HyDeploy

HyDeploy Project

Gas Network Innovation Competition // Cadent

Fourth Project Progress Report (PPR) // December 2020

HyDeploy

The HyDeploy project seeks to address a key issue for UK customers: how to reduce the carbon they emit from 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 establish the level of hydrogen that can be safely blended with natural gas for transport and use in a UK network, which the current evidence base would indicate is 20 mol%.

Under its Smart Energy Network Demonstration (SEND) programme, Keele University (Keele) is establishing its electricity and gas networks as facilities to drive forward innovation in the energy sector. The objective of HyDeploy is to trial natural gas blended with 20 mol% of hydrogen in a part of the Keele gas network which provides gas to 100 homes and 30 university buildings.

Before any hydrogen can be blended with natural gas in the network, the maximum percentage of hydrogen to be delivered must be approved by the Health and Safety Executive (HSE). It must be satisfied that the approved hydrogen blended limit will be as safe to use as the natural gas used throughout the UK today. Such approval is provided as an Exemption to current 0.1 mol% hydrogen limit 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 the exemption approval in November 2018, hydrogen production and grid injection units have been installed at Keele and a hydrogen blending trial programme has been operating since October 2019.

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

The past year has been an exciting and rewarding period for the HyDeploy project. The primary focus of the project has been the stewardship of operations at Keele University, safely delivering a blend of hydrogen and natural gas to 100 homes and 30 university buildings since October 2019.

The hydrogen blending undertaken this year represents the first fully operational gas network within the UK operating with hydrogen since the conversion from townsgas to natural gas was completed in 1976.

Overall, the past year has been an exciting time for the project as the realities of operating first-of-a-kind trials have been understood and capitalised on to inform future demonstration strategies through HyDeploy2.

Following the successful granting of the UK's first Exemption to the hydrogen limit within the Gas Safety (Management) Regulations, 1996 in November 2018, an intense process of design finalisation, fabrication & testing and installation & commissioning of all the necessary trial equipment was completed by October 2019.

Since then hydrogen blends have been successfully and safely delivered to consumers across Keele University, including; private homes; university owned rented accommodation; multi-occupancy buildings; catering facilities; communal buildings; laundrettes; lecture theatres and commercial boiler rooms.

The operational experience of this broad range of consumers has been in-line with expectations, with no issues reported or identified with appliance performance or safety. This has provided a meaningful experiential evidence base to demonstrate the acceptability of supplying a hydrogen blend to a wide range of users and confirms the basis upon which the application to the HSE for the Exemption was made.

Although the Exemption provides sanction to operate up to 20 mol% hydrogen without qualification of intermediate stages, the project took the decision to enact a carefully managed blend progression protocol to incrementally increase the blend level from the initial 2 mol% through to sanctioning up to 20 mol%. This provided confidence that across the hydrogen production, transportation and utilisation, no issues were being observed over the full hydrogen blend level range. This process concluded in February 2020 with all project-initiated blend level restrictions lifted.

Covid-19 was an unexpected situation for many, including the HyDeploy project. The impacts of Covid-19 restrictions led to reduced resource availability of critical equipment support teams as well as site access restrictions, therefore the necessary decision was taken to suspend operations in March 2020. This decision could be taken given that it was possible to revert the downstream gas supply back to natural gas, which demonstrates the inherent flexibility of blending when unexpected situations arise. The operational hiatus lasted for 10 weeks, with blending resuming in June 2020. Covid-19 effects extended beyond this period due to Keele University almost entirely shutting down and transitioning to home/online learning.

This impacted the downstream gas demand and reduced demand by 50% relative to expectations. Therefore, the operational environment represented a challenging set of conditions, nonetheless blending continued where the natural gas demand was within equipment flow limits.

The return of students to Keele later in the summer resulted to a renewed demand for gas to heat buildings and cook with. This opened up blending allowing satisfactory operations to return. To capture the blending opportunity that was impacted by Covid-19 the project consortium agreed to extend the Keele trial out to March 2021. This would allow further meaningful blending to take place over the critical Winter period, where the majority of annual gas demand is delivered.

Consumers have always been at the heart of the HyDeploy project. Throughout the trial regular lines of communication have been maintained to provide information to residents and progress updates. The billing protocols agreed with Ofgem were enacted ahead of the trial going live and have been maintained throughout, this has ensured consumers have never paid for the hydrogen received.

Overall, the past year has been an exciting time for the project as the realities of operating first-of-a-kind trials have been understood and capitalised on to inform future demonstration strategies through HyDeploy2. The focus will remain on maintaining safe and sound operations as the project enters its final stages.

Photo taken pre-Covid-19

2.0 Project manager's report

The HyDeploy project has had another successful year. The main achievement of the year has been safely managing the injection of a hydrogen blend into the Keele University gas network.

Following successfully commissioning the compound equipment in October 2019, the programme has been completely focused on safely managing the blending operations, robustly monitoring progress and managing the impacts of Covid-19. Over this period the team has continued to engage with local customers, as well as the wider gas industry community, government and international stakeholders.

Sanctioning blending and Injection

On October 30th 2019 at 1:15 pm the HyDeploy gas network at Keele University became the first to transport a hydrogen containing gas within the UK in over 40 years. This was a watershed moment in the story of decarbonisation with the UK. Demonstrating the ability to safely transport and use hydrogen blends lies at the core of the HyDeploy project. This historic moment is graphically captured in Figure 1.0 below.

The initial injection of the hydrogen blend was set to a few percent mol%. Given the decision to not flare gas, the first processing of the hydrogen blend during commissioning had to take place with the resulting gas being supplied to the downstream network.

Therefore, from the first generation and processing of the hydrogen, the trial was live. This meant that a cautious approach was appropriate to allow the subsequent equipment integration, commissioning and control tuning to take place with a comfortable operational margin below the Exemption limit of 20 mol%.

Figure 1.0: Initial blend on the 30th October 2019

Following the completion of the equipment commissioning, an agreed blend progression protocol was implemented to safely manage increasing the blend level in a methodical and robust manner.

The basis of the evidence presented in support of the Exemption application was that, no detrimental effects were expected across both network and appliance operations due to the introduction of the blend. The purpose of the blend progression protocol was to prove this across the full range of blend levels.

