Publishable Summary for 20IND10 Decarb Metrology for decarbonising the gas grid

Overview

The use of natural gas as a primary energy source represents a major issue to global warming. Decarbonisation of the gas grids is a possible solution, alongside electrification, to meet the climate change targets and reduce carbon dioxide emissions. This project will be the first large scale project of its kind that will tackle four measurement challenges that the gas industry needs to solve before the introduction of biomethane, hydrogen-enriched natural gas, 100 % hydrogen, and carbon capture and storage (CCS) can be used for decarbonisation of the gas grid. This project will cover the priority challenges within flow metering, gas composition, physical properties and safety (including monitoring of gas leaks) required to support these changes.

Need

The European Union has set a target for the reduction of carbon emissions by 55 % of 1990 levels by 2030 and to become carbon neutral by 2050. To support meeting these ambitious targets the Green Deal was introduced by the European Commission, which included several aims that align with this project, including increased use of biomethane and hydrogen to reduce natural gas in the gas supply, and the use of carbon capture and storage to reduce emissions from hydrogen and power production.

Early efforts have been made to understand the current measurement challenges of the energy gas industry through contacting stakeholders directly, running an online survey hosted by EURAMETs Task Group on "Metrology for Energy" (40 stakeholder entries) and via a workshop hosted by the EMN Energy Gases. The common topic that was prioritised involved activities required for the decarbonisation of the gas grid. Natural gas is currently the primary source of energy for heat in Europe and to meet climate change targets it is necessary to quickly introduce biomethane, hydrogen-enriched natural gas, 100 % hydrogen, and CCS technologies. The specific priority challenges identified by stakeholders were:

- An inability to **calculate flow of alternative energy gases** in the gas grid, such as hydrogen and hydrogen-enriched natural gas for **determining costs** when charging customers with the required accuracy.
- An urgent need for gas composition measurements in the gas grid to determine **energy content** (for costing) and **quality purposes** to avoid, for example, degradation of appliances. Currently a lack of traceable gas analysis methods for biomethane and 100 % hydrogen, and also the absence of a validated methods for rapid measurements of hydrogen in natural gas hampers the determination that blended gases are within tolerance limits and the compositional analysis of carbon dioxide in CCS for metering and purity.
- A lack of experimental results necessary to validate numerical methods adopted by industries for predicting the properties of the alternative gases highlighted above. Physical property measurements in the gas grid are important for **designing efficient decarbonised gas grids and CCS sites,** and for **accurate flow metering**.
- The modification of safety measures such as **leak detection** (where portable monitors should be able to distinguish between a hydrogen and natural gas leak) to support decarbonisation of the gas grid. Currently it is not possible to detect **leaks of carbon dioxide** above storage sites.

Objectives

The overall aim of this project is to develop metrology that will support decarbonisation of the gas grid. The specific objectives are:

1. Flow metering - to develop metrology infrastructure to support new flow metering requirements, including development of new traceable facilities to enable calibration of flow meters for hydrogen and hydrogen-enriched natural gas in the gas grid in accordance with the Directive 2014/32/EU Measuring

Instruments (MID) with maximum permissible errors as low as ± 1 % depending on the type of flow meter, and metering of carbon dioxide in Carbon Capture and Storage (CCS) processes in accordance with the Emissions Trading System (EU ETS) with an accuracy of ± 1.5 - 2.5 %.

2. Gas composition - to develop new primary reference materials and gas analysis methods to support the gas industry in performing gas quality measurements for pure hydrogen gas (ISO 14687 Grade A), biomethane (EN 16723-1) and hydrogen-enriched natural gas (EN 16726) for domestic use (e.g. boilers and cookers), and purity analysis of carbon dioxide for carbon capture and storage processes to meet the recommendations of ISO/TR 27921. Gravimetric uncertainties for amount fraction levels in the primary reference materials will be appropriate for the relevant documentary standard but always lower than 20 % relative. Additionally, to organise a proficiency test and comparison to support the gas industry in developing and validating traceable commercial on-line gas analysis instruments capable of quickly monitoring hydrogen amount fraction in natural gas to accurately control blending within target tolerances.
3. Physical properties - to develop metrology infrastructure to support measurement of physical properties for hydrogen-enriched natural gas, including development and traceable validation of analytical instruments that perform measurements of calorific values, density and Wobbe index as specified in ISO 6976, ISO 12213 and ISO 20765. Multiphase properties of mixtures composed of high levels of impurities in carbon dioxide will also be validated.
4. Leak detection - to develop metrology infrastructure to support new leak detection requirements for decarbonising the gas grid. This includes traceable monitoring methods for accurately quantifying leaks of hydrogen or hydrogen-enriched natural gas from pipelines at 25 % of the lower explosive limit (for health and safety reasons), and carbon dioxide leaks from pipelines or underground storage in CCS processes to meet the requirements of EU ETS (accuracy of ± 1.5 – 2.5 %). To support the future role of mobile platforms by ensuring they are capable of accurate measurement of leaks.
5. Impact - to disseminate and facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrument manufacturers), standards developing organisations (ISO/CEN/CENELEC) and end users (hydrogen industry, gas network operators and suppliers).

