC) funded project seeks to develop the evidence base to allow roll-out of a 20 mol% blend of hydrogen within the UK local distribution network by running trials on the public network.

Before any hydrogen can be blended with natural gas in the network, the percentage of hydrogen to be delivered must be approved by the Health and Safety Executive (HSE). It must be satisfied that the approved blended gas will be as safe to use as natural gas. Such approval is provided as an Exemption to the current hydrogen limit of 0.1 mol% within Schedule 3 of the Gas Safety (Management) Regulations (GS(M)R), 1996. These regulations ensure the safe use and management of gas through the gas network in the UK. Following such approval, hydrogen production and grid injection units are to be operated, and an extensive trial programme undertaken.

Blending hydrogen at 20 mol% with natural gas across the UK, would save around 6 million tonnes of carbon dioxide emissions every year, the equivalent of removing 2.5 million cars from the road.

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1.0 Executive summary

HyDeploy achieved further landmark successes in 2022 with the completion of the UK's first hydrogen blended gas injection into a public gas network and two further industrial based trials.

The village of Winlaton, near Gateshead, hosted 668 domestic properties including a church and a school, where the local existing gas distribution network transported hydrogen blended gas (20% vol hydrogen) for 11 months efficiently encompassing a supportive customer base with diverse appliances and energy suppliers. The trial showed that pipe and component materials performed well throughout the demonstration, with no increase in component failure frequencies when compared to the historical performance of this network on natural gas.

Extensive research has been conducted to consider the customer experience of using blended hydrogen in their homes. The results of this research mirror the findings from the Keele University trial despite the very different demographic of the customers involved.

Operational issues were dealt with by NGN using primarily 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). A full report of the trial has been published on the project website and can be found here: **www.hydeploy.co.uk/events**

The industrial trials undertaken built upon the success of both the Unilever steam boiler trial and Pilkington glass trial conducted in 2021, which demonstrated the ability to operate a range of existing industrial equipment on a hydrogen blend (7 MW steam boiler and 55 MW furnace). The 2022 trials expanded the depth of process coverage through two further trials. Firstly, a ceramics trial (bricks, tiles etc.) undertaken in partnership with Lucideon – the UK's leading ceramics research institution; demonstrating the ability to satisfactorily meet current product quality safety requirements with a hydrogen blend. Secondly, a trial focused on the production of baked goods (biscuits, bread etc.) in partnership with Campden BRI, who are the pre-eminent food research company within the UK; showing no observable difference from the various sensory, static and physical product quality assurance.

Extensive research has been conducted to consider the customer experience of using blended hydrogen in their homes. The results of this research mirror the findings from the Keele University trial despite the very different demographic of the customers involved. As the only UK blending trial, this research has provided a unique insight into how the public might react to a wider rollout of blended hydrogen in the home. The results suggest that the public can be broadly supportive of hydrogen in the home because of the perceived positive environmental implications, albeit not at the expense of the householder. The research demonstrated that initial concerns primarily related to cost and safety, but concerns were reduced over time as consumers became more informed, indicating that careful planning of communications will be important in gaining social acceptance for the roll out of hydrogen/blends.

Concerns of residents were higher upon first learning that they were part of the trial, but tended to reduce over time, often associated with gaining further information formally from the project or informally through peer networks

HyDeploy2 programme has been focussing on addressing the remaining areas and barriers to the role out of hydrogen blended gas networks across the UK. Much progress has been made in the areas of Gas Characteristics, Assets, Materials, Procedures, and Industrial and Commercial users for the above 2 barg distribution networks i.e., intermediate and high-pressure tiers. This evidence is important since being able to blend into different pressure tiers of the distribution network will build resilience and flexibility for customers to receive hydrogen blended gas.

The project continues to develop the necessary evidence in these areas and will enter the reporting phase in 2023 to document the completed safety evidence. The project continues its tripartite engagement with the HSE and BEIS in aid of the prospected BEIS policy decision on hydrogen blended networks and remains flexible in providing the necessary support and information as requested.

Overall, 2022 has been a very successful and productive year for HyDeploy2. The completion of the public trial was a huge success both from an engineering perspective, but also public perception through the social science work, complimented by the successful industrial trials broadening the application of hydrogen blended energy.

Now the project is fully focussed on addressing all remaining evidence gaps to build a comprehensive evidence base to justify the safe transportation and utilisation of hydrogen blended gas across the entire UK gas distribution networks and deliver the research to BEIS to support their projected 2023 policy decision on the technology.

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2.0 Project manager's report

The HyDeploy2 project has had a successful year, completing the UK's first hydrogen blend trial on a public network and completing two further industrial trials.

Key achievements

The key achievement of 2022 has been the successful completion of the Winlaton hydrogen blend trial. Blended hydrogen was first injected into the Winlaton trial network on 4th August 2021 before reverting to natural gas operations on 30th June 2022. The village of Winlaton was chosen as the site for the trial as it offered a high degree of variability with regards to materials on the network, appropriate size of network and statistical representation of housing in the UK. The Winlaton trial network consists of 668 properties comprising a school, church and a mixture of domestic housing and is situated in Blaydon near Gateshead. The network is owned and operated by Northern Gas Networks (NGN) who isolated the Winlaton trial network from the wider gas network and installed a dedicated supply pipe to feed the isolated network with blended gas from NGN's Low Thornley compound. The compound hosted the hydrogen storage and blending equipment and the entire trial operated for 11 months.

