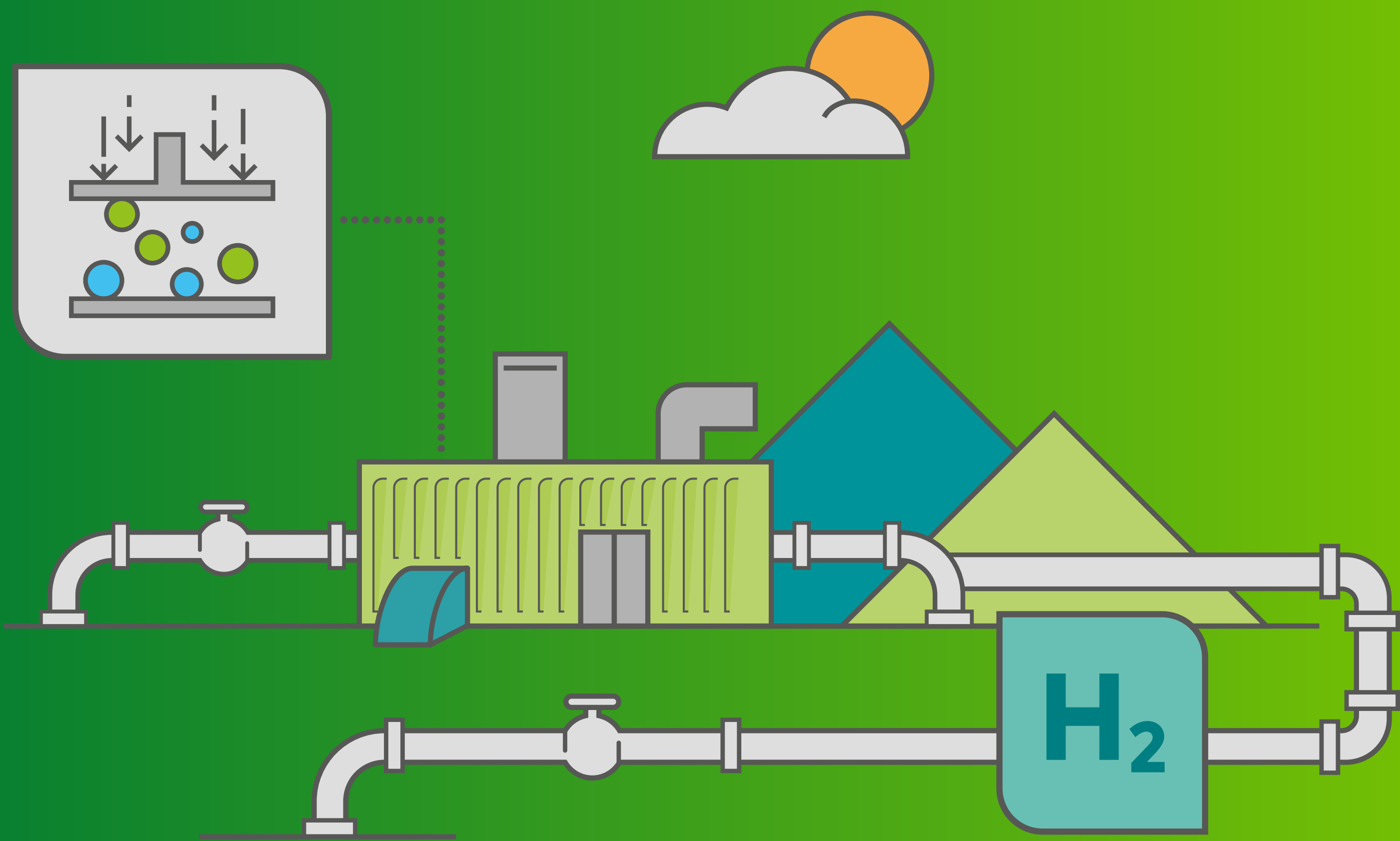
national gas



FutureGrid

Phase 2 Compression

SIF Beta Project

Progress Report 2024

Contents

Section 1
Foreword

National Gas is the backbone of Britain's energy system today. We deliver energy where and when its needed. We're also playing a leading role in the transition to net zero and a clean energy future.

In July, the UK Government announced their plans to establish a 'Clean Power 2030 Mission Control' to help achieve decarbonisation and provide Britain with cheaper, clean power by 2030.

To align ourselves with the Government's ambitions we are combining our wider energy transition portfolio with existing innovation projects and newly generated project ideas, to accelerate National Gas' decarbonisation efforts to meet the net zero targets. We have started by setting up a Clean Power 2030 focus group, which I will direct alongside my role leading the Innovation team. It is then our ambition to develop similar programmes focusing on delivering clean industry and clean transport for the UK.

Innovation will play a pivotal role in helping us deliver these ambitious programmes, and our existing funding mechanisms – the Network Innovation Allowance (NIA) and the Strategic Innovation Fund (SIF) – will continue to support with the delivery of key innovation work.

The SIF is the replacement for the previous Network Innovation Competition (NIC) and supports innovative activities that contribute to achieving net zero, by providing funding for larger-scale demonstration projects.

We previously utilised NIC funding to deliver FutureGrid Phase 1, a flagship project to build a high-pressure hydrogen test facility from decommissioned network assets, to carry out a range of tests in various network conditions and with different blends of hydrogen and natural gas. Phase 1 demonstrated that our assets can transport hydrogen safely and reliably. The results of the testing are extremely positive and provide an indication that there are no major blockers to repurposing our network to transport hydrogen.

We're now using SIF funding for the next stage of this research – FutureGrid Phase 2. This has been split into two ground-breaking beta projects: Compression and Deblending.

Corinna Jones
Director of Clean Power and Innovation

The Compression project is testing the performance of gas compressors with hydrogen, to develop an asset fleet that's fit for the net zero future. The project aims to demonstrate that the existing fleet can be modified cost effectively, to work with hydrogen. We will test a decommissioned gas turbine with different blends of hydrogen up to 20%, and then modify it, to test with 100% hydrogen. We'll also carry out offline testing of the full compression system with a range of hydrogen scenarios.

So far, we've made significant progress on the project, including identifying ways of working, establishing the delivery team, and deploying required governance and project controls. We've developed the detailed design of the facility and retrieved and inspected various assets that are planned to be repurposed. Alongside this, we've been preparing the selected compressor unit for decommissioning and made a start on the groundworks for the compressor facility.

Over the coming months, we're due to commence with the disconnection of the selected compressor unit, which will allow for its complete disassembly, before all component parts are transported to Spadeadam. We'll also be continuing to inspect and prepare various required assets and will be finalising the preparations for testing our gas turbine with various hydrogen blends, at the Ansty test facility in Coventry.

Alongside this, the Compression project team are leading our activities on building the clean industry programme, bringing together stakeholders from across our network to share learning from our Futuregrid and HyNTS programmes, to accelerate industrial decarbonisation.

Decarbonising our network is a significant but exciting challenge, one that FutureGrid Phase 2 is at the heart of. I'm looking forward to seeing how the project evolves and develops over the next year and beyond.

Section 2

Executive Summary

National Gas are undertaking an extensive programme of work to repurpose the gas transmission system to operate with hydrogen, as well as expanding the network with new hydrogen pipelines where necessary.

This programme focuses primarily on existing National Transmission System (NTS) customers such as power stations and industrial customers. Compressors are essential for maintaining the flow of gas throughout the NTS and ensuring security of supply for the UK. The FutureGrid Compression project will demonstrate that an existing compressor system can be repurposed to operate with hydrogen blends of up to 20% with minimal changes and also 100% hydrogen following strategic modifications. Demonstrating that existing assets can be repurposed rather than replaced will ensure that National Gas Transmission (NGT) is able to rely upon its existing fleet as much as possible, whilst awaiting policy decisions on hydrogen blends and 100% hydrogen.

The FutureGrid Compression project will relocate an existing compressor system to Spadeadam and build a 1km pipe loop around it, to carry out testing operations with hydrogen blends up to 20%. The compressor will then be replaced with a new compressor and gearbox to enable it operate with 100% hydrogen. In addition to this the Gas Turbine used to provide drive for the compressor will be tested separately at Siemens Energy/RWG's Ansty facility, to demonstrate the capability of the Gas Turbine to operate with hydrogen blends up to 20% and also 100% hydrogen. The data and learning gained from this project will provide essential technical and safety evidence which will be used to support NGT's safety case updates and engineering decisions made as part of Project Union. In addition, the project will also provide economical evidence supporting any investment decisions made as part of Project Union.

In the first year of the project, we have identified ways of working, deployed governance and project control plans and enhanced the delivery team. We have made significant progress in developing the detailed design, as well as retrieving and inspecting the assets to be repurposed, and preparing Huntingdon Unit A for decommissioning. The preparation for the Gas Turbine testing at Ansty is underway, with testing operations due to commence in early 2025. The project has encountered numerous challenges which NGT continue to manage. The successful completion of all testing operations from FutureGrid phase 1 has been a clear success, with all learning being used to support the approach to repurpose assets at FutureGrid Compression.

The challenges that we have encountered, and the approaches taken to rectify these issues are key learnings to consider as NGT transition the NTS for hydrogen blends and 100% hydrogen. Although the detailed design phase is taking longer than originally envisioned, the pathways we are taking to resolve the problems can be followed in the future. In addition to this, most of the lessons learned are unique to the nature of the test facility we are engineering. By designing a closed loop test system there are several significant hurdles involved, which we were not able to fully understand during the alpha phase, due to limitations with the time and resources allowed for this phase.

The benefits from this project will be realised via the deployment of hydrogen blends on the NTS, and eventually the rollout of Project Union across the UK. NGT have continued to make significant progress in both areas since the project has commenced. Project Union has recently completed Pre-FEED and preparations are underway to commence FEED of the first section – East Coast Hydrogen. The FutureGrid Compression project continues to align closely with these strategic programmes to ensure that the project learning and outputs are exploited.

NGT have made advances in opening the FutureGrid facility for third parties to use for testing. We have drafted a process for encouraging uptake in testing opportunities, to maximise the value delivered from the FutureGrid programme.

> "Compressors are essential for ensuring the flow of gas is maintained through the NTS and ensuring security of supply for the UK."

This project will develop evidence that our existing compressor fleet can be modified for hydrogen use in a cost-effective manner.

A decommissioned gas turbine representative of the current fleet will be fuelled by different blends of hydrogen up to 25% then, following modifications, up to 100% hydrogen.

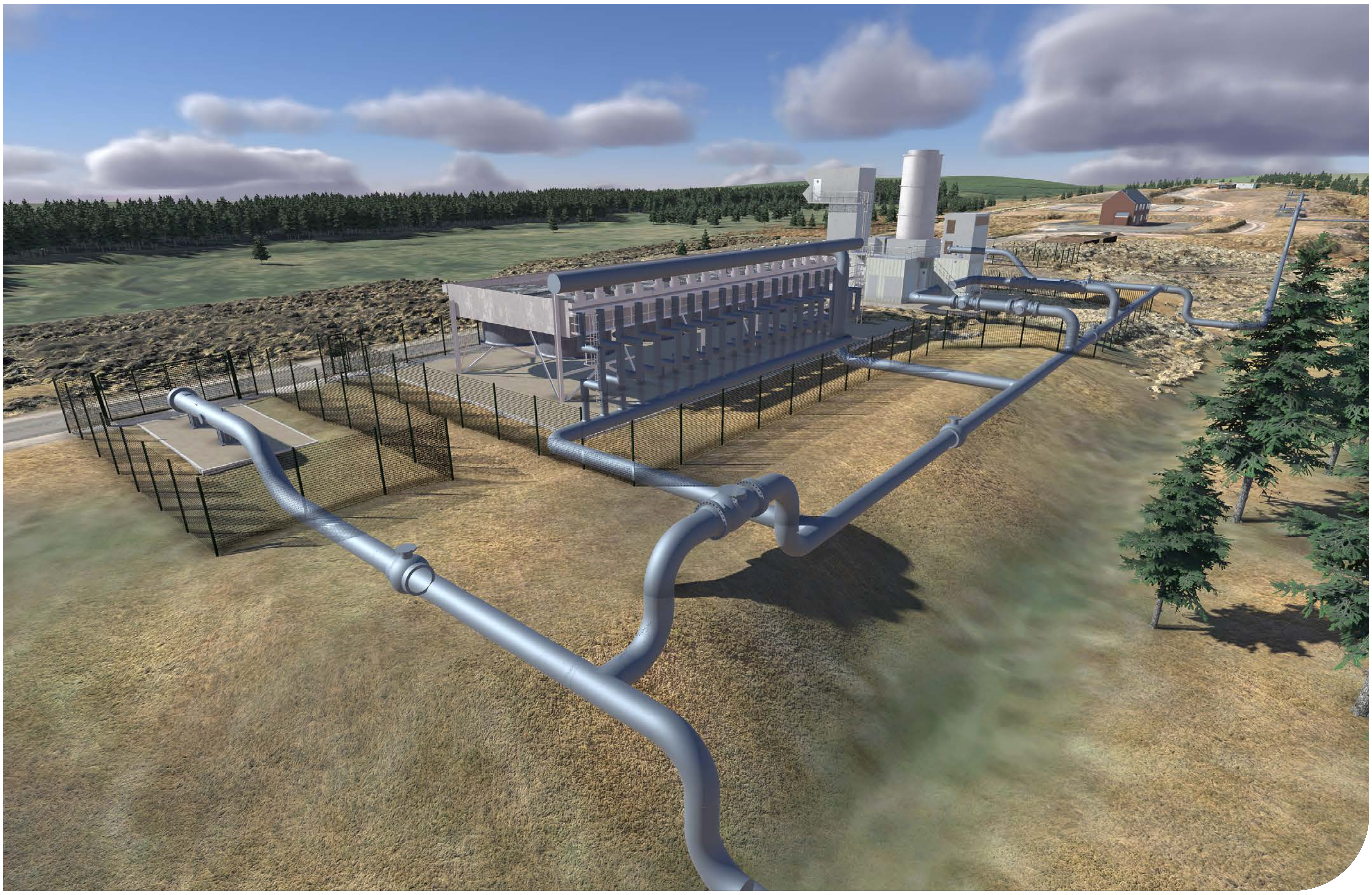
The full compression system including the power turbine, gas compressor, the cab and ancillary equipment will undergo comprehensive offline testing as part of the FutureGrid facility.