The terms of the granted Exemption did not specify this approach as being required to prove the safety of a blend, however the project took the decision that a controlled and methodical process was the best way to safely manage operations in this first-of-a-kind demonstration of a hydrogen blend. The necessary stage gates within the blend progression protocol are outlined in Figure 2.0 above right.

Figure 2.0: Blend progression protocol

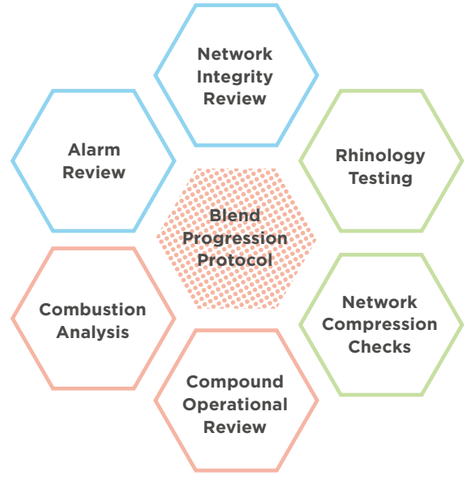


Figure 3.0: Inside the grid entry unit

Figure 4.0: Overall HyDeploy compound at Keele

Following each stage of progression, the imposed maximum blend level restriction was lifted, from the initial 2 mol% through to all restrictions be lifted within the exemption limit i.e. 20 mol%. With each sanctioning of a subsequent blend level, the operational requirements of the compound equipment changed, with more hydrogen at greater blend percentages required to be blended with natural gas. This meant that the control tuning within the equipment was an ongoing task, with troubleshooting and optimisation exercises required at each stage to ensure the best possible performance was being extracted from this first-of-a-kind technology.

This process of operational troubleshooting and optimisation led to the blend progression process taking slightly longer than originally anticipated, with the final stage of all restrictions being lifted within the 20 mol% exemption limit taking place in February 2020. Following this process blending was to be conducted within process limits, without any artificial constraints, and safe in the knowledge that the performance and safety of both the downstream network and appliances was demonstrated and documented.

Hydrogen production and blending equipment

The hydrogen production and blending equipment consisted of a 0.5 MWe Proton Exchange Membrane (PEM) electrolyser supplied by ITM Power and grid entry unit (GEU) supplied by Thyson Technology Ltd. The GEU was the first hydrogen-natural gas blending unit ever designed and constructed in the UK and the Keele University trial was the first time an electrolyser has been integrated with a gas network within the UK. Therefore, the trial offered many learning opportunities to understand how best to operate the combined generation and blending process. Figures 3.0 and 4.0 above show the inside of the GEU as well as the overall compound that was constructed.

The operational learning captured, particularly concerning hydrogen supply, from the Keele trial has been leveraged to inform the operational strategy of the subsequent trial at Winlaton, Gateshead that is being developed through HyDeploy2 and due to commence in Spring 2021. Through a methodical identification and troubleshooting process being delivered by a dedicated team of project personnel and technology specialists any operational constraints were able to be identified and worked through to enable the continuation of blending following any necessary remedial actions being undertaken.

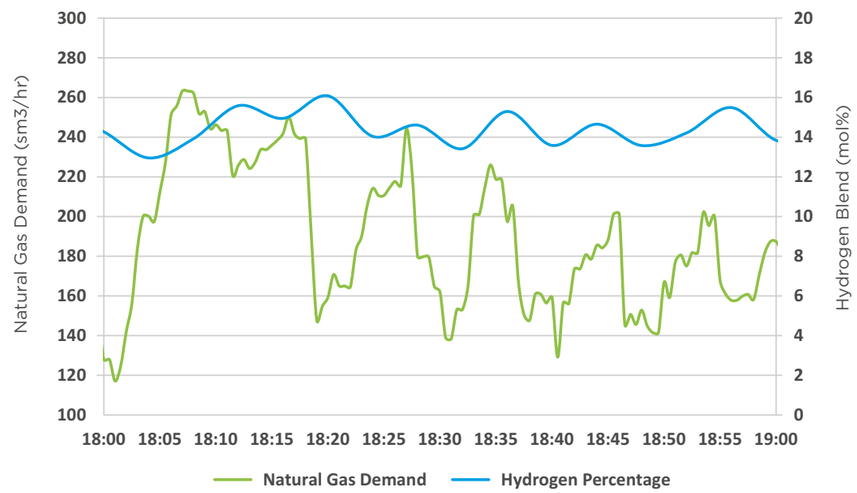
HyDeploy has provided the first insight into gas demand profiles at this level of granularity within the gas network. This is a key technical output of the project, as prior to commencing the trial there have been no studies or measurements taken to detail gas demand profiles at this depth of the gas network.

The gas demand profile, particularly it's variability, was a key operational consideration when managing the blend level. This is because the purpose of the GEU is to maintain a set flow ratio between the downstream natural gas demand and the hydrogen, to maintain a constant blend set point. Therefore, a greater degree of natural gas variability produces a more onerous operating environment as constant adjustments are required to maintain the hydrogen blend set point.

The natural gas flow variability was discovered to be much more variable than anticipated, which resulted in extended operational control tuning and increasing the margin of control applied to the blend set point to always ensure the integrity of the 20 mol% limit, as stipulated by the Exemption. Figure 5.0 below provides a typical example of this flow variability and the resulting blend percentage achieved during the same period. A time period of one hour has been selected so the full extent of the flow variability can be observed.

It can be seen that very rapid natural gas flow changes, both increasing and decreasing, were commonplace with eight rapid changes occurring within the hour profile shown in Figure 5.0 below.

Figure 5.0: Natural gas demand profile and blend percentage



It is also worth noting that the natural gas flow data shown is data taken every 30 seconds, which is the limit of granularity of the data acquisition system. Therefore, the real-world flow variability that was being controlled against was even greater than displayed in the above graph.

Network equipment

The purpose of the HyDeploy project is to demonstrate the safe transportation and use of hydrogen blends to support the roll out of hydrogen blending across the gas network.

The project has had strong support from the major boiler manufacturers who have maintained their appliances warranties for the duration of the trial at Keele.

