

SIF Beta Project Registration

Date of Submission

Sep 2023

Project Reference Number

10062040

Project Registration

Project Title

HyNTS FutureGrid Compression

Project Reference Number

10062040

Project Licensee(s)

National Gas Transmission PLC

Project Start

Sep 2023

Project Duration

40 Months

Nominated Project Contact(s)

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Project Budget

£43,694,476.00

Funding Mechanism

SIF Beta - Round 1

SIF Funding

£33,309,356.00

Strategy Theme

Net zero and the energy system transition

Challenge Area

Whole system integration

Lead Sector

Gas Transmission

Other Related Sectors

Gas Distribution

Lead Funding Licensee

NGT - National Gas Transmission PLC

Funding Licensees

National Grid - Gas Transmission (GB wide), NGN - North East, SGN - Southern England (inc South London)

Collaborating Networks

National Gas Transmission PLC

Technology Areas

Hydrogen

Summary

SIF Innovation Challenge

The National Transmission System (NTS) provides flexibility in the UK's energy system, through its capability to store energy for long periods of time. Hydrogen as an alternative to natural gas ensures that energy demands are met for heat, power, industry and transport in 2050. In order to transport & 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.

Energy network innovation evolution

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 demonstration to develop the technical and commercial evidence and enable the predicted benefits for repurposing compression assets. The cost of a new compression system can be approximately £60m per unit and there are 74 units 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 analysis of the compressor suggested that the compressor could operate with up to 50% hydrogen. Above 50% hydrogen, a compressor upgrade is required. This will be demonstrated in Beta bringing in Siemens for the required upgrades to the gas turbine and compressor unit. The innovative solutions in development through this project to enable reuse of the compressors are vital to reducing the cost to the consumer of the energy transition.

Project evolution: Alpha to Beta

The Alpha phase further developed our understanding of the feasibility of repurposing compressor assets. Beta will demonstrate this understanding and the potential for compression to meet the requirements determined through the whole system modelling with a minimal impact to the consumer. A gas turbine representative of the current fleet will be fuelled by different blends of hydrogen up to 25% hydrogen in natural gas and subsequently 100% hydrogen following modifications, providing technical and safety evidence for the repurposing of our current gas turbine fleet. Concurrently, the Cab and Ancillary equipment will undergo offline testing to determine the requirements for operation with hydrogen blends and 100% hydrogen. The system demonstration test loop will be constructed whilst the gas turbine tests and modifications take place, to enable evidence to be created throughout the project timeline and feed into Project Union in a timely manner. The test programme will be undertaken on the full compression system with hydrogen blends and 100% hydrogen, providing the evidence for the safety case, business case and technical feasibility.

Problem evolution: Alpha to Beta & Key User

Whilst the problem proposed at the start of Alpha remains consistent we have developed our understanding of the network requirements and feasibility for both the demonstration and implementation of the project outputs. Project Union our key user has now been approved for its PreFEED funding, with the first proposed compressor unit moving to hydrogen in 2028. Evidence for repurposing compressors for hydrogen is required prior to construction to feed into the Union business and project plan and allow sufficient time for procurement. The evidence for repurposing existing compressors for hydrogen is limited and would be required prior to including this in any business plan.

Project Partner Expertise

- DNV lead the demonstration of the compression system and have extensive experience of gas pipelines, large scale testing and of the current compression systems.
 - Siemens Energy a rotating machinery OEM whom will provide testing, modification and technical insight into repurposing compression system
 - Cullums experts on compressor ancillary equipment and cab units
 - Network partners - provide insight into deployment through their networks
- For the Beta phase additional partners have been included in the consortium to help deliver the demonstration.
- Premtech have expertise in engineering design and 3D modelling and will produce a virtual model of the test facility at Spadeadam as part of the detailed design phase.
 - Cardiff University have expertise in gas turbine research with the Gas Turbine Research Centre. They will peer review the evidence from the demonstration and provide input through project steering group meetings.
 - HSE are the UK's Health and Safety Executive and will provide input to the demonstration programme through project steering group meetings and peer review safety evidence generated throughout the project.

Addressing the needs of the user

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 options to replacement of current systems at a reduced cost to support users in their transition to net zero.

Project Description

The National Transmission System (NTS) is a network of high pressure natural gas pipelines, that supply gas to power stations, large industrial and domestic users, from natural gas terminals situated on the coast, to gas distribution companies and direct connects. In order to move gas from supply to demand, the system utilises several compressor stations located strategically across the country.

In order to achieve the UK's Net Zero targets by 2050, the gas networks will play an important part through the delivery of net zero gases such as hydrogen and biogas to users. These gases have different properties to natural gas and therefore need different control and management systems. Modelling of the energy system and interaction with our network through Discovery and Alpha has shown the need for compression and that our current systems are capable of meeting the current future scenarios, this work will continue in the Beta Phase.

