



Publishable Summary for 23IND05 H2FlowTrace

Flow measurement traceability for hydrogen in gas networks

Overview

To avoid the worst impacts of climate change, greenhouse gas emissions need to be dramatically reduced. This will only be possible by reducing the EU's reliance on fossil fuels. Hydrogen offers a sustainable alternative, which can be distributed through gas networks, with the ability to fulfil societal, economic, ecological and technological objectives. Hydrogen can be stored underground, or in the existing natural gas network, which allows it to meet fluctuating energy demands in a way that is not practical for renewable energy sources such as solar and wind. Although large-scale decarbonised hydrogen projects are expanding across Europe, there is no large-scale verified metrological infrastructure to perform traceable pure hydrogen flow calibrations for gas networks. This project will address this by contributing to the development of the required metrological infrastructure, which has the potential to reinforce Europe's leading position in the hydrogen economy.

Need

The EU is committed to making Europe the first climate neutral continent by 2050. Achieving this highly ambitious goal requires the complete transformation of the European energy system, which accounts for more than 75 % of the EU's greenhouse gas emissions [1]. Even in the medium-term, hydrogen will help meet the EU's 2030 climate and energy targets with the installation of at least 40 GW of electrolyzers which will produce 10 million tonnes of green hydrogen annually, and another 10 million tonnes will be imported. The EU's strategies on hydrogen and energy system integration (Next Generation EU recovery package [2], the European Green Deal [3], the EU Hydrogen Strategy [4]) will pave the way towards meeting this objective, but they also create significant technical, operational and safety challenges (e.g., traceable flow measurement, material compatibility, leakage, stricter Atmospheres Explosibles (ATEX) Directive 2014/34/EU requirements).

To achieve these targets the development of a hydrogen infrastructure needs to be rapidly accelerated. Pipelines are considered the most efficient solution to deliver high volumes of hydrogen, especially over long distances. In the last update, the European Hydrogen Backbone initiative [5] (31 European network operators with infrastructure in 28 European countries) stated a geographically extended vision for a dedicated hydrogen infrastructure stretching across these countries. By 2040, the proposed backbone could have a total length of almost 53,000 kilometres, consisting of approximately 60 % repurposed infrastructure and 40 % of new hydrogen pipelines. However, the lack of dedicated large-scale traceability, i.e., at flow rates and pressures applicable to the transmission and distribution gas networks, for the custody transfer of hydrogen, or hydrogen enriched natural gas (HENG) applications, is a major-well-known issue for fair trade in Europe. European network operators are asking National Metrology Institutes for hydrogen calibration services (addressed by Objectives 1, 2, 3), for their large-scale applications, in order to determine if traditional services could be used with calibration fluid transferability methods (Objective 4), or if actual hydrogen gas calibrations are needed.

Objectives

Report Status:
PU – Public, fully open

Publishable Summary

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European Partnership



**METROLOGY
PARTNERSHIP**



The overall objective of the project is to establish gas flow traceability for hydrogen in gas networks. The specific objectives are:

1. To establish a robust metrological infrastructure for flow rates up to 1300 m³/h at 0.1 MPa or 45 m³/h at 3.3 MPa(g) with a primary focus on pure hydrogen, but also enabling traceability for hydrogen/natural gas blends in small industrial meters, with a measurement uncertainty of 0.20 % or less.
2. To establish a robust metrological infrastructure for flow rates of 200 m³/h to 10 000 m³/h, and pressures of 0.3 MPa(g) to 6.2 MPa(g) for pure hydrogen and hydrogen/natural gas blends in large industrial meters, with a measurement uncertainty of 0.30 % or less.
3. To design and test traceability transfer skids for pure hydrogen and hydrogen/natural gas blends. In addition, to carry out intercomparisons to determine the equivalence of independent traceability chains based on primary standards, secondary standards using a bootstrapping/upscaling approach, and secondary standards calibrated with alternative fluids to hydrogen.
4. To perform (i) primary calibrations of domestic gas meters (ultrasonic, diaphragm, thermal mass flow) with air and/or methane and with pure hydrogen up to 30 m³/h at atmospheric pressure and (ii) primary and secondary calibrations of industrial gas meters (ultrasonic, rotary, turbine) with air and/or natural gas and hydrogen/natural gas blends at flow rates of up to 1000 m³/h and pressures of up to 6.2 MPa(g). Based on these results as well as existing data, to deliver statistically meaningful datasets for air, natural gas, or other alternative fluid calibration for the transferability to hydrogen gas flow conditions for domestic and industrial flow meters.
5. To demonstrate the establishment of an integrated European metrology infrastructure and to facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited calibration and testing laboratories, European Metrology Network for Energy Gases), standards developing organisations (ISO/TC 30, OIML TC 8/SC 7, CEN/TC 237) and end users (energy gas transmission, distribution operators, FARECOGAZ, ENTSG, Hydrogen Europe).

