SIF Alpha Project Registration

Date of Submission

Oct 2022

Project Reference Number

10037659

Project Registration

Project Title

Velocity Design with Hydrogen – Alpha

Project Reference Number

10037659

Project Licensee(s)

SGN

Project Start

Aug 2022

Project Duration

6 Months

Nominated Project Contact(s)

stuart.sherlock@sgn.co.uk

Project Budget

£513,689.00

Funding Mechanism

SIF Alpha - Round 1

SIF Funding

£462,320.00

Strategy Theme

Net zero and the energy system transition

Challenge Area

Heat

Project Summary

This project supports Innovation Challenge 4: Heat by allowing the gas distribution networks to safely minimize the costs of re-purposing existing transmission and distribution assets to carry hydrogen-natural gas blends and 100% hydrogen.

Gas network designers will be challenged to safely repurpose networks to low carbon heating gas with minimum costs while maintaining energy delivery. The energy delivered by hydrogen is one third of that delivered by natural gas per unit so, under many of the likely demand scenarios in the zero-carbon future, the flow rate of gas in re-purposed gas networks will need to increase.

Gas network designers need to know the safe design velocity limits so they can reduce to a minimum any need to increase pipe sizes to accommodate zero-carbon heating.

The network innovation involved is to design a suitably rigorous test campaign (to be executed in the Beta Phase) that will produce a new safe design velocity limit for hydrogen-natural gas blends and 100% hydrogen in the UK gas networks.

The Discovery phase concluded:

1. Hydrogen could enhance erosion rates due to a synergistic hydrogen embrittlement/erosion mechanism. This mechanism could be a credible risk to network integrity.
2. Particle (debris) transportation would be significantly different in hydrogen with a possible increased likelihood of pipe wall

erosion.
3. Initial investigation found a range of erosion rates expected, depending on the gas pressure and composition.
4. SGN experiences the presence of debris across all pressure tiers and has a significant impact in medium and low-pressure systems.
5. A cost benefit analysis of any velocity limit(s) is required.
6. Noise and vibration modelling has indicated there are differences in hydrogen and natural gas.

The Discovery phase recommendations:

1. The potential for enhanced hydrogen uptake and erosion rates are further investigated to determine the risk to network assets.
2. If synergy between hydrogen embrittlement and erosion is proven, then then current erosion models and velocity limits must be revised.
3. The erosion models require validation in hydrogen and hydrogen blends. Theoretical modelling must be included to ensure a representative full-scale test programme and design of the required facilities.
4. Further investigation is required to understand particle transportation and how this might affect erosion. Validation of existing particle transportation models in hydrogen is required.
5. Initial modelling has suggested differences in hydrogen and natural gas in noise and vibration risk. However, the models have not been specifically validated for hydrogen.

The Alpha Phase project should include:

1. Document the GB Gas network experience of network debris.
2. Industry engagement to obtain "buy-in" and direction towards a new industry design standard.
3. Design and cost the full-scale test facility and campaigns to be delivered in the potential Beta phase.
4. Cost-benefit modelling to balance design gas velocity increases against network reinforcement costs.

Addressing the Heat Challenge requires a transition to "business as usual" where UK gas network operators, professional bodies (IGEM) and designers to accept the new design limits as scientifically valid and are assured that the design limits when applied will maintain safety, reliability and affordability of low carbon heating.

Partners:

- SGN (Lead) is one of the four gas distribution network operators in the UK with 74,000 km of high, medium and low pressure pipes supplying gas to 5.9 million consumers.
- DNV is a leading provider of material testing services and operates lab and full-scale gas network test facilities as well as hydraulic modelling software and gas distribution domain expertise.

All UK gas distribution and transmission network designers will use this innovation; experience and data from all UK gas network operators and obtain industry "buy-in" of the outcomes is part of the Alpha scope.

Project Description

The UK natural gas pipe networks have the potential to flow blended hydrogen and to be re-purposed to flow 100% hydrogen.

