FINAL PUBLISHABLE REPORT

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Project full title	Flow metering of renewable gases (biogas, biomethane, hydrogen, syngas and mixtures with natural gas)

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RMG: -		

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1 Overview

The European Green Deal encourages the development of renewable energy sources and gases (biogas, biomethane or hydrogen) produced for this purpose. As their characteristics differ from the well-known natural gas, the industry needs to understand their impact on flowmeters and demonstrate their compliance with the Measuring Instruments Directive 2014/32/EU. To support this need, the NEWGASMET project partners published an overview of existing data and wrote recommendations on the design of gas meters. Durability tests were performed with biogas and hydrogen, while accuracy tests with hydrogen. Calibration benches have been adapted and European inter-comparison tests have been performed with hydrogen and methane.

2 Need

The European policy to increase renewable energy sources has a significant impact on the characteristics of energy gases throughout Europe and therefore on the European gas infrastructure:

- Power generation from wind and solar sources leads to the development of so-called “power to gas (P2G)” solutions; these plants will compensate for fluctuating electricity supplies by converting electricity into hydrogen to be injected in large quantities into the gas network.
- Biogas produced by the anaerobic digestion of organic waste needs to be directly measured in cogeneration facilities or before injection into the gas network after purification to biomethane.

The gas network is connected within Europe but the gas supply is dependent on the coordination of national operators for transport and distribution (TSO and DSO); this industry first needs were to draw an overview of existing disseminated scientific results related to metrology and different national renewable energy policies (objective 1). So far, gas meters have been tested, calibrated and certified for natural gas applications according to Measuring Instruments Directive and to CEN standards. Consequently, the evolution of the gas energy mix was expected to impact the accuracy of measuring instruments that are used to bill transactions according to commercial contracts. Although, experts were expecting a significant influence on the design of gas meters and on the tests performed, this impact was not fully evaluated (objective 2). This new context was also resulting in the absence of accredited laboratories to provide metrological calibrations of the meters that are used with renewable gases (objective 3). This project aimed to address the need for a common European approach to evaluate the conformity of commercially available meters to EN standards and to MID directive, and to provide recommendations to adapt their designs and the associated standards documents (objective 4).

3 Objectives

The overall objective of the project was to increase knowledge about the accuracy and durability of commercially available gas meters after exposure to renewable gases. This has led to the improvement of existing meter designs and flow calibration standards.

The specific objectives of the project were:

1. To assess the typical uses of renewable gas for which the effects on accuracy, costs and lifetime were not sufficiently known. Furthermore, to define an acceptable range of gas compositions, suitable to support the new “renewable” framework and to list the missing tests which needed to be performed during calibration to cover the use of renewable gases with existing gas meters.
2. To develop traceable methods for the type testing and verification of flow meters that are used to measure renewable gas flows in compliance with the requirements of the 2014/32/EU Measuring Instruments Directive and to determine the uncertainty budget. Uncertainties of 1/5 Maximum Permissible Error (MPE) had to be achieved for type testing and 1/3 MPE for field verification. In addition, this project studied and evaluated the integrity of the meters’ internal components, the

durability of the materials, the insulation of electronic components and other possible technical issues (dependent on the composition of the evaluated gas).

3. To validate the calibration methods and uncertainty budgets developed for two flow calibration standards via an appropriate inter-laboratory comparison and to carry out type testing procedures for domestic and commercial gas meters with hydrogen.
4. To contribute to the standards revision work in technical committees CEN/TC 237 and OIML TC8/SC7 to ensure that outputs from the project would be aligned with their needs, communicated quickly to those developing the standards and to those who will use them, and in a form that can be incorporated into standards at the earliest opportunity.

4 Results

When the project initiated, the industrial and metrology communities were preparing the important evolution of gas supply in Europe. Instead of transporting natural gas coming from well-known origins (such as North Sea, Russia, Algeria), new local sources would be developed with production of hydrogen, biogas, biomethane and syngas. All characteristics of transported gas were expected to be impacted by the injection and the mixture of so-called renewable gases in the network. Gas operators were, at that time, assuming that infrastructure (including meters) could be impacted too. The problem was that data were often not open-access. The aim of this project was to contribute to the progress of all interested parties in a better common knowledge concerning metering of renewable gases with the inclusion of National Metrology Institutes, of meters manufactures and gas operators.

Bibliography study about impact of renewable gases, overview of European context and gap analysis to assess gas meters conformity (objective 1)

The project aimed first at collecting available knowledge in 2020 on the performance of existing gas meters and to demonstrate whether they could be used with renewable gases. This study analysed data from laboratories and industry actors with a survey that has been sent to project partners and 57 other interested parties throughout Europe, including gas manufacturers, calibration laboratories (NMIs) and Transmission/Distribution System Operators (TSO and DSO).

The conclusions of this study were as follows:

1. Very few scientific data were available on the flow metering of renewable gases, especially about hydrogen metering, and this confirmed the real expectations of the NEWGASMET project,
2. Biomethane was considered throughout Europe as equivalent to natural gas and no impact was expected on the flowmeters' performance with this type of gas,
3. Hydrogen tightness of gas meters was a very specific challenge for the whole gas infrastructure and especially for gas flowmeters,
4. State of the art is that the impact of blending 10 % hydrogen with natural gas was not expected to affect metrology performance,
5. Use of biogas (or even syngas) was addressing the issue of contamination and composition variability related to the durability and accuracy of the instruments.

The literature study also defined an overview of the European gas network in relation to gas composition ranges as well as metering technologies used in the field. It was based on both published economic forecasts and answers to the survey. Depending on the type of gas, compositions were related to the blending rate for biomethane or hydrogen, or for the rate of contamination for biogas and syngas.

