

## NIA Project Registration and PEA Document

### Date of Submission

Mar 2022

### Project Reference Number

NIA\_NGGT0188

## Project Registration

### Project Title

Variable Hydrogen Blend Compression

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NIA\_NGGT0188

### Project Licensee(s)

National Gas Transmission PLC

### Project Start

March 2022

### Project Duration

1 year and 10 months

### Nominated Project Contact(s)

Lynsey Stevenson, Box.GT.Innovation@nationalgrid.com

### Project Budget

£140,000.00

## Summary

During the energy transition, it is likely that consumers will have differing gas composition requirements, and the National Transmission System (NTS) will have to transport varying percentages of natural gas and hydrogen within the gas blend. This creates a challenge for compression as centrifugal compressors will have to operate at variable speeds to compress varying gas blends. Automated systems at compressor stations will be required, which can sense the gas composition at the inlet of the compressor and feedback to control compressor operation. This desktop-based study will investigate the effects of varying hydrogen blend on the operational parameters of a compressor and research potential modifications to existing compressors, alternative compression technologies and sensing systems which could enable compression of variable gas blends on the NTS.

## Third Party Collaborators

Frazer-Nash Consultancy

## Nominated Contact Email Address(es)

Box.GT.Innovation@nationalgrid.com

## Problem Being Solved

There are 24 compressor stations on the NTS which have been designed for specific operational parameters such as flow rates, pressures and gas composition. The transition to hydrogen will present a challenge for compression, as the pressure ratio which can be achieved is dependent on the process gas. Due to the properties of hydrogen, the same pressure ratio which is currently achieved processing natural gas cannot be achieved without modifications to compression systems. It is also likely that consumers will have differing gas composition requirements in the future, and the NTS will therefore have to transport varying percentages of natural gas and hydrogen within the gas blend. This creates a challenge for compression as centrifugal compressors will have to operate at

variable speeds to compress varying gas blends. To enable the compressor to react to the gas blend as required, automated systems at compressor stations will be required, which can sense the gas composition at the inlet of the compressor and feedback to control compressor operation.

This desktop-based study will develop a model which will be used to determine the effects of varying hydrogen blend on the operational parameters of a compressor. The project will research potential modifications to existing compressors, alternative compression technologies and sensing systems to enable compression of variable gas blends.

## Method(s)

The project will develop a model of a typical compressor on the NTS which will then be used to study the effects of hydrogen blends of 2%, 20%, 50%, 80% and 100% hydrogen and limitations of future hydrogen service. Options for retrofitting the typical compressor will be investigated and the model adapted for a selection of the most viable options to determine their effect on compressor operation with hydrogen. The most promising retrofit option for each hydrogen blend will then be used to assess variability and explore the limits of varying hydrogen concentration above and below the specified blends. Potential sensing systems will be investigated which could detect hydrogen concentration and communicate hydrogen concentration in real time to enable the compressor to operate as required. A technical review of alternative compressor technologies will be undertaken, and the technologies will be compared with potential retrofit options.

## Measurement Quality Statement

The measurement approach used to meet Data Quality objectives will be through the identification of high calibre project partners who are experts in their given field. In this instance the project will be limited to a desktop study and analysis from TRL2 to TRL3 to inform new insights into the use of existing NTS compression assets with variable blends of hydrogen.

## Data Quality Statement

The project will ensure that data used is of sufficient quality to deliver project objectives by selecting a 'typical' compressor where there is sufficient operational and original design data to ensure a robust analysis can be undertaken. The relevant data and background information will be stored for future access within the National Grid Innovation SharePoint site.

## Scope

The project will be split into 3 Phased work packages:

### 1) Work Package 1 – Model Development (Duration – 9 weeks)

Lead – Frazer-Nash Consultancy and National Grid

Work Package 1 will include:

- Model existing compressor fleet: identify one compressor which is 'typical', where suitable operational and OEM design data is available, and derive compressor map. Create analytical model of a single stage compressor based on geometry and operational parameters of identified compressor.
- Model inclusive of hydrogen service: Assuming constant shaft speed and volumetric flow, understand the effect on stage loading and efficiency for a range of blends of hydrogen (2%, 20%, 50%, 80% and 100%).
- Model greater flow rate: Repeat model of stated hydrogen blends with a range of flow rates and identify upper limits on flow rate.
- Operational envelope: Derive limitations of future operation due to capacity and performance and understand the limitations from associated plant, including motor unit or gas turbine. Comment on wider network effects and how change in pipeline frictional losses may mitigate operational constraints. Estimate the effect on asset life.
- Compressor Efficiency: Estimate additional losses (e.g. inlet volute, exhaust, etc.) and multistage compressor efficiency considering different configurations (series and parallel) of compressors. Production of revised compressor map(s).

