HyDeploy

HyDeploy Project

Gas Network Innovation Competition // Cadent

Third Project Progress Report (PPR) // December 2019

HyDeploy

The HyDeploy 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 establish the level of hydrogen that can be safely blended with natural gas for transport and use in a UK network.

Under its Smart Energy Network Demonstration (SEND) programme, Keele University 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% volume of hydrogen in a part of the Keele gas network.

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 the Gas Safety (Management) Regulations. These regulations ensure the safe use and management of gas through the gas network in the UK. Following the exemption approval in 2018, hydrogen production and grid injection units have been installed at the site in Keele and now a hydrogen blending trial programme is underway.

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

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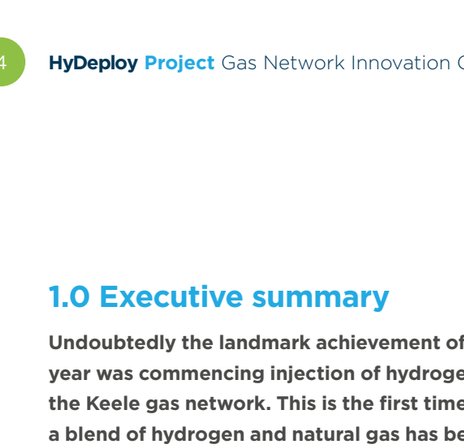
1.0 Executive summary

Undoubtedly the landmark achievement of the year was commencing injection of hydrogen into the Keele gas network. This is the first time that a blend of hydrogen and natural gas has been transported and efficiently utilised in the UK Gas network since the conversion from Towns gas.



The work carried out over this year has built a foundational relationship with residents along with building sound evidence to support the first public exemption application in 2020.

Following successfully securing the UK's first Exemption to the hydrogen requirements of the Gas Safety (Management) Regulations in November 2018, the programme this year has been dominated by detailed design, manufacture and installation of all the equipment necessary to produce hydrogen and then inject it into the network. Over this period the team has continued to engage with local customers, as well as the wider gas industry community, government and international stakeholders.

In the space of just under a year, all the equipment required to produce hydrogen, blend it into the grid as well as monitor the operation of network and appliances has been specified, designed, fabricated and installed. This report shows photographs of many of the key items of equipment and examples of the installation process to provide a graphic demonstration of the extent of the activities undertaken over the last year.

This equipment is now operational, successfully delivering hydrogen onto the gas network at Keele. There continues to be some fine tuning of the hydrogen production and injection equipment to maximise operation at the required blend levels across the range of gas demand.

The network is operating entirely as expected with consistent compositions of hydrogen being measured at the extremities of the network. The specifically installed appliances are operating in line with the findings from the laboratory programme, providing heat as designed. There have been no customer issues raised since blending commenced.

The project team is assiduously focused on monitoring the operation throughout the trial to ensure that as much learning as possible is gained from the trial, and that everything continues to operate as designed.

Customers are at the heart of the HyDeploy project, we are delivering low carbon heat without disruption. The work undertaken by the social sciences department reinforced how important it is to maintain contact with the customers on the trial network, even during 'quiet' periods of the project. The team is planning a 'behind the scenes' session for the local customers alongside the wider dissemination programme, to ensure that they are valued and have the opportunity to see the contribution they are making to delivering low carbon solutions.

Throughout this year, the project team has engaged with many stakeholders, particularly in regard to sharing the findings from the Exemption process, through technical papers as well as national and international conferences. The project is being carefully managed to deliver within budget. There have been some increased costs due to the extent of the scientific programme required ahead of Exemption, as well as the build programme on site at Keele. This has been mitigated through careful management activities to make savings where possible yet deliver the project in full within budget, but as with any project of this nature, this remains a risk through until it is complete. Similarly, there have been some delays in schedule, which have been managed, with an expectation that the programme will complete during summer 2020.

Overall this has been another successful and productive year of delivery, 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.

2.0 Project Manager's Report

The HyDeploy project has had another highly successful year. The main achievement of the year has been commencing the injection of hydrogen into the Keele gas network. This the first time that a blend of hydrogen and natural gas has been transported in the UK Gas network since conversion from towns gas to natural gas.

Following successfully securing the UK's first Exemption to the hydrogen requirements of the Gas Safety (Management) Regulations in November 2018, the programme has been dominated by detailed design, manufacture and installation of all the equipment necessary to blend hydrogen into the network. Over this period the team has continued to engage with local customers, as well as the wider gas industry community, government and international stakeholders.

