Pre-normative Research on Safety of Gas Networks with Hydrogen Blends

Project overview

Acknowledgment

The activity has received funding from the GNI Gas Innovation Advisory Group Fund project number 2021-029

Summary

This document summarises the main activities and outcomes of the Gas Innovation Fund project “Pre-normative Research on Safety of Gas Networks with Hydrogen Blends” undertaken by Ulster University. The scoping project began in August 2022 with the aim of developing a costed collaborative programme of pre-normative research to inform safety guidance for hydrogen-natural gas blends. To meet this aim, a series of workshops were undertaken to prioritise research needs. As a direct result of the gas innovation funded activity, a collaborative proposal targeting buried leaks and flame stability of hydrogen-methane blends was submitted to, and successfully funded by, the Centre for Advanced Sustainable Energy (CASE) in Northern Ireland (NI). CASE is funded through the Department for the Economy NI’s Green Innovation Challenge Fund.

Table of contents

1. Project introduction

Hydrogen is widely seen as one potential route to decarbonise the gas network on the Island of Ireland. In the Republic of Ireland, the National Hydrogen Strategy[1] sets out the role that hydrogen will play in supporting a net-zero energy system in Ireland by 2050. Similarly in Northern Ireland "The Pathway to Net-Zero"[2] outlines how the gas network will transition from natural gas to renewable alternatives such as hydrogen by 2050 to support Northern Ireland's emission targets.

It is well recognised that blending of hydrogen and natural gas in the network is an important transitional step in the move to 100% hydrogen. The properties of natural gas and hydrogen differ, and it is important to understand the implications of these differences from a safety perspective. Inherently safer design and incident handling requires an understanding of the underlying physical phenomena, hazards, and associated risks for hydrogen blends in pipelines. Unscheduled leaks, thermal and pressure effects of any resultant fires and explosions will define hazard distances for hydrogen blends and, thus, inform the revision of safety zones to account for use of hydrogen.

Decarbonising of the gas network by hydrogen presents diverse safety engineering challenges. A range of research gaps related to the safety of blends exist, but these can be resolved through collaborative research. This Gas Innovation Fund project enabled the first steps to be taken to identify and prioritise research gaps in the safety of blends to develop a collaborative programme of pre-normative research. The activity was led by the Hydrogen Safety Engineering and Research Centre (HySAFER) at Ulster University (UU), supported by Gas Networks Ireland (GNI). Wider input was captured through the involvement of stakeholders from industry, academia, and the responder community.

It should be noted that names of individuals who participated in expert workshops have not been included in this summary report.

2. Project objectives

The aim of the project was to develop a costed test campaign to address safety considerations of blends. The final plan of pre-normative research should include theoretical, numerical, and experimental studies.

Specific objectives of the project included:

- Analysis of research gaps informed by expert stakeholders.
- Review of existing leak management approaches and incident response guidance for natural gas.
- Establishment of a consortium with appropriate experimental and numerical expertise.
- Identification of appropriate funding mechanisms.

[1] https://www.gov.ie/en/publication/624ab-national-hydrogen-strategy/
[2] https://phoenixenergyni.com/assets/general/Pathway-to-Net-Zero-July-2023.pdf

Whilst the Gas Innovation Fund project represented the initial stage of activities only, it is intended that as further funding sources are identified the impact of the activities will grow, ultimately leading to:

- Scientifically informed leak management guidance for hydrogen-natural gas blends.
- Improved emergency planning and preparedness relating to hydrogen blends in the gas network.
- Reduced risk of incidents and accidents relating to hydrogen blends.
- New knowledge, and experimental data relating to leaks, fires and explosions of hydrogen blends.
- Models and tools for the assessment of hazard distances from hydrogen blends.
- Environmental and social impacts.

3. Stakeholder engagement

The project activities were presented to industry groupings for feedback, including the Institution of Gas Engineers & Managers (IGEM) and the European Gas Research Group (GERG). Two workshops were held to capture and reflect the views of key stakeholders in the planning of research activities. A gap analysis workshop was held with experts from across Europe, representing the natural gas and hydrogen safety communities. A further workshop was held with natural gas emergency responders focused on current practices for leak management and emergency planning.