### 2) Work Package 2 - Investigation of retrofitting options and review of alternative compressor technologies (Duration – 4 weeks)

Lead – Frazer-Nash Consultancy

Work Package 2 will include:

- **Retrofitting of existing centrifugal compressors:** explore retrofitting options across a variety of industries and select the most viable options for further investigation. Options to be review will include, but not be limited to, shaft speed increase, inlet guide vanes and inlet diffuser vanes. For each option identified, the compressor model will be adapted to represent the modification and the effects on operational limits explored.
- **Variability of hydrogen concentration assessment:** the most promising retrofit option for each hydrogen blend (2%, 20%, 50%, 80% and 100%) will be selected and the limits of varying the hydrogen concentration above and below the specified concentration will be explored. New performance maps for feasible concentration ranges will be derived. Potential sensing systems, which would enable the compressor to operate dependent on the hydrogen concentration of the process gas, will be investigated.
- **Technical review of alternative compressor technologies:** Identify current and novel compression technologies and create a weighted decision matrix to score each technology against key criteria such as efficiency, operational ranges, ability to handle variability in hydrogen blends and component lifespan. Extend the weighted decision matrix to include retrofitting options to provide a high-level comparison of all options investigated.

### 3) Work Package 3 - Cost Estimation and Reporting (Duration – 3 weeks)

Lead – Frazer-Nash Consultancy and National Grid

Work Package 3 will include:

- **Cost estimation:** A rough order of magnitude estimate of costs for reworking existing compressors to support different blends of hydrogen including an estimation of CAPEX, OPEX and expected asset lifetime versus the typical compressor. Recommendation on appropriate investment decisions based on each single hydrogen blend scenario. Recommendations on appropriate investment decisions based on the variability of hydrogen concentration assessments considering the lifetime and cost of replacement components based on operation with the ranges of hydrogen concentrations analysed in Work Package 2.
- **Reporting:** final project report detailing all work carried out, conclusions and recommendations to inform NTS compression strategy.

### Objective(s)

The main objective of this study is to support decision making on whether the NTS compression fleet is compatible with blends of hydrogen from 1 – 100% and assess whether variable blends can be tolerated.

- Display quantitative changes in operating envelope and required shaft power of compressor with 2%, 20%, 50%, 80% and 100% hydrogen.
- Understand changes of operating envelope and available power with current operational conditions.
- Understand the implications of a variable hydrogen concentration on compressor operating envelope and efficiency.
- Understand impact of hydrogen blends on lifetime of compressor and components.
- Understand change to maintenance regime required to accommodate hydrogen.
- Understand the suitability of alternative compressor technologies for compression of pure hydrogen and hydrogen blends.

Understand cost of replacement and retrofitting compared with current compressor fleet.

### Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The National Transmission System (NTS) is a key UK infrastructure for the transport of Gas to consumers, including those considered vulnerable. In a scenario where hydrogen replaces methane as a household heat source, it is essential the vulnerable are not excluded by virtue of fuel inaccessibility. In cases where vulnerable consumers already utilise gas, it is likely that in a net zero future the optimum option is to provide a consistent energy solution. The transition to hydrogen within the NTS provides continuity of access to the vulnerable of hydrogen as a replacement to methane, with ongoing benefits of efficiency and economy of scale within a closely regulated environment. This project supports the transition of the NTS to hydrogen which in turn supports the availability of gas to the

vulnerable.

## Success Criteria

The following key criteria need to be met for the project to be considered successful:

- Study objectives met to time and cost.
- Study findings inform NTS strategy for hydrogen compression.

## Project Partners and External Funding

Gas Network – National Grid Gas PLC

Technical & Industrial Lead – Frazer-Nash Consultancy

## Potential for New Learning

Although hydrogen compression is being investigated globally, the potential for retrofitting existing centrifugal compressors has yet to be investigated. The requirement for the NTS to transport variable blends of hydrogen during the energy transition, and the effects this would have on the compression fleet has not yet been investigated. The new learning created through this project is:

- The effects of the introduction of hydrogen into the NTS on an existing 'typical' compressor.
- The implications of a variable blend of hydrogen concentration on compressor operation.
- Potential retrofit options to enable variable blends of hydrogen to be compressed utilising existing assets.
- A high-level assessment of retrofit options versus alternative existing and novel compression technologies.
- Cost estimation for retrofitting and replacement of existing NTS compressors.

## Scale of Project

This project is a desktop-based study that will provide insight into whether there is an opportunity to repurpose existing compression assets for use with variable blends of hydrogen. This learning will help to inform the NTS strategy for compression of hydrogen for the energy transition and feed into further compression projects where hydrogen compression is to be demonstrated.