The HyNTS Compression project directly impacts the cost of transitioning the NTS to Hydrogen by targeting our highest cost asset and providing technical and commercial feasibility for repurposing vs replacement. The associated costs for replacement are ~£60m per unit which can be dramatically decreased by upgrading key components. The project will provide the technical and safety evidence for our first transition activity; Project Union. This project is creating an 100% hydrogen backbone linking industrial clusters and terminals, which will commence construction in 2026. If this project proves that the current compression systems are able to function with hydrogen we plan to implement the solutions into the project delivery.

The HyNTS Compression project will provide a technical demonstration and create a strategy for UK NTS Compression System transition linked to our implementation projects and wider business plan. The technical demonstration will be conducted initially on an offline facility, to enable gas turbine modifications in a clean room environment whilst gathering evidence on hydrogen capability, 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 ~65% of the NTS compressor units and provide insight into repurposing others on the network. The project will modify an existing unit to run on hydrogen and then test it at both blends of hydrogen and 100% hydrogen. Demonstrating not only the rotating machinery package capability but how the full system would operate on a hydrogen network.

Preceding Projects

10023632 - HyNTS Compression

NIA_NGGT0176 - HyNTS - Hydrogen Fuel Gas for NTS Compressors

10036949 - HyNTS Compression

Nominated Contact Email Address(es)

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Project Description And Benefits

Applicants Location

Location information

a) Project partners and Work Locations

National Gas - CV34 6DA

Siemens Energy - NE6 2UT

DNV - CA8 7AU

Cullum Detuners - DE75 7SW

Premtech - LE65 2UZ

Cardiff University - CF24 3AA

SGN - RH6 9HJ

NGN - LS15 8TU

HSE - SK17 9JN

b) Demonstration locations

FutureGrid facility, Spadeadam - CA8 7AU

GT test facility - Siemens Ansty - Pilot Way, Coventry CV7 9JU

Project Short Description

The HyNTS Compression provides the technical and safety evidence to enable repurposing of the National Transmission System (NTS) compression assets. The project aims to determine the technical and commercial feasibility, provide a technical demonstration and create a strategy for UK NTS Compression System transition. Discovery and Alpha have investigated the key challenges associated with compression of hydrogen and hydrogen blends and the Beta phase will demonstrate the proposed solutions.

Innovation Justification

Relevant State of the Art

Hydrogen compression systems are available to purchase as new units but this option will be costly for the energy transition. There has been some consideration for re-purposing units although most tests are on newer units than those seen on our network. Project HyFLEX has demonstrated 10% hydrogen on a Siemens SGT400 unit whilst several power stations are also considering re-purposing of their larger Gas Turbine (GT) units. We can not utilise this data directly for our assets but are utilising it to guide our activities.

In Europe, compression testing has been undertaken at a blend of 10% hydrogen, however this has not looked at the possibility of re-purposing existing equipment. A Solar Titan 130 turbine has been tested at up to 25% hydrogen at the Waidhaus compressor station in Germany, however, this does not show the full compression system operating on hydrogen. Our challenge looks at both existing equipment and blends of hydrogen up to 100%.

Innovative Solution

Alpha showed that existing Avon GTs can be modified to be fuelled with 100% hydrogen, eliminating carbon dioxide and monoxide emissions. Due to the high flame temperature of hydrogen, nitrogen oxide emissions will increase and the potential to reduce, remove or capture these emissions will be considered in the Beta phase of the project.

The initial analysis undertaken on the existing compressor unit suggests that the compressor may be able to compress blends of up to 50% hydrogen, if a drop in the pressure ratio achieved can be accepted. Beyond this 50% blend, modifications to the system in terms

of more stages of compression would be required.

The next step was to consider the compression opportunity with various hydrogen blends. To achieve compression of varying hydrogen blends, the compressor is required to rotate at varying speeds. Analysis was carried out on 60% - 100% hydrogen to determine the speed of rotation required. The Alpha phase investigated the implications of a varying hydrogen blends in more detail and the potential systems which could be utilised to sense the gas composition and feedback to the compressor to control the speed of rotation.

Each compressor unit on the network costs approximately £60m to replace. The project will consider the opportunity to re-purpose the current compression assets for use with hydrogen and any system modifications required. Determining the most cost effective, safe and efficient route to compress hydrogen is vital to keep costs at a minimum for the NTS transition, and therefore energy customers, through to 2050.

Beyond incremental innovation

Alongside the re-purposing of the unit, we will also consider how to eliminate NOx emissions reviewing both Selective Catalytic Reduction (SCR) and Dry Low Emission (DLE) technological options. To enable the compressor to react to the gas blend as required, automated systems at compressor stations will be required to sense the gas composition at the inlet of the compressor and feedback to control the compressor operation.