The trial showed that pipe and component materials performed well throughout the demonstration, with no increase in component failure frequencies when compared to the historical performance of this 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).

The commencement of the trial initiated the utilisation of the agreed billing process which was designed to ensure no customers on the Winlaton trial network were financially implicated by the hydrogen blended gas by ensuring customers received the hydrogen element of their gas for free.

Stakeholders from NGN's Market Services and Regulatory Compliance team, Xoserve, the Shipper and Supplier community and officials from Ofgem worked together to design, develop and deliver a billing process which enables network trial type activities using non-conventional gas (e.g., blended hydrogen) whilst safeguarding the customers from any detrimental financial implications due to the change of gas. The designed billing methodology was successfully utilised during the trial.

The industrial trials are a key element of the HyDeploy2 programme which will provide the evidence to demonstrate that hydrogen blended gas can be utilised in industrial and commercial sectors. A key achievement during this year was to deliver two further industrial trials, building upon the successful Unilever steam boiler trial and Pilkington glass trial conducted in 2021; which demonstrated the ability to operate a range of existing industrial equipment on a hydrogen blend (7 MW steam boiler and 55 MW furnace respectively). The 2022 trials expanded the depth of process coverage through two further trials which investigated the suitability of using blended hydrogen to manufacture numerous ceramic products from conventional construction materials such as bricks and tiles through to modern advanced ceramic products.

Communications and dissemination

Consumers lie at the heart of the HyDeploy project. The basis of blending hydrogen into the gas network is that it unlocks material quantities of decarbonisation, provides a foundation for deeper carbon savings through hydrogen deployment and achieves these without disrupting consumers. To formally analyse the experience of residents taking part in the trial, and in order to understand how the customer felt throughout the different stages of involvement with the HyDeploy project, from initially hearing about the project through to the end of the blending trial, HyDeploy worked with a team of researchers, who carried out independent research into customer perceptions of hydrogen and their experiences of the HyDeploy project both before the trial commenced and at the end of the blending trial. This builds on similar research carried out linked to the first HyDeploy trial phase at Keele University between 2019 and 2021, where residents were interviewed before and towards the end of the trial.

The Winlaton trial data set comprised 130 survey responses and 11 interviews carried out pre-trial, and 50 survey responses and 9 interviews carried out at the end of the trial.

Most surveys were carried out by a researcher on the doorstep of residents' houses, with some surveys completed independently online using a link in a letter, and others in hard copy using surveys left by the researcher and subsequently posted to the research team using a stamped addressed envelope. The interviews were carried out by telephone or online. Survey responses from the pre-trial phase comprised 49% men, 50% women, and 1% non-binary. Survey responses at the end of the trial comprised 51% men, 49% women.

The sample was skewed towards the older age group with 69% of pre-trial responses and 60% end-of-trial responses over the age of 60. 63% of pre-trial respondents and 66% of end-of-trial respondents were owner occupiers. The results suggest that the public can be broadly supportive of hydrogen in the home because of the perceived positive environmental implications, albeit not at the expense of the householder.

Following the successful completion of the Winlaton Trial in the August 2022, the Winlaton Trial Report was launched at an event held in the House of Lords in the Autumn of 2022. The event comprised of key note speeches from Lord McNicol of West Kilbride and senior members of the leadership teams from Cadent and NGN. The project team shared the progress to date and rounded off with a multidisciplinary panel discussion addressing the challenges and highlighting opportunities that hydrogen blended networks have to offer. The event was well attended by Ofgem and Government officials as well as a local resident from the Winlaton Trial who was able to share their first-hand experience of using hydrogen blended gas within their home.

NGN's Low Thornley site (the location of the hydrogen blend compound and injection units) had opened its gates in 2021 for site visits and continued to host visits throughout 2022. These visits were well attended - seeing several residents from the Winlaton trial network attend as well as wider industry leaders and Government officials.

Towards the end of the previous year (Oct 2021) HyDeploy featured in COP 26 where leaders gathered at Pilkington UK in St Helens, Liverpool City Region, to drive the conversation around hydrogen marking the North West 'stop' on the Decarbonised Glass Alliance's (DGA) Hydrogen Roadshow.

The event brought together HyNet and HyDeploy project team members with industry and local stakeholders to discuss the region's innovative hydrogen activities and development. It was here that the exciting news was announced of HyDeploy/Pilkington's pioneering project using a blend of hydrogen with natural gas in the furnace, running for a full five-day period. The successful demonstration proved that the full furnace could be run safely on the hydrogen blend, without compromising on quality standards or operational performance. Each day during the trial, two tonnes of hydrogen were consumed – which could have provided an equivalent hydrogen blend to approximately 30,000 average-sized homes.

The collective efforts of communication and dissemination enhanced the previously generated momentum for hydrogen blending as a critical step to unlock hydrogen deployment within the UK energy system.

Outlook for next period

Following the successful trial at Winlaton, the HyDeploy2 programme has been focussing on addressing the remaining areas and barriers to the role out of hydrogen blended gas networks across the UK.

Much progress has been made in the areas of Gas Characteristics, Assets, Materials, Procedures, and Industrial and Commercial users for the above 2 barg distribution networks i.e., intermediate and high-pressure tiers. This evidence is important since being able to blend into different pressure tiers of the distribution network will build resilience and flexibility for customers to receive hydrogen blended gas.

The project continues to develop the necessary evidence in these areas and will enter the reporting phase in 2023 to document the completed safety evidence. The project continues its tripartite engagement with the HSE and BEIS in aid of the prospected BEIS policy decision on hydrogen blended networks and remains flexible in providing the necessary support and information as requested.