Figure 6.0: Boiler research facility

However, they were keen to collect data to support the long-term operation of their equipment in preparation for hydrogen blend roll out. One of the larger boiler houses at Keele is adjacent to both the blended hydrogen network as well as one of the other natural gas networks which has no hydrogen injected into it.

This provided the opportunity to install a bank of boilers, with two from each of the manufacturers, one operating on the blend and the other on natural gas. An intensive operational regime was defined, with some boilers operating continuously at maximum load, some at minimum load and others cycling between the two. Currently the maximum firing boilers have consumed the equivalent quantity of gas that would be expected to be consumed in 15 normal years of operation, therefore the test conditions are providing a robust basis of assessment to determine any potential long-term implications. There have been no operational issues with any of the boilers since the trial commenced.

The boilers were extensively instrumented by the manufacturers and installed at Keele under a bespoke control system. They will run through the accelerated testing regime and then be provided back to the manufacturers at the end of the trial for assessment. The manufacturers will not know which boiler was operating on which gas. In the same facility two gas hobs were also set up in order to demonstrate to visitors the comparison between blend and natural gas operation.

Throughout the course of the year flue gas analysis readings have been taken on both sets of boilers and analysis undertaken. This research was peer reviewed by all four boiler manufacturers as well as two major suppliers of gas detection equipment to the UK market. It was agreed with the peer review team that current flue gas analysers are suitable for use with a hydrogen blend. This research has been made publicly available via IGEM and has resulted in a joint Gas Safe technical bulletin (TB) being issued with the Heating & Hot Water Industry Council (HHIC) summarising the findings. The technical bulletin was TB 157, published in May 2020, and provides the needed assurance of equipment continuity for the downstream industry.

Other analytical equipment was also installed at Keele. A continuously operating Gas Chromatograph was installed at the extremity of the trial network. This was provided by Emerson and is based on a standard OFGEM directed machine, but with the capability of measuring hydrogen. This was used to confirm real-time the composition of the gas in the network as well as understand time of flight through the network for comparison with network models.

Figure 7.0: Network GC

To support this, a further six sample points were installed across the network. These sample points enabled discrete gas samples to be taken for analysis in the Chemistry department at Keele and confirm that the blended gas remained mixed across the network. These offtake points also provided opportunity for rhinology samples to be taken to confirm that the odourisation of the gas remained within an acceptable tolerance.

Figure 8.0: Gas sample points

At each stage of the blend progression protocol two rounds of compositional analysis and rhinology were undertaken, on all six sampling points installed. The results demonstrated that across all blend levels a uniform hydrogen concentration was observed through the network and the odorant intensity remained acceptable. This evidence supports the introduction of a hydrogen blend into the gas network using business-as-usual (BAU) procedures and protocols.

Another key part of the Exemption was to demonstrate the suitability of network materials during the course of the trial. This was successfully achieved as part of the Exemption. However, to support roll out, further data is being collected through the installation of materials coupons in the gas line. These are located in the main compound and were introduced at the start of the trial. They will be removed at the end, and standard materials tests undertaken on the coupons.

Alongside the monitoring of appliances and network characteristics, regular reviews have been undertaken over the past year to assess the impact of a hydrogen blend on reported gas escapes as well as flammable gas & CO alarms across the blended network. This has been able to be achieved due to the uniqueness of the trial location, as Keele own the majority of properties receiving the blend, they have full visibility of any alarms/leaks that are reported.

No increase relative BAU frequencies in reported gas escapes, flammable detector activations or CO alarm activations have been recorded since the gas network has been supplied with a hydrogen blend.

This is in line with expectations prior to the trial commencing, however practically demonstrating these expectations through the collation of confirmatory evidence provides further confidence and reassurance concerning the introduction of a hydrogen blend.

Facilitating innovation

Innovation that promotes the decarbonisation agenda drives the HyDeploy project. To that end, the project has successfully collaborated with leading gas equipment suppliers to facilitate the development and field trialling of the next generation of analytical equipment designed to work seamlessly with hydrogen blends.

The trial gas detection solution for network engineers that was reviewed and approved by the HSE consisted of two currently available gas detectors, with one detector requiring a minor recalibration by the manufacture. Therefore, for the Keele trial a robust and reliable solution was achieved. However, it was recognised by the project that innovation could be leveraged to provide a single detector solution, which would replicate the current arrangements used by most GDNs. A functional specification was developed by the team and presented to the gas detector industry, for them to develop solutions.

Bascom Turner, who are one of the major suppliers to the UK market, took on the challenge and developed a market-based solution which incorporates all necessary technical functions within their existing gas detector offering to enable hydrogen detection and automatic adjustment of settings. This means a single detector can be used for both natural gas and hydrogen blended gas operation with no intervention from the operator.

Over the course of the last year this technology has been developed and the project has undertaken independent testing with HSE – SD, Cadent is currently undertaking formal field testing of the detector through the G23 process to allow the new detector to be approved for use across UK gas networks. This is a key example of where the HyDeploy project has facilitated market solutions to advance the adoption of hydrogen blends within the UK gas networks.

The pathway to net zero will necessitate compositional changes to the gas currently supplied to consumers, with the introduction of hydrogen and biomethane. Therefore, the need to understand gas compositions at a regional and local level, either directly at the point of use to optimise combustion or to inform a net zero compliant energy billing regime, will be fundamental to enabling the gas network to support the pursuit of achieving net zero.

The current reference technology utilised for these purposes is a GC such as the one shown in figure 7.0. A GC is well established technology with known operational performance and accuracy, which is why it has been the reference the technology for many decades. However, it is likely devices will be needed that provide compositional analysis which do not require a mains power connection (so can be installed remotely) and do not have the foot print or maintenance requirements of a GC.

Separate from HyDeploy, such developments have been underway by the Dutch research organisation TNO and gas equipment company Orbital Gas. HyDeploy offered up the blended gas network for them to install and field trial an innovative analyser capable of measuring the composition of blended natural gas. Figure 9.0 below shows the installation, which consists of three sensor probes installed at the boiler research facility outlined previously.

Figure 9.0:
Gas sensor probes

At the end of the trial the sensors will be removed and returned to TNO with an ambition for the next generation of the probe to be field tested in the follow-on trial at Winlaton under HyDeploy2. This is another example how demonstration trials can provide important resources and facilities for the private sector to bring forward and test solutions to unlock the wider market, beyond the core purpose of the programme.