The production of hydrogen and injection into the NTS is likely to be inconsistent due to weather fluctuations and varying demand, therefore we will need to understand how the system can manage variable blends of hydrogen and methane.

Readiness level & Scale

At the end of the project we will have an implementation plan aligned to the compressor strategy, with a detailed model of the network aligned to the systems transformation and Future Energy Scenarios. With updates through the period that are due to reflect the supply and demand of hydrogen in more detail through to 2050. The Cost Benefit Analysis will also be updated to enable integration into Project Union re-openers and future business plan activities.

The options for full-scale offline testing of compression assets are very limited. Construction of a test loop at Spadeadam was determined to be the best approach during Discovery and Alpha.

Funding route

Until the evidence has been provided that the gas network can accept hydrogen, natural gas will continue to be the transported fuel within the network and so any research into hydrogen requires funding outside of business-as-usual routes. SIF offers a unique opportunity to understand the safety and technical feasibility of re-purposing NTS compression assets and help to determine the most cost-effective solution for compression of hydrogen with collaborative partners.

Competitive Markets

Whilst Siemens are working with us on the re-purposing project, the route to re-purposing will be shared with other OEMs to encourage them to consider this option. Our engagement has already shown a difference in approach by one other OEM. The activity of re-purposing the network will be undertaken through our standard investment procedures which requires competitive tender.

Counterfactual

We have considered several routes to enable compression on the network, through our work, the most cost effective option, is to utilise the assets already deployed on our network. We have compared options for compression solutions in the appendix.

Impacts and benefits

SIF benefits

- Cost reductions in operating the networks and wider energy system (£m)

The re-purposing of the UK gas assets in the energy transition, is a key step in ensuring value for our consumers, with residual value of the current system being £6.5b. Supporting the continued utilisation of this system and maintaining the jobs associated, it is clearly an approach worth reviewing. A key element of the project is to ensure that in repurposing our assets we do not increase the cost of operating the compression equipment. Studies to date show that the rotating machinery maintenance costs do not vary for new vs old units. However, ancillary equipment and systems need further investigation.

- cost savings for users of network services & end consumers (£m)

The cost to re-purpose an existing compressor unit has been assessed against the cost of replacement. A methane compression unit

costs approximately £60m to replace. The early phase cost benefit analysis shows that savings of approximately £1.4b could be seen in repurposing our units instead of replacing. It is likely in the transition we will need to provide a selection of options for the various sites and systems. This includes extending the lifetime of the assets to manage blends and meet emissions targets to ensure assets are not replaced with systems that are not fit for purpose once the network reaches net zero. The costs to re-purpose are estimated as 100% H₂ = ~£29m, 50% H₂ = ~£17m & 25% H₂ = ~£11m. These numbers will be refined with the compressor strategy team as we deliver the HyNTS Compression project.

- new to market products, processes and services (qualitative)

Whilst compression is not a new product, in repurposing and modifying the equipment to accept hydrogen we will be creating solutions and management processes that could be utilised worldwide.

- carbon reductions – direct or indirect (MTCO₂e)

Natural gas compressor stations currently installed on the National Transmission System (NTS) emit greenhouse gases, through both combustion and venting of natural gas. From 2020 to 2021, compressor stations released approximately 165,000 kg of carbon dioxide and 2,240,000 kg of methane into the atmosphere. The development of hydrogen ready compression systems will eliminate carbon emissions whilst the deployment of NO_x capture will eliminate emissions and provide a truly green system. A parallel project; Ch4rge; looks to prevent natural gas emissions from our compressor units and will be considered for deployment on our system demonstration.

The prior phases of the project have found that it is feasible to re-purpose an existing Avon Gas Turbine to enable the turbine to be fuelled with up to 100% hydrogen. Implementing hydrogen as a fuel gas for gas turbines on the NTS would eliminate 165,000 kg of carbon dioxide emissions which are released at compressor stations annually. The transportation of a hydrogen gas blend vs. natural gas, will seek to reduce the 2,240,000 kg of methane which is released into the atmosphere annually.

Please refer to the business case and CBA in the project management work book for more information.

The Benefits Map can be found attached and demonstrates the key outcomes of the project.

