national gas transmission

SIF Project Registration

Date of Submission

Mar 2022

Project Reference Number

10022648

Project Registration

Project Title

Hydrogen Barrier Coatings for Gas Network Assets

Project Reference Number

10022648

Project Licensee(s)

National Gas Transmission PLC

Project Start

March 2022

Project Duration

2 Months

Nominated Project Contact(s)

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Project Budget

£74,706.00

Project Summary

The aim of this project is to explore technologies to enable the existing gas transmission network to supply hydrogen as a low carbon energy source to heat customers with the most rapid deployment. The project directly addresses the need to work with partners on how deployment of low carbon heating solutions can be better coordinated to minimise gas network constraints at lowest economic cost.

The National Transmission System (NTS) in the UK supplies gas to distribution networks whom in turn supply gas to 23 million homes in the UK as their primary heat energy source. The network varies in age and material composition which leads to variation in its capability with Hydrogen. Some pipeline materials may be prone to hydrogen embrittlement reducing their lifetime, hydrogen barrier coatings applied to the internal surface of the pipelines between the gas flow and the metallic pipeline structure could prevent the need to replace the assets. In enabling more of the existing NTS network to be utilised for transporting hydrogen, a fuel with a third the energy content of methane, we are providing resilience and storage, rather than relying on transient production.

National Grid are working with BEIS and the other gas networks to determine the opportunity for using the gas network for heat in the UK, a decision that plans to be made in 2026. In order to maintain robust supply of hydrogen the high pressure transmission network will need to be available as both storage and a connection between green production sources which will be more variable due to their reliance on weather. This would allow reliable accesses to low carbon fuels for domestic heating, allowing conversion of gas boilers to be an economic option while retaining their existing heating systems.

This two-month £76k project led by the National Grid will provide evidence to support an application for a follow on Alpha phase project to design, develop, demonstrate and test the proposed technology solution.

Our project partners are experts in the field of pipelines (National Grid), metallic coatings (Ultima Forma Ltd) and composites (Warwick Manufacturing Group) which will give us the best understanding of the cost and benefits associated to protective coatings compared to replacement.

This technology has benefits for all hydrogen storage vessels and could be applied to several applications above and beyond onshore

pipeline application.

VIDEO - https://www.youtube.com/watch?v=Jj0ko_KmlEs&list=PLrMOhOrmeR6ktSag0RbT7zPNVn0p1P2f6&index=34

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Problem Being Solved

The hydrogen strategy released by the UK government in August 2021 stated that in order to support the net zero targets of 2050, by 2030 there is an ambition to produce 5GWs of low carbon hydrogen. This ambition to provide low carbon hydrogen as a part of a suite of net zero energy sources provides clear guidance to the UK gas networks to progress our hydrogen transportation capability. The national transmission system (NTS) provides a supply of gas to 40 power stations, large industrial users and gas distribution networks from natural gas terminals situated on the coast. The NTS provides a resilient supply of natural gas today and aims to provide the same capability for hydrogen, especially in light of the variability in green hydrogen production.

In the transition to Net Zero by 2050 we are looking at utilising the current high pressure NTS to provide hydrogen as a net zero alternative to natural gas to our consumers. The first step of this will be to provide a hydrogen backbone (Project Union) that links industrial clusters to terminals improving the resilience of hydrogen supply. The Project Union looks to repurpose around 25% of the current gas transmission pipelines approx. 2000km, reducing the cost to consumers of the transition. The hydrogen backbone could provide hydrogen to heat consumers through projects such as East Coat Hydrogen and National grid Gas is working alongside the other gas networks and BEIS through the Hydrogen Grid Research & Development (HGR&D) programme to determine the opportunity for heat.

Under the HGR&D programme, the Network Safety and Impacts Board (NSIB) are looking at the possible safety challenges and developing a plan to enable BEIS to conclude the plan for Heat by 2026. A key challenge to the repurposing of the NTS pipelines and assets is the impact of hydrogen on the metallic materials, mainly through the process of hydrogen embrittlement. The use of coatings on current assets could be a cost effective solution for preventing hydrogen embrittlement instead of replacement of the assets with hydrogen resistant materials. We must understand this opportunity now to enable us to develop the solutions and provide guidance to BEIS by 2026.