A 1km compression test loop will be constructed out of decommissioned NTS assets to test the compressor systems in a range of hydrogen scenarios.

This will demonstrate the capability of both the rotating machinery package and the full system. It will give an understanding of how these would operate on a hydrogen network.

This testing is key to provide technical and safety evidence that demonstrates the compression assets can be repurposed for hydrogen blends up to 100% hydrogen.

The outputs of this project will ultimately help develop the business case for repurposing compression assets as part of Project Union, National Gas 100% hydrogen backbone across the UK.



Phase 2 development

Now that Phase 1 testing has been completed there are additional phases planned to adapt the FutureGrid facility and allow for further development. These are essential for understanding how a hydrogen NTS would operate. Designs are well underway at the time of publishing for Phase 2 Compression and Deblending.

FutureGrid

Deblending


FutureGrid
Compression

Section 3

Project Summary

Project Objectives

The National Transmission System (NTS) provides flexibility in the UK's energy system, through its capability to store energy for long periods of time. Using hydrogen as an alternative to natural gas ensures that energy demands are met for power, industry and potentially transport in 2050. To transport and store hydrogen across the UK, compression is required. Compression provides flow and builds linepack at times of increased demand in certain locations of the network. This demand is generated from heating (distribution networks), large industrial users or power generation. In the future, energy could be stored as hydrogen linepack in the NTS at times of excess renewable electricity generation and low gas demand.

The re-purposing of NTS compressor systems for hydrogen has not been demonstrated, although desktop studies indicate its feasibility and cost effectiveness. There is a need to provide a technical demonstration to develop the required evidence and enable the predicted benefits for repurposing compression assets. The cost of a new compression system is approximately £60m per unit and there are 57 units in use on the NTS today, therefore, re-purposing existing assets would bring about large cost savings to the consumer. We have determined that gas turbines could be modified to be fuelled with up to 100% hydrogen, and previous analysis of the compressor has suggested that they could operate with up to 50% hydrogen. Above 50% hydrogen, a compressor upgrade is required. This will be demonstrated in this Beta phase. Siemens Energy will be responsible for the required upgrades to the gas turbine and compressor unit. The innovative solutions being developed throughout this project will enable the repurposing of compression systems and are vital to reducing the cost of the energy transition for consumers.

Project Deliverable Update

SG1 M2 WP1: PMO activities completed for Design Sign off

Several core Project Management activities are led by NGT, to ensure any issues are proactively identified and effectively mitigated, to minimise the likelihood of any delays or additional costs to the project. These activities also ensure that the outputs of the project are being achieved. We have set up several key forums to monitor progress and assure the quality of the project outputs, through to completion.

A weekly project management meeting is used to review programme milestones and identify and discuss outstanding issues and high-level actions. A quarterly project risk review is conducted to identify all risks and their severity. In addition to this, we hold various internal meetings and steering groups to ensure the project management activities are conducted swiftly and any concerns are raised at the earliest opportunity.

SG1 M2 WP2: Business & Safety Function for Design Sign off

NGT leads the activities associated with this milestone, to ensure that the project is aligned to the NGT Compressor Strategy and that any project outputs are being fed into the Project Union baseline.

The project team has successfully drafted the Master Test Plan which will be a live document, refined throughout the project. Several internal steering groups are held, to ensure the deliverables within this milestone are being completed. We have regular meetings with the Project Union team to exchange knowledge and ensure alignment. We also hold a regular steering group for our internal Subject Matter Experts, to update them on progress and give them an opportunity to collaborate and input to the project using their specialist knowledge.

SG1 M2 WP3: Offline Test facility facilitation in progress and gas turbine ready for decommission

Siemens Energy is the lead partner for this milestone, with other partners supporting where required. The aim of this milestone is to design and modify the Ansty facility to enable the Gas Turbine (GT) to be tested with blends of hydrogen and 100% hydrogen. The modifications required for the GT to be suitable for 100% hydrogen also falls within this milestone. Once the modification is completed, the GT testing will resume at Ansty for 100% Hydrogen.

In this reporting period we have designed the components required for the 25% blend test and 100% hydrogen test at Ansty. Siemens Energy have procured all the long lead items required for the facility upgrade, to ensure there are no further delivery delays.

SG1 M2 WP4: Business & Safety Function activities complete for Design Sign off

All partners are responsible for this work package, with DNV being the main partner conducting site installation and testing. Where industry standards are available these will be employed. Where deviations to these are required, these changes will be fully risk assessed and documented. As facility operator, DNV are ultimately responsible for ensuring the safe operation of the facility. The design, installation, commissioning, testing and operation must be safe and legally compliant.

The test loop detailed design is scheduled to be completed in this reporting period. At project commencement, we broke this milestone into two elements, to manage its delivery more efficiently. These are: test loop design (pig trap to pig trap) and compressor facility design.

SG1 M2 WP5: Business & Safety Function activities complete for Design Sign off

NGT leads the activities for this work package, with support from other project partners. In this reporting period we have successfully completed four quarterly project reviews with our monitoring officer. We have taken the feedback provided and incorporated it into our reporting packs. We have also completed a stage gate review (Stage Gate 1) with UKRI and Ofgem, upon completion of the test loop design.

In addition to this, we are in regular co-ordination with the Project Union team to draft an implementation plan. We also have a presence on the Project Union steering boards, where we provide regular project updates.

Governance Acronym Key

'SG' – stage gate
'M' – milestone
'WP' – work package

Project Innovation Update

The compression assets on the NTS represent high value items that, if repurposed, would bring big benefits to the UK consumer.

This project is designed to gain understanding and inform regulatory safety and business decisions via a safety case. It will achieve this via 4 primary objectives:

1. Understand the practical considerations that repurposing our compression assets for hydrogen blends and 100% hydrogen will require, to ensure safe, functional operation
2. Conduct a full-scale demonstration of the existing compression assets
3. Understand the limitations of our existing assets on network performance
4. Understand the value to the UK consumer that can be realised from repurposing our compression assets

The project is an excellent opportunity to understand the complexities involved with repurposing the compression assets on our network. Some of the challenges encountered during the project are bespoke to the project setting. Others provide valuable insight into the challenges that will arise during repurposing. A full list of systems and differences during design and operation for the different fluids, is being compiled as part of the project.

The full-scale demonstration requires a rigorous design at a level that seldom happens for conceptual studies. This provides valuable information in terms of technical function, safety, and associated cost implications for our network, to allow us to make the best decisions in the interest of the consumer.

The existing assets may not be the optimum assets for the task required, but if their limitations are such that they can usefully provide acceptable levels of service at a vastly reduced cost to new assets, they still represent great value to the UK consumer through this period of energy transition. This project seeks to understand this detail. The demonstration methodology and design is such that we will be able to assess and understand the usefulness of the existing compression assets and their value to the UK consumer. Hence, we will be able to make appropriate decisions on the repurposing of assets.

The project is on track to produce the data we need, to understand the complexities of repurposing the compression assets. This will allow us, and others, to make decisions that represent the best value for the UK consumer.

The principle innovative aspect of this project is investigating how to handle hydrogen safely and effectively in a pipeline system that was designed and built for operation with natural gas. It includes an impact assessment of each component, to determine suitability for use. Some of this assessment can be achieved using engineering judgement and, in some cases, where research and existing industrial processes exist, it may be easier to use these to understand the impact. These decisions are being considered at every stage of the design development. Some aspects will require separate standalone testing, and further research bespoke to the NTS assets. The findings will inform the suitability of the NTS assets with hydrogen.

This innovation project will make improvements to the process of repurposing natural gas assets for hydrogen operations. It will also make improvements to services. It is building knowledge and expertise across the industry, to ensure the UK consumer is well positioned to benefit from safe and effective network operation with a new process fluid.

Project Challenges

The project has encountered numerous challenges during the first 12 months, however a collaborative approach between project partners has helped to ensure that these are proactively managed, with any blockers being identified, shared, and escalated where necessary, to achieve a resolution. Some challenges are unique to the tasks associated with designing, building, and running an offline test facility and the learning achieved throughout the project will be a huge aid for NGT, when it comes to implementing the novel innovation methods being investigated. A sample of the key challenges encountered in the previous 12 months include:

Asset Condition

Over 600 meters of decommissioned pipeline from various parts of the network has been stored at one of NGT's decommissioned sites near the village of Cawood. The site had a severely potholed access track unsuitable for heavy loads. Following obtaining permission from NGT properties and the landowner, road repairs were carried out, so heavy wagons could utilise the re-instated road for pipeline transportation to Spadeadam.

As more and more Liquefied Natural Gas (LNG) is imported into the United Kingdom, NGT are faced with the growing challenge of naturally occurring radioactive materials (NORM). NORM originating from radon gas has propagated across the NTS and therefore, NGT has complied with strict regulatory procedures when transporting contaminated decommissioned assets. The levels of NORM found throughout this phase of works would be unlikely to cause immediate cause for concern in terms of health issues, from short term exposure levels. However, as NGT is very safety and environmentally conscious as a business, we have carried out more cleaning works than originally anticipated, to provide decontaminated, clean sections of pipelines for future testing. The level of cleaning required, along with the programme impact and cost was not forecast to be as significant as has occurred.

As the pipeline has been removed from service some new challenges have arisen regarding minor scuffs and scrapes to the outer wall of the pipeline sections. Soil stress has degraded some outer coatings, and the decommissioning and outdoor storage of some assets has meant the coal tar enamel coating on some sections of pipeline has failed, where it has dried out. In these instances where failed CTE or minor damage has been noted, a full coating strip and P11 mechanical damage assessment has been undertaken, to ensure to the integrity of the pipeline, for continued use with hydrogen.

Unit A from Huntingdon has some minor defects but is in good condition overall. Before the unit is sent for testing at the RWG facility in Ansty near Coventry, repairs are being carried out to the Gas Turbine, as a recent borescope inspection showed that a crack was present on the starter fairing. Therefore, a new one has been ordered.

Decommissioning of Huntingdon Unit A

Disconnection of the unit from the network mechanically and electrically has been the main focus for decommissioning. Working with the decommissioning team, we have worked out a mechanical disconnection design that does not need to be carried out during a full site outage. Electrical isolation of the unit needs to be completed and is going through planning and design, this entails physical power isolation and then control system re design and disconnection from the main site control system.

The release of Unit A for FutureGrid Compression has unfortunately been delayed due to uncertainty in the wider business resilience plan. This relates to the delayed operational acceptance testing of the newly commissioned Units D and E, as commissioning teething issues were encountered. The issues identified had a knock on effect to the original planned time scales for FutureGrid, however NGT are confident we can minimize any impact to the projects critical delivery path.

Design interdependencies

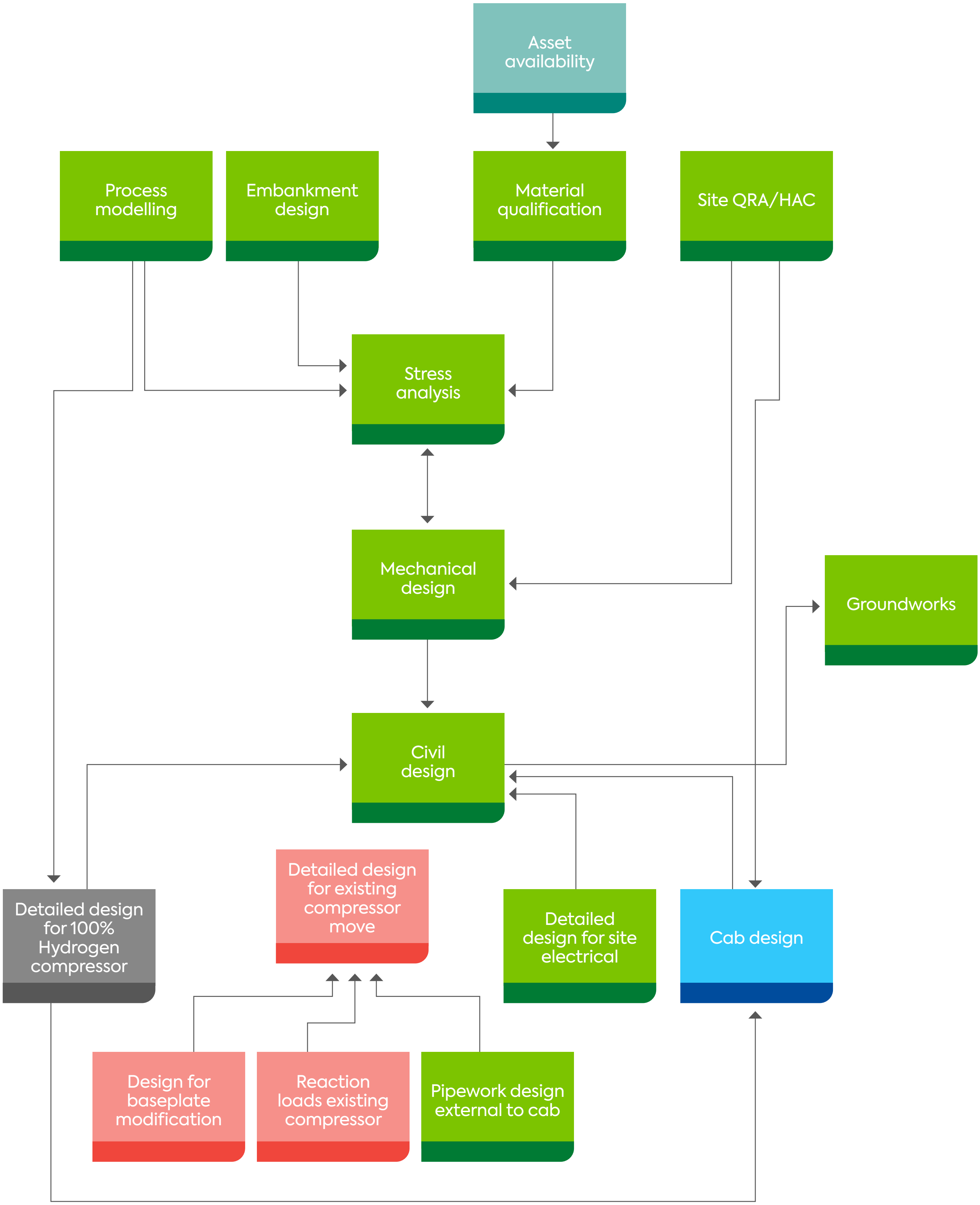
Figure 1 (see page 12) highlights the complex interactions between the design deliverables required for Phase 2 Compression, which pose significant challenges. At the core, foundational elements such as process modelling, and asset availability play crucial roles. These elements are essential in the early stages, influencing subsequent tasks like stress analysis and mechanical design. Stress analysis, in particular, is pivotal as it directly impacts both mechanical and civil designs, ensuring all structural and mechanical components can withstand operational stresses.