Key challenges

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 and therefore the demand for hydrogen to be able to conduct research has increased. There was a period of hydrogen scarcity within 2022 which presented a key challenge to maintain operations at Winlaton, but this was addressed through carefully developed supply contracts which ensured blending continued throughout the period of the trial.

The increase in hydrogen research has resulted in a greater draw on the HSE's time to address safety related generated evidence from numerous hydrogen programmes across the UK. This has presented some challenges in being able to share specific details of the programme with the HSE with some uncertainties around future resourcing to be able to review the HyDeploy evidence. This has been the key discussion within the tripartite engagements between HSE, BEIS and the project team. Engagements continue to address the challenge and the project remains flexible in providing the necessary support to aid BEIS' policy decision on hydrogen blended networks.

Overall, it has been a successful year for the project: completing the UK's first trial transporting hydrogen blended gas within a public gas network; increasing knowledge to address gaps for blending hydrogen gas into higher pressure networks, and further demonstrating the compatibility of using hydrogen blends within industrial and commercial processes. Hydrogen blending technology is being recognised as a vital enabling technology for the UK to reach Net-Zero. The successes of the last year are due to a competent, dedicated and engaged project team working collaboratively towards collective goals.

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3.0 Business case update

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 role of hydrogen in achieving this has received increased attention over the last few years. This culminated in the Hydrogen Strategy[1] released during 2021. This built upon the recommendations from the Committee on Climate Change (CCC)[2] in its Net Zero report, as well as the Prime Minister's ***'Ten Point Plan for a Green Industrial Revolution'*** released in Autumn 2020 and subsequent Energy White Paper.

The invasion of Ukraine by Russia in February 2022 has re-defined global energy markets, causing macro inflationary pressures due to its impact on energy prices. This market shock has put into focus the pressing need to move away from fossil fuels, to both decarbonise the energy system and promote energy security. This dual driver has led to an acceleration of the global low-carbon hydrogen market, with major investment packages announced such as the Inflation Reduction Act in the USA and the 3-billion-euro hydrogen bank in the EU.

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.

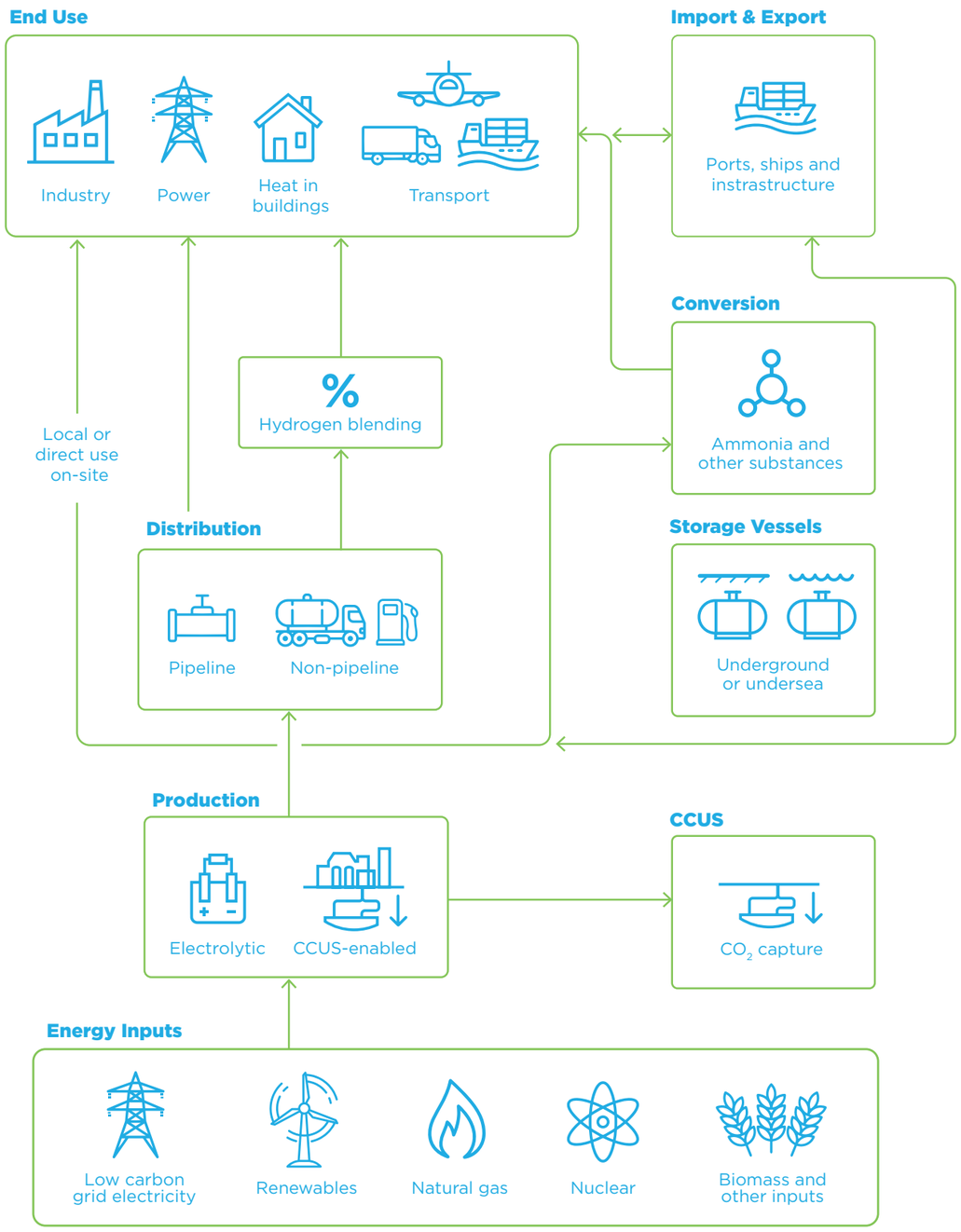
Much activity has been underway over the last 18 months to establish the low-carbon hydrogen market[3], via the sanctioning of support packages (£240 million Net Zero Hydrogen Fund and £26 million Industrial Hydrogen Accelerator) and the Hydrogen Business Model (HBM).