Social science

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.

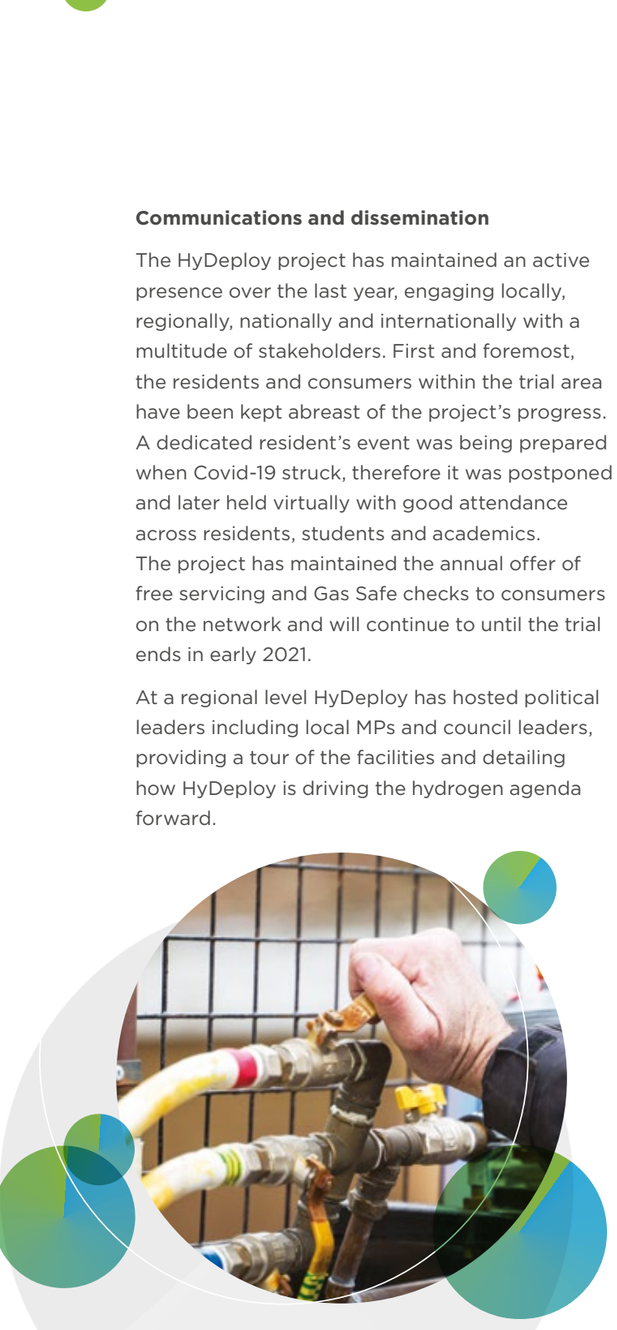
To formally analyse the experience of residents taking part in the trial, along with their views and feelings of consuming blended gas, a social science programme was undertaken by Keele University. This consisted of pre-trial interviews to baseline the resident's views and expectations, in-trial interviews to understand the impact of being apart of a live trial, and will conclude with post-trial interviews to see if any change in attitudes towards hydrogen blends has resulted from participation in the trial.

The residents demonstrated an overall positive enthusiasm to being a part of the first hydrogen blended trial and took pride in being at the vanguard of hydrogen deployment. A degree of understandable trepidation was initially present due to the first-of-a-kind nature of the trial. However once information was shared on the rigorous safety assessment underpinning the trial, particularly concerning the necessary approval by the HSE, any sense of potential anxiety largely turned to interest and excitement. The results of the social science study, once reached, will be published to inform the wider industry and policy makers concerning deployment strategies for hydrogen.

Communications and dissemination

The HyDeploy project has maintained an active presence over the last year, engaging locally, regionally, nationally and internationally with a multitude of stakeholders. First and foremost, the residents and consumers within the trial area have been kept abreast of the project's progress. A dedicated resident's event was being prepared when Covid-19 struck, therefore it was postponed and later held virtually with good attendance across residents, students and academics. The project has maintained the annual offer of free servicing and Gas Safe checks to consumers on the network and will continue to until the trial ends in early 2021.

At a regional level HyDeploy has hosted political leaders including local MPs and council leaders, providing a tour of the facilities and detailing how HyDeploy is driving the hydrogen agenda forward.



At a national level the project hosted a virtual launch that was well attended by over 100 stakeholders and has featured on many conferences, webinars, articles and presentations to the wider industry. The visibility of HyDeploy is such that the project has featured in responses provided during parliamentary debates in both the House of Commons and the House of Lords.

At an international level the project continues to maintain good connections with similar hydrogen programmes across the world and has held dedicated discussions with projects in the USA and Australia as well as in Europe to disseminate evidence and understanding relating to hydrogen blends.

As part of the final reporting and dissemination after the Keele trial ends in Spring 2021, the supporting evidence base underpinning the Exemption is due to be published via IGEM to aid industry progression and understanding.

Covid-19

The global pandemic resulting from Covid-19 was not a scenario the HyDeploy team had planned for. Nonetheless, when the impacts of the pandemic became known the team responded quickly. Moving to remote working was enacted immediately and individual team members were able to navigate the transition very well, even when organisations hurdles had to be overcome.

The immediate practical implications of Covid-19 led to a reduction in technical resource by key equipment suppliers as well as significant site access restrictions. The combination of these two effects necessitated a decision to suspend operations until more resource could be guaranteed and site access granted. The operational hiatus lasted 10 weeks between March – June 2020. Once operations returned a robust assessment regime was undertaken to ensure any site works incorporated Covid-19 compliant working practices.

Keele University remained largely shutdown over the Summer which reduced gas demand by 50% relative to typical demands during the Summer. The Summer was always going be a low flow period given the naturally lower gas demand, however the impact of naturally lower demand was increased by the Covid-19 effects. Upon return of students later in the Summer gas demands returned to normality, which coincided with cooler weather returning, these two effects combined to open back up the blending window and allow greater quantities of hydrogen to be blended.