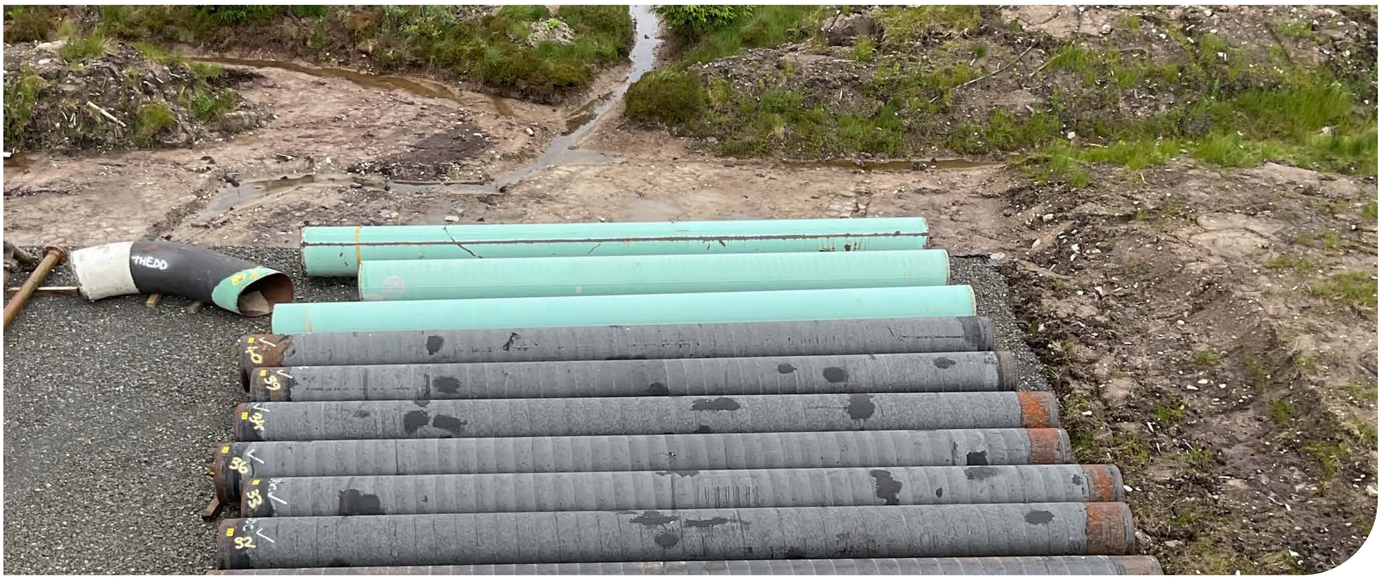
Mechanical and civil designs are closely interconnected, with outputs from stress analysis informing these areas. Mechanical design further affects the detailed design for both the 100% hydrogen compressor and the existing compressor move. This necessitates precise planning to adapt existing infrastructure and integrate new technologies seamlessly. Additionally, material qualification and site quantitative risk assessment/hazard analysis and control (QRA/HAC) are critical for ensuring safety and reliability. These assessments influence groundworks, embankment design, and cab design, all of which are vital for the project's physical implementation.

Several challenges arise from these interdependencies. Coordination and timing across all the project partners are crucial, as delays in one area can cascade and impact multiple components of the design. Effective resource management is crucial, ensuring that materials and assets are qualified and available on time to maintain the project schedule. The complexity of integrating new technology with existing infrastructure requires meticulous planning and design, particularly in aligning new and legacy systems. Comprehensive safety assessments and compliance with regulations add another layer of complexity, necessitating thorough integration into the design process. Lastly, the project demands cross-disciplinary collaboration, requiring effective communication and coordination among mechanical, civil, and electrical engineering teams to address interdependencies and ensure smooth project progression. This has been made very challenging by the detailed requirements for each discipline only becoming apparent with iteration, and the coordination and feedback into other disciplines complex.

In summary, the design interdependencies in the FutureGrid Phase 2 Compression project illustrate the complexity and challenges of coordinating multiple interconnected tasks. Addressing these challenges requires careful planning, resource management, and cross-disciplinary collaboration to ensure successful project delivery.

Figure 1 – Design dependencies





Project Learning

Package Configuration

The test loop is designed to have a cab that would house the rotating machinery. The test will be carried out using decommissioned assets from Huntingdon Unit A which comprises a gas turbine, power turbine & compressor. However, the test loop will have a gearbox as part of the equipment in the cab. As a result, it was discovered that a bigger sized cab would be required. To cater for the difference in cab size, CFD modelling was used.

Decommissioned Asset Condition

As safety is top priority in this project, the condition of the assets is examined via inspection before transporting to the FutureGrid Compression site at Spadeadam. One key learning was the amount of cleaning required for the pipes due to the presence of NORM (Natural Occurring Radioactive Materials). Some pipes were identified as NORM contaminated during pipe inspection. This meant that a significant amount of cleaning was required to make the pipes acceptable for building the compression test loop. This also incurred additional costs to the project.

Opportunities

Development of corporate knowledge of safety implications of hydrogen in natural gas systems
The National Gas project team is taking every opportunity to learn and build knowledge to bring into the business that will allow us to safely operate and manage the NTS network through the transition to hydrogen. It will be imperative that knowledge can be built quickly across the whole business, in the context of our assets, to ensure the risk profile of the business is maintained. This project is taking the opportunity to collate learning points and disseminate these across the business.

Development of corporate understanding of cost implications of process fluid change to hydrogen
As part of this project, decisions are being made to ensure the safe, functional operation of NTS assets within a closed loop system. The information that arises because of this project design is being captured and analysed to ensure those that are relevant to operating the NTS (not the closed loop system) can be disseminated to the teams working on Project Union.

Opportunity to incorporate constraints from Project Union
We are developing close links with the Project Union team to ensure we are well placed to understand whether there are any situations that arise on the NTS that we can choose to incorporate into the project, as Project Union progresses. If any arise, this will help us make future decisions and represent the best value to the UK consumer.

Contribute to continuous improvement of project delivery in the innovation project space
It has become apparent that for this very complex project that requires cross discipline and for cross industry knowledge to come together, it would have benefitted from a FEED study element, to provide detailed understanding of deliverables and the resources required to deliver them. This would have allowed for a better-defined requirement from each party and a clearer plan and programme to be developed from the outset. This project will provide feedback on how the structure of the project could have been improved to aid delivery.

Section 4
Knowledge creation & dissemination

Lessons Learned

Decommissioning design for disconnection

The disconnection and dismantling of the unit were reliant on the release of the unit and the initial plan was to complete the full disconnection during a station outage. Due to various operating complexities, the System Operator (SO) were unable to release the unit when required, which made it difficult to complete the work during the identified outage. We managed to work with the decommissioning team to come up with an alternative solution, to disconnect the unit without needing an outage. This demonstrated that multiple options and ideas should have been explored early in the project to relieve the pressure associated with the unit release.

Start of the project regarding Alpha and Beta

As we have moved from the Alpha phase into Beta, we have identified a couple of gaps in scope. While this was expected due to the size and nature of this project, a detailed plan has been developed to cover any gaps in scope and identify any potentially required logistics to get the compressor unit where it needs to be at critical points in the project. This highlighted that more time should have been allowed at the start of the project to further define and refine the scope, this would save time in the long run because the partners can start activities earlier.

Section 5
Intellectual Property (IP) Rights Generation

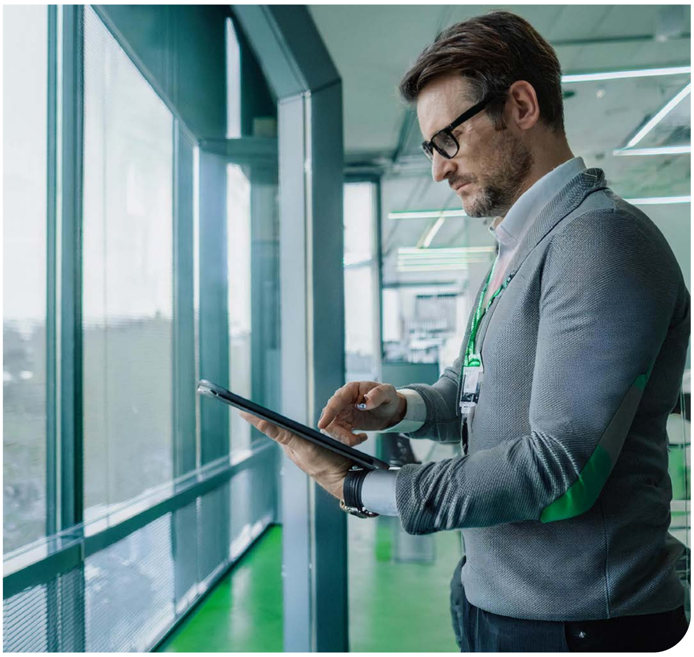
Compression Facility Design

A key focus of the first phase of the project has been establishing the requirements and developing the design to move from the concept explored in the alpha phase towards a detailed design for the beta phase. The processes carried out in the design phase are in alignment with industry accepted practices for pipeline and compression facilities, however given the unique nature of the facility, several novel approaches are being undertaken. The knowledge and experience attained throughout this first year of the project will be invaluable to NGT and the partners, for consideration when Project Union progresses. There is also an element of the learning which could potentially be exploited via knowledge sharing, however at this stage, the value attained through the design process will best be realized via the repurposing of existing assets under Project Union. This learning, along with other project lessons learned, is reflected upon at monthly project reviews and the QRM's. Further information will be shared with other networks upon request for any technical information or learning sought.

100% Hydrogen Compressor

Another focus for the project has been the refinement of the plans for the 100% Hydrogen compressor. The key foreground IP for the project will be realized for this when the commissioning, and operational phases of the project commence. This will be when valuable learning can be extracted from the project which does not clash with existing background IP (i.e. the compressor design and internals).

Section 6
Data Access Details



Details on network or consumption data arising during a SIF or NIA-funded project can be requested by interested parties, by emailing: .box.GT.innovation@nationalgas.com.

National Gas already publishes much of the data arising from our SIF/NIA projects at: smarter.energynetworks.org

In addition to this, as part of the communication and engagement plan, NGT has held webinars for the purpose of sharing knowledge throughout the duration of the project. We plan to continue these events as the project continues. There are also specific events planned for the completion of different blends of hydrogen. These webinars and events will be open to all interested parties. We have also set up a shared email box in which any queries about the project can be addressed. The email is: futuregrid@nationalgas.com.

The website nationalgas.com/futuregrid also contains presentations, videos, files and images relevant to the project which can be accessed by interested parties.

Section 7

Route to Market / Business As Usual

Project Union/Blending

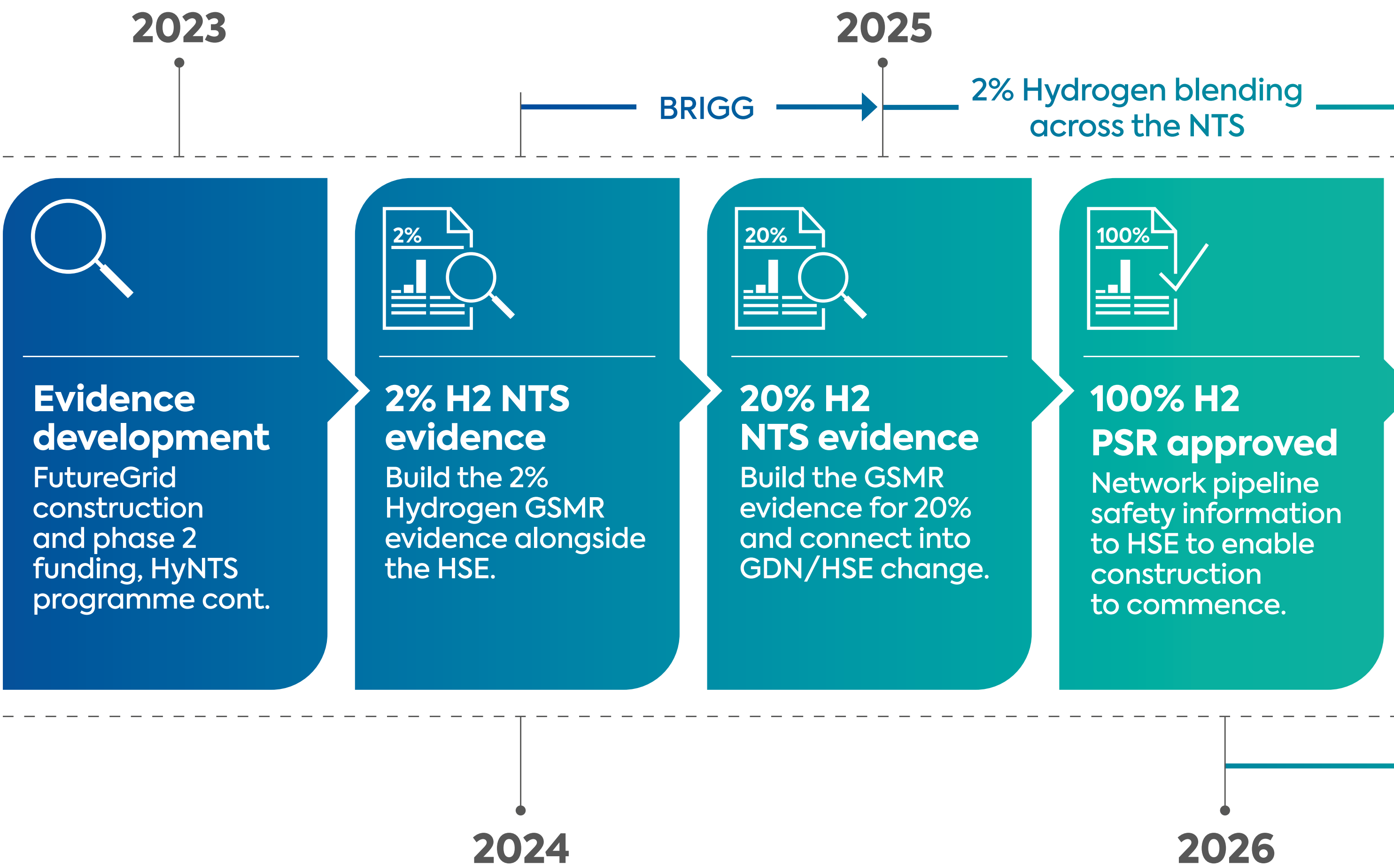
A key component in the transition to hydrogen is building the evidence and safety case that we can safely operate a hydrogen network to the same standards that we operate our natural gas network today. Ultimately, the importance of FutureGrid within our Hydrogen programme has become greater, with the project spearheading the technical demonstration and development of safety evidence for operating a network with hydrogen, which includes both blending and 100% hydrogen. This has increased FutureGrid and the wider innovation portfolio's criticality in the development of Project Union, and the conversion of the NTS to incorporate hydrogen blending.