The UK hydrogen strategy recognises that there are a range of applications where hydrogen has a key role, in industry, power, transport and heat in buildings. The importance of blending is identified, as shown in the Strategy's figure on the hydrogen value chain.

As previously announced in the 10 Point Plan, the government has laid out that by the end of 2023 it wishes to work with industry to ***"Complete the testing necessary to allow up to 20% blending of hydrogen into the gas distribution grid for all homes on the gas grid."*** Material progress towards this objective was delivered through 2022, with the completion of the final consumer trial in Winlaton as well as a number of successful industrial trials (glass, ceramics, household products and baked goods). BEIS has been developing a Value for Money (VfM) case to support the policy process, where a position on the system benefits of hydrogen blending was consulted on through the 2022 hydrogen transport and storage business model consultation[4]. It is still anticipated a blending policy decision will be announced in 2023, and the final stage of HyDeploy2 will seek to support BEIS through this policy landing period.

Blending provides the basis to establish and build out hydrogen production capacity, address regulatory hurdles, build the wider hydrogen supply chain and importantly provide an opportunity for customers to become accustomed to hydrogen being part of the energy mix. Over time, building on this platform, it is expected that parts of the gas system could migrate to full hydrogen. This will require resilient hydrogen supplies, the next level of regulatory and operational changes as well as suitable appliances. Programmes such as H21, H100 and Hy4Heat have progressed these network and appliance issues. Manufacturers such as Worcester Bosch and Baxi have both developed ***"hydrogen ready"*** boilers to facilitate that transition, as well as other appliance manufacturers developing hydrogen cookers and fires.

The hydrogen value chain



These have been visibly demonstrated at the Hydrogen Home[5] established by Cadent, BEIS and NGN during 2021. The first in a series of 100% hydrogen trials will be conducted in SGN's network, under the Fife H100 project. The second trial (the hydrogen village) is currently being evaluated by BEIS, where the two candidate locations are Whitby in Cadent's network and Redcar in NGN's network. A decision on the location of the hydrogen village is expected in 2023.

Delivering low carbon heat via gas capitalises on existing network assets cost effectively and means that customers do not require disruptive and expensive changes in their homes. Alternatives such as electrification using heat pumps will also make a material contribution, particularly in sectors where they are most suited such as new build and off-grid homes. Achieving Net Zero will require a mosaic of technologies, all delivered simultaneously in pursuit of a common goal.

Hydrogen blending exploits the existing gas network by reducing the carbon intensity of heat delivered, requiring no changes to appliances and the gas network which provides a non-disruptive solution for customers. It can operate seamlessly with a range of future heat scenarios, and provides a deliverable pathway and early carbon reductions in the built environment.

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.

The HyNet project[6] provides a platform for early roll out of blending into the local distribution zone to decarbonise domestic heat in combination with full hydrogen to industry to deliver deeper decarbonisation. It also provides a platform for flexible hydrogen fuelled power generation to balance intermittent renewables, as well as facilitating complementary zero carbon solutions for transport. The HyNet infrastructure has been deliberately designed to interface with key distribution offtakes from the National Transmission System, allowing early deployment of blending by Cadent. Following the successful selection as a Track-1 cluster in 2021, alongside the East Coast Cluster[7], the first tranche of HyNet's low-carbon hydrogen production (1GW) was shortlisted in 2022 within the CCUS Cluster Sequencing programme along with a number of industrial capture plants. The HyNet cluster will produce initially 9 TWh per annum of low carbon hydrogen production from its first two lines, rising to over 30 TWh by 2030.

Significant progress was made through 2022 to transform the low-carbon hydrogen landscape from strategy to reality. This included development of business models, investment packages and primary legislation (Energy Bill[8]), and all set within a global context of needing to advance low-carbon hydrogen markets to both decarbonise energy supplies and increase energy security. 2023 will prove to be a pivotal year for hydrogen blending, with the completion of the HyDeploy2 programme and the crystallisation of the BEIS policy decision.

[1] 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] www.gov.uk/government/news/government-unveils-investment-for-energy-technologies-of-the-future
[4] www.gov.uk/government/consultations/proposals-for-hydrogen-transport-and-storage-business-models
[5] www.energylivenews.com/2021/07/16/fuel-of-the-future-uks-first-hydrogen-powered-homes-open-to-the-public
[6] www.hynet.co.uk
[7] www.eastcoastcluster.co.uk
[8] www.bills.parliament.uk/bills/3311

4.0 Progress against plan

The project has proceeded well against the original plan up to the commencement of the Winlaton trial, after which the change in Project Direction has led to the development of an updated project plan with progress against each programme elements summarised below.