Electrolyser

Electrolyser FAT

Hydrogen Production and Blending Equipment

The gas network is capable of delivering energy to customers throughout the year. The energy flows are therefore highly variable. This is particularly the case on a network such as that at Keele with a low diversity of appliances and some dominant larger boilers. Therefore, the hydrogen grid entry unit which meters the hydrogen into the network must be able to do so across a wide range of gas flows. Whilst the equipment has some strong similarities to a biomethane grid entry unit, this requirement to reliably blend at set levels is novel.

Thyson were selected as the equipment provider for the Grid Entry Unit (GEU) and undertook final design and fabrication based on the specification and design developed during the Exemption process. The equipment completed fabrication in the summer and was initially Factory Assessment Tested (FAT) using inert gases at their facility. This was followed by a second FAT phase at NGN's Low Thornley site. This allowed full blending to be assessed with the product flared, unlike at Keele University. The unit performed well within the parameters that could be tested remotely from a live network and was accepted for delivery to Keele.

In parallel ITM's electrolyser unit was fabricated at their Sheffield works. The FAT was also undertaken in the summer. Following acceptance this was then transferred to Keele, along with the intermediary hydrogen buffer tank.

Whilst the offsite fabrication of the key equipment was being undertaken, the necessary network modifications took place at Keele University, along with the early site works on the compound. The network modifications were necessary to divert the gas lines to the compound, whilst retaining the ability to isolate the whole HyDeploy facility to ensure continuity of supply to Keele.

The site works comprised installation of the necessary transformers and other utilities as well as foundations for the containerised equipment which was delivered and installed. Once the equipment had passed its G17 Sign off, the lead Contractor Otto Simon Limited, provided evidence that installation was complete, meeting OFGEM's 7th SDRC.

Compound Site Works

Delivery of equipment to Keele

Installed Compound equipment

Network Equipment

As part of the wider trial programme various key items of equipment were also installed on the network at Keele to inform wider roll out of hydrogen blends.

The project has had strong support from the major boiler manufacturers who have stood behind their appliances for the duration of the trial at Keele. 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 has provided the opportunity to install a bank of boilers, with two from each of the manufacturers, one operating on 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. The boilers were extensively instrumented up by the manufacturers and installed at Keele under a control system provided by Orbital.

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 simple gas hobs were also set up in order to demonstrate to visitors the comparison between blend and natural gas operation.

Other analytical equipment was also set up 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 is 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.

To support this, a further 6 sample points were installed across the network. These sample points enable discrete gas samples to be taken for analysis in the Chemistry department at Keele and confirm that the blended gas remains mixed across the network. These offtake points also provide opportunity for rhinology samples to be taken to confirm that the odourisation of the gas remains within tolerance. Pressure and temperature measurements are also possible to provide data to validate network modelling.

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.

The compound and network analytical equipment provides a wealth of data to monitor operation during the trial. A data aggregation system was developed by Orbital which is being used by the trial management team to assess the operation of the primary production and blending equipment as well as network parameters.

Procedures, operations and training

As part of the Exemption application the procedures associated with the gas network as well as in properties were assessed and reviewed. Whilst the changes were relatively limited, it has been important to ensure that the operatives have the necessary equipment and were fully trained.

During the scientific programme ahead of the Exemption it was established that CO sensors can be cross sensitive to hydrogen. Therefore, a solution had to be found for both First Call Operatives (FCOs) as well as network repair teams. For Keele a suitable approach was developed using two gas detection units. This equipment was installed and appropriate protocols developed.

Under separate programmes an enduring approach has been developed to support roll out which does not require this kind of arrangement.

Separately standard domestic CO alarms were tested to assess any likely impact of false alarms due to cross sensitivity to hydrogen. This work indicated that this was unlikely to be an issue, however this is being constantly monitored during the trial.

FCO training was an important part of this year's programme and a comprehensive training programme was developed and over 100 Gas operatives and FCOs went through the programme and were appropriately assessed.

Through Gas Safe, a Bulletin was developed for gas engineers operating in the region and likely to operate on the Keele network during the trial. This was primarily a familiarisation process as there were no significant changes to the way in which work should be carried out, but it was important that they were informed about the trial and know that they could contact Keele Estates or the appliance manufacturers if they had any questions. Boilers and meters on the network have a HyDeploy sticker on them to notify engineers about the trial along with necessary contact details.

Sanctioning Blending and Injection

In order to transition from equipment installation through to blending a comprehensive project approval protocol was developed. This addressed the necessary approvals relating to equipment installation and G17 sign off, requirements from the Exemption process, operational processes that had to be in place, further gas safe checks on the network, wider regulatory and billing regime requirements, customer engagement, and university governance.