Progress beyond the state of the art and results

To establish a robust metrological infrastructure for flow rates up to 1300 m³/h at 0.1 MPa or 45 m³/h at 3.3 MPa(g) with a primary focus on pure hydrogen, but also enabling traceability for hydrogen/natural gas blends in small industrial meters, with a measurement uncertainty of 0.20 % or less. (objective 1)

This project will ensure the traceability for pure hydrogen / HENG for small industrial meters by delivering a small-scale transfer skid using sonic critical flow venturi nozzles (CFVN) (for flow rates up to 720 kg/h – 7800 m³/h at 0.1 MPa(g) or 270 m³/h at 3.3 MPa(g)) with a bootstrapping approach that uses the primary standards developed within the EMPIR JRP 20IND11 MetHyInfra. The targeted measurement uncertainty is 0.20 % or less.

To establish a robust metrological infrastructure for flow rates of 200 m³/h to 10 000 m³/h, and pressures of 0.3 MPa(g) to 6.2 MPa(g) for pure hydrogen and hydrogen/natural gas blends in large industrial meters, with a measurement uncertainty of 0.30 % or less. (objective 2)

This project will gather and collate information from previous projects on the traceability of flow metering (EMPIR JRPs 18NRM06 NEWGASMET [6], 20IND10 DECARB [7] and 20IND11 MetHyInfra [8], and Metrology Partnership JRP 21GRD05 MET4H2 [9]) in order to build on the knowledge acquired and to provide the missing large-scale traceability for hydrogen and HENG applications. This will ensure traceability for large industrial meters by design and testing a large-scale transfer skid, using master meters, which will go beyond the state of the art by offering traceability and a path to accreditation for pure hydrogen and HENG (for flow rates up to 1000 m³/h at 6.2 MPa(g)) for large scale flow metering. The targeted measurement uncertainty is 0.30 % or less.

To design and test traceability transfer skids for pure hydrogen and hydrogen/natural gas blends. In addition, to carry out intercomparisons to determine the equivalence of independent traceability chains based on primary standards, secondary standards using a bootstrapping/upscaling approach, and secondary standards calibrated with alternative fluids to hydrogen. (objective 3)

The largest European hydrogen or HENG testing facilities will derive their traceability directly via the small-scale and large-scale transfer skids developed during this project. These infrastructures will be able to claim realistic and verified uncertainties during a laboratory comparison with a validated transfer standard (the transfer skid), which will be fully traceable to pure hydrogen gas flow. Some existing calibration facilities currently base their traceability chains on alternative fluids. During the facility intercomparison, the validity of this alternative fluid approach will be evaluated, by direct comparison with the hydrogen primary standards and bootstrapping approaches. The SSTS and LSTS, designed and tested in this project, will be used to deliver hydrogen and HENG traceability for gas networks after the project's end date.

To perform (i) primary calibrations of domestic gas meters (ultrasonic, diaphragm, thermal mass flow) with air and/or methane and with pure hydrogen up to 30 m³/h at atmospheric pressure and (ii) primary and secondary calibrations of industrial gas meters (ultrasonic, rotary, turbine) with air and/or natural gas and hydrogen/natural gas blends at flow rates of up to 1000 m³/h and pressures of up to 6.2 MPa(g). Based on these results as well as existing data, to deliver statistically meaningful datasets for air, natural gas, or other alternative fluid calibration for the transferability to hydrogen gas flow conditions for domestic and industrial flow meters. (objective 4)

Calibrations will be performed for at least 25 domestic and 15 industrial gas flow meters, using hydrogen, HENG and alternative fluids. This will be a larger sample than has been tested in any other project to date. The evaluation of mathematical models for the transferability of alternative fluid calibrations for each flow metering technology will be a meaningful outcome for the National Metrology Institutes and for the end users (gas network operators, energy companies, gas providers). It will be the first time that a large dataset for calibrations with air, natural gas, nitrogen, helium, hydrogen and HENG (from this project and previous EURAMET and national projects) will be analysed to determine the robustness of using alternative gases instead of the real application gas. This dataset, which is sought after by the industry, will be extremely valuable and it will be made available from the project through its open science practices.

Outcomes and impact

Outcomes for industrial and other user communities

This project will create impact on the Transmission System Operators' (TSOs), Storage System Operators' (SSOs) and Distribution System Operators' (DSOs) hydrogen blending strategies. Many European natural gas operators already released roadmaps targeting 2030 or 2050 for decarbonising the gas infrastructure. The retrofitting and repurposing of existing gas grids will provide an opportunity for a more cost-effective energy transition in combination with a (relatively limited) newly built infrastructure dedicated to hydrogen. Using the existing natural gas networks for hydrogen transport could require the repurposing or substitution of already installed measuring devices. With this in mind, the outcomes of this project will support accurate transmission and distribution, in a safe and cost-effective manner, removing the most-critical barriers for the adoption of hydrogen as an energy gas.