Project Union will deliver a hydrogen transmission backbone, connecting industrial clusters and strategic hydrogen production sites with storage and users across the UK, by the early 2030s.

Through the phased repurposing of existing assets, alongside new infrastructure, a hydrogen backbone of up to 2,500km will be created. The backbone will initially link strategic hydrogen production sites, including the industrial clusters, with storage and users across the UK by the mid-2030s and provide the option to expand beyond this initial hydrogen transmission network, to connect additional consumers.

The timeline below indicates the development of this evidence with 2% hydrogen, followed by 20% hydrogen blend evidence and then 100% hydrogen evidence. This is followed by the relevant policy updates and the ultimate rollout and construction across the network. These dates indicate where the network could take hydrogen at those levels and is still subject to the resultant supply and demand of hydrogen:

Figure 2 – Blend evidence timeline



To develop the necessary technical evidence for both Blending and Project Union as part of our hydrogen programme, we utilised FutureGrid. FutureGrid Phase 1 was completed earlier this year, aiming to explore the feasibility of repurposing the NTS to transport hydrogen. This project, an essential part of the National Gas HyNTS programme, aligns with the UK's net-zero ambitions, by demonstrating the operational viability of the system with varying hydrogen blends, using decommissioned assets typical of the natural gas network today, ultimately aiming for 100% hydrogen conveyance.

Testing was successfully completed on the FutureGrid Flow Loop in March 2024. All gas compositions were tested as per the test programme, along with additional tests identified as opportunities for further data collection.

Performance testing included the operation of ball valves, flow control valves, regulators, and filters. The performance of different types of flow meters was also investigated, along with a gas chromatograph for gas quality. Venting operations were also carried out, and a vibration survey was undertaken on the facility.

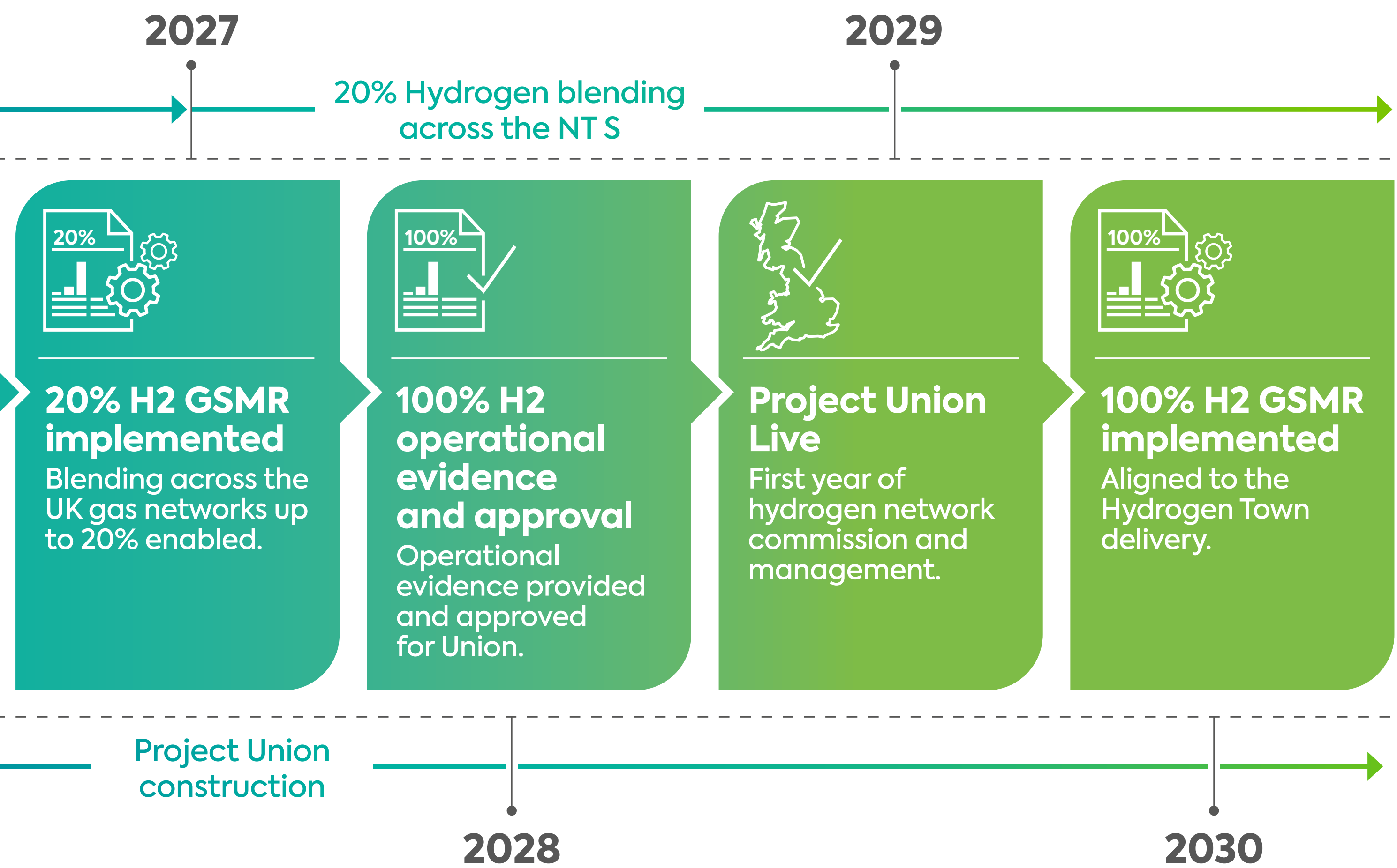
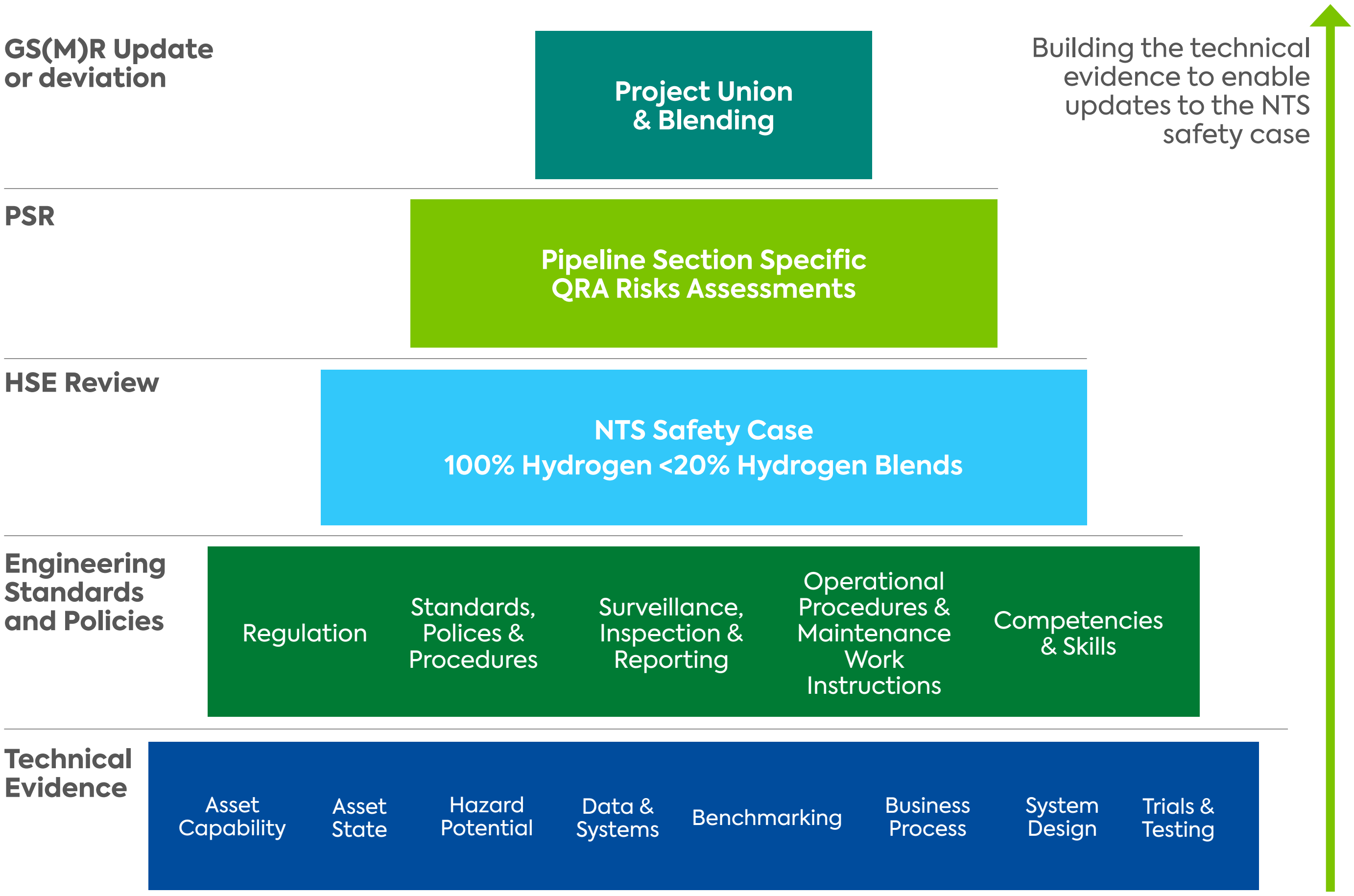


Figure 3 – Foundation diagram (Our approach to delivering the NTS Safety case)



The FutureGrid project has greatly enhanced the understanding of how the NTS will operate with hydrogen blends and 100% hydrogen. FutureGrid forms part of the wide range of innovation projects that play a key part in developing the technical evidence for the transition of the network to hydrogen, As illustrated in Figure 3, the foundation of the work we do is building the technical evidence, which in turn drives updates to the engineering standards and policies that are required. This feeds into the HSE safety review, which in turn identifies the relevant policy changes needed to transport hydrogen and hydrogen blends across our network, to ultimately enable Project Union.

FutureGrid Compression will continue to develop our understanding of how our compression systems will operate with hydrogen blends (with minimal modifications) and with 100% hydrogen (with major modifications). The demonstration being carried out is essential to the development of the evidence which will underpin our blended hydrogen safety case and our Project Union safety case.

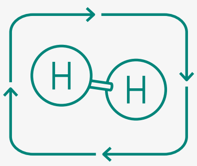
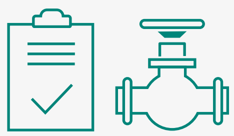
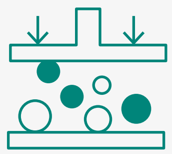
The learning from this project will be essential to support the identification and selection of compression options as part of Project Union, and will underpin both the repurposing of existing compression systems up to a 25% Hydrogen blend, and also carrying out strategic modifications to equipment (e.g. the compressor, enclosure, safety systems) at 100% hydrogen. Repurposing the compression assets for continued operation with a hydrogen blend and/or with 100% hydrogen, will be the most direct opportunity to integrate the knowledge and innovation which is being developed as part of this project.

There are assets which are not included in the FutureGrid facility which will require some understanding about how they operate. We will close these gaps using findings from other innovation projects in our hydrogen safety case portfolio. These will start to build the foundational technical evidence, and any standards and procedural updates needed, while further specific Quantitative Risk Assessments (QRAs) will inform and enable Project Union and blending. There will be an ongoing requirement for new innovative technology to be developed, to support any differences in how a hydrogen NTS will operate. The FutureGrid facility will continue to provide a vital role in full scale demonstration of this new technology, with the 100% Hydrogen metering project an example of this.

Added Value Opportunities

National Gas have identified four key value generators associated with the FutureGrid programme. Much of this value has been realised during phase 1 of the programme, with the phase 2 Compression facility yet to be built. The outputs from the phase 1 progress sets a positive pathway which can be replicated for the Compression facility. An update on the value realised to date across the FutureGrid programme including indications of future value is provided below:

Table 1 – Value realised to date

Value Generator	Value realised to date
 **Phase 1 facility: FutureGrid Test Loop**	• Ongoing and completed NIA projects achieving cost savings due to the use of the facility as detailed in "Completed projects linked to FutureGrid" section below. • FutureGrid Deblending for Transport project utilising the facility for Phase 2 rather than building an additional facility, saving £5m.
 **Technical evidence from FG and wider innovation portfolio**	• Phase 1 technical reports fed into the HSE safety case review for hydrogen in the NTS. Comprehensive reports providing key evidence and supporting an efficient and timely review of the NTS' role in hydrogen transportation. • Exchange of high level data and concepts as part of national and international working groups to further knowledge development.
 **Phase 2 facility: FutureGrid Compression Loop**	• Initial promotion and engagement on the facility is generating interest with national and international asset manufacturers and gas networks. • Opened discussions with Baker Hughes and Solar (Compressor manufacturers) who were initially very reluctant to even discuss repurposing of equipment. Potential for future testing and similar benefits realisation with lower repurpose v replace costs.
 **Skills and competencies development**	• Initial discussions about potential opportunities for utilising the Phase 1 facility as part of training packages. • Ongoing engagement and development of the facility, bring key experts in our natural gas network to support the work, understand the outcomes from testing and develop their knowledge.