The hydrogen networks can contribute to the Challenge 4: Heat, through the transformation to meet national 2030 and 2050 emissions targets.

To demonstrate how the current gas networks can be intelligently and efficiently transition to provide low carbon heating, the gas velocity constraint(s) for hydrogen, applied at the design stage, need to be identified.

The constraint(s) determined will impact directly onto the levels of capital investment required in the transition of the system to accommodate blended and 100% hydrogen.
Hydrogen delivers approximately one third of the energy per unit compared to natural gas so, depending on the evolving demand of heating gas through the transition to low carbon heating, it is likely that re-purposing existing gas networks may require increased design gas velocities if pipe sizes are not to be increased.

Increasing the design velocity safely will minimise the costs of re-purposing the networks.
Current design velocity limits are long standing industry practice; the innovation lies in establishing if these limits are appropriate for low carbon heating gas supply and the entrainment behaviours of debris in hydrogen and gas blends is unknown.

Network designers apply a standard industry practice that limits the design velocity of the gas under peak flow conditions to limit erosion from entrained debris and other integrity risks due to excessive noise or vibration.

Preceding Projects

Nominated Contact Email Address(es)

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Project Approaches And Desired Outcomes

Innovation Justification

The problem to be solved is allowing network gas designers the freedom to safely maximise the flow of low-carbon heating gas in existing networks while minimising the need to increase pipe sizes throughout the energy transition.

The project is innovative because there has been no suitably rigorous physical testing to quantify the entrainment of typical debris present in UK Gas Networks by hydrogen-natural gas blends and 100% hydrogen and to establish design limits so that asset integrity, and environmental, risk is not increased.

The energy sector is challenged to deliver the transition to low and zero carbon heating while keeping costs to consumers to a minimum and maintaining reliability and safety. This project will provide some of the assurance that designers need to deliver these goals.

Our solution will ultimately deliver a valid trusted design velocity limit, for low, and zero, carbon heating gas, that designers can rely on in ensuring the gas distribution networks remain safe and reliable throughout the transition.

Literature surveys reveal that the work on this subject to date has been theoretical using digital hydraulic models, (ENA are currently running a hydraulic modelling project related to this topic - see details here: https://smarter.energynetworks.org/projects/nia_ngn_302/) which can be used as additional input to this project. We have been unable to find any practical physical test work done that can be relied on to establish safe design gas velocity limits using representative conditions, materials and debris in the UK gas distribution networks.

While hydraulic modelling offers some indication of the entrainment capacity and effects of low carbon heating gas, a suitably rigorous physical testing campaign is required to fully evaluate actual behaviours and effects in representative conditions and existing network components.

If the project is not done, UK gas network operators are at risk of:

1. Unnecessary spending on increasing network pipe sizes to maintain the current design velocity limits while delivering increased unit rates of low and zero-carbon heating gas.
2. Increased damage to pipework and components from erosion and vibration or increased environmental impact from noise if the design velocity limits are set too high.

UK gas network operators are required to maintain safe and reliable networks and deliver gas uninterrupted to consumers through-out the energy transition.

Increasing the diameter of pipe in the network costs approximately £250,000.00/kilometre (< 8 inch pipe only); with 290,000 km of gas transmission and distribution pipe in the UK, there is an obvious benefit in minimising any pipe replacement needed to meet gas velocity design limits while distributing increased gas volumes throughout the energy transition.

The UK gas distribution industry has well over 100 years' experience in the safe design of networks and has developed and proven design standards based on this experience. The energy transition, with the change to low and zero-carbon heating gas, presents the network designers with heating gases of which there is no industry experience or practical knowledge of the impact of these gases on:

- Entraining typical debris present in the networks (much of it as a legacy from town gas supply)
- Quantifying the potential for erosion damage and possible interaction with other damage mechanisms (hydrogen embrittlement) to be considered in establishing velocity limits.
- The effects of noise or vibration caused by turbulent low, and zero, carbon gas flow on existing network components
- The velocity and flow regimes in which entrained debris starts to cause unacceptable damage to gas network components.