National Metrology Institutes are currently receiving more and more requests from the industry for traceable hydrogen calibration services for their metrological flow meters. However, as large-scale hydrogen metrological infrastructures are too costly to be built by a single National Metrology Institute, it appears impossible to duplicate the traceability chain in each EURAMET country. A key outcome will be to deliver new integrated metrological services for large-scale hydrogen or HENG flow metering as needed by the industry and end user communities.

This project will deliver traceability at the largest flow rate range, directly linked to the requirements of gas network applications, by exploiting two traceable transfer skids (via CFVNs (sonic nozzles) or master meters) up to 1000 m³/h at 6 MPa. The project's outcomes will enable end users to prove their uncertainty claims for pure hydrogen or HENG, using the Integrated European Transfer Standard, at the required < 0.30 % flow rate level (targeted).

Finally, clear statements on the potential transferability of hydrogen calibrations to alternative fluid calibrations will be provided by the consortium based on a solid statistically meaningful measurement dataset. The industrial community will benefit greatly from the technical guidance provided by the expert group, and representatives from industry often express the need to make this dataset publicly available, which will be done as an outcome of this project. In addition to the realisation of methodologies and recommendations for new/updated standards, this project will also enhance public confidence in the H₂ market by ensuring reliable

H₂ metering. Therefore, the outcomes of this project will provide "a small step for the EU Green Deal, but a giant leap for the decarbonisation of Natural Gas grids".

Outcomes for the metrology and scientific communities

The main objective of this project is to deliver new metrological capabilities in Europe. National Metrology Institutes (NMIs) and Designated Institutes (DIs) involved in this project will be able to propose new services to their customers by exploiting the transfer skids developed during this project. The participating NMIs will declare validated uncertainties (targeted at lower than 0.30 %) based on a bootstrapping method that is traceable back to the primary standards for pure hydrogen and blending. The European Reference for Gas Metering (EuReGa) partners are all represented in the consortium, which will lead to ready adoption of the integrated service by the gas flow measurement industry.

The participants with industrial-scale hydrogen and HENG calibration facilities (EnagasTSO, DNV, RMA, FORCE) will be able to perform a laboratory intercomparison in this project with the large scale transfer standard to prove their claimed uncertainties.

The outcomes from this project will benefit the metrology and scientific communities by providing a large, meaningful dataset of calibrations with hydrogen, HENG and alternative fluids. Using this dataset, the achievable measurement uncertainty of various flow meter technologies will be determined, and robust guidance will be provided on the efficacy of calibration with alternative fluids. The new knowledge generated will be published in peer reviewed journals.

Fundamental scientific knowledge concerning the underlying flow physics of CFVNs (sonic nozzles) will be obtained by performing calibrations with both hydrogen and nitrogen (at mass flow rates that will be larger than those performed in EMPIR JRP 20IND11 MetHyInfra). The Joule-Thomson effect and the pressure and temperature dependency of the isentropic exponent will be investigated for CFVNs (with a diameter larger than 3 mm).

Outcomes for relevant standards

The consortium comprises experts in flow metering that are deeply involved in numerous national and international technical standardisation groups (ISO, OIML, CEN, WELMEC). Using guidance from EMPIR JRP 18NRM06 NewGasMet, this project aims to demonstrate the transferability of alternative gas calibrations to applications with hydrogen or HENG. Clear conclusions will be drawn, and the outcomes will be transferred to the legal metrology community as input for the modification of existing standards, including those which are under the control of the CEN TC 234 and CEN TC 237 working groups: EN12480, EN12261, EN1359, EN14236 and EN17526.

Longer-term economic, social and environmental impacts

Like natural gas, the successful implantation of hydrogen in energy systems will be underpinned by metrology. Providing good practice and traceability for hydrogen flow measurement will ensure that planned decarbonised gas networks will be able to operate efficiently and that billing, fiscal and custody transfer measurements will be trusted. This will ensure that the public continues to support the transition to net zero carbon dioxide emissions. This will also support the development of the hydrogen industry and a healthier market for providers of hydrogen technologies and services. It will also encourage innovation and new employment opportunities for European citizens. By taking a leading role in these areas, EU member states will benefit, in the longer-term, from greater energy security and they will be better positioned to export these technologies and services internationally.

List of publications

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

Project start date and duration:		1 September 2024, 36 months
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Internal Beneficiaries:	External Beneficiaries:	Unfunded Beneficiaries:
1. Cesame, France	7. DNV, Netherlands	14. Emerson M, Netherlands
2. CMI, Czechia	8. EnagasTSO, Spain	15. EHS, Germany
3. FORCE, Denmark	9. GERG, Belgium	
4. PTB, Germany	10. NaTran, France	
5. SMU, Slovakia	11. RMA, Germany	
6. VSL, Netherlands	12. TG, Italy	
	13. UNIBO, Italy	
Associated Partners:		
16. METAS, Switzerland		
17. NEL, United Kingdom		