Fifty-eight individual items required sign off for the project Steering committee to sanction first blend into the network. This was achieved in October 2019 and initial injection subsequently commenced.

It is not possible to flare gas at Keele, therefore, once hydrogen injection commenced, the blended gas is delivered onto the network. Therefore, a structured process was undertaken to manage an incremental increase of blend rate. Extensive data was collected relating to operation of the hydrogen production and injection equipment, the network composition, the operation of the instrumented appliances, the rhinology of the gas, monitoring of any emergency call-outs and any wider issues raised on the network. A Trial Management Team was formed, comprising representatives of all consortium members with ultimate veto from Keele. This was used to govern the transition through intermediary blend levels.

Whilst there were inevitably snagging issues relating to the hydrogen production and injection equipment, no operation was identified as a 'show stopper'. Importantly all the safety systems operated as designed, ensuring that continuity of gas service was maintained and operation has remained within the parameters defined by the Exemption. The blend level has been well controlled despite highly variable gas flows, as shown in the example figures, below shown at the 10% blend level. No issues have been identified on the network to date. The HSE undertook a successful inspection of the as built facility.

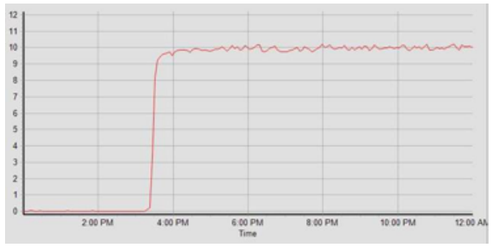


Figure showing an example snapshot in time of hydrogen blend percentage (at 10% in this case) over a 12-hour period being maintained whilst the gas demand varies naturally in the figure to the right

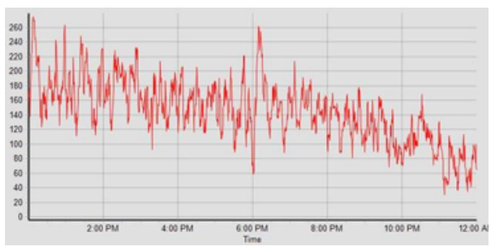


Figure showing an example snapshot in time of natural gas demand variation over a 12-hour period

FAT of the grid entry unit at Low Thornley

Communications and dissemination

Customers are at the heart of the project. The construction phase has more limited impact on customers compared with the house to house testing during phase 1, however contact has been maintained. A second round of gas safe checks were undertaken early in 2019 which provided a point of contact. Information about the finalised billing regime also provided another.

In parallel, the Social Science department at Keele undertook research into customer perception of low carbon energy and the trial itself. This is being developed into a paper and will complement work undertaken by Newcastle University linked to the HyDeploy2 programme.

More widely, the project undertook a major technical dissemination workshop at Buxton in January 2019 with over 100 participants from across the gas industry here in the UK and from abroad. This was a two-day workshop sharing the key findings relating to the Exemption. A higher level 'lessons learned' workshop was also held with key officials from BEIS. Team members have produced a number of seminal papers, including participating in a hydrogen series by the IChemE, and a peer reviewed reference paper relating to the Exemption evidence for the Clean Energy Journal. Papers have been presented at a wide variety of conferences around the globe including in Australia. Towards the end of the year, an international film crew attended the project as part of a programme about the UK's journey to Net Zero, which will be aired in 2020.

Outlook for next period

Now that the trial is underway and hydrogen injection has commenced, the main activity is monitoring the performance of the production and blending equipment, as well as the operation of the network and appliances, to inform the wider roll out.

The team will be engaging with customers on the network as well as wider stakeholders. Events are planned in early 2020. This includes a "behind the scenes" opportunity for Keele customers to ask more questions now that everything is operational, as well as an event targeted at policymakers. A series of tours are planned over the next 6 months to reach out to a wide range of stakeholders.

During 2020, the trial will complete and the equipment decommissioned ready to be transferred to the first public trial site in the NE, as part of HyDeploy2. At this point HyDeploy at Keele will be closed out.

Key Challenges

The construction phase of any project has its challenges primarily relating to maintaining schedule and budget. As previously acknowledged, there were some delays during the first phase of the programme relating to the extent of the scientific programme necessary to provide the evidence for the Exemption. The build phase was originally scheduled to last 9-10 months. The equipment was signed off as being fully installed in just over 11 months from the receipt of the Exemption, which is testament to the team and its management. Given the innovative nature of the equipment, there have been inevitable snagging issues to resolve during commissioning and early periods of operation, but these have been successfully addressed.