This project will enable new design standards to be accepted by the industry and become new "business as usual".

Benefits

The project, once the Beta phase is delivered, will deliver net benefits to consumers by:

1. Giving network maximum flexibility in re-purposing the networks to zero-carbon heating
2. Minimising network reinforcement costs
3. Ensure that the design velocity limits for hydrogen and hydrogen-natural gas blends are safe and there is no reduction in integrity

standards or increased risk.

A simple financial business case (initially focussing on the on the low-pressure network only) is attached. This shows that with the current broad assumptions about the level of network reinforcement (to increase the pipe diameter and reduce velocity) could cost the consumer between £550 million and £2.75 billion throughout the energy transition if the current velocity limits are maintained. Further costs can be anticipated in reinforcing higher pressure tiers and pressure reducing facilities.

A detailed business case will be developed in the Alpha phase. To do this, a representative network model(s) will be run against likely hydrogen and hydrogen-natural gas blend demand scenarios to quantify the length of network subject to reinforcement. The reduced reinforcement length delivered by incremental gas design velocity increase up to a safe limit can then be quantified.

The business case relies on minimising the cost of replacing gas distribution pipes to maintain velocity design limits under peak flow conditions. Finding this safe limit will offer designers maximum flexibility in repurposing the networks and minimise network reinforcement (pipe size increase) costs required to keep any increased gas flow rates within safe velocity limits.

The Alpha phase will:

1. Gather data and experience from industry including:

- All UK Gas distribution Network Operators.
- The gas National Transmission System (NTS) operator (National Grid Gas).
- The industry body IGEM.
- Relevant regulatory and advisory bodies such as the Network Safety & Impacts Board.

2. Cost and scope a test campaign that is accepted by the industry as valid for the Beta results to be used to amend engineering practice and standards.

3. Build a detailed business case that clearly quantifies the length of UK gas pipe that would be subject to reinforcement at the current limits and demonstrate the savings in reinforcement costs delivered by new, safe, design velocity limits.

The benefits of the project are in several areas

1. To consumers:

- Safe and resilient supply of heating gas is maintained throughout the energy transition.
- The costs of re-purposing the networks will be kept at a minimum.2. Economic benefits:
- Supply of heating gas to UK consumers will be maintained throughout the transition to zero-carbon heating by making maximum use of the existing gas network assets and components.

3. Impact on Government priorities:

- Government can be assured that the conversion and transition priorities set can be suitably structured, and the industry can be assured that the priorities can be met within suitable constraints.

4. Environmental impacts, either positive or negative:

- The environmental impact and risk profile of gas distribution operations in the UK will be improved by better understanding of the implications of re-purposing existing networks.

5. Expected regional or wider energy supply resilience benefits:

- Spreading the knowledge of the outcomes to the industry as "business-as-usual" with incorporation into design standards.
- Maintained or improved integrity risk.
- Knowledge and validation of digital models used in developing network strategy and design.

6. Impacts on consumers of the whole energy system, both individuals and collectively, including those with any vulnerabilities or experiencing fuel poverty

- The resilience of the whole system will be maintained and improved through-out the energy transition.

Risks And Issues

The current risk identified are largely around a suitably defined scope and boundaries of the investigative work required to be completed in the Alpha phase.

Specific scope risk items are:

1. Obtaining suitable engagement by stakeholders and provision of data and debris samples within the Alpha phase delivery schedule.
2. A clear limit of the scope of study to exclude the possible impact on Service Connections and consumer gas meters.
3. Identification of other integrity impacts on existing network materials of construction and integrity of hydrogen and hydrogen gas blends beyond the expected mechanisms of erosion, embrittlement, noise, and vibration.

Risk associated with cost and schedule:

1. Sufficient information to design and sufficiently cost the Beta phase test campaigns within the Alpha schedule constraints
2. Obtaining timely input from other parties such as academic institutions, regulatory & advisory bodies and equipment suppliers that may be identified after project start, as the project progresses.