The operational impacts of Covid-19 were partly mitigated by the time of year the main effects were felt, given that the majority of gas usage is during Autumn and Winter. Therefore, to recapture blending opportunity the project team took the decision to extend the trial through the Winter/Spring of 2020 and end the trial by March 2021. This will allow an additional full Winter season to be captured and deliver material quantities of hydrogen blending to consumers.

Programme budget

The programme budget has been stewarded throughout the programme to always ensure HyDeploy delivers on its objectives. Individual partners have displayed a meaningful focus on efficient management, which resulted in enabling the operational extension to March 2021 to be approved without needing further funding, despite the impacts of Covid. The project is on budget and will safely deliver a successful trial within the total original budget.

Outlook for next period

The trial at Keele University has been operational since October 2019 and will continue through to March 2021. Therefore, in the immediate future the project team's focus is on maintaining safe and reliable operations to maximise hydrogen delivery. The project will enter into its final stages shortly which will consist of safely ending the trial and carrying out any necessary physical works. Alongside the practical stewardship of the trial through to its completion, the project will be focusing on community engagement and dissemination to ensure the learning and outcomes of the project are able to be leveraged to inform decision making and assessments by the broader industry.

Key challenges

The key challenge that required careful navigation was the impacts of Covid-19. Both in the immediate short term, which as previously discussed ultimately led to a 10-week operational suspension between March – June 2020, but also concerning the impacts on gas demand over the summer. In addition the team needed to work and collaborate effectively, switching remote working.

The project team was only able to react to Covid-19, however have done so in such a way to substantially mitigate the overall impacts. Controlling budget expenditure is always challenging when delivering innovation programmes. However, the individual ownership of financial stewardship that has been demonstrated by the project team and its management resulted in being able to successfully respond to the challenges imposed by Covid-19 and overall mitigate its effects within the original budget. There have been inevitable operational snagging activities that have required troubleshooting, with any necessary remedial works carried out as needed and in a safe manner.

Maintaining high standards of safety was, and continues to be, a top priority for the project team. No loss time injuries have been recorded over the course of the trial and only one minor injury relating to shutting a door on a finger was experienced. Given the number of suppliers and subcontractors who have been on site throughout the trial, this record is testament to the dedicated focus on safety that has been displayed by the project team.

Overall this has been another successful and productive year of delivery. The project is making truly ground-breaking progress relevant not only to blending of hydrogen, but to the wider role of hydrogen in our energy system. This has been achieved through a competent, dedicated and engaged project team working collaboratively.

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. In its Net Zero report, the Committee on Climate Change (CCC)[1] identified that Hydrogen is a necessity and not just an option to meet Net Zero. For the UK to deliver on its commitments, it proposed a requirement for 270 TWh/yr of low carbon hydrogen, noting the areas where it was most likely to be required:

> 'In order to develop the hydrogen option, which is vital in our scenarios, significant volumes of low-carbon hydrogen must be produced for use in industry and in applications that would not require initially major infrastructure changes e.g. power generation, injection into the gas network and depot-based transport.'

More recently in the Prime Minister's 10 Point Plan, hydrogen was identified as one of the 10 key planks required on the journey to Net Zero. Importantly, this document set interim targets to unlock progress in the shorter term. Most notable aspects are shown in the call out box, with grid blending explicitly referenced.

The Energy Minister has recently set up the Hydrogen Advisory Council[2] "to inform the development of hydrogen as a strategic decarbonised energy carrier for the UK." Government is seeking to issue its hydrogen strategy in Spring 2021.

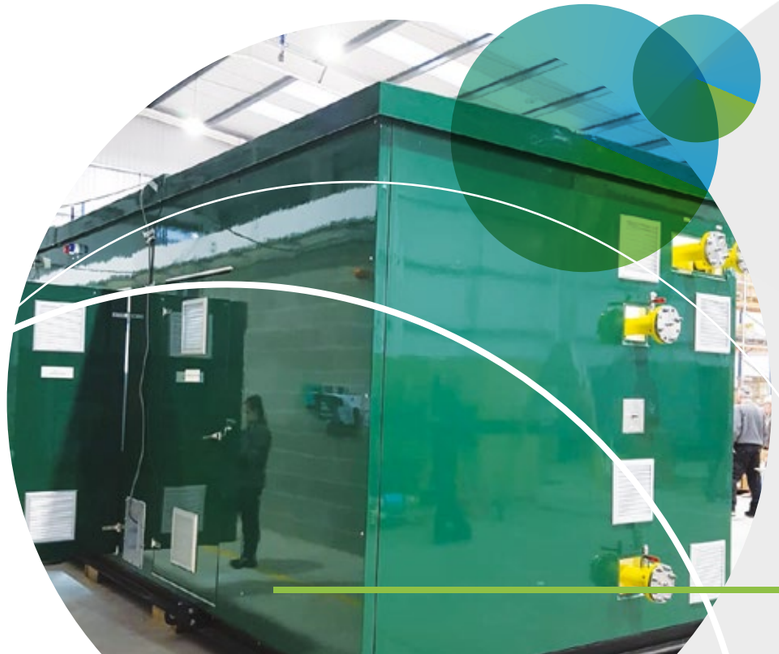
Blending provides the basis to establish and build out hydrogen production capacity, address regulatory hurdles, build the wider hydrogen supply chain and importantly provide an opportunity for customers to become accustomed to hydrogen being part of the energy mix.

Over time, building on this platform, it is expected that parts of the gas system will 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 are designed to progress 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.

Delivering low carbon heat via gas utilises 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 make a significant contribution but in reality to deliver Net Zero will require a combination a large range of technologies. However, as recognised in BEIS Heat Strategy[3], in its RHI consultation, and in a 2018 report for the National Infrastructure Commission[4], electrification requires substantial consumer capital outlay and disruption, as well as substantial reinforcement of the electricity grid and additional generation capacity – recognising the combined implications of electrification on passenger vehicles.

The HyDeploy approach is to exploit the existing gas network by reducing the carbon intensity of heat delivered through blending of hydrogen, delivering up to 29 TWh per annum of low carbon heat. This approach requires no changes to appliances and the gas network, providing a non-disruptive solution to customers. It can operate seamlessly with a range of future heat scenarios, and provides a deliverable pathway. The HyNet project[5] seeks to demonstrates how blending into the local distribution zone to decarbonise domestic heat can work in combination with higher blends and full hydrogen in 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. NGN's InTEGReL project[6] will demonstrate how hydrogen in the gas network can be integrated with operation of the electricity network to maximise the benefits to both.