Progress beyond the state of the art

The current state of the art for the objectives and planned outcomes from this project are:

Flow metering

New measurement infrastructure will be developed in the related EMPIR JRP 18NRM06 NEWGASMET and new data will be collected characterising the performance of existing commercial domestic and distribution gas flow metering technologies with hydrogen. There is some field experience for metering of carbon dioxide in CCS applications, but there is a lack of independent flow measurement facilities and primary standards. This project will develop traceable flow calibration facilities and primary standards for pure hydrogen and hydrogen-enriched natural gas which will extend the range of flow rates and mixtures that can be tested. A meter testing programme will target existing commercial gas flow meters, but also newly developed domestic gas flow meters designed for use with hydrogen. New primary flow standards will be developed for metering carbon dioxide and representative CCS mixtures, and several flow meter types will be tested. The test programme will include CCS mixtures with carbon dioxide in both gas and liquid states.

Gas composition

New purity specifications have been published in gas quality standards for alternative gases to natural gas for the gas grid including hydrogen, biomethane and hydrogen-enriched natural gas, as well as carbon dioxide for CCS. Some gas standards and analytical methods have been developed for selected impurities, but further effort is required before gas industries can verify the quality of their gas as specified in these standards. This project will focus on further developing analytical methods and primary reference materials to meet these specifications.

Physical properties

Due to the limited, or lacking, characterisation of gaseous binary mixtures including hydrogen, currently available thermodynamic models for natural gas and biogas are principally built using general empirical mixing rules not necessary based on specific interaction potentials. The availability of experimental measurements of thermodynamic properties and calorific values of binary mixtures allows laboratories to define dedicated mixing

rules and to obtain accurate thermophysical properties even when the mixtures contain more than two components.

Leak detection

Portable gas alarms (used by emergency services and maintenance engineers to identify gas leaks) are suitable for natural gas but have not been tested for use with hydrogen or hydrogen-enriched natural gas. Industry has advised their need for monitors that can distinguish between natural gas and hydrogen, which this project aims to address. Carbon dioxide leaks from CCS infrastructure is a safety concern and can also lead to inaccuracies when monitoring losses of carbon dioxide in the process. This project will investigate suitable solutions for monitoring and quantifying these leaks such as through the use of Differential Absorption Lidar (DIAL) which has not been tested with carbon dioxide previously. Current approaches to understand material performance have been developed for natural gas networks, and this project will investigate their applicability and appropriateness for hydrogen and hydrogen-enriched natural gas.

Results

The following details results from project activities that have now been completed (not including ongoing work):

Flow metering

- A comprehensive review on latest findings for hydrogen and hydrogen-enriched natural gas in European grids was completed.
- A literature review on hydrogen and carbon dioxide metering studies and new metering developments was completed.
- An online survey addressing several key stakeholders across Europe on Carbon Capture and Storage operations and metering development was completed. VSL has upgraded its primary standard flow facility to CO_2.
- DNV successfully adapted its flow facility to H2 and blends.

Gas composition

- A new literature review has been written on new requirements for Primary Reference Materials to support decarbonising the gas grid; this was provided in the form of a report which is available on the project website.
- A new suite of Primary Reference Materials to support hydrogen blending in the gas grid; these mixtures contain varied levels of hydrogen in natural gas has been prepared
- The preparation of a new suite of impurities in CO_2 to support the Carbon Capture Utilisation and Storage (CCUS) industry. Impurities include water, ammonia, CO and NO_2 has been completed. In addition, a mixture containing multiple permanent gases in CO_2 has been prepared based on advice from the project's stakeholder board.
- A literature review has been completed detailing new technical purity specifications from documentary standard relating to hydrogen, biomethane and CO_2 for CCUS.
- The Consortium has agreed with industrial partner Air Liquide on the mixtures that will be prepared for the biomethane proficiency testing scheme and has already enlisted 6 participants for this scheme.