Much of the effort and resource used this year was focussed on the HSE challenge and review of the evidence base to support the first public trial exemption which led to the successful awarding of the Exemption.

Further supporting analysis for repurposing cast iron was generated during the challenge and review phase to provide the level of demonstration deemed necessary. Hydrogen blend injection mobilised soon after the awarding of the Exemption and resources focussed on maintaining the continuous operation of the hydrogen blend trial.

In parallel, collation of evidence required to support national roll-out began in the area of industrial gas users. Following the project re-direction this has been ramped up to cover all existing barriers to hydrogen blends roll-out on the wider gas distribution networks (specifically the intermediate and high-pressure tier networks).

Programme element	Progress
1. Evidence for Wider Roll-out – Materials & Assets	To identify a representative documentation of network assets, a review of Cadent's and NGN's asset database was reviewed as well as IGEM's TD suite of standards to highlight which assets exist on the network and what materials of construction are used in their production. This enabled the production of an asset register for the project. An initial assessment of these assets highlighted a list of materials of construction. The materials were then assessed to identify if existing literature provided satisfactory evidence enable the use of these materials in hydrogen blend environments, thus identifying the gaps within the literature where there is a lack of materials data to be able to make such assessments. This was a considerable task given the breadth of materials that exist on the gas network and as such took longer than originally scoped. Once complete, this informed the materials test programme as well as working with colleagues on the H21 programme to peer review and share information where applicable. The materials test programme commenced in 2022 and is due to complete in 2023 with the focus on conducting in-situ mechanical testing of metallic components exposed to hydrogen, such as irons and stainless steels which operate on the below 7 bar pressure networks up to high strength steels which operate on the above 7 bar pressure network. An asset assessment methodology has been developed in collaboration with the H21 programme to be able to efficient assess categories of assets, this is being finalised with the expectation of completing the asset assessment in 2023 following the output of the materials test programme, which directly feeds into the asset assessment. International relationships continue to be fostered, whereby SANDIA labs have conducted in kind testing of iron in-situ to assess fatigue crack growth behaviour. The ability for existing assets (and therefore materials) to be compatible with hydrogen blends is critical to achieving national roll-out and any materials data generation test programme can be resource intense. Therefore, active collaboration has been conducted with all other UK based hydrogen asset materials research and development programmes to gain value from one another, peer review and to avoid duplication of work and effort, this has resulted in a successful collaboration meeting between Cadent's HyDeploy, NGN's H21, SGN's LTSFutures and National Grid's FutureGrid.

Programme element	Progress
2. Evidence for Wider Roll-out – Domestic Appliances	During the first half of 2022 the Winlaton trial was underway, where nearly 1,500 natural gas appliances were safely operating with a hydrogen blend. The domestic appliance evidence developed to support the Exemption application for the trial was developed in such a way to be generically applicable across the nation. The domestic appliance evidence base submitted was based on a representative sample of 13 appliances, which collectively encompassed the design variability of natural gas domestic appliances since the first tier of appliances were introduced in 1976 – following the conversion from towns gas. This technical structure allows the results of the testing to be nationally applicable, instead of limited to the Winlaton geography. The most notable results within the domestic appliance workstream were those relating to understanding the impact of introducing a hydrogen blend within hazardous appliances i.e., those producing dangerous levels of carbon monoxide. A significant safety credit was observed following the introduction of a hydrogen blend, as carbon monoxide levels were seen to reduce by between 80-90%, often reducing back to a tolerable level. The evidence base presented to the HSE was approved for use to unlock the Winlaton trial exemption. The trial itself provided a confirmatory demonstration of the expected suitability of natural gas appliances. Overall, the domestic appliance workstream has demonstrated that existing natural gas domestic appliances are compatible with hydrogen blends from both a performance and safety perspective. The evidence generated to date has led to Worcester Bosch, Baxi and Ideal Boilers all publicly stating their product ranges are compatible with hydrogen blends.
3. Evidence for Wider Roll-out – Gas Characteristics	The focus of work through 2022 for the gas characteristics workstream related to the development of analytical evidence to support the production of procedures. This body of analysis built upon the foundational work that preceded it, where the fundamental gas characteristics were studied through both experimental work and analytical techniques. The key work packages of 2022 related to fire/explosion risk-distance analysis to support the development of building proximity distance (BPD) guidance for hydrogen blended networks, and collaborating with the H21 project to undertake large-scale experiments on direct purging to support previous desk-based analysis. The former of these work packages has led to a holistic understanding of the BPD requirements for hydrogen blended pipework, across all distribution network pressure tiers. No material difference in BPD requirements was identified between natural gas and hydrogen blended systems. The second of these work packages involved the construction of a bespoke research facility, leveraging the micro-grid installation at DNV's Spadeadam facility. A series of direct purging experiments are due for completion in early 1Q23 to provide supportive data on direct purging requirements for a hydrogen blended system. 2022 represented a shift in focus for the gas characteristics workstream, away from first principle scientific evidence generation (leakage, flammability etc) and towards the identification and closing of final evidence gaps that relate to the application of gas characteristic understanding to support the development of operational procedures.