To deliver hydrogen will require an appropriate policy regime. BEIS is undertaking work on business models to achieve this. This work has gathered pace in 2020. BEIS now have a dedicated team supported by contracted consultants. The objective is to issue a 'minded-to' consultation on hydrogen business models alongside the Hydrogen Strategy in Spring 2021. Such a business model is critical to transitioning from demonstration programmes such as HyDeploy into deployment, consistent with the new 10 point plan.



The 10 point plan for a green revolution

Policy impacts. Aiming for **5GW Hydrogen production capacity by 2030** in partnership with industry**. Lower carbon heating and cooking with no change in experience for domestic consumers through hydrogen blends and reducing the emissions of the gas used by up to 7%.**

Target milestones

- **2021** Publish our Hydrogen Strategy and begin consultation on Government's preferred business models for hydrogen
- **2022** Finalise hydrogen business models
- **2023** 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
- **2023** Support industry to begin hydrogen heating trials in a local neighbourhood
- **2025** We hope to see 1 GW of Hydrogen production capacity
- **2025** Will support industry to begin a large village hydrogen heating trial, and set out plans for a possible pilot hydrogen town before the end of the decade

[1] Net Zero - The UK's contribution to stopping global warming, CCC May 2019

[2] https://www.gov.uk/government/groups/hydrogen-advisory-council

[3] The Future of Heating, DECC 2016

[4] Cost analysis of future heat infrastructure options, Report for, National Infrastructure Commission, Element Energy Limited, E4Tech, March 2018

[5] www.hynet.co.uk

[6] https://www.northerngasnetworks.co.uk/ngn-you/the-future/integrel/

4.0 Progress against plan

The project is proceeding well against the plan, with strong progress made against each of the programme elements summarised below.

Following the commencement of the trial in October 2019 the project team has been focused on delivering against the programme commitments and ensuring a successful trial is achieved.

This has involved undertaking a methodical blend progression protocol to increase the maximum allowable blend level from the initial 2 mol% to the exemption limit of 20 mol%. Following this schedule of works, a regular and robust regime of operational checks, reviews and analysis maintained a high degree of operational visibility across the project.

This ensured the skills and expertise of the project team and associated key subcontractors could be harnessed to maximise blending throughout the year, within process constraints, and respond as needed to any situation requiring more focused or specialist attention.

The original trial end date was due to be in Summer 2020. Due to unforeseen circumstances relating to Covid-19 and its impact on the trial, the end date of the trial has been extended to March 2021. This remains within the NIC definition of a material change and through careful and considered stewardship of the budget the project was able to sanction such an operational extension within the original budgetary envelope. Focus shall soon turn to the final stages of the trial and successfully closing out the project.

Programme element	Progress
1. Site communications and stakeholder engagement	An extensive communications and engagement plan was developed, submitted to Ofgem and was approved under the relevant University governance process. Communications material was produced, including the project website with necessary booking processes and systems. A dedicated customer liaison officer facilitated a successful programme. Excellent customer participation was secured during the house to house testing phase, with positive feedback. During the second and third phases of the programme, the impact on customers is much less significant, although engagement has continued. A second round of Gas safe checks was undertaken in 2019 and the billing regime for the trial was agreed with OFGEM, communicated to the customers and instigated. In parallel, the Social Science department at Keele undertook research into customer perception of low carbon energy and the trial itself. This engagement continued into the trial phase, including a final round of gas safe checks. With the Covid impacts, online events were arranged with residents, other members of the Keele community and local and national stakeholders.
2. Pre-Exemption activities to develop the Exemption / safety case	This was the most extensive element of the programme during the first phase of the project, as it provided the detailed evidence base for the Exemption. This work drew on the national and international evidence base available, as well as detailed experimental and test work undertaken as part of the project. This was completed and the Exemption granted in November 2018. This provided the basis for the equipment to be fabricated and installed in the second phase and operations in the third phase.
3. Specification and design of hydrogen production and mixing units	During the first phase of the project a detailed functional specification was developed, an extensive tender process undertaken to select a supplier for the GEU and detailed design work undertaken. In parallel a basis of design and FEED was undertaken for the electrolyser, followed by detailed design. This information formed an integral part of the Exemption submission, and the foundation for the second phase of the project.

Programme element	Progress
4. Write safety case and apply for GS(M)R Exemption	The full Exemption was developed and submitted in June 2018. This was followed by a period of robust interrogation including over 140 clarification questions, to ensure that the evidence was fully understood. An Exemption to blend at 20%Mol for the trial on Keele's network was granted on 1st November.
5. Regulatory and billing arrangements	Billing. A billing regime was developed and agreed with Ofgem for for the trial at Keele. Based on the billing management system used by the University, the practical details were developed to implement the approach. This is a conservative regime, ensuring that no customers are adversely affected during the trial Electrolyser ownership. This has proven to be a greater regulatory challenge than had been originally anticipated. Given the small scale of the operation there had been an expectation that it would be possible to secure a suitable derogation to allow the GDN to own the equipment. An alternative ownership solution had to be implemented. This was successfully delivered through some changes with the arrangements with ITM, in order to transition to the third (operational) phase of the programme.

Programme element	Progress
6. Predevelopment installation activities	The Basis of Design for the equipment and modifications to the network was developed as part of the Exemption submission. Some early work on the network and services was undertaken where they could be integrated into wider university schedules.
7. Secure project gateway clearances	Internal project gateway clearances were achieved. The key criterion was granting of the Exemption from the HSE. The other requirements were: securing of the necessary planning permission; and the formal agreement by the University Executive Committee. The process was carefully managed to enable Steering Committee sanction the day after the Exemption was granted to expedite project progress, and the consumers were informed the next day.
8. Installation of hydrogen injection equipments	A detailed execution plan was developed for the hydrogen production and injection equipment. Final detailed design work was undertaken, orders placed and the equipment fabricated. An extensive programme of acceptance testing was undertaken. The GEU was initially tested at the fabrication works, followed by a second phase of 'Factory Acceptance Testing' at NGN's Low Thornley site where the blended product could be flared. A similar programme was undertaken for the electrolyser fabrication and factory testing at ITM's works. In parallel site works were undertaken, including provision of utilities and connections, and the compound itself. During summer 2019 and early autumn, the individual equipment items were transported and installed onsite. All the necessary documentation and assessments were undertaken, including the G17 process to ensure that the equipment was designed, fabricated and installed appropriately. The HSE attended the site to review the final installation.