Together these factors mean that the trial period is likely to complete Mid 2020, a few months later than originally planned. This will still allow the equipment to be transferred to the first public trial later in 2020 as originally scheduled under HyDeploy2. Budgets have also come under pressure, again with higher expenditure during the Exemption phase than expected as well as inevitable cost increases during construction. However, savings have been made where possible. Providing the programme continues as planned, the project can be successfully completed within the available budget .

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

The UK is committed to a pathway to reduce carbon emissions through the Climate Change Act. The major change in 2019 was a revision to the Climate Change Act, committing the UK to achieving Net Zero rather than just an 80% reduction by 2050.

This is a very significant change; now all parts of the energy sector will need to deliver. This has led to heightened awareness of the imperative of addressing climate change, and the pressing need to make progress.

The commitment to Net Zero followed a report by the Committee on Climate Change (CCC)[1]. In this report, the CCC identified that Hydrogen is a necessity and not an option to meet Net Zero. For the UK to deliver on its commitments, it has explicitly identified the requirement for 270TWh/yr of low carbon hydrogen. It also identifies the need to make rapid progress in appropriate parts of the energy system where major changes are 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).'

In its subsequent 2019 Progress Report, the CCC reinforced that: 'In order to develop the hydrogen options, which are vital in our net-zero scenarios, significant volumes of low-carbon hydrogen must be produced'.

This recognises that blending of hydrogen is a vital part of the roadmap. 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 and Hy4Heat are designed to progress these network and appliance issues. Manufacturers such as Worcester Bosch, who have worked closely with HyDeploy team, are developing hydrogen ready boilers to facilitate that transition. This could mitigate the impact of roll out by leveraging the natural replacement cycle. This transition has been mapped through work such as that undertaken by the ENA in its Pathways to Net-Zero Report[2].

Delivering low carbon heat via the network and low carbon gases capitalises on huge investment customers have made over previous decades and continue to make today in the network and it also means that customers do not require disruptive and expensive changes in their homes. Alternatives such as electrification using heat pumps will make a contribution; in reality to deliver Net Zero will require a combination of both. However, as recognised in BEIS Heat Strategy[3], in its RHI consultation, and in a 2018 report for the National Infrastructure Commission[4], this approach 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 of passenger vehicles.

The HyDeploy approach is to position the existing gas network in a low carbon and eventual net zero future by reducing the carbon intensity of heat delivered through blending of hydrogen, delivering up to 29TWh per annum of low carbon heat. This approach requires no changes to appliances and network providing a non-disruptive solution for customers. It can operate seamlessly with a range of future heat scenarios, and provides a deliverable pathway. The HyNet project[5] 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 deep 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 Integral project demonstrates how hydrogen in the gas network can be integrated with operation of the electricity network to maximise the benefits to both.

To deliver hydrogen in the early 2020s will require an appropriate policy regime to be in place also. BEIS is undertaking work on business models. Initially this has been through its work on CCUS, building on work of the CCUS Advisory Group (CAG), and a recent public consultation[6].

There is also an ever-increasing focus on hydrogen in its own right. BEIS has supported early developments under its Hydrogen Supply Programme and has recently announced the Clean Hydrogen Fund. These programmes enable early development and send strong signals to the market about government's future intent. However, a firm policy regime is becoming increasingly urgent to ensure that programmes such as HyDeploy can transition into full rollout, across the UK, to make a positive contribution to 4th and 5th Carbon Budget shortfalls.

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

[2]Pathways to Net-Zero: Decarbonising the Gas Networks in Great Britain, ENA, October 2019

[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/

[7]https://www.gov.uk/government/consultations/carbon-capture-usage-and-storage-ccus-business-models

4.0 Progress against plan

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

Following granting of the Exemption by the HSE in November 2018, and subsequent sanction by the project Steering Committee, the project moved immediately into the second phase – the fabrication and installation of the hydrogen production and injection equipment. Installation was successfully completed in 11 months and injection commenced in October 2019. A programme of managed blend increase has been undertaken, including extensive monitoring of network operation.

This trial phase is expected continue until Summer 2020.

As flagged in the previous progress report, securing the Exemption was somewhat delayed compared with original plan, due to the size of the evidence base that had to be collated and intensive evaluation phase. It has not been possible to make up this delay during phase 2, hence the expected later finish date. However, this is not expected to be more than a 3-4 month delay, well within the NIC definition of a material change. It is also possible to maintain the HyDeploy2 programme with equipment being transferred to the first public trial site in time to commence blending at the end of 2020.