3.1 Gap analysis

A hybrid meeting was held in November 2022, bringing together experts from industry and academia. The participants included those with expertise in theoretical, numerical, and experimental studies, and operators who could benefit from a pre-normative programme of research. Specifically, representatives of the following organisations participated: Delgaz Grid, DNV, Engie, Gas Networks Ireland, GRTgaz, The European Gas Research Group (GERG), Health and Safety Executive UK, Nedgia, Nortegas, Storengy, TNO, Ulster University, and the University of South Eastern Norway.

The research gaps were split into three main categories. Only the prioritised topic(s) in each, as opposed to all gaps, are noted here.

1. **Unignited releases and dispersion**

   Validation data for free jets of unignited methane and H2NG blends is needed for benchmarking analytical and numerical models.[3]

[3] Studies have recently been undertaken by Sandia National Laboratories in the US to close this gap. Two papers were presented International Conference in Hydrogen Safety, Quebec, Canada, September 2023: "Dispersion of under-expanded hydrogen-methane blended jets through a circular orifice" Gopakumar Ramachandran, Ethan S. Hecht.

Dispersion behaviour of a blend from a buried leak and the tracking behaviour was identified as a key research gap. There is an absence of quantifiable data in the public domain. Work in this direction is needed.

2. **Thermal and pressure effects of fires**

   The impact of walls, barriers and surfaces on fires was deemed important. *It should be noted here, that subsequent work undertaken at UU identified flame stability as a topic in need of further investigation, particularly the difference in behaviour of hydrogen, methane, and hydrogen-methane blends.*

3. **Explosion prevention and mitigation**

   Delayed rather than immediate ignition of a turbulent jet and the subsequent pressure and thermal effects was deemed a priority. It was agreed that there is a need for an experimental and numerical program focused on the delayed ignition of jets to understand the implications on the resultant over-pressure for increasing hydrogen content.

   The potential for DDT (Deflagration-Detonation Transition) with hydrogen, particularly in a congested environment was identified as a concern and the situation is unclear for blends. However, it was noted that prioritising avoidance of a detonation rather than investigation in this direction would be key.

3.2 Responder workshop

An in-person workshop focused on "Emergency Response with Hydrogen Blends" was organised within the scope of the Innovation Fund project. The participants included representatives from across the Irish gas operators, including those with responsibility for emergency response and leak management. There was representation from ARUP, DNV, Gas Networks Ireland, Mutual Energy, and Phoenix Energy.

The workshop included a discussion on the specificities of hydrogen, current emergency response procedures in the distribution and transmission networks, and lessons learnt from HyDeploy[4]. Existing practice in leak management and response were discussed with a view to understanding how the introduction of hydrogen may impact current guidance and procedures. The purpose of the workshop was to raise awareness of and inform research activities on the safety of blends.

The workshop provided participants with an opportunity to raise any concerns around the introduction of hydrogen, and to help identify what elements of existing guidance may be impacted. The outcomes of the workshop included:

"Dispersion, ignition, and combustion characteristics of low-pressure hydrogen-methane blends", Gopakumar Ramachandran, Ethan S. Hecht.

[4] https://hydeploy.co.uk/

- Enhanced understanding of hydrogen properties amongst workshop attendees
- Dissemination of ongoing research activities on the safety of blends at UU and beyond
- Enhanced understanding at UU of the leak response procedures and management approaches taken for natural gas.

4. Prioritised research gaps

Whilst a number of gaps were identified across the areas of leaks, fires and explosions, two research gaps related to **hydrogen blends** in particular were highlighted through stakeholder engagement as requiring further investigation:

1. Behaviour of buried leaks
2. Delayed ignition of jets

Furthermore, research activities at UU identified a third area as needing investigation:

3. Flame stability

5. Funding pathways

The Gas Innovation Fund has acted as a springboard to further funding. Willing partners with theoretical, numerical, and experimental expertise, and the capability to address the research gaps highlighted have been identified. The consortium, led by UU is actively pursuing further funding in this direction at regional, national and European levels.