Programme element	Progress
9. Installation of network monitoring equipment	Network monitoring includes sample points strategically located around the trial network to enable compositional, pressure and temperature data. These provide confirmation of network gas flows and enable validation of network models. These have all been installed, including 6 sample stations for temperature pressure and bag samples and a network Gas Chromatograph. A dedicated appliance test facility has been established. Four key manufacturers have each provided two fully instrumented boilers which have been installed in a strategically located university boiler house such that they can be operated on natural gas and a hydrogen blend respectively. Based on duty cycles selected by the manufacturers to represent accelerated life time tests, they are being operated and monitored during the entire trial phase. Following the trial these will be stripped down and 'blind' assessed by the manufacturers without knowing which of their units was operated on a blend. This will provide ground breaking evidence of blend operation to support long term deployment.

Programme element	Progress
10. Pre-injection processes	The processes were agreed as part of the Exemption and detailed operational plans were developed. Pre-trial tests of installations and network were undertaken to ensure that the gas safe position is maintained and that a clear reference was developed against which the trial phase can be benchmarked. The gas detection solution agreed as part of the Exemption was implemented, with equipment procured and installed at the University Security, such that FCOs attending site have appropriate access to equipment ready to use. A training programme was developed and delivered for all operatives and other network stakeholders in the delivery of the trial phase. This ensured that the revised procedures for the trial, including changes to gas detection were fully implemented. A Gas Safe Bulletin was developed with the support of the appliance manufacturers to ensure gas safe engineers operating in the region are fully briefed. In order to transition from equipment installation through to blending a comprehensive project approval protocol was developed. Fifty-eight individual items required sign off for the project Steering committee to sanction first blend into the network.
11. Injection plant and equipment operation	Project sanction was secured to commence injection in October 2019. Since then and throughout 2020 the hydrogen generation and injection equipment has been operated and optimised to deliver a successful trial. The compound equipment has undergone regular monitoring to ensure sound operations and allow any situations requiring investigation and potential remedial works to be undertaken without delay. Both the hydrogen generation and injection equipment have undergone all necessary annual checks as per their Written Schemes of Examination (WSoE), Operations & Maintenance (O&M) manuals and the Pressure Systems Safety Regulations (PSSR).

Programme element	Progress
12. Data gathering during the trial	A full suite of data has been collected during the trial. This includes: • **Compound operation:** Electrolyser and GEU operation, including evidence of satisfactory blend control • **Network operation:** Satisfactory Rhinology, compositional evidence across the network, demonstrating maintenance of blend level as well as monitoring general network operation • **Appliance operation:** Combustion temperature and flue gas checks on commercial and test boilers, as well as CO alarm operation and customer feedback Throughout the operation to date the equipment has operated safely, ensuring that the blend limit is not exceeded. There have been no issues on the network with satisfactory rhinology, well controlled network composition and no unusual issues on the network. The appliances have all performed as expected, with no CO alarm issues, nor adverse customer feedback. Materials samples are installed in the gas line; these will be removed at the end of the trial and tested.
13. Incremental injection	Under the blend progression protocol the blend levels have been incrementally increased through 2 mol%, 5 mol%, 10 mol%, 12 mol%, 15 mol% and then finally allow restriction within the 20 mol% limit was lifted in February 2020.
14. Plan follow-up project on public network	Based on the extensive understanding developed in the HyDeploy programme at Keele, the plans for the public trials were developed. HyDeploy2 successfully secured funding and commenced in April 2019.
15. Keele site reinstatement / Handover	Not scheduled to commence until 2021 when the trial will end.

Programme element	Progress
16. Dissemination and reporting	A number of technical papers have been developed to disseminate the findings from the Exemption process. This included a paper in Clean Energy, 2019, (Vol. 3, No. 2, 114–125) entitled: HyDeploy: The UK's First Hydrogen Blending Deployment Project. A series of Articles were delivered through the IChemE, and further papers presented at the International Conference on Hydrogen Safety. Articles have also been written for the Gas Safe Register magazine along with formal technical bulletins issued as a result of research undertaken through the trial. A two-day technical workshop was delivered in January 2019 and attended by around 100 gas industry experts from the UK abroad, disseminating the key findings. A workshop was also held for officials involved in hydrogen at BEIS during the summer. The project has been presented at a range of events during this period including those organised by the HSE, IGEM, CIBSE, EUA, Energy Efficiency Alliance, the Pipeline Industry Guild, Association of University Engineers, Utility week, BlueFlame, "Hydrogen Reality – Why Now?", UKRI Supergen, "Delivering the Hydrogen Economy North West", Staffordshire Chamber of Commerce, The National Hydrogen conference, an IChemE webinar, The Hydrogen APPG. The project has also been presented internationally in Madrid, Bangladesh, Hong Kong and Adelaide. The Advisory board has now convened four times, facilitating direct engagement with both national and international stakeholders. Once the facility was operational, recording and filming was undertaken with the BBC and CNN.
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 on page 29 shows the progress against budget to the end of November 2020. The programme is being managed for overall delivery within budget.

The complex and extensive scientific programme associated with the Exemption submission required a greater level of effort than originally anticipated. Some rebalancing of the scientific effort across the programme enabled this to be addressed.

As flagged previous progress reports, the Grid Entry Unit was more expensive than anticipated, and the costs during the build phase were higher than budget. The overall budget has been managed to accommodate this by making savings where possible, but stewardship continues to be an area of focus.

One of the key mitigants has been collaborative work with manufacturers and suppliers relating to the experimental programme to offset costs. Similarly, the installed equipment means that data collection during the trial has been considerably lower cost than originally budgeted. Inevitably individual programme elements will vary compared with budget, 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.