Programme element	Progress
4. Evidence for Wider Roll-out – Industrial & Commercial Gas Users	The industrial and commercial (I&C) workstream became a central pillar of the 2022 scope for HyDeploy2. The scope of work delivered spanned multiple areas from physical trials, to regulatory/compliance analysis and the crystallisation of the overall technical strategy for implementing a hydrogen blend within industrial settings. The physical trials undertaken built upon the success of both the Unilever steam boiler trial and Pilkington glass trial conducted in 2021. These trials demonstrated the ability to operate a range of existing industrial equipment on a hydrogen blend (7 MW steam boiler and 55 MW furnace). The 2022 trials expanded the depth of process coverage through two further trials. The first of which was a ceramics trial undertaken in partnership with Lucideon – the UK's leading ceramics research institution. This involved the manufacturing of a spectrum of ceramic products, from standard construction materials (bricks, tiles etc) through to advanced ceramics. A wide range of process conditions were necessary, including sub-stoichiometric firing conditions and firing temperatures reaching nearly 1,700°C. The programme of work demonstrated the ability to satisfactorily meet current product quality safety requirements with a hydrogen blend. The second trial undertaken in 2022 focused on the production of baked goods (biscuits, cakes and bread). This programme was undertaken in partnership with Campden BRI, who are the pre-eminent food research company within the UK. The programme of work required the design and installation of a bespoke gas train system to provide a hydrogen blend to the commercial ovens. A full range of physical product quality testing was conducted, alongside blind sensory testing (taste testing). No observable difference was registered from the sensory testing and no statically significant difference was measured through the physical testing. A wider engineering and regulatory compliance study was conducted, to create a framework for segmenting and analysing the diverse range of current industrial settings. This framework has been developed to consolidate the relevant findings across the I&C workstream into a code of practice for industrial sides to apply upon the implementation of a hydrogen blend within a specific region.
5. Evidence for Wider Roll-out – Procedures	A critical aspect of safe management of the gas network and installations is the correct application of operational procedures. In 2022 the approach has been to assess the full suite of a single GDN's procedures since the majority of GDN procedures are technically very similar. In this case, NGN's suite of procedures was selected, a total of circa. 660 procedures and the Energy Network Association's 74 GIS documents (Gas Industry Standards) which are applicable to all GDNs. An initial assessment of the documents resulted in a total of 310 procedural documents being highlighted as having a potential implication if the gas being transported were to change. These documents were reviewed in a 'page turning' exercise by ROSEN which output over 5,500 technical questions. An expert panel was set up to address these technical questions called the Procedures Peer Review Group (PPRG). The PPRG (consisting of Cadent, NGN, Progressive Energy, ROSEN, DNV, HSE-SD, IGEM and Dave Lander Consulting) have been working through the technical questions, some of which required some further studies to be conducted. The focus continues to be on addressing the outstanding technical questions which will be output by ROSEN into procedural supplements which will be shared with relevant standards bodies to inform standards development for hydrogen blended networks.

Programme element	Progress
6. Extension of evidence base required for wider deployment	See sections 1-5.
7. Generic activities applicable to all sites	Following the accepted material change request, only one Exemption-based network trial was undertaken as part of the HyDeploy2 programme. Therefore, please see section 9 and 10 of this table.
8. Local engagement and evidence gathering	The project has been in communication with trial residents, industry stakeholders and policy makers. These activities have helped build momentum around hydrogen blending – which is now a key element of the UK Government's hydrogen strategy – with hydrogen blending playing a central enabling role of the hydrogen economy. The significance of which has been seen in the Government's ten-point plan which sees a policy decision to be made on hydrogen blending within the UK in 2023. To formally analyse the experience of residents taking part in the trial, and in order to understand how the customer felt throughout the different stages of involvement with the HyDeploy project, from initially hearing about the project through to the end of the blending trial, HyDeploy worked with a team of researchers, who carried out independent research into customer perceptions of hydrogen and their experiences of the HyDeploy project both before the trial commenced and at the end of the blending trial. At the end of the trial, respondents were asked about whether they would be willing to have 100% hydrogen in their home, after being informed that this would involve some level of disruption. 46% of survey respondents said yes, 30% said maybe or that they were unsure, and 12% said no. Where respondents gave a positive response, this was due to this being seen as a positive step to address climate change, although most answers were caveated often with the need for further reassurance about the effectiveness of hydrogen as a solution, that it was safe and that the cost was not borne by the householder. Several residents stated that their positive views of 100% hydrogen had been influenced by taking part in the HyDeploy blending trial, suggesting that blended hydrogen may have a role towards acceptance of higher percentage use of hydrogen in the home.
9. Develop and submit site specific exemption.	The Exemption application to blend up to 20% hydrogen into the Winlaton trial network was submitted in June 2020 and reached a successful conclusion with the award of the Exemption being granted in July 2021.
10. Site preparation, installation, and commissioning	The Winlaton Trial site was successfully prepared, installed and commissioned in August 2021.