New risks or issues will be identified early by:

1. Regular stakeholder engagements so that buy-in of the projects scope and outcomes is maintained.
2. Should a need to evolve the scope be identified (that could impact costs, schedule, or outcomes) the project management team will establish the potential impacts and escalate to the Project Monitor and UKRI for a management-of-change discussion.

Monitoring and mitigating risks and issues will be done by:

1. A clear and detailed Alpha phase scope defined and presented to stakeholders at the start of the project; any changes requested will be quickly acted on.
2. Regular project progress meetings will be held with all partners to review progress, identify new developments, and assess their impact on costs, schedule or outcomes.
3. Weekly measurement of time & costs versus budget will be maintained throughout with a proa-active approach to identifying possible missed milestones and schedule limits.

Mitigations:

1. The Discovery phase outcomes have guided the Alpha phase scope; some contingency has been included in schedule and costs to allow for some evolution of the scope if required by stakeholders.
2. Good project management practice and discipline will be maintained to ensure progress against the agreed scope is maintained to completion.

Given that there is an element of research in this project, we assume there maybe some evolution of the scope and/or the boundaries of the project as we proceed; we have made some allowance for this in the planning of the project. We do not anticipate significant or "show-stopper" changes to arise and the project outcomes will include the results of the research.

We believe the stake-holder engagement risks (receiving timely and pertinent input) will be managed by:

1. Early engagement of stakeholders (prior to project kick-off)
2. Active management of the stake-holder engagement plan
3. Contingency provision in the schedule and project costs for "sub-contractor" costs should this be required to cover inputs (debris samples, data sourcing & transfer, time, academic institution costs) from stakeholders

Awareness of risks or issues with stakeholders will be covered under the stakeholder engagement plan.

While project partners (and stakeholders and sub-contractors) will retain and utilise "background IP" (the skills knowledge, experience and data required to deliver the project, this may involve usage of Partner's licenced software) as necessary to deliver the project, we anticipate that the "Foreground IP" developed during the project will be shared freely with the industry.

No Commercial Product Development is anticipated.

No sharing of background IP with sub-contractors is anticipated to be necessary; all Foreground IP will be freely shared amongst partners, stakeholders, sub-contractors, and the wider industry.

Project Plans And Milestones

Project Plans And Milestones

Please see attached appendix containing a detailed description of the project plan.

The key milestones will consist of:

1. A conceptual design of the test facilities
2. A detailed test plan
3. Completion of laboratory testing (Monthly milestones against actual progress)
4. Network & stakeholder engagement (Monthly milestones against actual progress)
5. Completion of the cost benefit model (Monthly milestones against actual progress)

Regulatory Barriers (Not scored)

We expect no impact on, or requirement for compliance to, regulatory barriers with this project.

The Foreground IP developed during the project will be shared with the UK industry to be incorporated in accepted engineering design standards and practice.

The test campaigns are expected to be completed with sufficient rigour that the results will be challenged and accepted by the industry body (IGEM) and gas network engineering professionals to be incorporated in engineering practice design standards.

Business As Usual

Stakeholders will be invited to participate as observers and contributors of information, experience and data (and possibly debris samples) at the start of the Alpha phase and the progress and outcomes will be shared as part of the stakeholder engagement plan. This will ensure there is broad "buy-in" of the Alpha phase scope, progress and outcomes, as well acceptance that the completed test campaign, planned for the Beta Phase, is sufficiently rigorous and valid to be incorporated in accepted practices and design standards.

Appropriate representation (consisting of distribution network maintenance and designers) will be requested from each UK Distribution network and the National Transmission System operator) will be requested to:

1. Provide data, information and experience on the presence and nature of debris in their networks, and
2. Accept the intended Alpha and Beta scopes will be sufficiently rigorous and valid for the outcomes to be accepted into design codes and standards.