Programme element	Spend to date (£)	Budget to date (£)	Total budget (£)
1. Site Communications and stakeholder engagement	337,085	266,893	266,893
2. Activities to develop exemption	1,808,113	1,470,340	1,470,340
3. Specification and design of H^2 production and entry units	537,930	231,912	231,912
4. Write safety case and apply for exemption	124,589	117,081	117,081
5. Regulatory and billing arrangements	20,514	175,656	175,656
6. Predevelopment installation activities	98,006	125,501	125,501
7. Secure project gateway clearances	121,270	213,940	213,940
8. Installation of hydrogen injection equipment	2,238,371	1,909,931	1,909,931
9. Installation of network monitoring equipment	320,912	462,045	462,045
10. Pre-injection processes	9,265	67,264	67,264
11. Injection plant & equipment operation	192,793	362,776	362,776
12. Data gathering during the trial	120,625	285,330	285,330
13. Incremental Injection	31,743	219,724	219,724
14. Plan follow-up project on public network	11,585	95,428	95,428
15. Keele Site reinstatement / handover	26,716	135,013	135,013
16. Dissemination and reporting	75,725	341,636	341,636
17. Project management	911,445	781,117	781,117
Total	**6,986,686**	**7,261,586**	**7,261,586**

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 Successful delivery reward criteria

All scheduled Successful Delivery Reward Criteria were completed in full during this period, as tabulated below and as evidenced to OFGEM.

SDRC1: Communications plan
24th November 2017

SDRC2: Laboratory Appliance Tests
30th March 2018

SDRC3: Onsite Survey programme
25th May 2018

SDRC4: Exemption Submission
30th June 2018

SDRC5: HSE Granting of Exemption
1st November 2018

SDRC6: Transition to Phase 2
1st November 2018

SDRC7: Installation Completion
10th October 2019

SDRC9 Public Network Trial Definition
16th March 2020

SDRCs 1 to 4 & 9 were all completed on time. There was a slight delay to SDRC 5 and 6, with a slightly later submission and a longer determination of the complex Exemption than originally anticipated. There was a consequential delay to **SDRC7** which was slightly augmented due to the complexity of the build. **SDRC8 (End of Trial)** and **SDRC10 (OFGEM Final Reporting)** will be completed by **31st March 2021**. These cannot be completed until the end of the now extended trial period.

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, providing the foundation for delivery of the ongoing programme, as well as informing the approach to be taken for HyDeploy2. Four key areas have been identified:

Consumers are engaged with the decarbonisation agenda

The continued engagement with the local community and undertaking of dedicated social science research has provided a useful barometer to understand the views and attitudes of consumers as they relate to their energy supplies. Consumers are far more engaged on the topic of decarbonisation that would have been assumed only a few years ago, and in general consumers are being more enthusiastic and vocal about the need to decarbonise all energy supplies. This demonstrates the importance of programmes such as HyDeploy in delivering against this increasing expectation.

The importance of collaborative working

The delivery of the Keele trial has only been possible through the collaborative spirit of the project, with a strong delivery team consisting of organisational partners who have been working together for a number of years now and key subcontractors. Through leveraging individual and organisational knowledge and expertise, no problem has shown to be insurmountable.

Expect the unexpected

This time last year, no-one was expecting a global pandemic. However, a strong experienced team is able to address challenges successfully. Good people make all the difference.

Every penny counts

The first two phases of the programme, consisting of securing the Exemption and procuring the compound equipment, ultimately went over budget due to necessary additional expenditure.

This meant that additional financial scrutiny had to be applied to all areas of the project, with all partners empowered to deliver in the most efficient manner possible. This focus on saving budget where possible whilst delivering on the project's commitments provided the capacity to be able to sanction an operational extension to mitigate the impact the Covid-19 pandemic had on the trial over the Summer.

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. Many of the key project delivery risks have been successfully addressed and closed out over the last year:

Safe operations

Health and Safety lies at the heart of all network operations, and the HyDeploy trial is no different. A rigorous focus on safety has resulted in no loss time injuries over the course of the equipment installation, commissioning, monitoring and troubleshooting, which has involved multiple suppliers and subcontractors often working in close proximity (pre-Covid-19). Following the development of Covid-19 all works, however small, were reviewed to ensure their working practices complied with all restrictions and guidelines. Only if the works were deemed necessary and safe to carry out where they sanctioned to be conducted.

Covid-19

A global pandemic was not a risk that had sat on the project risk register. However, the team structure and levels of co-ordination developed through three years of collaboration provided a bedrock for the team to manage the risks well. Most of the organisations transitioned to online working seamlessly, and the calibre of the individuals meant that where organisations were less well set-up, staff themselves found workarounds.

The primary impact Covid-19 has had on the project was the 10 weeks operational hiatus in early summer and the resulting lower gas demand during late summer. The impact of these effects has been mitigated through the sanctioning of the operational extension to March 2021.

Excessive expenditure risks

The project budget was under a degree of strain going into the operational phase of the project due to necessary expenditure to secure the evidence base needed for the exemption, and the procurement of the compound equipment.

Given the first-of-a-kind nature of the trial an element of uncertainty remained concerning the necessary budgetary capacity required to deliver the trial. This situation led to all budget areas being reviewed and streamlined to ensure sufficient capacity was available to manage these risks, whilst still delivering on the project commitments.

Business as usual risks

Whilst the project is focused on delivering a blend of natural gas and hydrogen into a UK network for the first time, many of the activities are 'business as usual' for gas networks. Both Keele University and GDNs remain focused and vigilant to ensure that the network continues to operate safely as usual.

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 Director 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 The project team

HyDeploy 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 HyDeploy. 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 HyDeploy. The project supports their other work exploring the future role of gas. They own and operate the gas network in the North East, Northern Cumbria and much of Yorkshire.

Progressive Energy is an independent UK clean energy company. It is undertaking the management of HyDeploy through its development and implementation.

Keele University is hosting HyDeploy on its campus and the University's Materials Department are carrying out research on the impact of hydrogen on materials.

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 trial.

ITM Power manufacture integrated hydrogen energy solutions and will be supplying the hydrogen production unit for HyDeploy.

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 is co-ordinating the Exemption application to the HSE.

Otto Simon Limited are an engineering consultancy and project delivery organisation, responsible for the installation of hydrogen equipment onsite.

HyDeploy

Visit **www.hydeploy.co.uk**
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