Programme element	Progress
11. Live trial	The Winlaton Trial network began operation on 4th August 2021 before reverting to natural gas operations on 30th June 2022. The village of Winlaton was chosen as the site for the trial as it offered a high degree of variability with regards to materials on the network, appropriate size of network and statistical representation of housing in the UK. The Winlaton Trial network consists of 668 properties comprising a school, church and a mixture of domestic housing and is situated in Blaydon near Gateshead. The trial showed that pipe and component materials performed well throughout the demonstration, with no increase in component failure frequencies when compared to the historical performance of this 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). A full report of the trial has been published on the project website and can be found here: **www.hydeploy.co.uk/events**
12. Site reinstatement and engagement close out	Hydrogen blending operations successful came to completion on 30th June 2022 at which point the Winlaton network was reverted to natural gas operations ensuring continued delivery of gas to customers without disruption. The Winlaton Trial Report was launched at an event held in the House of Lords in the Autumn of 2022. The event comprised of key note speeches from Lord McNicol of West Kilbride and senior members of the leadership teams from Cadent and NGN. The project team shared the progress to date and rounded off with a multidisciplinary panel discussion addressing the challenges and highlighting opportunities that hydrogen blended networks have to offer. The event was well attended by Ofgem and Government officials as well as a local resident from The Winlaton Trial who was able to share their first-hand experience of using hydrogen blended gas within their home.
13. Network models for deployment	The HyDeploy project is key to informing UK Government's energy strategy. The BEIS 10 Point Plan states that BEIS will, *"work with industry to complete testing necessary to allow up to 20% blending of hydrogen into the gas distribution grid for all homes on the gas grid"* and across the two NIC's, HyDeploy has undertaken two successful trials demonstrating hydrogen blending within consumer homes. However, the gas distribution networks are not physically configured so that consumer homes are separate from industrial and commercial users, so in 2021 a 'Material Change' to the 'Project Direction' was agreed with Ofgem to focus the remaining programme on developing the evidence required for the entirety of the gas distribution networks. Subsequently the entirety of the gas distribution networks has been agreed with BEIS as the system boundary, and network model for deployment, on which they will make a policy decision on hydrogen blending in 2023. In 2022 the Energy Networks Association (ENA) published the potential bending opportunity of 35TWh pa. within the gas distribution networks, equating to fully heating around 3 million homes and the ability of saving 6 million tonnes of CO2 each year.

Programme element	Progress
14. Regulatory and commercial basis for deployment	To successfully deploy hydrogen blending across the UK, two secondary pieces of legislation require consideration; • 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. Following the successful trial at Winlaton, the project has been developing an evidence base to assess the suitability of blending hydrogen within the entire system boundary of the distribution networks, with the objective of increasing the hydrogen limit within schedule 3 of GS(M)R from 0.1% to 20%. The project has worked closely with the Future Billing Methodology project, which assessed how to maintain fair billing for consumers when introducing different gases. The project concluded in June 2022 that hydrogen blending can be enabled and compliant with the existing Gas Calculation of Thermal Energy Regulations.
15. Skills and training	This was completed in 2021.
16. Communications and dissemination	The communications strategy for 2022 was largely focused on supporting delivery of the first public trial, along with national engagement about the role for hydrogen blending. There has been considerable engagement with key officials within BEIS regarding the role of gas blending. This has been recognised, with BEIS setting out ambitions to make a policy decision on hydrogen blending in 2023. 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. Three papers were accepted for presentation and publishing at the International Conference on Hydrogen Safety. This included: an overarching paper of the evidence base; a paper on the consequence experimental testing, and a paper on the appliance test work. This allowed for international dissemination of the generated evidence. All presented papers have been published in the International Journal of Hydrogen Energy over 2022. A second podcast was conducted following the commencement of the Winlaton Trial, which was aimed at giving gas engineers an insight into the HyDeploy projects. A recording of the podcast can be found on the HyDeploy website **www.hydeploy.co.uk** Hydrogen blending showcased at COP 26 in October 2022. Leaders gathered at Pilkington UK in St Helens, Liverpool City Region yesterday, to drive the conversation around hydrogen marking the North West 'stop' on the Decarbonised Glass Alliance's (DGA) Hydrogen Roadshow. The event brought together HyNet and HyDeploy project team members with industry and local stakeholders to discuss the region's innovative hydrogen activities and development. Home to glass-making since 1826, Pilkington UK's Greengate site in St Helens has recently undertaken two ground-breaking demonstrations of using hydrogen to replace natural gas.

Programme element	Progress
17. Project management	Effective project management is necessary to deliver a project with 6 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 programme and budget reporting is in place, and a comprehensive project risk register being used to manage the programme. Subsidiary working groups monitor and progress individual work streams.

5.0 Progress against budget

The table opposite shows the progress against budget to the end of November 2022. The programme is being managed for overall delivery within budget.

Progress this year has predominantly been delivered as per the original budget.

The majority of spend has been on conducting the trials; domestic Winlaton Trial (programme element 11) and two industrial trials (programme element 6), developing the outstanding evidence to roll-out hydrogen blends and project management accounting for the remainder.

Due to a collaborative working approach with manufacturers and other hydrogen-related projects, budgeted spend for certain programme elements has been sufficient to cover actual spend with forecast funds remaining to allow further focus in other programme elements.

Inevitably individual programme elements will vary compared with the original budget, especially following the project re-direction in Q4 of 2021, but this is being actively managed with a process of monthly reporting and review, enabling proactive decisions to be made to deliver the project to plan.

Overall, the delivery of the programme has been stewarded in such a way to ensure cost effective progress towards programme objectives.

Programme element	Spend to date (£)	Budget to date (£)	Total budget (£)
1. Exemption evidence - Materials	793,158	811,825	934,031
2. Exemption evidence – Appliances	710,478	418,248	497,965
3. Exemption evidence – Gas Characteristics	1,775,184	1,396,563	1,486,829
4. Exemption evidence – Gas Detection	56,784	209,885	223,292
5. Exemption evidence – Procedures	401,152	226,450	299,170
6. Extension of evidence base required for wider deployment	1,508,997	1,213,834	2,191,524
7. Generic activities applicable to all sites	730,421	955,505	1,016,544
8. Local engagement and evidence gathering	274,958	1,127,795	1,428,912
9. Develop and submit site specific exemption	667,926	383,761	757,072
10. Site preparation, installation and commissioning	2,092,108	1,798,205	2,279,219
11. Live trial	217,135	625,553	1,771,399
12. Site reinstatement and engagement close out	17,370	158,291	168,403
13. Network models for deployment	4,070	32,450	34,523
14. Regulatory and commercial basis for deployment	28,128	95,720	205,244
15. Skills and training	7,863	24,300	68,940
16. Communications and dissemination	55,054	69,380	312,068
17. Project management	1,332,149	801,469	1,293,606
Total	**10,672,935**	**10,349,232**	**14,968,741**

6.0 Project bank account

Bank statements have been provided to Ofgem. Due to the confidential nature of the project bank statements, they have not been included in this report.