These key areas offer a significant opportunity over the medium to long-term, to generate value for the consumer through the continued use of the facility and its outputs. The value should not be underestimated, particularly when considering the cost reductions that future projects can achieve by utilising this facility rather than setting up their own individual test rigs. Establishing an individual test rig for each project is not only extremely expensive, but also becomes increasingly challenging when using decommissioned assets that have been in service on the network. This process requires substantial time for individual design and development. In contrast, using an existing facility like FutureGrid, where the testing can be tailored and integrated into the facility, significantly reduces the time and resources needed to produce the required testing outputs.

Deviations from Application Plan

A key change in the work undertaken so far has been the identification of the need for carrying out a thorough end to end analysis of each system, prior to its relocation. A key assumption made during the alpha phase was that it would be sufficient to use the existing design information and red line drawings to be able to reassemble the Compression system. However, this additional analysis is essential, to give confidence that the demonstration exercise can be carried out safely.

The detailed design process has identified additional activities that are required which were not originally forecast in the project RASIC. NGT is closely monitoring this to ensure these activities are accounted for by the project partners.

Commercialisation Pathway

In the first 12 months of the project, huge progress has been made in areas which will underpin the commercialisation of the technology being demonstrated in this project. The completion of the FutureGrid phase 1 testing has provided a large amount of empirical evidence which supports the case for repurposing the NTS, for both hydrogen blends and 100% hydrogen. Ultimately, it is via the repurposing of NTS assets, that the technology being developed in this project will be commercialised. The driver behind this commercialisation strategy is the need to meet the UK's net zero emissions target by 2050. Following government direction, that the UK should develop 5GW of low carbon hydrogen production by 2030 (raised to 10GW by the revised British Energy Security Strategy in April 2022), Gas Networks need to develop a commercial approach to transport, and transition from methane to hydrogen at best value to the consumer. This also aligns with the 2030 Clean Power target.

All gas turbine Original Equipment Manufacturers (OEM's) are currently developing the capability to operate their equipment with increasing levels of hydrogen. Positive competition is encouraged, as this brings the best solutions to the surface and in turn, benefits all involved, including the consumer. With respect to HyNTS, the gas turbine capability is a generic offering available to all customers of Siemens Energy. The materials are selected for the specific gas and the flow path is designed for the suction and discharge conditions. Since there are so many compressor manufacturers globally, there is already a well-developed competitive market. In the deployment of any re-purposing activity, competitive tenders will be undertaken as per regulatory requirements. Throughout the project, we have been regularly engaging with other OEM's to understand the approaches adopted by them and to help stimulate this market.

The primary customer for the outcomes of this project are gas network operators utilising centrifugal compression, however, many other industries, such as oil and chemical industries, also utilise these systems and may also benefit. NGT will carry out strategic engagement with these industries, as learning from the project continues. All partners will gain a level of knowledge that could enable them to provide additional value to the UK through export. The solutions developed could be utilised globally, providing an opportunity for the project partners. This project will further develop the UK knowledge base, which could in turn generate employment opportunities, furthering this innovation research and creating engineering expertise and skills.

Section 8

Policy, Regulatory & Standard Barriers

Policy

There are a number of policy barriers that will need to be overcome to fully utilise the findings from this initial project. In 2023, the Government outlined their plans to allow for blending hydrogen into the gas distribution network. This policy decision will need to be extended to transmission i.e. Government will need to agree blending into the transmission network. Once agreed, there will need to be changes to key legislation, such as GS(M)R and the UNC to facilitate the policy change and to make sure the policy is implemented.

To progress to 100% hydrogen, Government will need to agree the need for the strategic development of a hydrogen network. Once agreed, legislation will need to be developed that facilitates the ongoing development of a hydrogen market that utilises the 100% hydrogen infrastructure.

In addition, there will need to be policies in place that allow for the development of hydrogen production and demand side measures that promote hydrogen consumption. The utilisation of the network for hydrogen blends and 100% hydrogen relies on a sufficiently mature hydrogen economy to be developed, to ensure that there is sufficient hydrogen produced/consumed to allow for blends/100% hydrogen to be deployed. As there is not currently large volumes of hydrogen produced anywhere in the UK, the hydrogen market will require suitable policies that encourage and stimulate the development of the low carbon hydrogen market.

The development of the Hydrogen Transport Business Models (HTBM – to be published in 2025) and the process to develop an initial hydrogen network via the Hydrogen Allocation Round are examples of policy that looks to drive the development of a 100% hydrogen system. This commitment will need to continue and develop to allow the hydrogen economy to grow.

Regulatory

Regulatory barriers or uncertainties that may hinder Beta delivery

So far, there are still no regulatory barriers that prevent the delivery of the project through Beta. This phase will enable the delivery of evidence, knowledge and technologies related to the repurposing of compression units, to enable future application on our hydrogen investment activities such as Project Union. Uncertainty in the RIIO-2 funding mechanism requirements and timelines, could lead to projects not progressing in the assumed funding route or timescales proposed. However, discussions are ongoing to ensure we are approaching the activities in the correct manner with Ofgem, DESNZ, UKRI and the HSE.

Long term regulatory barriers for implementation

Our network supplies natural gas to industrial, power and heat applications today and has the opportunity to support the transport of Hydrogen in future. The NTS' first application of hydrogen in the UK will be through Project Union, beginning construction in 2026, to re-purpose 2000 km of pipeline, to enable inter-connectivity between the industrial clusters and strategic UK locations such as St Fergus and Bacton.

There are several policy and regulatory systems currently in review focused on the introduction of hydrogen, through both blends and 100% hydrogen. Primary and secondary legislation will need to be updated to enable hydrogen within the network and allow deployment on the NTS. Alongside this, rules will need to be agreed, such as the Uniform Network Code (UNC) and Gas Safety (Management) Regulations (GS(M)R) to incorporate hydrogen blending and, if required, be adapted for hydrogen transportation.

Implementation requirements

To implement the outcomes of this project, we will require the ability to deploy hydrogen into the NTS network and onto operational sites. GS(M)R and associated rules do not currently enable this. We may need derogations or sandbox environments on our compressor stations, to allow our first applications post project delivery. Although, it is thought that the regulatory framework will be in place to enable Project Union on which this project will deliver. An early demonstration of the gas turbine fuel gas opportunity is being explored via other projects in our innovation portfolio.

Regulatory support

None required, current engagement through engagement with Ofgem and DESNZ should provide the outcomes required to implement this option in the future. As we continue planning for the commercialisation of the FutureGrid facility, we will engage with Ofgem and UKRI to develop a mechanism which supports this.

Standards

Whilst as a business we work to a rigorous set of policies and procedures that ensure we fulfil our legal and moral duties to the communities in which we operate, this project is operating in a slightly different set up. It is not connected to the National Transmission System and will not be 'transporting gas'. As such, it will not be governed by the legislation for that. However, it will be located within a COMAH site and legislation that governs activities on those sites must be satisfied. Therefore, we expect that the standards to which National Gas operate, are to be employed and adhered to.

Where these standards cannot be adhered to, we expect risk assessment and documentation to detail any exceptions. This approach ensures we can extract maximum learning from the project. Any standards that cannot be followed for this project can be understood in the context of whether they would be a challenge to follow on the live network, and may require modification, or whether they are simply a feature of the full-scale demonstration. Further work may be required if current standards cannot be followed. It is imperative that the network assets can be operated to standards, as this provides excellent assurance to the Safety Management System.

When considering the deployment of the project learning, NGT will update any internal standards for hydrogen blends/Project Union as part of the Safety Case update that would be required in advance of this occurring on the NTS. The learning from this project will go a long way to help inform the eventual standards updates along with key industry recognized standards.

Section 9
User Needs

Repurposing for NGT

The National Transmission System is a network of high-pressure gas pipelines, that supplies gas to power stations, large industrial and domestic users, from natural gas terminals situated on the coasts of England and Scotland, to gas distribution companies and direct connects. To move gas from supply to demand, the system utilises several compressor stations, located strategically across the country, 60% of which are our primary focus to upgrade first. Compressors are essential to Great Britain's energy systems as they play a role in managing the linepack on the NTS and being able to proactively manage where energy is sent, and when.

The users of the project output will be onshore and offshore gas networks both in the UK and globally, alongside many industrial users of rotating machinery. This project provides alternative, reduced cost options to the replacement of current systems, to support users in their transition to net zero.

The gas networks will play an important part in achieving the UK's net zero targets, through the delivery of Net Zero gases, such as hydrogen and biogas. These gases have different properties to natural gas and therefore, it is important we understand how they behave and recognise how they differ from natural gas.

Modelling of the energy system and interaction with our network through Discovery and Alpha, has highlighted the continued need for compression. Now that Project Union is progressing into FEED, the future compression need will be further refined.

The FutureGrid Compression project is set to significantly reduce the costs of transitioning the NTS to hydrogen by targeting the most critical assets. By upgrading components for hydrogen use, while maintaining existing unaffected assets, the project is expected to save over £30M per unit.

This initiative will ensure that our compression systems are well-equipped to function efficiently with hydrogen, providing the technical and safety evidence necessary for both Blending and Project Union. This project is poised to create a robust hydrogen backbone, connecting hydrogen production, users, and storage, and paving the way for construction in 2026.

FutureGrid Compression will provide a technical demonstration, utilising the empirical evidence to develop a strategy for UK NTS Compression System transition, linked to our implementation projects and wider business plan. The technical demonstration will commence at Siemens Energy RWG Ansty facility, utilising existing learning attained through alternative GT fuel testing, to aid the testing of the equipment with hydrogen and gather evidence on hydrogen capability. This will then be followed by the full compression system test at the DNV Spadeadam site as part of the FutureGrid facility.

The demonstration will provide the technical and safety evidence for the re-purposing of 49% of the NTS gas turbine units and provide insight into repurposing others on the network. The project will demonstrate the capability of an existing system with minimal changes to operate with hydrogen blends before then carrying out modifications where required, to enable testing to be repeated with 100% hydrogen. This will demonstrate not only the rotating machinery package capability, but how the full system would operate on a hydrogen network. The learning, experience and evidence gained through this project will also be very useful to other users identified above, by demonstrating that repurposing is an option for an NTS compressor system.

Through this phase of the project, we have developed the Master Test Plan for both component testing and system testing. As this projects' goal is to develop evidence, the best way to satisfy the user needs is to ensure that the evidence generated is the correct evidence. In order to do this the Master Test Plan has been developed in coordination with the project design and requirements. It is a live document which tracks the expected evidence from the project and will continue to be developed throughout the project. At a high-level, the key details from the test plan will be shared as part of knowledge dissemination, as these are areas that other parties would take an interest in.

The user journey for repurposing compressor system assets for use with hydrogen involves building technical evidence that a particular asset operates with blends or 100% hydrogen. For Gas Turbines, the output will be understanding the efficiency of the combustion process with a different fuel, the impact this has on temperatures and the power output in addition to the makeup of the exhaust gases. For compressor systems the key output will be the performance envelope and how this deviates as the hydrogen blend increases. As the project starts to acquire data, the economic assessment will continue to be validated, to determine which systems can be repurposed and which would be replaced. This learning will also be useful as it may inform future maintenance requirements.

This project will demonstrate that repurposing is a safe, timely and cost-effective option when compared with complete replacement of complex industrial systems. As a result of the project, there will be sufficient evidence to support the technical,

safety, environmental and engineering aspects of the investment decisions which would be made by an asset manager. This project has identified that lead time is a key user need and that repurposing as opposed to replacing, will offer significant benefits and flexibility, rather than being tied into the large supply chains that an entirely new system would involve.

The outputs from this project will provide the evidence and long-term strategy for hydrogen compression, to ensure the energy transition is as cost effective as possible for consumers. The project is vital to keep costs to a minimum for the deployment of hydrogen in the gas networks. This evidence will support repurposing decisions being made as part of Project Union and the deployment of hydrogen blends onto the NTS. The alignment of the project with NTS net zero strategy is crucial, and the projects are being coordinated, to ensure that any assumptions made in Project Union and Blending deployment feed into the projects' requirements. At the same time, the project outputs are being aligned with key decisions, to ensure that user needs are reflected where possible.

This project will not have an impact on energy consumers through the project period but will through implementation. The approach to Project Union is to repurpose selected feeders without constraining the existing natural gas supply on the NTS. The transition of compressor units will adopt the same approach, ensuring that work on the compressor sites does not impact the natural gas equipment that is still required to operate.

The high pressure NTS links key supply points in the UK to industrial consumers, power consumers and Distribution Networks (SGN, Northern Gas Networks (NGN), Wales and West Utilities (WWU) & Cadent). Our first transitional project of our high pressure gas network to hydrogen will be through Project Union which commenced Pre-FEED in February 2023 and is due to start construction in 2026.

This project will convert 2000km of pipeline to 100% hydrogen, linking the industrial clusters (Humber, Teeside, Merseyside, Grangemouth, Southampton & South Wales) with key supply points such as St Fergus, Bacton & Isle of Grain. Along the Project Union route there are many industrial and power customers that we need to transition with us. We are actively engaging all affected by the project, to ensure they can transition alongside the network. Learning from this project will be shared with these customers that in some instances will also require compression solutions for hydrogen.

Acceptance of hydrogen blends is the enabler to transitioning the network to 100% hydrogen, giving a clear option for new hydrogen production facilities, and helping to stimulate this market. By accepting hydrogen onto the network, the hydrogen economy will grow, to enable the eventual transition of the NTS to 100% hydrogen. Furthermore, through blending, we are extending the life of our current assets by repurposing them to use hydrogen. This delays the potential for major upgrades or new equipment which ensures customers are not impacted and delivers value through not having to buy new equipment for using a 2% hydrogen blend for example.

Siemens Energy has considered other users of the gas turbines (GTs) in the UK that may benefit from the knowledge gained in this project. We will consider sharing learning with them to help them transition their systems to Net Zero. These include global gas networks, industrial users and power stations. Siemens Energy will look to engage these partners through the project, to share learning and demonstrate hydrogen compression. Currently, Siemens Energy have over 100 customers in the UK, so the learning from this project could also help improve the hydrogen supply chain regarding compression of hydrogen and delivering greater value to the consumers.