Heat consumers in the UK will benefit from this work through the elimination of the cost in transferring their heat supply to another medium and through reduction in billed cost for maintenance and replacement of gas assets.

Project Approaches And Desired Outcomes

The Big Idea

The Gas Transmission Network is a national asset that consists of buried pipes and values below ground and auxiliary and service units above ground. All of these components have been designed for natural gas but are potentially vulnerable to failure from hydrogen embrittlement. The big idea is to explore the possibility of re-purposing this asset to distribute hydrogen, focusing on the most vulnerable components first but considering the network as a whole.

This approach directly addresses the scope of this call by providing a resilient supply of hydrogen for heating to a wide range of industries and domestic users from a broad spectrum of green and blue hydrogen sources, sited around the UK.

To protect a material from hydrogen gas requires a permeation barrier that is continuous, without joins or flaws. Suitable materials are generally those with higher density, hence metals are about a billion times less permeable to hydrogen than polymers.

Our idea is to apply a thin (less than 1mm) metallic coating to the inside surface of the existing transmission network components and equipment, using a metal that is not susceptible to hydrogen embrittlement. Our proposal is to evaluate the possible ways that this could be achieved and the network components to which it could be applied. The project will explore the potential materials and methods that could be used to apply metallic permeability barrier as a continuous layer. The potential use cases in the gas transmission industry will be identified and prioritise those that could provide rapid impact to the network. Coupon tests will be conducted on the typical materials used in network components to identify any issues with chemical or physical incompatibility and identify potential scalable production methods. The project will include the possibility of new components that would allow wider distribution of hydrogen, for example, using composite pipes. The project will include a cost analysis to evaluate the potential benefit of different technologies and impact on end users.

Ultima Forma Ltd is an established electroforming manufacturer, working on several funded projects related to hydrogen containment for pressurized gaseous hydrogen and cryogenic liquid hydrogen. Ultima Forma also produces components for critical industries and is ISO 9001 compliant. Patents have been filed for gas permeation barrier for hydrogen gas tanks for ground transport applications and has experience of applying metals to a wide range of substrate materials, including steels.

Innovation Justification

Electrodeposition of metals is not a new technology and applications for this additive manufacturing process do exist in industry for example GKN's use in aircraft wing leading edges. Ultima Forma has unique process controls using near ambient temperature electrolyte to create impermeable hydrogen barriers. Ultima Forma filed a patent application for electroformed gas permeability barriers in Feb 21. Ultima Forma also has a multi-layering metal process for creating functionally graded materials where materials yield strength and modulus can be independently varied should this be required to bring additional performance to gas networks.

Through conversations with National Grid, the National Composites Centre, the EIC (Energy Innovation Centre) and presentations to gas networks innovation groups, no-one has flagged to the consortium that this approach of deposition of metal barrier coatings inside existing pipes, or within new pipes has been tried before. There is genuine interest from the national and regional gas networks in the potential for adding a thin hydrogen permeability barrier to existing infrastructure. This feasibility study would deliver sample parts and a study to provide the evidence for decision makers to back a more extensive trial.

This project will build on knowledge gained through current APC funded project HYSTOR, a composite hydrogen storage project, and a DFT funded cryo hydrogen feasibility study, both led by Ultima Forma. Ultima Forma is working on hydrogen permeability concepts with Reaction Engines, Stratospheric Platforms and the NCC.

Example useful transferable findings include;

- 30 micron thickness samples tested at TWI under 200bar showed no permeability on their test equipment.
- Research conducted by Ultima Forma's CTO, Prof Andy Bushby identifies copper as a dense, cost effective permeability barrier that is resistent to hydrogen embrittlement
- Electroformed copper strains within gas networks at operating pressures will be acceptable
- Deposition onto composites and steels are possible with trials having been made
- Cost effective conductive coatings have been researched and trialled
- Hydrogen barrier can continuously follow a non even surface so long as continuous conductive surface available

The electroforming process is one of ionic deposition onto parts submerged within electrolyte baths. The opportunity to take this

manufacturing process and incorporate it into a mobile factory within a pipe is completely novel and offers the potential of significant cost and environmental saving to upgrade rather than replace existing steel networks.