## Technology Readiness at Start

TRL2 Invention and Research

## Technology Readiness at End

TRL3 Proof of Concept

## Geographical Area

United Kingdom – Warwick and Glasgow

## Revenue Allowed for the RIIO Settlement

None – Hydrogen network focused project

## Indicative Total NIA Project Expenditure

£140,000.00

## Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

### Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

#### How the Project has the potential to facilitate the energy system transition:

For the transition to hydrogen, the NTS will need to ensure hydrogen can be supplied to consumers reliably from producers. Compression is required to move gas from the producer to the consumer, build linepack to store gas and direct flows within the network. It is likely that during the transition consumers will have varying gas composition requirements, varying from 100% hydrogen to 100% methane. This project will investigate the potential to retrofit existing assets to enable varying hydrogen blends to be transported through the NTS.

#### How the Project has potential to benefit consumer in vulnerable situations:

Although this project does not directly affect vulnerable consumers the energy transition may and as such, we must consider the effect of the work we are doing through the NIA funding. The National Transmission System (NTS) is a key UK infrastructure for the transport of Gas to consumers, including those considered vulnerable. In a scenario where hydrogen replaces methane as a household heat source, it is essential the vulnerable are not excluded by virtue of fuel inaccessibility. In cases where vulnerable consumers already utilise gas it is likely that in a net zero future the optimum option is to provide a consistent energy solution. The transition to hydrogen within the NTS provides continuity of access to the vulnerable of hydrogen as a replacement to methane, with ongoing benefits of efficiency and economy of scale within a closely regulated environment. Ensuring robust NTS assets and consistent hydrogen production options will support the transition of the NTS to hydrogen which in turn supports the availability of gas to the vulnerable.

### Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

#### Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

RIIO-1 question - N/A

#### Please provide a calculation of the expected benefits the Solution

The project results will inform our hydrogen compression strategy and therefore could provide savings in future applications. Each compressor on the network will cost at least £40m to replace, therefore the opportunity to repurpose existing assets could result in significant savings.

#### Please provide an estimate of how replicable the Method is across GB

The project is focussed on compression of variable hydrogen blends on the NTS; however will be relevant to gas distribution networks, where hydrogen compression may be required in the future.

#### Please provide an outline of the costs of rolling out the Method across GB.

The cost of rolling out technology capable of compressing variable blends of hydrogen on the network is unknown and further development on the application and commercial model is required, this will be completed through the project period.

### Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

- A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).
- A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)
- A specific novel operational practice directly related to the operation of the Network Licensees system
- A specific novel commercial arrangement

RIIO-2 Projects

- A specific piece of new equipment (including monitoring, control and communications systems and software)
- A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven
- A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)
- A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology
- A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution
- A specific novel commercial arrangement

## Specific Requirements 4 / 2a

### Please explain how the learning that will be generated could be used by the relevant Network Licensees

The research and analysis undertaken in this project will be applicable to pipeline operators and will inform the strategy for hydrogen compression for the energy transition.

### Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

RIIO-1 question - N/A

### Is the default IPR position being applied?

- Yes

## Project Eligibility Assessment Part 2

### Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

### Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

There will be no duplication of activities done as part of this program. The work undertaken globally on compression systems has looked at the development of new technologies, and not at the option of repurposing existing assets to ensure the energy transition can be undertaken at as low a cost as possible to the consumer.

### If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

N/A

## Additional Governance And Document Upload

## **Please identify why the project is innovative and has not been tried before**

In Europe, compression testing has been undertaken at a blend of 10% hydrogen, however this has not looked at the possibility of repurposing existing equipment. The potential for compressors to handle a variable blend of hydrogen has not been investigated before, and an understanding of how current compression systems would handle a variable gas blend is required to prepare the NTS for the transition to hydrogen.

## **Relevant Foreground IPR**

The results of the project will enable us to inform the NTS strategy for hydrogen compression and the potential to retrofit existing compression assets, but will not create any new systems.

## **Data Access Details**

Data for this project, and all other projects funded under the Network Innovation Allowance (NIA) funding scheme, can be found or requested in a number of ways:

- A request for information (RFI) via the Smarter Networks Portal at <https://smarter.energynetworks.org>. National Grid Gas Transmission regularly publishes much of the data arising from our innovation projects on the ENA portal, before submitting a RFI check this website.
- Via our managed mailbox [box.GT.Innovation@nationalgrid.com](mailto:box.GT.Innovation@nationalgrid.com). Further data can be shared upon request through the innovation mailbox. Each request will be assessed by the GT Innovation Team for its merits and viability.

## **Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities**

Variable hydrogen blend compression has not yet been developed and therefore is a low TRL system with high levels of risk associated. We do not have any baseline TOTEX allowances in RIIO-2 to cover such projects, it is therefore relevant for NIA funding.

## **Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project**

The application and technical challenges around the compression of hydrogen and hydrogen blends require early-stage research to be conducted and therefore carries additional exposure to risk – the NIA funding reduces exposure to the risk and enables the feasibility of repurposing existing assets to be assessed.

## **This project has been approved by a senior member of staff**

Yes