Distribution Networks - We have partnered with SGN and NGN to better understand their requirements for gas demand in the transition and will gain insight from Cadent and WWU as key stakeholders. All the gas networks are part of the Hydrogen Grid R&D (HGR&D) activity led by the Department for Energy Security and Net Zero (DESNZ), looking to understand the use of hydrogen for domestic heating in the future. This project will feed into the HGR&D HSE evidence assessment, to enable clear decisions to be made on hydrogen in our UK gas networks. Whilst there has been little need for compression in the distribution networks to date, future scenarios have been identified, where this could be required. In the instance that a unit is not powerful enough for NTS applications, we will investigate repurposing these to support distribution activities.

Alongside the direct engagement undertaken above, we will be attending conferences throughout the year to discuss the progress of the project. To make sure the outputs of the project deliver benefits for the UK, we have developed a communications plan that will allow access to the facility through several forms of media. The 'digital first' approach will allow any interested party to understand the basis of the work and the benefits it delivers. In-depth conferences, training sessions and events will provide detail to cross-industry partners and potential hydrogen customers. Collaboration with other TSO's is underway through the H2Gar working group and through benchmarking. This has been set up to share information regarding hydrogen blending and 100% hydrogen, so that minimal duplication occurs between TSO's, which will help deliver value to the consumer.

Dissemination of our knowledge and understanding will play a crucial role in the uptake of hydrogen technologies in the future, as well as making sure we meet the UK's Net Zero targets. The flexibility in the facility design allows it to be a centre of excellence and training, throughout the project and beyond.

Repurposing Market Opportunities

The FutureGrid Compression project examines the key challenges associated with compression of 100% hydrogen and blends of hydrogen through the NTS assets. To develop the Phase 2 facility, we have established a collaborative partnership with Siemens Energy which plays a crucial role in adapting our infrastructure to serve our repurpose methodology.

Table 2 below highlights the compressor types present on the NTS and corresponding quantities. The Siemens SGT-A20 (Avon) is the most common type of compressor, making up 43% of the fleet.

Table 2 – List of compressor types on the NTS.

Gas Turbine	Units	% of Network
Siemens SGT-A20 (Avon)	28	43%
Siemens SGT-400	5	8%
Siemens SGT-A35 (RB211)	6	9%
Baker Hughes LM2500 DLE	10	15%
Solar Titan 130	8	12%
Total gas turbine units	**57**	**87%**
Electric Drive	**Units**	**% of Network**
35 MW	3	5%
24 MW	2	3%
16 MW	1	2%
8 MW	2	3%
Total electric units	**8**	**13%**
Total units	**65**	

Repurposing the compression fleet as part of the FutureGrid compression project highlights a business case which aims to provide a cost-effective solution for the transition from a natural gas system to a hydrogen operated grid network. The project aims to determine the technical and commercial feasibility, provide a technical demonstration, and create a strategy for UK NTS Compression Systems. The largest cost in the current assumptions for migrating the NTS to hydrogen is the cost to replace the compression systems.

Different scenarios have been analysed to examine the cost of repurposing the NTS assets based on the amount of hydrogen introduced into the system. Table 2 below shows the various scenarios considered.

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Table 3 – Costs to repurpose compressor units under varying scenarios.

Option		Total forecast expenditure	Saving vs. Baseline
No Change	Cost of not transitioning to hydrogen	**(£6.5bn)**	**(£2bn)**
Baseline	Replacement of all units	**(£4.5bn)**	
Option 1	Repurposing to 100% hydrogen	**(£3.1bn)**	**(£1.4bn)**
Option 2a	Repurposing to 25% and then repurposing 100% hydrogen	**(£3.3bn)**	**(£1.2bn)**
Option 2b	Repurposing to 25% hydrogen and then replacement	**(£4.7bn)**	**(£0.2bn)**
Option 3a	Repurposing to 50% and then repurposing 100% hydrogen	**(£3.4bn)**	**(£1.1bn)**
Option 3b	Repurposing to 50% hydrogen and then replacement	**(£4.8bn)**	**(£0.3bn)**

Table 3, above, highlights the repurposing costs under different scenarios, ranging from direct replacement of the assets to a repurposing cost that is dependent on the extent of hydrogen integration into the system. Financial projections for various repurposing scenarios have been developed to compare against the baseline of full unit replacement, which totals £4.5 billion. These scenarios highlight a significant opportunity to minimise disruptions from new construction and extend the operational lifetime of the existing assets. Furthermore, the transition supports the strategic goals of minimising environmental impact and maximising financial value to consumers.

Section 10

Impacts & Benefits

Project Progress

In readiness to start the project, we completed key activities including resourcing the project team, establishing the project governance, and reviewing the project plan. We now have a full team in NGT, working closely with the project teams of the partners, to deliver the project. We've established clear lines of governance to ensure robust delivery of the project, including establishing risk review meetings, monthly steering groups, quarterly review meetings, stage gate review meetings and internal project reviews.

In addition to this, we have divided the project into work packages as per the original Project Management data book and have each internal project resource leading the associated activities to ensure the project is being completed within the required timescales. This also enables any efficiencies within the project. The overall programme is reviewed monthly, in detail, to ensure any critical paths are identified and associated actions are prioritised.

The main achievements in this reporting period are as follows:

1. **Ansty components defined and procurement of long lead items:** The components required to conduct modifications to the Ansty facility for a 25% blend of hydrogen and 100% hydrogen were defined and the procurement of long lead items was conducted to avoid any delays to the programme.
2. **Shipment of assets to Spadeadam:** National Gas had required assets stored on its site in Cawood. In addition to this, there were assets being sourced from live de-commissioning projects. We have conducted the necessary checks and, where necessary, conducted additional cleaning to the assets. Most of the assets (excluding compressor unit) have now been transported to Spadeadam.
3. **Design of the pipe loop (Pig trap to pig trap):** The design of the pipe loop system is completed, the only outstanding action is to confirm the philosophies of the new 100% hydrogen compressor and the process flow modelling co-relate with the parameters defined for this design. HAZID and HAZOP activities have also been conducted as part of this work package.
4. **De-commissioning strategy:** We have worked tirelessly with our internal teams to ensure that Huntingdon Unit A can be de-commissioned this year. In addition to this, we have also worked with the partners to ensure that it is being de-commissioned in the most efficient manner (E.g. conducting a de-commissioning design) to avoid any damages to the unit and delays to the project.
5. **Initial Ground works:** The top soil for the route has been stripped, also the area has been pegged per route design. This was conducted to minimise the risk for any ecological constraints near the construction programme and to avoid any potential impacts.

Changes to expected Impacts & Benefits

Of the impacts and benefits considered as part of the project justification all of these are considered to still be applicable. One impact has been supplemented with details given below:

New to market products, processes and services (qualitative) – The experience attained from the design phase of the project will influence the processes used during the Front End Engineering Design (FEED) and Detailed Design phases of Project Union. Although this was always envisioned, the transfer of this knowledge and experience is something the project team will prioritise, as the next phase of Project Union commences.

Challenges

As an innovation project, the set of expertise and knowledge is spread across many different partners and departments. A significant challenge of this project has arisen from the multi-partner approach and the assumptions that had been taken by each at the time of signing the contract. This project will use elements of the NTS network in a closed loop system, with a fixed volume fuel supply, and a new process fluid. To ensure safe and functional operation elements of process design, thermodynamic modelling, computational fluid dynamic modelling, mechanical design, compression performance testing expertise, and gas network operation expertise must be brought together. Where the natural gas industry and its partners have existed with little requirement for change to the underpinning design for so many years, the scale of change was not fully appreciated at the discovery or alpha phase. These have come to light during this beta phase and have had implications to the programme, but not the overall output of the project. A future project should consider these challenges and implement a Front End Engineering Design (FEED) study as a first stage of the beta phase.

One of the project challenges to date has been ensuring partners have correct technical resources in place to execute a safe and functional demonstration and build the safety management system to support this. It has taken time to transfer knowledge from the National Gas team to the DNV team but will ensure the same rigorous processes that are employed for our rotating machinery system assets are in place for the partners to operate their COMAH site safely.

A significant challenge of the project so far has been the requirement to repurpose assets. This is necessary to ensure the existing NTS assets are demonstrated to be fit for purpose for hydrogen, but presents significant challenges in terms of reclamation, logistics, asset condition and suitability for use with hydrogen. There are differences in operation caused by not having a pipeline to feed and remove gas from the assets. There are also operational differences that mean security of supply to the gas network is not affected. Some of the systems that currently protect security of supply to the NTS will not be required. A rigorous assessment of all the systems is being conducted to ensure all the risks of change are accounted for, understood, mitigated and documented. This information will be invaluable for the business, as we look to conduct impact assessments to repurpose parts of the network. Trying to repurpose as many assets as possible in a small rig mean that the geometry of the loop and the areas where the assets are joined, is causing unusual stress exceptions, that would not be seen on the existing network because these different assets are joined over hundreds of kilometres of pipeline. This is something that we are currently working to resolve.

The thermodynamics of the closed loop system are another area novel to a gas network operator. Modelling software is being used to try to understand the most credible scenarios that will arise during operation, and a multi-partner approach to solve these problems is being successfully employed.

Future Value to Consumer

When considering opportunities to enhance the value to the UK consumer, NGT have identified 2 key streams associated with the FutureGrid Compression project which would allow additional data to be acquired, additional development of new equipment, and also potential revenues associated with this:

1. Incorporation of asset(s) into the phase 2 loop for testing throughout SIF programme.
2. Testing on the facility post phase 2 compression loop testing either exclusive or collective use.

Development of Compression loop to include further assets & connection opportunities to maximise post phase 2 testing.

As part of the wider National Gas hydrogen programme, there is a continuous cycle of review, to identify where there is a need for further work and to develop the evidence case for transporting hydrogen across the NTS. This continues to identify further projects that require practical demonstrations and, where relevant, require the use of the FutureGrid Facility. Currently there are 4 further NIA projects identified, that are to utilise the FutureGrid Phase 1 facility to deliver future value to the consumer. They are outlined in Table 4, below:

Table 4

Project Title	Description
100% Hydrogen Gas Metering Project	This project will see the design, construction and installation of a new metering and gas analyser test skid at the FutureGrid facility. This new skid will not only enable testing of new hydrogen-ready metering technology as part of initial Phase 1 testing, but also future metering and gas analyser innovation projects beyond FutureGrid Phase 1. This new 100% hydrogen metering skid will be installed alongside the existing one on the FutureGrid facility (see figure 1) and shall comprise of three meters in a series on the mainstream, with a bypass stream running in parallel. These three meters being: a turbine meter, ultrasonic SICK meter and a Coriolis meter. The initial testing taking place in this project will further increase our understanding of the capability of current hydrogen-ready meters and gas analysers in a blended and pure hydrogen environment.
Composite Pipe	HIVE Composites Ltd is pioneering the development and demonstration of next-generation Thermoplastic Composite Pipes (TCP) tailored for hydrogen transportation. The innovative project seeks to revolutionise the hydrogen sector, offering a more efficient, durable and sustainable alternative to traditional pipelines, especially where steel pipes are not viable. By capitalising on thermoplastics' unique characteristics, the project aims to facilitate a smoother transition to hydrogen-based industrial processes, a critical move in achieving a carbon-neutral future. Pipelines will be the principal means of distributing hydrogen to industry. However, hydrogen can cause embrittlement in steel pipes, reducing the safety of new and existing assets. This project set out to investigate the feasibility of next-generation TCP using pre-treated tape to provide performance close to welded pipes yet manufactured many times faster. Having the potential opportunity to test the capability of the composite pipe on the FutureGrid facility will give real-time data of the capability of composites to be used on the National Transmission System.
High Pressure Venting Demonstration	The project explored the possible impacts of transition from natural gas fuel to hydrogen (or to hydrogen/natural gas mixtures) on the requirement to depressurise transmission pipelines and associated equipment for maintenance or other purposes. NGT currently employ gas recompression or venting to atmosphere as a means of achieving safe conditions for intrusive work. The project investigated the impact of the presence of hydrogen on these and other potential technologies for providing safe conditions of work. The FutureGrid facility might be chosen as a potential demonstrator site to test the venting, flaring and recompression of assets that may be deemed suitable for hydrogen use based on the outcomes of this innovation project. The venting may be demonstrated as a result of high-pressure venting that might be taking place at the FutureGrid facility as limited data into this is currently available.
Bohr Energy	Bohr energy is developing gas quality analysers that require a more limited amount of supporting equipment at a smaller cost to the traditional gas chromatograph we see on the NTS. The advantage of this is that as we move forward on the NTS with blends of hydrogen and deblending of it too, you will need more gas quality data to determine what is in the pipeline. The Bohr energy analyser can be trialled on the FutureGrid facility replicating the changing conditions of the NTS and compared to the already installed gas chromatograph.
TUV SUD	TUV-SUD have developed Hydrogen meters that have already been tested in a laboratory scale and require larger scale, real life testing to prove efficiency and accuracy of their meters compared with some of the existing meters on the market. The testing of the TUV SUD meters would involve three weeks of testing on the FutureGrid facility, utilising the existing meter skid that is being constructed for the Gas Metering project. This testing will increase the range of meters suitable for the use of Hydrogen on the global market as well as provide a better understanding of the capability and accuracy of hydrogen meters in a blended and pure hydrogen gas stream.

We have demonstrated value to the consumer by looking to conduct these projects on the already operational facility, and there are potential future opportunities to carry out projects of a similar nature, which will enhance further value to the consumer. The successful approach being used to maximise the value attained from the FutureGrid phase 1 facility will also be utilised by FutureGrid Compression.

Section 11

Risks, Issues & Constraints

Risks & Issues

The FutureGrid team have highlighted the top 5 Compression risks related to the project, that could impact the successful completion, these are highlighted in Table 5.

Table 5 – Top 5 Phase 2 Compression Risks

Risk	Likelihood
The assets may not be of the required condition to support the build of the compression rig.	Medium
Long Lead assets may not be available in required timescales.	Medium
Scope Ambiguity impedes progress of design.	Medium
There is a risk Huntingdon Unit A may not be available in the required timescales.	Medium
Operating Philosophy is not being conducted the same time as design.	Medium

The foremost risks involve the possibility that the assets may not meet the required condition to support the construction of the Compression facility. This could cause significant delays and incur additional costs as remediation or the procurement of new assets may be required. To mitigate the risks, asset pre-assessment will be conducted prior to installation. Furthermore, valves will be serviced by National Gas Services (NGS) to remediate potential asset defects.