Additional representation will be requested from the industry professional body (IGEM) as well as interested academic institutions and equipment suppliers where they have an interest in the scope and outcome of the project and can add to the general acceptance and "buy-in" of the outcomes.

On completion of the project, the industry professional body (IGEM) and the Network operators will be responsible for updating existing design standards and codes of practice to reflect the recommended gas design velocity limits.

Other licensees will be engaged during the project delivery and will be aware and accept the project outcomes.

Beyond the stakeholder engagement plan built into the project delivery, events to present and discuss of the project outcomes will be planned in conjunction with IGEM.

Once the final project recommendations have been challenged and reviewed by Licensees and industry professionals and bodies, the Project partners will support IGEM and partners as required to draft amendments to design standards and codes.

We anticipate that Licensees and IGEM will, having bought into the project process and outcomes, will quickly incorporate the outcomes into their codes and standards as a matter of due care and diligence in the application of appropriate practices in the design and operation of their networks.

While increased design velocity limits will offer designers more flexibility as heating gas is transitioned to zero-carbon with direct savings in ensuring no unnecessary pipe replacement, this is balanced with their responsibility to apply due management of asset integrity risk in their operation of the networks. If the outcomes of this project offer a suitably rigorous and valid derivation of suitable design velocity limits, operators will have every incentive to quickly build these limits into their design codes.

Commercials

Commercialisation

The project outcomes will not be commercialised. The ultimate outcomes of the project and any learnings will be shared with, and must be accepted by, the industry as safe and valid for incorporation into standard engineering and design standards and practices. Therefore, the project process and results must be open to challenge and acceptance by stakeholders and the wider industry.

The project plan for both the Alpha and Beta phases will include stake-holder engagement plans to ensure that input of experience and data, and acceptance of the results across the industry, is ensured.

No investment beyond the costs of the Alpha and Beta phase projects is needed.

Intellectual Property Rights (Not scored)

All "Foreground IP" that is developed during the project, which could include:

- The input data, samples and experience of UK gas network designers.
- The scope, methodology and costs of the test campaigns.
the results of the test campaigns and their acceptance by the industry as valid.
- Will be shared royalty-free with Project Partners and the wider industry to encourage knowledge sharing and acceptance by the industry.

No Commercial Product is expected to be developed in this project.

Background IP belonging to Partners will be retained by them but will be used to deliver the project.

Background IP will include:

- Domain expertise in the design and operation of gas networks
- Expertise in the design of lab and full scale materials testing campaigns
- Proprietary hydraulic modelling and network simulation software and expertise in their use.

Costs and Value for Money

The Alpha phase of the project will cost £513,689 in total, of which the project team will contribute 10% of the project costs. We have requested funding for £462,320.

The money being spent will deliver new accepted industry knowledge and safe practice so there is no way of commercialising or otherwise generating a return on the money spent. Hence our application for SIF funding of the project.

The bulk of the outputs will be delivered by DNV (reflected in the costs breakdown) with engagement support from other licensees and industry bodies.

No sub-contractor costs are included at this Alpha phase as none are anticipated to deliver this scope. A contingency "Other Costs" is suggested in the Project Finance to make provision for costs that may be incurred by academic institutions or industry and advisory bodies that may need to come on board during the Alpha phase.

This project will add value over partner's business-as-usual activities by contributing improved design and engineering practices to deliver a safe and cost-efficient heat energy transition.

The costs outlined are built using competitive industry rates.

The project team and resources have been broadened from the Discovery phase to ensure wider engagement by the industry while the core leadership and delivery of the project is retained by SGN and DNV.

Supporting Documents

Documents Uploaded Where Applicable

Yes

Documents:

Application Submission - Velocity Design With Hydrogen - Alpha.pdf

SIF Alpha Project Registration 2022-10-03 6_04

10037659 SIF Alpha Close Down Report 2023-03-31 10_00

SIF Alpha Project Registration 2024-02-20 10_46

This project has been approved by a senior member of staff

☑ Yes