The original plan was to develop one costed proposal. However, by tackling the research gaps separately it has already been possible to successfully secure funding for “Phase 1” of the numerical activities from the Centre for Advanced Sustainable Energy (CASE). CASE is funded through the Department for the Economy NI’s Green Innovation Challenge Fund and aims to transform the sustainable energy sector through business research.

Funding has been secured and activities are ongoing to undertake pre-normative research investigating the behaviour of buried leaks and flame stability of hydrogen-methane blends.

Partners have been identified, and funding is being sought to investigate delayed ignition of hydrogen and methane blends.

6. Safety of hydrogen blends in the Northern Irish Gas Network (Phase 1)

As a direct result of the Gas Innovation Funded project, a proposal was prepared, submitted to, and successfully funded by the Centre for Advanced Sustainable Energy (CASE) in Northern Ireland.

The activity represents phase 1 of planned activities and has the full title “Safety of hydrogen blends in the Northern Irish Gas Network (Phase 1): Dispersion at different blend concentrations, flame stability and blow-out”.

The 18-month research project (1/10/23 – 31/03/25) brings together UU with three gas operators: GNI (UK), Phoenix Energy, and Mutual Energy.

The focus of the project is pre-normative research to inform safety guidance, and to underpin safety cases. The budget of £209k / €247k will cover numerical work in three specific technical directions:

1. Flame stability of hydrogen and hydrogen methane blends.
2. Buried leaks.
3. Injection and mixing.

A schematic of the work packages (WPs) is shown in Figure 2.