Project Plans And Milestones

Project Plan And Milestones

The Discovery Phase will consider the feasibility of applying a variety of hydrogen barrier coatings to the inside of high pressure gas network components in 5 inter-related work packages:

1. WP1 will consider potential coating technologies and materials selection for hydrogen permeation barriers. The WP will be led by Ultima Forma (UFL) and draw on published literature and knowledge within the consortium. The output will be a summary of potential materials and application technologies (D1) that will feed information to WP5.
2. WP2 will be led by National Grid (NG) and consider the possible use cases within the gas distribution industry, including existing and new pipe networks as well as other potential applications. The output will a summary of potential use cases (D2) and used to inform WP3.
3. WP3 will be led by UFL and consider the manufacturing steps necessary to apply hydrogen permeation barrier coatings to the steels used in the current gas industry. NG will provide coupons of representative steels to UFL to demonstrate the necessary process steps, including cleaning, coating chemistry requirements and deposition rates. Coupons will be assessed for continuity of the coating and adhesion. The results of these test will be used to propose the requirements for a remotely operated, automated process that could be used to deposit metal inside an existing pipeline components (D3). The WP will compare the metallic application technologies such as electroforming and liquid metal spraying with non-metallic application technologies and their capability in a live network environment.
4. WP4 will investigate the potential for new pipeline materials as an alternative to coatings and will be led by Warwick Manufacturing Group (WMG). Coatings will be considered for Type 3 pressure vessels using the technologies investigated in previous WPs and reported in (D4).
5. The outputs of WP 1-4 will inform the cost analysis of the various solutions to assess their feasibility and potential impact for low carbon heating (D5).

The project will be managed by NG with input to the weekly meetings and the final report (MS1) from UFL and WMG.

Alpha phase - the processes and use cases selected in the discovery phase will be applied and tested in above ground static components such as filters and scrubbers.

Beta phase - these findings will be translated to below ground components using automated processes.

Key Risk - Timeframe (mitigation: start building relationships before project start)

Further risks can be seen in the risk register

Route To Market

The discovery phase will inform us of the best options for protecting our National Transmission System (NTS) assets from the effects of Hydrogen. It is likely that different use cases on the NTS will benefit from different coatings, materials and systems and therefore we may have multiple options to progress into Alpha and Beta. Therefore in the Alpha and Beta phase it is likely that the consortium will grow to incorporate partners whom are experts in pipeline assessment/repair, robotics, alternative coatings and alternative materials.

It is believed that electroforming could provide a cost effective solution for certain NTS assets and scenarios, in the case that discovery proves this hypothesis. Ultima Forma's core electroforming technology would be further developed in line with the chosen application method for the NTS through Alpha and Beta. A collaboration with an pipeline assessment and repair partner would be required during the Beta phase to enable the development of the applicator. Ultima Forma's business model would most likely be to license the technology and to provide materials and support services to the applicator owner. Non-exclusive licenses would be sought allowing the freedom to exploit the technology beyond the UK.

Warwick Manufacturing Group through the project will be developing their expertise in composite pipeline applications which can be exploited through future projects in the UK and across the globe. It is possible that with new connections to the gas network, for instance for transport applications, new pipeline materials and coatings could provide a longer lasting solution than our current pipeline materials. If this hypothesis is proven correct, in Alpha and Beta we would look to include composite manufacturing partners to further demonstrate the opportunity.

The Beta phase of this project will include pipeline trials to significantly de-risk future activity. Roll-out of the technologies developed would require a major project to be led by the National Grid, supported by the project partners and other UK suppliers. National Grid's plan for developing a hydrogen backbone in the UK looks to start PreFEED in 2022 and Construction by 2025. The PreFEED work will provide us insight into the selected pipelines to enable us to focus our first application. The planned approach will need to be decided for FEED in 2023 and therefore the feasibility and development of these technologies needs to begin now to allow

demonstration in 2023.

Costs

Total Project Costs

74706

SIF Funding

74706

This project has been approved by a senior member of staff

☑ Yes