- Whole System - Providing a strategy for compression and developing whole system knowledge will allow compression to be implemented across gas networks and hydrogen production facilities, where required in the UK. Enabling hydrogen to be distributed through the gas pipeline network will allow the market for industrial and residential products that run off hydrogen to be both feasible and enter the market at a competitive price because the cost of transition to blended gases running in the network will be minimised.
- Consumer impact - The utilisation of existing NTS assets with hydrogen prevents the need for installation of new significant investment systems and time delays for Net Zero. Consumers will benefit from the introduction of hydrogen either through energy storage for electrical applications or reduced impact of replacement domestic heating systems.
- Economic benefits - Determining the most cost-effective method of hydrogen compression for the NTS, providing a reduction in consumer costs through the transition and into Net Zero.
- Government priorities - Developing UK capability, skills and competencies for Net Zero solutions, providing significant opportunity for export. UK technology solutions development increasing the value of UK industry, encouraging inward investment into the UK hydrogen economy.
- Environmental impacts - The CO₂ saving is substantial if the hydrogen is produced by renewable energy (green hydrogen), further reducing the country's reliance on fossil fuels and pulling demand for more renewables.
- Resilience benefits - the project will benefit resilience during the transition to hydrogen by enabling compression of hydrogen blended and 100% hydrogen networks, building linepack and providing pressures and flows to meet demand for industry, power and distribution networks.
- Safety - Prevents having to transport hydrogen above ground, eliminating the likelihood of transportation accidents

Project Plans And Milestones

Project Plans, Milestones & Risks

What is your project plan? What are your milestones? What are the risks associated with your project?

The Beta phase project is split into 5 high-level work packages with stage gates to review key outputs.

WP1 Project management - National Gas Transmission (NGT)

Project timelines, risks and costs will be managed through robust management of the project plan and monthly project reviews covering timelines, costs and risks. Our approach to the financial management will be through delivery of the milestones proposed in the project plan. Peer review of our activities for technical, safety and regulatory will be undertaken by the HSE and Cardiff University.

Success criteria (SC)/deliverables (D): Project management activities successfully delivered including stage-gate reviews, steering meetings, financial reporting, risk management, objectives on track and project evidence reviews.

WP2 Business Case and Safety Case - NGT

Development of our understanding of the Hydrogen landscape to refine our hydrogen compression model and the hydrogen compressor implementation plan, ensuring applicability to NGTs compressor operations and strategy, including Project Union. Refinement of the CBA.

SC/D: Continuous monitoring and updates of the safety case, cost benefit analysis, NTS hydrogen modelling, compression strategy and Project Union engagement.

WP3 Component Evidence - Siemens Energy

Deliver the offline test and modification of the gas turbine. Siemens will develop the test facility and carry out the tests fuelling the gas turbine with hydrogen blends upto 100% hydrogen, facilitating the necessary upgrades required. Cullum Detuners will carry out offline tests on the cab system and upgrade the system to run on hydrogen.

SC/D: Detailed design and build of offline test facility for the gas turbine. Successful decommissioning, transport, testing and modification of the gas turbine providing key evidence for re-purposing this asset. Successful upgrades to cab equipment.

WP4 System Evidence - DNV

Deliver the whole system test of the compressor unit. The test loop will be constructed at the Spadeadam FutureGrid facility followed by installation of the compressor components. A newly designed compressor will be installed for testing with blends $>50\%$, as shown in Alpha. The whole system test will provide key evidence of the ability to re-purpose compressors for hydrogen and how it will impact the wider energy system.

SC/D: Detailed design of test loop, construction, commissioning and testing of compressor unit with hydrogen.

WP5 Implementation, Data Analytics and Reporting - NGT

Deliver evidence, technical and progress reports throughout the project. The implementation plan and CBA will be reviewed and updated as appropriate. Reviews by the UKRI Monitoring Officer will also occur on a quarterly basis.

SC/D: MO reviews, testing evidence reviews, technical and progress reporting for each Stage-gate.

Stage Gates

The following stagegates will enable us to ensure the project only continues if the value proposition stands throughout the programme.

- StageGate 0 - Kick Off (Sep 2023) Project documentation, contracts and second level plan in place for project start
- StageGate 1 - Design Sign Off (April 2024) Test loop detailed design complete to be reviewed before progression to next stage
- StageGate 2 - Gas Turbine Ok to Ship (Apr 2025) Offline gas turbine hydrogen modifications and tests complete - evidence provided for gas turbine capability with hydrogen
- StageGate 3 - Test Loop Commission (Oct 2025) Test loop construction complete - check point prior to testing commencing

- StageGate 4 - Compressor Ready to Upgrade (Feb 2026) Evidence for compression up to 50% H2 complete and checkpoint prior to upgrading compressor for 100% H2
- StageGate 5 - System Test Check Point (Aug 2026) Mid point testing check to provide insight into capability of system and conclude final test elements are still fit for purpose
- StageGate 6 - Project Close (Dec 2026) Project closure and reporting, including dissemination

Risks & Risk Strategy

Please see the full risk register for detailed Regulatory, Commercial, Technical and Safety risks and mitigation's.