7.0 Project deliverables

All scheduled Project Deliverables were completed in full during this period, as tabulated below and as evidenced to OFGEM.

SDRC1: Communications plan
25th October 2019

SDRC2: Evidence Base for First Trial
30th June 2020

SDRC3: Exemption Submission
22nd September 2020

SDRC4: Winlaton Trial Commencement
4th August 2021

SDRC5: Evidence Base for Roll-Out
31st March 2022

8.0 Data access details

No public network or consumption data has been collected on this project to date.

9.0 Learning outcomes

The following key learning points have been identified during this period, and provided the foundation for delivery of the ongoing programme, as well as informing national roll-out.

Policy coordination. As the focus of the project shifted from consumer trial exemptions to unlocking policy ambitions, it became clear that a new way of working with relevant regulatory bodies was necessary. Within the context of delivering specific safety case exemptions a bilateral process was found to be the most effective delivery vehicle for constructive engagement. Within the context of policy development, a trilateral engagement process involving regulatory bodies and policy makers was identified as being necessary to provide a platform for continued dialog and engagement.

Adaptability. In the aftermath of the global pandemic, working patterns have been materially impacted across the energy ecosystem, with a greater use of remote tools and working environments. This has necessitated the project to be adaptable and flexible to continue to drive progress in all areas whilst enabling individuals and organisations to transition to post-pandemic operating models.

Supply chain management. As well as the direct impacts of the global pandemic, there have been many indirect impacts, specifically on supply chain delivery. The knowledge and experience of supply chains cannot be underestimated, and leveraging that expertise through dedicated engagement has been found to be immensely valuable to the delivery of the project by thinking about the broader risks to the supply chain at the early stages of engagement and agreeing appropriate contracts which provide mitigations.

People. The HyDeploy programme completed its 6th successive year of successful project delivery through 2022. 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.

10.0 Intellectual Property Rights

No registerable IPR has arisen during the period.

11.0 Risk management

Effective risk management is critical for successful project delivery. A risk register is being used as a project management tool.

Going into 2022 the key project delivery risks were associated with manoeuvring the workstreams to align with the new project direction agreed with Ofgem in Q4 2021 and successfully completing the Trials (Winlaton & Industrials).

Hydrogen Supply. 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.

Stakeholder Engagement. An increase in hydrogen related safety studies has increased the draw on key stakeholder resources within the gas industry, particularly safety studies requiring the attention of the HSE. The project continues its tripartite engagement with the HSE and BEIS in aide of the prospected BEIS policy decision on hydrogen blended networks and remains flexible in providing the necessary support and information as requested.

Going forward the key risks being managed relate to:

Contract Management. The final aspects of evidence to support a BEIS policy decision on rolling out hydrogen blended networks is being developed with several expert contractors supporting and providing the work. This is being addressed by tight management of contractors by Cadent.

Public Perception. With the increase in hydrogen related research, particularly where research is customer facing, has led to greater public engagement. Clear communications with robustly developed strategies continue to ensure public engagement provides clarity on the concepts, challenges and opportunities blended hydrogen presents for the UK PLC.

12.0 Accuracy assurance statement

This report has been prepared in accordance with the Gas Network Innovation Competition Governance Document published by Ofgem. The project has been subject to review and challenge by the Cadent Project Manager and signed off by Damien Hawke, Cadent Safety & Network Strategy, who is Project Sponsor for this NIC project.

Damien Hawke has confirmed that the processes in place and steps taken to prepare this Project Progress Report are sufficiently robust, and that the information provided is accurate and complete.

13.0 Partner summaries

HyDeploy2 is being delivered by the HyDeploy consortium, which has technical expertise and practical experience. The partners are:

Cadent Gas (formerly National Grid Gas Distribution) is leading HyDeploy2. They own and operate four of the eight gas distribution networks in the UK, including the West Midlands.

Northern Gas Networks is partnered with Cadent to deliver HyDeploy2. They own and operate the gas network in the North East, Northern Cumbria and much of Yorkshire.

Keele University is providing learning from the first HyDeploy trial and providing continuity of consortia through the HyDeploy2 trials.

HSE Bespoke Research and Consultancy is the consulting arm of the Health & Safety Executive. They will be providing the scientific evidence which will support the safety case for the public trials.

ITM Power manufacture integrated hydrogen energy solutions.

Progressive Energy is an independent UK clean energy company. It will be supporting the management of HyDeploy2 through development and implementation.

In addition to the core project partners the project is supported by a number of key companies:

Kiwa specialise in gas testing. It is carrying out offsite testing on a range of common household appliances to inform the project, and will lead the gas safety appliance checks on the campus.

Dave Lander is an internationally recognised expert in gas quality and safety and co-ordinated the Exemption application to the HSE.

HyDeploy

Visit **www.hydeploy.co.uk**
Send **info@hydeploy.co.uk**