Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Nov 2023

Project Reference Number

NIA_NGT0226

Project Registration

Project Title

Modelling Hydrogen Impact on Pipeline Steels (HIPS) – Phase 1

Project Reference Number

NIA_NGT0226

Project Licensee(s)

National Gas Transmission PLC

Project Start

December 2023

Project Duration

0 years and 7 months

Nominated Project Contact(s)

Robert Best, box.GT.innovation@nationalgas.com

Project Budget

£527,467.00

Summary

The short- to medium-term impact of hydrogen on internal, gas-facing defects is becoming well understood via testing underway worldwide. However, there is limited data on how high-pressure hydrogen affects the long-term performance of pipeline steels.

Barrier coating systems have been considered to mitigate the effects of hydrogen embrittlement. Whilst testing has shown reduced permeation of hydrogen through coatings there is a gap in quantifying the benefits of such barrier systems in terms of increased pipe lifetime or mechanical performance.

This project aims to create a model to investigate the long-term effects of hydrogen on pipeline materials. This will feed into assessments of pipeline hazards, influence business case analyses of hydrogen barrier systems, whilst also informing leakage rate assessments and resulting effects on pipeline coatings.

Third Party Collaborators

Ultima Forma

Nominated Contact Email Address(es)

Box.GT.Innovation@nationalgrid.com

Problem Being Solved

The short- to medium-term impact of hydrogen on internal, gas-facing defects is becoming well understood via significant testing being undertaken worldwide. However, there is limited data on how high-pressure hydrogen affects the long-term performance of steel pipeline materials in the absence of growing internal defects.

Barrier coating systems have been considered to mitigate the effects of hydrogen embrittlement, however, whilst testing has shown reduced permeation of hydrogen through coatings there is a gap in quantifying the benefits of such barrier systems in terms of increased pipe lifetime or mechanical performance in high-pressure hydrogen environments.

This project aims to create and validate a model to investigate the long-term effects of hydrogen on pipeline materials. This model can then be used in multiple ways including, but not limited to: assessment of the impact of external damage over time; the efficacy of hydrogen barrier systems to reduce or prevent reduction in pipe properties; assessment of leakage rates and the resulting effect on pipeline coatings.

Method(s)

A systems engineering process will be applied to this project, designed to capture all relevant information and ensure a structured approach, whilst delivering in an optimised timeframe. The project will comprise 2 work packages at this stage:

WP0: Project Management, Standards & Reporting

WP0.1 – Project Management Documentation (including Project Schedule, Lessons Log, Risk Register, Issues Register)

WP0.2 – Technical Report including Technical Summary

WP0.3 – Policy & Procedure Review

WP0.4 – Project Closure Reporting

WP1: Model Development

WP1.1 – Literature Review & Benchmarking

WP1.2 – Basic Hydrogen Impacts Model Development

WP1.3 – Define Test Programme (Validation Plan)

WP1.4 – Define Future Phase Plan (including defining and building consortium and finalising costs)

At the end of the project a decision will be made to progress to a second stage during which the developed model will be calibrated, validated and then implemented.

Measurement Quality Statement

The measurement approach used to meet Measurement 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 model creation at TRL2 to TRL3. Model quality will be assessed via user acceptance testing against the initial objectives of the project. Future phases will be used to validate the model against empirically derived data if deemed necessary.

Data Quality Statement

The project will ensure that data used is of sufficient quality to deliver project objectives through the development of a robust plan considering key input data requirements. The relevant data and background information will be stored for future access within the National Gas Transmission Innovation SharePoint site.

Scope

The National Transmission System (NTS) in the UK offers a resilience to the UK's varying energy demand and supply. It enables suppliers to input gas at one location in the country and transport it to consumers via the distribution networks whilst simultaneously acting as a storage system to ensure there is energy available even on the coldest winters day. The NTS currently transports natural gas which on combustion produces carbon dioxide plus other greenhouse gases which contribute to climate change. The UK has set an ambitious target of eliminating net carbon emissions by 2050 and a wide range of green technologies are required to reach this goal.

A key technology in this transition is hydrogen as an alternative for carbon fuels in heat, transport, and industrial uses. Transporting hydrogen across the UK and connecting renewable energy producers to customers is an opportunity for the NTS and a potential way to extend the life of assets already paid for by UK consumers. However, the NTS was not designed to transport hydrogen and learning needs to be developed on the capability of these assets in this new use case.

No direct financial benefits are expected from this project, however the model created should support the assessment of defects on hydrogen pipelines and as such can help reduce costs associated with undertaking unnecessary mitigation measures and/or costs associated with the consequences of failures.

In Scope

- Above ground and below ground pipe and piping
- Steel pipe parent metal (all grades on NTS), seam welds (all types on NTS) and girth welds (all types on NTS)
- All types of internal and external pipe coatings and paints
- Ingress of hydrogen over time on "defect-free" pipelines
- Impact of hydrogen on mechanical properties over time
- Extent of hydrogen permeation over time

Out of Scope

- Non-steel assets (except pipeline coatings/treatments)
- Non-pipe assets

Objective(s)

This project aims to create a model to investigate the long-term effects of hydrogen on pipeline materials. This model can then be used in multiple ways, including, but not limited to:

- Assessment of the impact of external damage over time
- Assess the efficacy of hydrogen barrier systems to reduce or prevent reduction in pipe performance
- Assessment of leakage rates through pipes over time
- Effect of permeated hydrogen on pipeline coatings

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.