- Regulatory - There are several risks associated with the uncertainty of the hydrogen demand and supply in the UK. This makes it difficult to provide a clear view of how each compressor across the network will transition. This programme of work focuses on delivering evidence to re-purpose our assets to both blends and upto 100% H2 so that we can utilise the existing systems on our network for as long as possible during the transition. As a clearer view of the future requirements are developed we will refine our compressor strategy using these tools to ensure minimum cost to the consumer.
- Commercial - There is a risk that the re-purposing of the existing assets cannot be proven through this programme of work and replacement is the only option available. We are minimising this risk by reviewing global activities in this space and ensuring that our desktop work provides a clear understanding of the technical risks.
- Technical - Natural gas has very different properties to hydrogen and therefore the compression units will interact differently with it. We will look to manage this with the modifications made to the system.

Regulatory Barriers

Regulatory barriers or uncertainties that may hinder Beta delivery

There are 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.

We have considered the potential regulatory impact relating to the transfer of ownership of the decommissioned NTS assets to DNV GL for the construction of the facility at the Spadeadam site. Standard Special Condition (SSC) A27 of the NGT licence prohibits NGT disposing of any transportation asset without the consent of Ofgem. In this instance, as the assets that NGT would be transferring would be disconnected from the NTS and decommissioned, then the prohibition on NGT disposing of them in SSC A27 does not apply, as the assets are no longer deemed to be 'Transportation Assets'.

Long term regulatory barriers for implementation

Our network supplies natural gas to industrial, power and heat applications today and has the opportunity to support transport with Hydrogen. 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 in review around the introduction of hydrogen, considering 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 adapted for hydrogen transportation.

Implementation requirements

In order to implement the outcomes of this project we will require the ability to deploy hydrogen into the NTS network or/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 could be possible prior to the end of the system demonstration, as this is looking to be developed through a Challenge Round 2 SIF project.

Ongoing conversations with Government, Ofgem, and other relevant organisations

Engagement with our stakeholders in the deployment of hydrogen and the timelines associated is vital to the success of hydrogen deployment to ensure Network Exit and Entry agreements (NExA/NEA) are aligned to the network approach in the vicinity of these customers. We have already begun these discussions with the majority of our key stakeholders through Project Union, these interactions have been very positive with an agreement that a hydrogen backbone in the UK is a requirement.

We continue to support Government and Ofgem in gathering the evidence required to deliver policy and regulation that will enable the energy transition through working groups such as Hydrogen Grid Research and Development (HGR&D) and Gas Goes Green (GGG). Evidence of our networks' capability to support the transition is beginning to be reviewed by the HSE and development of approaches to blending both commercial and technical, are underway through these collaborative working groups.

Regulatory support

None required, current engagement through engagement with Ofgem and DESNZ should provide the outcomes required to implement this option in the future.

Longer term policy considerations

The policy landscape is already beginning to enable the deployment of hydrogen and through the continuation of the policies on hydrogen in industry, transport and power we will be enabled to deploy the findings of the SIF projects. The announcement of the industrial cluster decarbonisation plans has been key to our hydrogen backbone proposal and with further progress of the later track clusters we can support further decarbonization in the UK. Business model and regulatory regimes alongside these policies will ensure the robust and accelerated transition of the hydrogen infrastructure in the UK.

Consideration of interconnectors with Europe and their route to hydrogen deployment in their systems has already begun with the European hydrogen backbone proposal incorporating the NTS. Europe have accelerated their transition to having a blend of hydrogen in the network to 5% by 2024. In order to maintain interconnection with our counterparts, we must be enabled to blend hydrogen into our gas networks, whilst protecting customers that cannot accept this with de-blending technologies.

Business As Usual

Business as Usual Adoption

The project will develop 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.

The project team has expertise in asset strategy, asset management, rotating machinery, system control and hydrogen. The team have the seniority and expertise to direct the project outputs and requirements to ensure implementation. We are working closely with the compression asset strategy team to build the outcomes of this project into our asset strategy for the future.

Idea to adoption

The hydrogen and compressor asset strategy teams will be responsible for the implementation of the compression strategy and this projects outputs. Through the project, there are several evidence deliverables that will feed into our price control business plan and associated hydrogen implementation projects such as Project Union, with re-purposing of assets due to begin 2026. Our business is dedicated to ensuring that the learning from this project is deployed, we see value in the project delivery which can be seen in the financial contribution.

Project Champion

The project has several champions across the network, which form our internal steering group and will be responsible for driving the technology into the NGT business. The project is endorsed and supported by all levels of management demonstrated through our financial contribution and ongoing steering group. The innovation team are responsible for delivery of the project and ensuring delivery of value into the business through implementation and into the wider UK and global network landscape. This will be supported by the:

- Project Union Director responsible for delivery of Project Union and associated network re-purposing programmes
- Commercial team developing our future network for topics such as blending, carbon capture etc...
- Asset Management Plan (AMP) asset strategy manager deploying the project outcomes into future business plans and asset strategy
- Subject matter experts for compression and operational deployment of the systems ensuring we provide the right level of evidence and data
- Systems operation and management of the network ensuring they can manage the network with the physical assets we make available to them
- Dissemination and project's learnings shared with other licensees

The project will include regular stakeholder updates throughout, to ensure key UK and Global stakeholders are engaged and learning

is shared. This will enable other gas networks, hydrogen production facilities and industrial consumers to utilise our results to support hydrogen compression across the UK. We will also provide an overview of the outputs to the wider energy system as the ability for the network to provide linepack storage could play a strategic part in the electricity networks of the future.