The second risk highlights the potential that the long lead items required to build new/re-purposed assets may not be available in the required timescales. Siemens Energy have recently informed us that the Unit Control Panel cards have very long lead times, this can potentially cause delays to the 25% testing being undertaken at Ansty. This delay, however, will have no impact to the overall project programme.

The third risk stems from scope ambiguity, which could impede the progress of the design phase. As mentioned earlier in this report, there are a lot of design dependencies which provide an added level of complexity. There is a risk that the designs are not completed in the required timescales due to the addition of some activities which were not originally listed in the RASIC. In some areas, the activities required to achieve a safe functional design have been underestimated. NGT is leading on workshops to identify gaps in scope and determining which activities are in and out of scope. We are also holding regular project meetings with the partners to ensure the smooth delivery of design deliverables.

There is a risk Huntingdon Unit A may not be available in the required timescales, leading to a delay in the project delivery. NGT has an alternative gas turbine available in case this risk materialises. In addition to this, NGT has escalated this to Senior Leadership to prioritise the release of Huntingdon Unit A.

Finally, there is a risk that the operating philosophy may not be completed concurrently with the design. In a typical design stage, the operational philosophies are completed and agreed first, as these influence the final design. By not doing this, this may lead to assumptions on the design which may need to be revisited at a later stage, causing additional time and costs to the project. To mitigate the risk, NGT is working in collaboration with all the project partners regularly, to define most of the operational philosophy of the project.

These risks underscore the importance of proactive project management and collaboration among all the project partners to ensure the timely and successful delivery of Phase 2 Compression.

Constraints

Many technical constraints exist in this project. The premise of the project to prove operation with repurposed assets mean that assets need to be decommissioned from the network, inspected, transported, and installed on a remote site (that removes the societal risk of operation). Each of these activities presents its own challenge. The timing of the decommissioning is complex due to the requirement to protect security of gas supply to the UK network; assets can only be removed when network demand is appropriate in order to allow safe removal (ordinarily April to September). The complex and hazardous nature of the network means a rigorous change control must be conducted to ensure removal is safe and that security of supply is protected. This is a project in its own right and is constrained by network demand, appropriate funding and competent resources being available.

Once the assets have been disconnected safely from the network they can then be decommissioned and removed. This is also constrained by appropriate funding and competent resources being available. It introduces risk to the physical asset condition as historically the assets that are removed from the NTS are not reused. It involves a lot of management by the FutureGrid team to ensure that the assets are treated as sensitively as possible and all the relevant parts are retained, appropriate tests conducted, and appropriate storage found.

Once the assets have been disconnected and decommissioned, they can then be inspected to determine suitability for use in the facility. A constraint for this project is that they must be in acceptable condition for use with hydrogen, which is a higher threshold than for natural gas.

Another constraint of the project is that it is to be conducted at a remote site. This allows the safe operation to be demonstrated to the regulator without incurring any societal risk. The remote site location presents its own challenges. There is no high-pressure gas pipeline to supply the fuel gas that is required for operation. Instead, the fuel will be available in sufficient volume for delivery only by constructing a gas storage array. This array will be a fixed volume (not a pipeline) and means that as the gas fuel leaves the will be a substantial drop in temperature due to expansion. This effect must be countered with a preheat. Another constraint of having a fuel array rather than a pipeline is that the amount of gas available at one time is limited. Hence, the test runs will be short and any operational issues will delay each performance test, as the fuel array will need to be refilled.

Another constraint of the remote site is that there is no high-pressure pipeline to send away the compressed gas. Instead, a closed-loop system is to be constructed. This presents its own thermodynamic constraints. The temperature will rise with each compression cycle and then this hot gas will return to be the inlet gas of the compressor. This necessitates using an aftercooler to remove as much of the heat as possible after each compression cycle. The aftercooler is an expensive asset and National Gas only have one available for use. The process modelling has conducted a heat exchanger capacity assessment which concluded that the unit was slightly undersized for the operation, but would be sufficient if it works exactly as the data sheet describes. The actual performance will not be know until it has been decommissioned and inspected, and even then, the ambient conditions must be favourable for it to be able to remove the heat generated during the transient heat spike periods. A further constraint of this project is thus the weather conditions on the day of running.

Section 12
Working in the Open

Communications Plan

As part of the project, various methods of communication and engagement were planned, with the aim of creating awareness of the ongoing work. This included conferences, site visits, lunch and learn sessions, podcasts, webinars, blog posts etc.

At the beginning of the project, lunch and learn sessions were delivered by the FutureGrid team, to create awareness of the project. This was targeted at the various departments within the National Gas business. It worked well, as it served as a platform to engage with SMEs and other teams within the business.

Since the project kick-off, the FutureGrid Compression team have hosted several site tours and 'show and tell' events where visitors had the opportunity to see the Phase 1 facility, as well as Phase 2 view, layout, and assets. This has enhanced their physical appreciation of the build process, overall facility, and its eventual operation.

During the first half of 2024, the team attended a range of conferences including Innovation Zero and the Korea City International Meeting. The focus was to promote the project and engage with the Energy Institute, as well as members of the public who attended the events in mass. The team were available at the promotional stands to engage with the public as they visited throughout the events.

Talks have also been delivered at various events such as the EPSRC amongst others. Blogposts on LinkedIn have created a platform for public engagement, giving them real time updates on the project work. The posts have featured pictures and videos of the site and facilities. Podcasts and webinars have been planned for the coming months, commencing in the second half of 2024.

Stakeholder Engagement

A key stakeholder group are the end users of the National Transmission System. There is no specific subset that are only focused on the compressor operation of the network, they are concerned about how the network can perform and operate for them. The end users need assurance that the network can meet the requirements they have in the future. It is not for them to determine the best, most cost-efficient, and technically sound way to operate the network, that is our role as National Gas. Therefore, consulting on the need for compression is not appropriate, instead, we need to consult on what our consumers and connected customers need, so that we can ensure we outline the most cost-effective transition plan for the network to meet these needs.

Ultimately, the transition strategy for the network is to enable Project Union, our 100% hydrogen backbone and support the transition of the network to hydrogen blends. Therefore, when we consider the consumer interactions on Compression, it is the alignment with the wider Project Union consumer engagement that we draw upon, to understand the views of our connected customers, on our plans, the opportunities and the challenges they may face. The activities carried out as part of Project Union have been extensive and dynamic, covering a broad spectrum of stakeholders which are integral to the energy systems landscape. Throughout the project, hundreds of stakeholders, including energy system experts, consumer representatives, members of various working groups and supply chain entities have been actively involved. This extensive interaction has been crucial in shaping the project direction and building on the business case for compression, and has helped refine the project in order to produce tangible outputs.

Knowledge Dissemination

Learning & Sharing – The FutureGrid Compression team have quarterly meetings with other gas turbine OEMs aside from Siemens Energy. We also have monthly steering & working group engagements to keep in touch with industry progress on the topic of hydrogen.

Team Collaboration – The FutureGrid Compression team continuously work closely with various stakeholders including Statutory Government Departments such as UKRI, OFGEM, DESNZ, Gas Distribution Networks, OEMs such as Siemens Energy, Baker Hughes, Solar Turbines etc, engagement groups such as H2GAR (Hydrogen Gas Asset Readiness), Energy Institute, Hydrogen UK etc.

Stakeholder Engagement – For the assets, Siemens Energy are developing a programme to address emission concerns which could emanate from operating the SGT-A20 with Blends & 100% hydrogen. This also applies to the other OEMs who have their assets across our fleet including pipes, valves etc. While for the hydrogen supply chain, the storage management, pipeline operators & refuelling stations are exploring the smooth supply of hydrogen to meet demands across the network.

Section 13

Costs & Value for Money

Table 6

	SIF funding requested	Total actual project spend
National Gas	£4,199,542	£576,693
DNV	£19,458,824	£2,506,650
Siemens Energy	£9,943,113	£1,118,231
Cullum	£2,007,145	£223,269
Premtech	£680,155	£335,358
Cardiff	£677,937	£179,198
NGN	£24,200	£7,260
SGN	£12,640	£3,792

Project Costs

The first year of the FutureGrid Compression project has focused on the preparation of the assets required for the installation and build of the facility. In addition to this, significant time has been spent on the design and safety assessment of the facility. Most of the funds spent to date relate to the design and engineering of the facility and procurement of long lead items.

Despite the significant uncertainties associated with a large engineering research project, which carry inherent risks of overspend and extended timelines, the project is adhering to budget and is on schedule, demonstrating the effective management and planning by the team. This approach not only emphasises our commitment to efficiency, but also minimises any costs for consumers.

When the project bid was originally submitted, a project forecast plan was included and used as a baseline for financial forecasting. When the project commenced, we conducted detailed planning sessions and realised that changes to the payment plan would be required, as some of the activities have shifted during this time. This was relayed to UKRI at the quarterly project meeting.

We have been tracking the forecast vs actuals for each reporting period and have been comparing it with the forecast stated in the baseline and at each respective quarter. The changes in each quarter were reported along with the relevant reasons. There were some areas where we had spent less than initially planned. The reasons for this were discussed in the quarterly reporting meetings. This spend was then realigned to be spent at a different time within the project.

In this reporting period there is no unspent SIF funding to be returned to the consumers. Likewise, there have been no additional revenues earned related to the Project that will be returned to consumers.

Variations

There have been no variations to the project in this reporting period.

Partner Contributions

National Gas are currently planning to provide more than £150,000 of assets additional to their partner contributions. This is currently being detailed and will be reported in the next reporting period.

The FutureGrid Compression partner contributions demonstrate the significant benefits brought to the project, with a total of £6.7 million in contributions, and £658,823 realised thus far. These contributions span a range of assets, expertise and support from key stakeholders as highlighted in the table. DNV's technical assistance and Siemens Energy test bed facilities and HyFLEX knowledge enhance the projects technical capabilities. Cullums and Premtech have contributed design skills and resources valued at £350,000 and £54,240 respectively. Additionally, Cardiff's engagement through PhD studentship is preparing for the projects future research applications. These contributions are not only maximising the projects financial and operational capacity, but also ensuring the scalability and sustainability of hydrogen infrastructure development.

Table 7 – Partner in kind contributions for Phase 2 Compression

Partner	Description of contribution	Value of contribution	Frequency of value incurred	Value realised to date	Value remaining
NG	Assets, senior leadership support, expenses, dissemination.	£1,240,880	Ongoing	£111,300	£1,129,580
DNV	Technical support, assets, storage, training, comms, expenses.	£2,580,000	Ad hoc	£638,000	£1,942,000
Siemens Energy	Test bed facility, knowledge (HyFLEX) and resource.	£2,472,000	Ad hoc	£0	£2,472,000
Cullums	Design phase contributions for skills and labour.	£350,000	Ongoing	£100,000	£250,000
Premtech	Training materials, comms and conferences, additional time.	£54,240	Ad hoc	£23,190	£31,050
Cardiff	PhD studentship – currently being advertised.	£85,000	Ongoing	£5,700	£79,300
Total		**£6,782,120**		**£878,190**	**£5,903,930**

Opportunities to return Value to Consumer

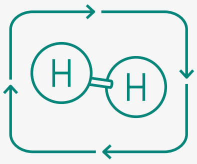
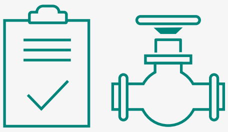
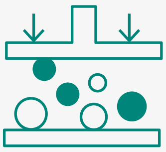
The FutureGrid programme will deliver the evidence base to support NGT's target to decarbonise the National Transmission System (NTS) at the lowest cost to the consumer, by transitioning the current natural gas network to hydrogen and other low carbon gases, such as utilising Carbon Capture & Storage. The UK consumer funds a significant proportion of these projects through regulated funding mechanisms and incentives such as the Network Innovation Allowance, Strategic Innovation Fund and in the past, as for Phase 1 of FutureGrid, the Network Innovation Competition. As such, it's important not to consider only the project in question, but the wider portfolio of work when analysing the cost associated with delivering these key projects, and the value generated. Returning value to the consumer, who ultimately funds these projects, is crucial to ensure public support and trust in the transition to a sustainable energy system. This not only justifies the investment but also ensure consumers directly benefit from the outputs of the project.

Value Generators

There are several opportunities in which value can be generated from the FutureGrid facilities, which can in turn result in value delivered back to the consumer. There are also several areas that must be considered in developing a strategic approach. These include: where can value be generated from FutureGrid, how do you maximise the value and monetise it, how do you recognise cost avoidance and what governance is required to manage the process and money generated?

First, we look at how value is generated. Here we have identified four key "Value Generators" that are presented by the FutureGrid Programme, and its associated Test Facilities, see Table 8:

Table 8 – Value generators

Value Generator	Value realised to date
 **Phase 1 facility: FutureGrid Test Loop**	• NIA projects utilising the Phase 1 Test Loop to facilitate testing an unproven technology. • Exclusive use of the facility for testing – has to fit in during other planned work. • Collective use / testing on the facility during operations – either the SIF or other uses. • Inclusion of asset(s) to the facility to be tested over longer duration while facility used for other testing.
 **Technical evidence from FG and wider innovation portfolio**	• Key testing outputs and data from FutureGrid Phase 1 programme. • NIA project outputs including test reports and data. • Additional testing information and SME expertise of commercial value.
 **Phase 2 facility: FutureGrid Compression Loop**	• Incorporation of asset(s) into the phase 2 loop for testing throughout SIF programme. • Testing on the facility post phase 2 compression loop testing either exclusive or collective use. • Development of Compression loop to include further assets & connection opportunities to maximise post phase 2 testing.
 **Skills and competencies development**	• Use of either the FutureGrid Phase 1 or Phase 2 facility to carry out a number of routine operations. • Development of apprenticeship / training schemes. • Incorporate with DNV training and Hazard Awareness courses to sell to external markets.

These key areas offer a significant opportunity over the medium to long-term, to be able to generate value back to consumer because of further usage of the facility and its outputs. The value must not be underestimated from the cost reduction FutureGrid offers in allowing further projects across our program to be able to utilise the facility, rather than needing to set up their own individual test rigs. Setting up an individual test rig for each project is not only extremely expensive but becomes very difficult when requiring decommissioned assets that have seen service on the network. This also takes a significant amount of time requiring individual design and development, as opposed to being able to consider an existing facility such as FutureGrid and tailor the testing for this existing facility.

