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 electrolysers 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 Atmosphères Explosibles (ATEX) Directive 2014/34/EU requirements).term, hydrogen will help meet the EU's 2030 climate and energy targets with the installation of at least 40 GW of electrolysers 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 -term, hydrogen will help meet the EU's 2030 climate and energy targets with the installation of at least 40 GW of electrolysers 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

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

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EURAMET. Neither the European Union nor the granting authority can be held responsible for them.

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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 largescale 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 largescale 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.-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

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 to1300 m^3/h at 0.1 MPa or 45 m^3/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 m^3/h to 10 000 m^3/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 m^3/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 m^3/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 (ISOTC30, OIML TC 8/SC 7, CEN/TC 237) and end users (energy gas transmission, distribution operators, FARECOGAZ, ENTSOG, Hydrogen Europe).

Progress beyond the state of the art and results

To establish a robust metrological infrastructure for flow rates up to 1300 m^3/h at 0.1 MPa or 45 m^3/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 m^3/h at 0.1 MPa(g) or 270 m^3/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. Two sets of CFVN were designed, manufactured, dimensionally calibrated and finally calibrated with hydrogen. The nozzles from both sets can be mounted in the SSTS. -scale transfer skid using sonic The first calibrations with hydrogen were performed on the primary standard of CESAME. After being calibrated, the set of 6 small CFVN (1.6 mm diameter for mass flow rates up to 20 kg/h) was implemented into the SSTS to perform the calibration of the set of 6 large CFVN (4.4 mm diameter for mass flow rates up to 120 kg/h) with pure hydrogen and natural gas at NaTran. These results will be published and publicly available in 2026.

To establish a robust metrological infrastructure for flow rates of 200 m^3/h to 10 000 m^3/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 m^3/h at 6.2 MPa(g)) for large scale flow metering. The targeted measurement uncertainty is 0.30 % or less.

So far, the two specialised master meters, have been calibrated with HENG at FORCE using their primary high-pressure gas flow standard and will be calibrated with pure hydrogen using the SSTS and calibrated large CFVNs as transfer standards at DNV in February 2026.

Some challenges have been encountered in receiving the master meters, the timeline of the project needed to be adjusted according to the lead times involved and further technical problems occurred on one of both master meters that needed a revision after which its calibration results were accepted.

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. 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. -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 executive design and the P&ID of the SSTS have been reviewed and approved by the partners. The SSTS Site Acceptance Test was successfully performed in November 2025 at NaTran with pure hydrogen. A first uncertainty budget for the establishment of the calibration and measurement capability of the SSTS was made.

So far, the executive design of the LSTS was reviewed and approved as well by the partners of the project. A decision was made to use two G400 sized (maximum flow rate at 650 m^3/h) rotary type master meters, which were subsequently secured and calibrated as described above. The DNV hydrogen calibration described above will establish a link with DNV's traceability based on alternative fluid calibration. The LSTS assembly, the preparations for its commissioning and performance of its site-acceptance-test are ongoing at the time of writing (c.f. A3.2.5) and it should be validated in September 2026.

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 m^3/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 m^3/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.

After a large study of the current state of art, the sample size for the large test campaign was determined, with the help from the EMN Mathmet, and then the test protocols were defined with the partners. Thanks to the contributions of manufacturers and partners, the first calibrations started in January 2026. So far, calibrations have been performed for 6 domestic gas meters and 3 industrial gas meters. The campaign should be completed by Autumn 2026.

Outcomes and impact

<u>Key dissemination and communication activities</u>

The A5.1.13 online stakeholder workshop was held in September 2025. 63 attendees registered, with a good representation of the target audiences (meter manufacturers, gas network operators and standardisation groups). Feedback on the proposed test plans was mostly positive and provided useful insights for the final revision.

Three abstracts were accepted to the Flomeko 2026 conference in Nara, Japan, 17-20th May

- WP1 on definition and calibration of both sets of CFVN
- WP2/3 on development of the SSTS and the LSTS
- WP4 paper on the aims of the test programme and presenting initial results for 6 meters

<u>Outcomes for industrial and other user communities</u>

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. The stakeholder committee of H2FlowTrace includes TSOs, DSOs and SSOs from France, Italy, the Netherlands, among other European countries. The network of GERG is also leveraged for broader impact-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 effective manner, removing the most critical barriers for the adoption of hydrogen as an energy gas-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 effective manner, removing the most critical barriers for the adoption of hydrogen as an energy gas-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 -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 m^3/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 H_2 market by ensuring reliable H_2 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".

<u>Outcomes for the metrology and scientific communities</u>

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).

<u>Outcomes for relevant standards</u>

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. During the first half of the project, participants have shared H2FlowTrace updates in key technical committees in CEN (TC234, TC237), ISO (TC30, TC197), OIML (TC8/SC7), among others.

Initial WP4 results for 4 diaphragm meters show close agreement in the calibration curves for hydrogen and nitrogen (or air) without the need for corrections. If these results are replicated for the other diaphragm meters soon to be calibrated in WP4, it will allow the consortium to advise CEN TC237/WG8 that the EN 1359 accuracy testing procedure does not need to be updated to include hydrogen as a test gas. This would be a very positive outcome that would minimise future costs for MID type approval.

Longer-term economic, social and environmental impacts

Like natural gas, the successful integration 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-term, from greater energy security and they will be better positioned to export these technologies and services internationally.-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/

<table>
<tr><td colspan="2">Project start date and duration:</td><td>1 September 2024, 36 months</td></tr>
<tr><td colspan="3">Coordinator: Rémy MAURY, Cesame Tel: +33652519387 E-mail: r.maury@cesame-exadebit.fr
Project website address: https://h2flowtrace.eu</td></tr>
<tr><td>Internal Beneficiaries:
1. Cesame, France
2. CMI, Czechia
3. FORCE, Denmark
4. PTB, Germany
5. SMU, Slovakia
6. VSL, Netherlands</td><td>External Beneficiaries:
7. DNV, Netherlands
8. EnagasTSO, Spain
9. GERG, Belgium
10. NaTran, France
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16. METAS, Switzerland
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