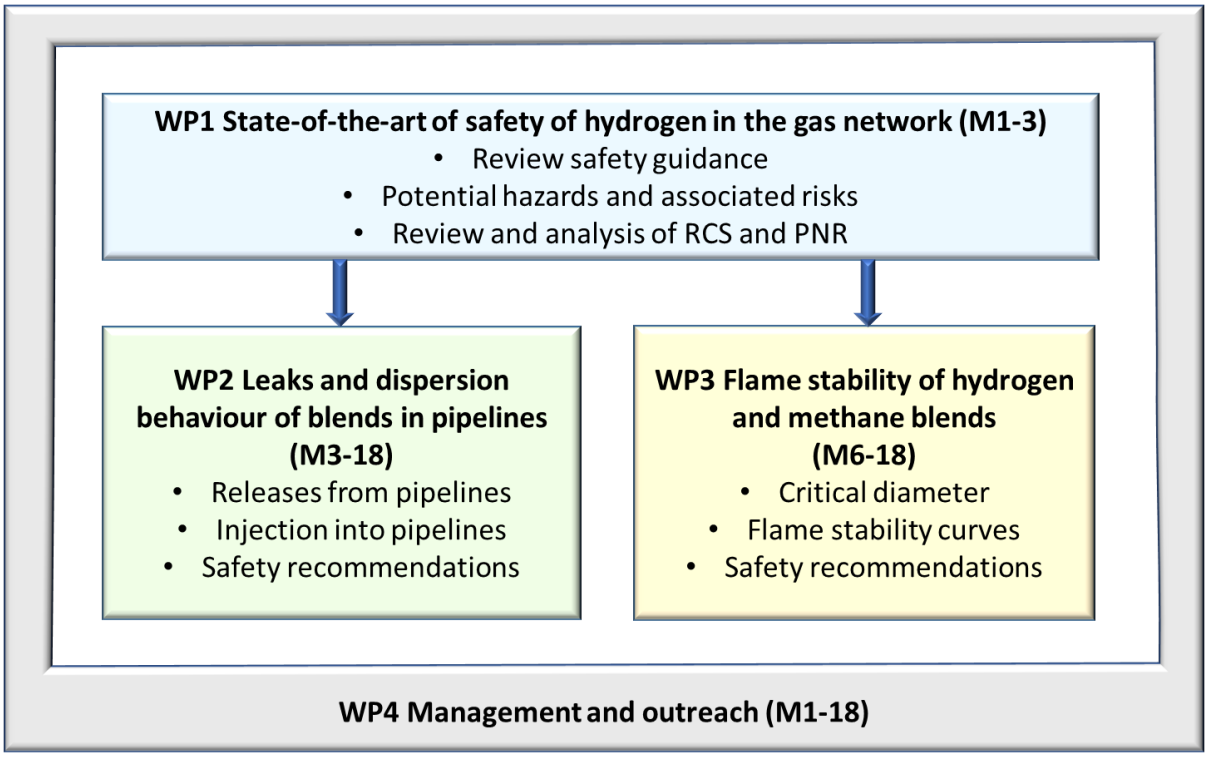

Figure 2. Safety of hydrogen blends in the Northern Irish Gas Network: Work Packages

It is expected that the outputs of WP2 and WP3 will assist with partially closing the research gaps identified through the Gas Innovation Fund activity.

Within WP2, task 2.1 is devoted to the modelling and simulation of buried leaks. CFD models will be developed to simulate flow through porous media to predict leak behaviour for a range of blend concentrations in scenarios pertinent to the NI Gas Network.

Through WP3. Flame stability behaviour of hydrogen, methane and hydrogen-methane blends will be described and flame stability curves for a range of blend ratios will be developed.

7. Gas innovation fund project: progress against planned milestones

The activity was initially foreseen as a 6-month scoping project, the work began in summer 2022 with a kick-off meeting at the end of August 2022. The objective of the study was to develop a collaborative programme of pre-normative research to inform safety guidance for hydrogen-natural gas blends.

There were 5 planned milestones outlined in Table 1 below. Whilst the project took longer than intended the outputs have been more significant than originally planned. Specifically, rather than a proposed plan of work, further funding has been successfully secured and research activities are underway.

Table 1: Project milestones

	Planned Milestone	Status
1	Scoping meeting between UU and GNI	• Completed as planned.
2	Workshop with responder community	• Workshop delivered.
3	Expert gap analysis workshop leading to potential consortium.	• Workshop delivered and built upon through follow up activities.
4	Initial plan and costed proposal	• A proposal has been successfully funded to address 2 research areas • Further funding is being sought. Partners and a plan is in place.
5	Presentation of proposal plans to relevant stakeholders and as a deliverable document.	• The ongoing and proposed activities have been presented to relevant stakeholders (IGEM, GERG, Research community) • A proposal has been submitted and funded.

8. Longer term outlook

The initial activity funded by the Gas Innovation Fund has led to pre normative research activities which will address research gaps of interest to the international community.

CASE project Safety of hydrogen blends in the Northern Irish Gas Network is on track. The first sets of results on buried leaks and flame stability have been published[5] and

[5] CFD modelling of methane dispersion from buried pipeline leaks: experimental validation and hazard distance estimation, Mohanty, S., Brennan, S. & Molkov, V., 31 Jul 2024, In: Process Safety and Environmental Protection. 187, p. 1540-1557 17 p.

it is expected that a complete report will be available in March 2025. It is planned that the outputs of the project will ultimately inform gas network operator safety cases and leak management guidance. There is interest and support from three organisations to undertake experimental activities in support of buried leaks and delayed ignition if further funding is secured.

The Gas Innovation fund has enabled UU to build an international consortium of capable partners with appropriate theoretical, numerical, and experimental expertise. Further funding is actively being pursued, underpinned by the research completed to date.

9. Conclusions

The objectives of the Gas Innovation Fund project "Pre-normative Research on Safety of Gas Networks with Hydrogen Blends" have been met, and the project has led to a fruitful ongoing research collaboration between UU, GNI and key stakeholders.

Numerical simulations of the critical diameter and flame stability for hydrogen flames, Kazemi, M., Brennan, S. & Molkov, V., 15 May 2024, In: International Journal of Hydrogen Energy. 59, p. 591-603 13 p.