Adoption of the outputs of this project are focussed on the NTS, internal team engagement is vital for this and will be a focus for the project team. Siemens Energy has customers across the UK and globe utilising their compression systems who could benefit from the outputs of this project with whom learning will be shared with and we are also engaging with other compression OEMs to provide insight into our repurposing plans and encourage them to provide similar options in the future. The knowledge gained by suppliers will enable them to provide hydrogen ready compression systems and associated equipment, and where possible, help to modify existing assets for use with hydrogen in the UK and internationally.

Funding strategy for adoption of your innovation

As the hydrogen economy grows, and there is more demand for hydrogen, an increased number of compressor stations will require conversion and the HyNTS Compression project will inform the most cost effective way to do so. The modelling work undertaken in the project will also provide insight into the amount of compression required throughout the transition as we gain improved insight into hydrogen supply and demand.

The development of the UK compressor stations is funded through the Ofgem regulatory price controls directed by the networks business plan. Reducing the cost of these investments is the core focus of this project.

The learning gained during the project will allow existing compression systems to be upgraded to manage hydrogen and develop the most cost-effective solution for replacement when necessary throughout the UK. The learning could also support the development of hydrogen ready transmission compression assets across the globe and could be exploited as such.

Interest from other Networks

Whilst NGT is the only transmission network in the UK we are members of several working groups with global transmission networks through which we are sharing learning, this includes the H2GAR Compression working group members and several global Transmission System Operators.

Commercials

Consumer interaction and engagement

Interactions with energy consumers

The high pressure gas National Transmission System (NTS) links key supply points in the UK to Industrial consumers, Power consumers and Distribution networks (SGN, NGN, WWU & Cadent).

Industrial & Power Consumers - Our first transitional project of our high pressure gas network to hydrogen will be through Project Union which commenced Pre-FEED in Feb 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 customers 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 require compression solutions for hydrogen also.

The HyNTS compression project will provide some key inputs to Project Union, such as supply pressures, flows and linepack capability, alongside key inputs into the cost of the transition of the network. The compression assets are the most expensive assets on our network to replace and re-purposing these will reduce the cost of the network transition for all consumers.

Siemens has considered other users of the gas turbines (GTs) in the UK that may benefit from the knowledge gained in this project, where, we will be actively sharing our outcomes with them to help them transition their systems to Net Zero. These include global gas networks, industrial users, power stations etc... Siemens will look to engage these partners through the project to share learning and demonstrate the possibilities of hydrogen compression.

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, there have been future scenarios reviewed 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 disseminate the progress in 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.

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.

Our network modelling activities will continue into the Beta phase and we will look to improve our model datasets through engagement with whole system stakeholders. We have been working with the Electricity System Operator through their bridging the gap activities to support engagement of our network stakeholders and future hydrogen customer base. This work alongside other activities to provide better scenarios for the future will help us refine the compression system required for net zero.

Impact on existing or future energy consumers and their premises, for example, through charging or contractual arrangements or supply interruptions

This project will not have an impact on the 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.

At present, there is not a clear understanding of how hydrogen networks will be regulated nor a clear understanding of the charging routes. There is likely to be an impact on consumers of gas as we transition to Net Zero, but at this point in time, this cannot be

quantified.

Supply shortages and interruptions

Expected number and duration of any interruptions to consumers

The project will be undertaken on offline facilities to prevent any risk to supply of natural gas and safety risks associated to testing with hydrogen. As part of the Discovery phase, several sites were considered for the compression system test, including operational sites. The selection of the DNV Spadeadam and Siemens facilities is due to their remoteness and ability to manage the testing of these large units safely.

In the implementation of this project we are proposing no interruption to consumer supply, as our compressor sites host several compressor units, which provide resilience, but are unlikely to operate all at once. The selected unit to be transitioned would be taken offline whilst the other compressor units operate as required. This is a common occurrence during planned maintenance. We would interface closely with the Gas System Operator (GSO) to ensure that units selected would not provide an issue to the wider network and undertake work at suitable times of the year (i.e. during any planned Summer outage)

Reason for any interruptions

The proposed compressor unit is planned for decommissioning in April 2024, this will follow our standard decommissioning approach, but taking extra care with the equipment to ensure it can be re-utilised. These activities are undertaken regularly with no interruption to consumer supply. We do not foresee any interruptions caused by this project.