Physical properties

- The activities within this objective require gas mixtures for which in depth planning including the confirmation of the required compositions is still ongoing.

Leak detection

- A literature review on commercial sensors or instruments for detection hydrogen leaks has been performed, and manufacturers have been contacted to provide their devices to our project for testing in subsequent activities.
- A report has been produced assessing modifications needed to the NPL DIAL capability to detect CO_2 emissions from industrial sites or leaks and on the selection of the wavelength region required for accurate measurement. A new source configuration for the NPL DIAL has been implemented together with a CO_2 specific detection channel, on which tests have been carried out to check performance.
- A literature review on the potential releases and like dispersion characteristics of carbon dioxide, biomethane and hydrogen/hydrogen enriched natural gas from leaks and infrastructure failure in the gas grid has been completed.

Impact

To promote the uptake of the project results, 4 presentations have been made at 4 scientific conferences, on the project. 1 peer reviewed paper has been published. Partners have attended the meetings of 1 international and 1 national standardisation committees and will provide input to these committees when suitable results are available.

Impact on industrial and other user communities

This project will develop metrology that will support decarbonisation of the gas grid. The project's objectives were developed from the outcomes of a survey hosted by the EURAMET Task Group on "Metrology for Energy" thus providing direct industry input to the scope of the project.

The project results will lead to the following:

- Gas distribution networks will be able to **charge customers correctly** when introducing new energy gases by utilising the new capabilities for flow metering.
- Process gas chromatographs used by gas distribution networks for **determining energy content** of gas can be adapted to measure hydrogen-enriched natural gas with minimal effort and cost.
- Gas industry will be able to procure fit-for-purpose online analysers capable of keeping hydrogen levels in natural gas within **strict blending tolerances**.
- Industry can utilise improved data for **predicting physical properties** of hydrogen, biomethane or hydrogen-enriched natural gas in the grid, or carbon dioxide for CCS (including phase changes).
- Accurate models describing thermophysical properties of complex mixtures of enriched natural gases will allow the gas industry to access to reliable information useful to **improve performance and efficiency** of distribution grids and power plants, thereby reducing costs.
- Gas distribution networks (and the ancillary services supporting them) will have suitable equipment to identify and measure **gas leaks of hydrogen and hydrogen-enriched natural gas** from the gas grid and leaks of **carbon monoxide** in hydrogen-enriched natural gas.
- Industries running CCS processes can identify **leaks of carbon dioxide** from their sites in order to minimise them and quantify the losses.

Impact on the metrology and scientific communities

Ultimately it will be the role of the National Metrology Institutes and Designated Institutes to provide the top-level traceability for the measurements (flow, gas composition, physical properties and leakage) performed within the gas industry. This is the first project that solely focuses on the metrology requirements for decarbonising the gas grid so it will deliver significant impact to the metrology community.

The project results will lead to the following:

- National Metrology Institutes can provide new offerings for **primary reference materials** and **primary standards for flow metering** to support new requirements for measurements for hydrogen, biomethane and hydrogen-enriched natural gas in the grid and carbon dioxide for CCS.
- Gas analysis laboratories can **expand their services** to include hydrogen, biomethane and carbon dioxide purity measurements as required by ISO 14687 (Grade A), EN 16723-1 and ISO/TR 27921.
- Flow laboratories will be able to **expand capabilities** to provide calibrations of flow meters intended for new gases for the decarbonised gas grid and carbon dioxide for CCS.
- Through participating in the project's proficiency testing scheme and comparison, commercial laboratories providing purity analysis services for the biomethane and hydrogen industries can **check their performance** and obtain evidence to claim for ISO 17025 accreditation.
- The scientific community will be able to access new experimental measurements necessary to insight interaction potentials occurring between molecules of different species, giving the opportunity to experiment new and more **accurate expressions for thermodynamic equations**.

Impact on relevant standards

The outcomes of this project are expected to directly support revision or development of many standards, but a priority will be given to those that are directly related to the project objectives.