An assessment of distributional impacts (technical, financial and wellbeing related) for this project has been carried out using a bespoke assessment tool, which assesses the project as having a positive, negative, or neutral effect on consumers in vulnerable situations. To help inform the assessment, this tool considers the categories of consumers identified in the Priority Services Register. This project has been assessed as having a neutral impact on customers in vulnerable situations; this is because it is a transmission project.

Success Criteria

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

- Study objectives met to time and cost.
- Project deliverables completed and approved by National Gas Transmission (see below)

The following deliverables are planned:

D1 - Literature review report of models, methodologies and innovation projects

D2 - First level model of hydrogen impacts on pipeline materials (HIPS)

D3 - Validation test programme and consortium plan

D4 - Project management, technical and closure reports

Project Partners and External Funding

Gas Network – National Gas Transmission PLC

Technical Lead – Ultima Forma Ltd, with sub-contract to University of Oxford and Queen Mary University of London

Potential for New Learning

The project will develop a science-led model to help understand the performance of pipeline steels in hydrogen service over the long required lifetimes of pipelines. This approach will support the safety case for hydrogen transmission pipelines and will inform decisions related to the assessment of defects/damage to pipelines. The model will also provide critical inputs to the business case for development of hydrogen barrier systems as a mitigation strategy for hydrogen embrittlement. These results might be informative to other transmission networks globally as well as domestic and international GDNs.

Learnings will be disseminated via final project reports which will be made available as pe the NIA publication requirements.

Scale of Project

This project phase is desktop-based and focussed on development of the model and demonstration of use. Future phases will validate the model and enable quantitative data to be generated. The mechanisms involved in hydrogen permeation and embrittlement are complex and multi-faceted, as a result, in order for the model to be usable a minimum level of development and testing is required. If the project scope was reduced, the resultant model would be severely limited in value to National Gas Transmission, likely necessitating additional research, with associated costs, to fill the capability and knowledge gaps.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL3 Proof of Concept

Geographical Area

England, United Kingdom

Revenue Allowed for the RIIO Settlement

None – Hydrogen network focused project

Indicative Total NIA Project Expenditure

External – £ 395,600.00

Internal – £ 12,866.67

Admin – £ 110,000.00

Total – £ 527,466.67

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 National Transmission System (NTS) will need to ensure hydrogen can be supplied to consumers reliably and safely. This project will support the update of applicable policies and standards for hydrogen transmission, for example, the assessment of third-party damage to our pipelines.

The model created will also be used to inform the business case surrounding the use of barrier systems to reduce hydrogen embrittlement. Provided there is a valid business case, these barrier systems could enable an accelerated transition to hydrogen by reducing the time and costs associated with replacing pipeline assets.

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)

N/A

Please provide a calculation of the expected benefits the Solution

The model created in the project is expected to give the following benefits:

- Improved understanding of the long-term performance of steel pipelines in high-pressure hydrogen
- Quantify the benefits of hydrogen barrier systems in terms of pipeline lifetime extension
- Quantification of the permeation of hydrogen through pipeline materials
- A flexible model potentially able to feed into future continuous monitoring systems (integrity management via virtual data twins)

The overall benefit will be the ability to transport hydrogen in lieu of natural gas thus contributing to greenhouse gas emission reductions. Repurposing existing assets will represent the lowest cost and quickest solution to the end-user.

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

The intention is that the model created will be applicable to all pipelines on the National Transmission System. With potential updates to account for lower pressure tiers and/or additional steel grades, the model could also be used by GDNs or other TSOs operating steel pipelines in hydrogen or hydrogen-nature gas blends.

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

The cost of roll-out across the entire NTS is dependent on the required level of input data, this will be determined during the project. Once the required data has been collated the application of the model is expected to be low cost.

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 model created in this project will be applicable to pipeline operators and will inform the strategy for pipeline/asset operation once transitioned to hydrogen or hydrogen-natural gas blends.

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

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 programme. Whilst there might be models and/or relationships available for aspects of the created model, there are no models publicly available which cover all aspects of hydrogen permeation and embrittlement in pipeline steels.

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

There are currently no published models that are specific to hydrogen embrittlement off pipeline steels from gaseous hydrogen. Models/relationships exist to describe parts of the phenomenon but not the entirety embrittlement process. This will, therefore, be the first model of its kind. Furthermore, no sophisticated models quantifying the effectiveness of barrier systems for hydrogen embrittlement reduction are publicly available, making this approach novel.

Relevant Foreground IPR

This project and the resultant outcomes/deliverables will conform to the default treatment of IPR as set out under the agreed NIA Governance (where the default requirements address two types of IPR: Background IPR and Foreground IPR).

This project is expected to generate foreground IP in terms of a model capable of assessing the long-term performance of pipeline steels in high-pressure gaseous hydrogen environments. The management of the IP related to this model will be agreed in collaboration with the project supplier and subcontractors within the framework of the NIA contract.

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 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@nationalgas.com. Further data can be shared upon request through the innovation mailbox. Each request will be assessed by the National Gas Transmission 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

The model being created is specific to hydrogen and hydrogen-natural gas blends and is not applicable to the existing petrol gas only system and therefore does not represent a business-as-usual activity.

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

Whilst there is confidence that a model can be developed, this is a novel approach and as such carries risk. Furthermore, the development of this model is a low TRL level activity, it is therefore relevant for NIA funding. The use of NIA funding allows the benefits of the research to be shared amongst the UK gas networks.

This project has been approved by a senior member of staff

☑ Yes