Interruptions caused through implementation are unlikely as work would be managed to ensure a consistent supply of gas regardless of the units transition. Project Union will be developing the detailed transition plans for the network to hydrogen which will aim to cause minimal impact to consumers. This project will interact closely with Project Union to ensure this approach is feasible.

Measures taken to ensure consumers have access to the energy services they require

We have been working closely with the GSO to understand the best routes for Project Union and the impacted compressor sites. GSO have helped us prevent constraint to the natural gas supply across the UK through the routes identified. The HyNTS project will not have an impact as per the discussion points above, but we will continue to support Project Union to ensure this is maintained.

Investigation into alternative ways to implement the Project

As we do not foresee any consumer interruptions, we have not been required to investigate alternative implementation methods. Through Beta we will continue to monitor this and act if this changes.

Commercialisation

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.

Primary customer segment beyond the networks

All gas turbine Original Equipment Manufacturers (OEM's) are currently developing the capability to operate their equipment on 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.

Working groups such as H2GAR* and GERG** encourage knowledge sharing with European and UK hydrogen projects, which promotes and allows collaboration between different industrial partners and academia to bring the best and most innovative solutions (and to share best practises) to the end users/consumers. The ability to operate on hydrogen fuel will reduce the carbon footprint of the gas turbines consistent with global efforts to combat climate change.

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. 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 in furthering this innovation research and creating engineering expertise and skills.

Customer value proposition

The cost reduction in the transition to hydrogen will provide cost benefit to the consumer and enable a Net Zero future.

Outline of the route to market and potential new partnerships

Siemens has begun to engage their wider customer base to share learning from the project and understand their customers plans during the energy transition. We have shared insight from the project to date with other OEM's, such as Solar and Baker Hughes, whom originally did not have a plan to enable re-purposing of legacy equipment, but in most recent calls are moving to support this at least for small blends of hydrogen. We will encourage this further to enable cost savings during the energy transition.

Partner capital requirements to commercialise

The focus of this project is to enable re-purposing at a minimal cost to the compression system owner. There will be a requirement for capital investment in upgrading the system to enable hydrogen blends, however, this is lower than the total cost of replacement.

Scalability across the GB network and new markets

Siemens will enable the ability to operate on hydrogen to be offered to all current and future Siemens Energy aero-derivative gas turbine operators. Their compressor products are available to anyone across the globe in any market segment (given there are no legal imposed sanctions). After the Beta phase, there is the opportunity for this learning to be implemented in many industries including oil, gas, chemical, mining, food, paper, steel and medical. SIF governance terms around commercialisation will be met through the negotiated contract terms.

The use of hydrogen reduces carbon dioxide emissions and therefore reduces exposure to carbon emissions penalties and will prolong the viability of installed gas turbines. This extension in life of the existing assets means CAPEX can be realised over a longer period, reducing the whole-life cost of the operating assets to ensure consumer value.

A global leader in the energy sector, Siemens Energy offers the capability to use hydrogen fuel without external partnerships. Where the value proposition is favourable, partnerships will be considered. Siemens Energy compressor products have been commercialised since around 1868 with more than 12,000 products installed worldwide, thus they have an existing, successful route to market.

As the OEM of the equipment, Siemens Energy have no capital, but do have a large commitment to R&D within their business allowing them to invest into our portfolio of products to constantly improve performance, reduce emissions and extend life. This allows the business to grow and commercialise new R&D products.

*H2GAR - Hydrogen Gas Asset Readiness group - UK and EU Transmission System Operators investigating the Hydrogen readiness of assets

**GERG - European Gas Research Group

Intellectual Property Rights

What are the Intellectual Property Rights (IPR) arrangements for your project? We do not plan to defer from the proposed approach to IPR in the SIF governance, to ensure that the project outputs and results can be maximised to provide value to the consumer.

What are the Intellectual Property Rights (IPR) arrangements for your project?

For SIF projects, each Project Partner shall own all Foreground IPR that it independently creates as part of the Project, or where it is created jointly then it shall be owned in shares that are in proportion to the work done in its creation. The exact allocation of Foreground IPR ownership will be determined during the contractual negotiations with the Project Partners on the agreement for the project.

Also, if the party appoints a sub-contractor, the agreement with that sub-contractor should have similar IP provisions to those in this agreement and which at least achieve the same aims as the agreement regarding IP.

Once the Project is completed, Relevant Background IPR will be licensed for use by the Project Partners in connection with another Project Partners' Foreground IPR solely to the extent necessary to use that Foreground IPR, upon terms to be agreed.

Describe how each Project Partners complies with Chapter 9 SIF Governance Document.