The impact on standards from the project results will be as follows:

- Development of new capability for performing **flow metering for alternative gases** (including new achievable uncertainties) will be fed back to OIML/TC 8/SC 7.
- Improvements in capability and the new analytical methods for gas composition and purity measurements will be fed back to ISO/TC 158, ISO/TC 197, ISO/TC 193, ISO/TC 265 and CEN/TC 408 for the **development of test methods** and to advise on whether **gas specifications set in current standards** may be achievable.
- New models and capability for **physical property measurements** of new energy gases and carbon dioxide, respectively, will be fed back to ISO/TC 193 and ISO/TC 265.
- CEN/CENELEC SFEM WG Hydrogen writes **annual reports stating the measurement needs** and new standards required for hydrogen and hydrogen-enriched natural gas; the work of this project will **address several of the challenges identified** which will position several committees to develop new standards necessary to decarbonise the gas grid.

Longer-term economic, social and environmental impacts

Decarbonisation of gas grids will **reduce the dependence from fossil sources** of energy in favour to a sustainable, efficient, clean and neutral use of energy resources. Whilst energy sources are diversifying in Europe, natural gas is still the primary fuel source for heating in Europe. Decarbonising the gas grid will allow the natural gas industry to continue using existing infrastructure rather than switching solely to alternative energy options which would either be costly or not viable in the short to medium term due to high energy demand. Utilising the existing gas grid to widely supply energy across Europe is far cheaper than building new electricity infrastructure. As hydrogen can be produced from either steam methane reforming (natural gas) or electrolysis (splitting water), decarbonising the gas grid in fact allows the market to open up to more energy sources including renewables (wind, solar, tidal etc.), as well as continuing to rely on natural gas (or biomethane) as the feedstock. A major advantage of converting renewable energy to hydrogen rather than relying only on electricity is that the gas grid can then store excess electricity in the form of hydrogen (it is too challenging to directly store electricity which would therefore be wasted).

Switching from gas to alternative energy supplies, such as electric-only, would require customers to replace their appliances which would be very disruptive and costly. By injecting biomethane and/or hydrogen into natural gas, consumers can continue to use their existing appliances with no noticeable effects.

Developing new capability to monitor for gas leaks (in hydrogen-enriched natural gas and 100 % hydrogen) is imperative for ensuring health and safety in the gas industry and will protect citizens.

The industries that would be supported by this project will be able to progress the **European Green Deal**; a plan to make the EU's economy suitable by solving climate and environmental challenges. Hydrogen-enriched natural gas, biomethane injection, 100 % hydrogen grids and CCS all contribute to reductions of carbon dioxide emissions which support countries in meeting targets set by the Climate Change Act 2008. The CCS activities within this project would not only support decarbonising of the gas grid, but all CCS processes including those used in tandem with power production and direct extraction of carbon dioxide from the air.

As a direct environmental impact from this project, companies will have the ability to accurately measure carbon dioxide in CCS processes to track their carbon dioxide emissions in accordance with EU ETS. The development of metrology infrastructure as described in this project will significantly speed up the uptake of activities for decarbonising the gas grid happening across Europe.

List of publications

1.*Sampling methods for renewable gases and related gases: challenges and current limitations*, Arrhenius, K., Francini, L. & Büker, O., Analytical and Bioanalytical Chemistry (2022), DOI: https://doi.org/10.1007/s00216-022-03949-0

This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

Project start date and duration:	01 June 2021, 36 months	
Coordinator: Dr. Arul Murugan, NPL Tel: +44 (0) 20 8943 6382 E-mail: arul.murugan@npl.co.uk Project website address: https://www.decarbgrid.eu/		
Internal Funded Partners: 1. NPL, United Kingdom 2. BAM, Germany 3. CEM, Spain 4. INRIM, Italy 5. NEL, United Kingdom 6. PTB, Germany 7. RISE, Sweden 8. TUBITAK, Turkey 9. VSL, Netherlands	External Funded Partners: 10. Air Liquide, France 11. DNV, Netherlands 12. Enagas TSO, Spain 13. NEN, Netherlands 14. RUB, Germany 15. TU-Ch, Germany 16. TUBS, Germany 17. UNL, Portugal 18. UVa, Spain	Unfunded Partners: -
RMGx: -		