Actioning Customer Revenue

The revenue generated from the use of the facility can provide a cash output. The key question that remains is how to treat the revenue. There is of course the annual process with Ofgem which actions the funding directions and allows for return of project underspends and revenues. However, given the size and scale of FutureGrid, its continued potential and the opportunities across the UK engineering landscape, there are alternatives that can be considered to utilise this revenue, to generate further value for the UK consumer and ultimately achieve net zero at the lowest cost. There are three key methods of treatment for the consumer value generated as a result of either an innovation project by National Gas or one of the networks utilising the facility or from the use of the facility by a third-party for testing and/ or training. These three methods are discussed below:

Figure 4 - Key methods

Direct payback

This is the most straightforward of the methods and simply states that any revenue generated i.e. the 5% additional cost added to DNV testing costs, would be returned directly to the consumer. The method to achieve this is through annual reporting using the Regulatory Reporting Pack (RRP) to identify revenue made and therefore the appropriate adjustments to the finances for overall cost recovery and return across National Gas' innovation portfolio spend.

FutureGrid demonstration fund

This fund considers additional tests, Research and demonstrations which could be conducted on the FutureGrid facility to further key knowledge and data gaps. It also considers the further development of the FutureGrid facility itself to allow for more enhanced testing and greater metrics beyond what is currently capable. Utilisation of this fund would require, a level of governance approval, with a suggestion that external input from UKRI or Ofgem being deemed appropriate for the utilisation of this fund.

Innovation SME community growth fund

This option considers building an innovation fund to support Small to Medium Enterprises (SMEs) Especially those in their infancy who requires specific support in demonstrating a technology or progressing a concept which would support the transition of the UK Gas network to net zero. Importantly, what would be different about this is that the funding would be Grant based and so have less stipulations than other funding such as NIA. It could be used in conjunction with other funding, but it would be provided as a support fund for development.

Section 14

Special Conditions

Table 9

Condition 1	No Spend until SIF Contracts	Ensuring that no spend occurs on Compression or Deblending before the SIF contracts are signed.	C	This was fulfilled with contracts signed ready for the project start in September 2023.
Condition 2	Financial Contribution reported by NGT	Reporting on the financial contributions made to the projects as set out in the applications.	C	This was completed as part of the project start-up with financial contributions made to bank account.
Condition 3	Meeting Arrangements	Participating in all meetings arranged/invited to by Ofgem, UKRI and DESNZ.	G	Engaging with all meetings set out to date and preparations underway for dissemination conferences including Innovation Zero and EIS.
Condition 4	Stage Gate Scoping	Scoping the requirements and success criteria for each stage gate within the Projects.	G	Process agreed and preparations completed for Deblending Stage Gate 1 and nearing completion for Compression.
Condition 5	Dissemination of Annual Progress Report	Uploading annual progress reports to ENA's Smarter Networks Portal, along with dissemination to a wider audience.	G	Underway for first progress report – with further discussion on content requirements to be had at QRM4.
Condition 6	Impact Monitoring & Evaluation Plan	Producing an Project Impact Monitoring and Evaluation Plan. This will outline how the Project will monitor and evaluate the delivery of the benefits, along with quantifying and qualifying the realisation of the benefits, also including the approach for reporting this to Ofgem.	–	To be started at the end of the project phase.
Condition 7	SIF Community Forums	Attending and contributing to SIF community forum events.	G	Ongoing requirement, attended Newcastle Community Day in November along with Project Partners.
Condition 8	Policy, Regulation and Standards	Updates at each quarterly meeting on any regulatory, policy and standards barriers along with any change requirements which may impact beta phase delivery. In addition, providing (within annual progress reports) an update on any of the above barriers requiring changes/derogations.	G	Ongoing monitoring and discussion of impacts – nothing significant to note but continue to monitor.
Condition 9	Updated 60 second videos	A 60 second video summarising the project.	C	Videos completed and uploaded. Deblending click here Compression: click here

Key

–	Not started	C	Complete	G	On Track	A	At Risk	R	Delayed

Table 9 – continued

Condition 10	Consumer Engagement	Update on the consumer engagement plan developed by the project team every six months including highlighting engagement and interaction with energy consumers and any impact the projects may have on them or future energy consumers.	G	Initial report provided and currently being updated – the frequency of future updates to be agreed.
Condition 11	Post Beta Phase Roadmap	Providing a roadmap for activities post-Beta Phase, focusing on how and when Deblending will become business as usual within the NTS and potentially other GB gas or electricity networks.	G	Dual pathway approach to blending and 100% hydrogen through Project Union demonstrating feasibility, with ERM delivering detailed plan.
Condition 12	Commercialisation Strategy	Updating on the commercialisation strategy, focusing on what National Gas and Partners have considered for the commercialisation of Compression.	G	Initial report provided and currently being updated – the frequency of future updates to be agreed.
Condition 13	Hydrogen	Updating on the projects ability to obtain the required volumes of hydrogen and outlining opportunities there are for the project to use green hydrogen. In addition, how hydrogen trial projects can be used to help stimulate the development of green hydrogen market.	G	DNV continuing engagement across diverse supply chain to seek the volumes required and seek green hydrogen opportunities supported by NG.
Condition 14	Maximising Future Value of Facility	Maximising, for all consumers, the future value of all activities occurring at the Compression facility in Spadeadam beyond the Beta Phase.	G	Initial report provided and currently being updated – the frequency of future updates to be agreed.
Condition 15c	Cost reductions & value adding opportunities	Identify opportunities to reduce project costs, increase contributions from project partner or identify further value which can be extracted from the project.	G	Initial report provided and currently being updated – the frequency of future updates to be agreed.

Key

–	Not started	C	Complete	G	On Track	A	At Risk	R	Delayed

Due to the importance of some Special Conditions, NGT have compiled reports detailing progress in these areas which are live documents shared with UKRI throughout the project. A summary of these key special conditions is shown below:

Special Condition 10 – Consumer engagement

To comply with special condition 10, the FutureGrid project has implemented comprehensive consumer engagement strategies. These include regular updates and transparent documentation ensuring all stakeholders are informed about project progress and developments. Phase 2 compression has utilised the Project Union engagement plan to identify and involve many stakeholders. The activities carried out as part of Project Union have been extensive and dynamic, covering a broad spectrum of stakeholder's integral to the energy systems landscape. Throughout the project, hundreds of stakeholders, including energy system experts, consumer representatives, members of various working groups and supply chain entities have been actively involved. This extensive interaction has been crucial in shaping the project direction and building on the business case for compression. As engagement continues throughout the duration of the project, NGT will broaden the scope of stakeholder engagement and immediate next steps to include engagement with:

- A wider pool of hydrogen Production, hydrogen Demand and hydrogen storage projects.
- Co-ordination between NGT and Gas Distribution Networks (GDNs) at a regional level to understand interdependencies and forecasts of supply and demand between Project Union and regional network plans.
- Following completion of pre-FEED route optioneering, engagement with key statutory stakeholders (e.g environmental stakeholders) to share approach to constraints analysis and future route refinement.

With regards to the Phase 2 Compression project, we will continue to maintain ongoing engagement as part of the broader Project Union engagement strategy. This comprehensive engagement covers all elements of the transition of the network to hydrogen and the impacts and considerations required. As this engagement evolves, we anticipate more refined outputs that will contribute essential knowledge to our hydrogen transition plan. We will continue to review the outputs and ensure these are integrated within the plans.

Special Condition 12 – Commercialisation strategy

As the Phase 1 project has developed, so too has interest on both a national and international stage. Our collaborative partnership with Siemens Energy plays a crucial role in this. By leveraging Siemens Energy' technology and expertise, particularly in the retrofit of the Avon A20 gas turbines, we are working towards a shift to hydrogen fuelled infrastructure without bearing the substantial costs of buying brand new equipment. This partnership not only helps adapt our infrastructure to serve towards our repurpose methodology but also builds critical technical skills within our team which could reduce the reliance on external services and therefore enhance operational efficiency.

Furthermore, the facility serves as a collaborative platform, setting a new standard for industry cooperation. By partnering with leading OEM's, and TSOs, we refine our hydrogen compression techniques that can be demonstrated at the FutureGrid facility, ensuring efficient and adaptable operations for a decarbonised transmission network. The empirical data collected will enable us to update and validate operational standards for hydrogen operation.

The approach taken to date for Compression across our network is one that will continue to develop and grow overtime. We have a team of highly skilled engineers that are familiar with the operation of the compressors and the opportunities and challenges they present. This is built through the skills and experience of working with the Compressor OEMs and learning about the technologies. There are still cases where the compressor OEMs are specifically required but this approach keeps more skill in house and allows for the flexibility across a range of asset manufacturers. As the diagram shows on the previous page, there is a lot of knowledge and IP to be generated which does not fall directly under Siemens Energy protected IP. This knowledge and IP can be utilised for the wider compressor strategy and bring significant benefits when considering the options for alternative compressor units from OEMs other than Siemens Energy which are being tested.

Special Condition 14 – Maximising future value for the facility

The FutureGrid facility will continue to act as a key enabler for demonstrating innovative technology for the NTS today or supporting different needs as NGT repurposes its network for Net Zero. The best commercial use of the facility time is a combination of developing the safety case for repurposing the NTS via Project Union, the identification of critical new technology which will be required to operate a net zero network and third-party testing. There is also a key role for the FutureGrid facilities to play in the development of skills through real-life training opportunities and demonstrations that the facility can provide. Via these workstreams FutureGrid will help to develop a diverse supply chain, with skilled and competent engineers helping to deliver net zero opportunities at a lower cost. There have been a number of NIA projects that have been demonstrated at FutureGrid or are upcoming that form part of the evidence based safety case for integrating hydrogen across the NTS. Below is some of the value that has been realised to date:

1. Initial promotion and engagement on the facility is generating interest with national and international asset manufacturers and gas networks.
2. Opened discussions with Baker Hughes and Solar (Compressor manufacturers) who were initially very reluctant to even discuss repurposing of equipment. Potential for future testing and similar benefits realisation with lower repurpose v replace costs.

As discussed in more detail in the Special Condition 14 Report, there are several factors that will determine the potential areas where value could be generated, how much value there could be and how this value is best returned.

Special Condition 15c – Cost reductions & value adding opportunities

When we consider cost savings across the FutureGrid Programme, we can consider these in three categories as demonstrated below:

Figure 5

Opportunities realised

These are opportunities and value that has been realised and as such a saving can be attributed, whether that is through the FutureGrid Programme or associated hydrogen work such as an NIA project saving money.

Opportunities under review

These are opportunities that are currently being identified and developed. These could be early-stage opportunities for the end of the project or could be those in-flight options and opportunities to cut costs for upcoming activities.

Potential future opportunities

These are opportunities that are hard to fully articulate until more is understood about the program or potential demand/requirements from external forces as such these are watchlist items and when they become clearer, they are opportunities that will become under review.

This logical categorisation provides a platform to allow for easy demonstration and tracking of opportunities across the portfolio. They allow us to focus in on those areas where cost savings are more likely to ensure that these are realised and allow us to continue to seek further opportunities. Due to the nature of the programmes of work some of the lead times there may be periods where there is little movement on the opportunities as they require the next stage of activity to begin. This allows us time to plan and ensure that the opportunities are maximised wherever possible. The following sections look in a little more detail at the opportunities realised, and review and potential future opportunities, discussing what we've achieved to date and what could be achieved in the future. An example of opportunities realised has been in the contracting and project kick off phases. Legal negotiations around contracts are a challenge so a change in methodology was done for phase 2 and this achieved was by aligning the project partners across both projects The savings are outlined below:

- **FutureGrid Phase 1 Cost**
  £128k
- **FutureGrid Compression submission estimate**
  £100k
- **FutureGrid Deblending submission estimate**
  £50k
- **Actual total across both**
  £124k (£79k/£45k)
- **Saving**
  £26k

Section 15

Material Changes

To date no material changes have been submitted for the project. As key risks continue to materialize, the project team will continue to closely monitor these and ensure the project continues to comply with the criteria as set out in the SIF governance document.

Contact Details

For further information about the project and to request a copy of the full technical report (please note restrictions apply to free access), please get in touch with the team:

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Note: all links on the page these can be accessed on the digital version of the report available at **nationalgas.com/FutureGrid**

Appendix 1

Acronym Key

Acronym	Definition	Acronym	Definition
AGI	Above Ground Installation	NDT	Non-destructive Testing
ALARP	As Low As Reasonably Practicable	NGN	Northern Gas Networks
ASME	American Society of Mechanical Engineers	NGS	National Gas Services
CO_2	Carbon dioxide	NG	National Gas
DNV	Det Norske Veritas	NIA	Network Innovation Allowance
ENA	Energy Networks Association	NIC	Network Innovation Competition
EU	European Union	NTS	National Transmission System
FAT	Factory Acceptance Test	OFGEM	Office of Gas and Electricity Markets
GB	Great Britain	PIG	Pipeline Inspection Gauge
GDN	Gas Distribution Network	PMC	Pipeline Maintenance Centre
GSMR	Gas Safety Management Regulations	PPR	Project Progress Report
H2 GAR	Hydrogen Gas Asset Readiness	PSI	Pound per Square Inch
HAMM	Hazard Assessment Methodology Manual	PSR	Pipeline Safety Regulations
HATS	Hazardous Assessment of the Transmission System	PSSR	Pressure Systems Safety Regulations
HSE	Health and Safety Executive	QRA	Quantitative Risk Assessment
HSE-SD	Health and Safety Executive – Science Division	R&D	Research and Development
HyNTS	Hydrogen in the National Transmission System	RF	Raised Face
ILI	In Line Inspection	RTJ	Ring Type Joint
IPR	Intellectual Property Rights	SAT	Site Acceptance Test
IPRM	Internal Project Review Meeting	SCADA	Supervisory Control and Data Acquisition
IT	Information Technology	SIF	Strategic Innovation Fund
LMF	Leobersdorfer Maschinenfabrik	SME	Subject Matter Expert
LSAW	Longitudinal Submerged Arc-Welding Pipe	TSOs	Transmission System Operators
MAPD	Major Accident Prevention Document	TWh	Terawatt hour
MOP	Maximum Operating Pressure	UK	United Kingdom
MPI	Magnetic Particle Inspections	UT	Ultrasonic Testing


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