We intend to ensure each Project Partner will comply with Chapter 9 SIF Governance Document through the contractual terms governing the project. However, precisely how this is done will be subject to contractual negotiations with the Project Partners on the agreement for the project. The approach used for FutureGrid Phase 1 (NIC funded project) will be the basis for the contractual terms, with the relevant SIF governance requirements and project partners integrated into the contract. This will provide the most efficient way to reach a contractual agreement as the SIF elements have been agreed through Alpha and the DNV site interactions have been built into the FutureGrid Phase 1 contract. Negotiation of the contract will begin from application to ensure we are ready to begin the project in September 2023.

Costs and Value for Money

Total Project Costs - £37,003,556 (£43,694,476 including contribution in kind (CIK))

- Seeking SIF funding for £33,303,556
- 10% Financial contribution of £3,700,000
- CIK of £6,685,120

Partner Costs

- National Gas Transmission (NGT)

£4,199,542 - £3,700,000 = £499,542 - 2% of SIF funding

£1,240,880 CIK

- DNV

£19,458,824 - 58% of SIF funding

£2,445,000 CIK

- Siemens Energy (SE)

£9,943,113 - 30% of SIF funding

£2,472,000 CIK

- Cullum

£2,007,145 - 6% of SIF funding

£378,000 CIK

- Premtech

£680,155 - 2% of SIF funding

£54,240 CIK

- Cardiff University

£677,937 - 2% of SIF funding

£85,000 CIK

- Southern Gas Networks (SGN)

£12,640 - <1% of SIF funding

- Northern Gas Networks (NGN)

£24,200- <1% of SIF funding

The majority of the SIF funding is associated to DNV and SE whom will be doing the majority of the build and test activities, this is inline with the project deliverables required to provide the system capability evidence.

Subcontractor Costs

The HSE will be subcontracted into the project by NGT. They are critical to the project as they will peer review the evidence generated from the demonstration, providing expertise in safety aspects of the project including materials, explosive atmospheres, hazardous areas and risk. £228,010

Andrew Francis and Associates (AFAA) will be subcontracted into the project by Premtech to provide specialist stress analysis. This work is critical in ensuring the facility does not fail during testing. £75,000

Cullums will be subcontracting Elta Fans, Flamgard, Alnscough, Kaefer and Total hire to enable the cab build for the compressor. £149,000

Value For Money

The test facilities will be constructed using assets which have been decommissioned from the Gas Transmission Network. This results in a large cost saving on materials in the project whilst allowing the project to gather evidence on repurposing network assets for hydrogen. An estimated value of these assets supplied is £980k looking at scrap and reuse value at the point of application.

In preparation for this bid the project team engaged with Ofgem, DESNZ, HSE and UKRI to determine the best route for funding this activity. It was concluded SIF was an appropriate route forward even though the total cost was above the SIF £10m threshold.

Whilst the total cost of this project is high the potential benefits are huge for the energy consumer as we transition from natural gas to hydrogen. We have included stage gates throughout the programme to enable us to pause and ensure that the continuation of the project is still providing us these presumed benefits. We will enable a consortium including Ofgem, UKRI, HSE and DESNZ to make this decision with us at each stage gate. The project team are also engaged in the Project Union Pre FEED to ensure learning is shared across the programme of work.

In kind contributions from the partners range from stakeholder engagement through to development of testing facilities and management of COMAH requirements. These activities come at a cost to the project partners but also provide them long standing capabilities past the end of the project. We have ensured a balance between funding and in kind contribution to maximise value for the consumer.

How the costs outlined compare to normal industry rates

The project rates utilised are aligned to the partners typical rates and are provided in detail by each partner in their funding section. The project cost for deploying a compressor unit on a green field site with a km of pipeline is very competitive with costs seen in deployment activities in the range of:

- ~£4m per km of pipeline
- ~£60m per compressor unit deployed

The project costs do not only cover the deployment of the system but also the pre work, testing and assessment with a broader portfolio of partners than would be seen in typical deployments. The savings seen in comparison to conventional costs are in part due to the partners engagement in the project and understanding of the opportunity this project provides them in the energy transition.

Project team and resources

The core project team of DNV, SE and Cullum continues into the Beta phase with an addition of Premtech to enable the detailed design activities. Alongside this the addition of Cardiff university to provide technical guidance and review and the HSE to provide health and safety guidance has been made in the Beta phase. The gas networks NGT, SGN and NGN continue into the Beta phase to support implementation planning. Alongside this we have developed an advisory group of networks from across the globe to ensure shared learning and prevent duplication.

ITM Power will not continue into the next phase due to concerns around their IPR and NGET will not sit as a project partner but will be approached through the modelling activity to ensure a whole system approach alongside other electricity networks, producers and users.

Document upload

Documents Uploaded Where Applicable

Yes

Documents:

HyNTS FutueGrid Compression Beta.pdf

SIF Beta Project Registration 2023-09-27 3_50

This project has been approved by a senior member of staff

Yes