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 will continue into the trial phase.
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.
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%volume 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 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 in order to transition to the third (operational) phase of the programme.
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.

Programme element	Progress
8. Installation of Hydrogen Injection Equipment	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.
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. The trial management protocol was developed in order to govern transition through intermediate blend levels. This includes review of compound and network operation. Throughout the operation to date the equipment has operated safely, ensuring that the blend limit is not exceeded. The equipment is being fine-tuned to maximise operation at the set blend levels across the range of gas demands and rate of changes.

[5]www.hynet.co.uk

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

[7]https://www.gov.uk/government/consultations/carbon-capture-usage-and-storage-ccus-business-models

Programme element	Progress
12. Data gathering during the trial	A full suite of data is being 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 protocol the blend levels have been incrementally increased through 2%, 5%, 10%, 12% and 15% with the expectation of reaching the maximum blend limit shortly. Blending has been successful with no issues identified on the network or appliances.
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.

Programme element	Progress
15. Keele Site reinstatement/ Handover	Not scheduled to commence until 2020.
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. 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. Now that the facility is operational, recording and filming is planned 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 below shows the progress against budget to the end of October 2019. 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 has enabled this to be addressed. As flagged in the previous progress report, the Grid Entry Unit was more expensive than anticipated, and the costs during the build phase were higher than budget. The overall budget is being managed to accommodate this making savings where possible, but 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 will be 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	255,433	247,979	266,893
2. Activities to develop Exemption	1,913,435	1,470,340	1,470,340
3. Specification and design of H_2 Production & 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	2,084,462	1,882,619	1,909,931
9. Installation of Network Monitoring equipment	261,109	462,045	462,045
10. Pre-Injection processes	9,265	67,264	67,264
11. Injection plant & equipment operation	843	253,943	362,776
12. Data gathering during the trial	0	285,330	285,330
13. Incremental Injection	0	117,139	219,724
14. Plan follow-up project on public network	11,585	54,358	95,428
15. Keele Site reinstatement / handover	0	63,578	135,013
16. Dissemination and reporting	142,766	232,255	341,636
17. Project Management	818,009	697,018	781,117
	6,399.215	**6,697.957**	**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

SDRCs 1 to 4 were all completed on time. There was a slight delay to SDRC5 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.

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:

The importance of clear Management Processes and Protocols
The transition from installation to initial blend, as well as the subsequent blend increments has been carefully managed through clear protocols. The Go Protocol for blending was monitored through a Red Amber Green process comprising 58 items with a clear sign off process for each, storing the evidence of completion. It provided clarity to the project team on key priorities for action, and an auditable trail for future reference. Similarly, the trial phase has been managed with a clear summary report produced regularly to consolidate key data into a single point of reference.

Management of interfaces
This has been a complex build programme. The Physical works team has overseen and managed the build, ensuring that interfaces between network and compound as well as equipment within the compound have been actively managed. By having the key experts working together issues have been addressed effectively.

Customer engagement
Customers are at the heart of the HyDeploy project – delivering low carbon heat without disruption. The work undertaken by the social sciences department reinforced how important it is to maintain contact with the customers, even during 'quiet' period of the project. The team is planning a 'behind the scenes' session for the local customers alongside the wider dissemination programme, to ensure that they are valued and have the opportunity to see the contribution they are making to delivering low carbon solutions.

Support of the local team.
The project comprises 6 consortium partners as well as myriad of individual suppliers and consultants. They have all worked together well. However, it has been very clear that having the support of the local team at Keele, and in particular the unstinting dedication of the Gas Network Controller has been critical for delivery. Without his commitment to delivery this project would not be the success that it is.

10.0 Intellectual property rights

No registrable 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:

Programme Construction Risks.
Over this period conventional construction risks have needed to be managed. First and foremost, this was delivered safely under CDM regulations. Managing both cost and schedule risks during construction has been critical, requiring a well-defined execution plan.

Regulatory Risks.
It was not possible to secure a derogation to enable the Gas Distribution Network Operator to own the hydrogen production plant. An alternative solution has been implemented, so this risk was closed out.

Implementation of agreed operational procedures.
As the project entered the operational phase, it was critical that the operational procedures agreed with the HSE were fully implemented. This is was undertaken through the development of an extensive training programme which was successfully delivered.

Business as usual risks.
Whilst the project is focused on delivering a blend of natural gas and hydrogen blend onto 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.

The project team remains committed to managing the safety, cost and schedule risks throughout the final phase, operational of this programme.

12.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.

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.

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

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.

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.

Progressive Energy is an independent UK clean energy company. It will be supporting the management of HyDeploy 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 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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