Recommendations for the adaptation of gas meters design, of traceable methods for type testing and for calibration (objective 2)

An expert group was formed to discuss the compliance requirements for gas meters that are implied by the MID when renewable gases are used. Specifically, the conformity requirements set out in CEN/TC 237 standards for different types of gas meters, and in OIML R137:2012, has been evaluated for renewable gases.

The group of experts was comprised of different laboratories and notified bodies involved in certification process for gas meters such as VSL (NMI in the Netherlands), LNE and Cesame (respectively Notified Body and NMI in France), CMI, FORCE, PTB (both Notified Body and NMI in Czech Republic, in Denmark and in Germany), NEL (laboratory in UK) and ISSI. Based on the gas composition ranges defined in first part of the project, the work of the group experts was to determine and evaluate the essential conformity requirements of the 2014/32/EU Measuring Instruments Directive for gas meters using renewable gases.

The experts group evaluated the appropriateness of the different standards used for gas meters certification and identified issues that require further investigation. Most of these standards are under the responsibility of CEN/TC 237 “Hydrogen Technologies” which was created 20 years ago to publish harmonized standards. These 4 documents are used by industry both manufacturers and operators to ensure conformity of meters like EN 12261:2018 „Gas meters - Turbine gas meters“, EN 12480:2018 „Gas meters - Rotary displacement gas meters“, EN 1359:2017 „Gas meters - Diaphragm gas meters“ and EN 14236:2018 „Ultrasonic domestic gas meters“. During the course of the project, a 5th document has been published EN 17526:2021 “Gas meter - Thermal-mass flow-meter based gas meter” and has also been included in the scope of NEWGASMET study.

The experts group formulated in different specific reports practices, for example for definition and adaptation of test gases in order to cover the scope of renewable gases. They insist about the need for new requirements regarding durability of meters to be used with gas closest to the intended use and the need to evaluate possibility of hydrogen embrittlement. They also required new experience tests in order to define durability timespan over 1000h, depending on the technologies.
With the objective to keep the same energetic density, gas operators will possibly have to increase gas pressure in network. The expert group recommend that the flow range limits and the maximum pressure absorption requirements are reviewed considering the use of (partly) renewable gases.

They took also into consideration work done about gas tightness tests and pressure absorption tests in this study, which although are known as potential impact for some renewable gases (especially hydrogen).

Work of the experts group identified also potential additional theoretical uncertainty sources, due to renewable gases flowing through the gas meter, and made recommendations on improving and/or modifying current natural gas certification/calibration/verification facilities and gas meters. When looking at the uncertainty budget in general the inputs to the budget are mostly not related to the type of gas, but one had to make some considerations especially when measuring hydrogen but also converting calibrations from an alternative gas to the application gas. In some cases, use of calibration test gas closest to operational conditions is recommended.

Evaluation of meter integrity after durability tests with renewable gas (objective 2)

Durability tests were performed where three major steps were defined in a specific test protocol; (1) customary calibration by a European National Metrology Institute with air, (2) exposure to renewable gas, and (3) air calibration and investigation of gas meters by Energy Dispersive X-ray Analysis Scanning Electron Microscopy (EDX-SEM) after exposure. The meter types studied were domestic diaphragm, ultrasonic, and thermal mass meters that 4 market-leading suppliers have donated.

The prior air calibrations were completed, after which the gas meters were installed in a biogas plant by ISSI in flowing conditions and in two test benches with static hydrogen exposure. For reference, gas meters were also exposed to natural gas in flowing conditions. The exposure lasted for twelve months. Some meters have been removed after a shorter duration. The effect on meter performance has been determined by comparing air calibrations after exposure with the initial air calibrations in CMI laboratory.

This test program led to the following statements:

1. All tested diaphragm gas meters were within tolerance, as defined in CEN/TC 237 standards, after durability tests with natural gas.
2. All tested accuracy class 1.5 diaphragm gas meters were within tolerance of twice initial MPE after they were subjected to durability testing with hydrogen.
3. Most of tested diaphragm gas meters were within tolerance of twice initial MPE after they were subjected to durability testing with biogas. Different issues were nevertheless observed attributed to blockages in the gas meters internals.
4. All tested thermal mass meters were within tolerance of 2% drift after they were subjected to durability testing with hydrogen. A wider spread is observed in comparison with diaphragm gas meters.

These results have been completed with EDX analysis of the inner parts by ISSI. This has provided data about the effects of biogas or hydrogen on materials used in gas meters. For natural gas and hydrogen little effects were observed; for biogas corrosion of gas meters internals and salt deposition were identified and recommendation is to identify critical parts for which a material compatibility list must be defined.

As an add-on activity to the project, durability tests on the pressure transducers used in in volume conversion devices were performed with hydrogen in static conditions. Prior and recalibration of the pressure transducers did not indicate an important shift at the pressure point P_{max}. Some inconclusive results occurred at Pmin.at .

Furthermore, a study has been undertaken on the hydrogen tightness of gas meters. This was performed with a specific test bench designed for that purpose which showed that pressure loss could be observed, depending on the meter type, however at a rate below the criterium of tightness. The project published the gas tightness results in a newsletter and in a specific report which is available as open-access document on website.

Regarding durability tests NEWGASMET is a first interesting step. For fully understanding durability, further experience covering the lifetime of the gas meter is needed, e.g. by periodically verifying gas meters installed in the field where renewable gases are used.

Validation of calibration methods for two flow calibration standards (first part of objective 3)

During a literature study of the most important journals and conferences, more than 60 publications were identified to provide information about flow standards that are usable for testing and calibrating gas meters with renewable gases. Classification of their contents has been summarised with respect to influences and restrictions; this study has been used to create a generic uncertainty budget and benchmarking of available flow standard techniques to measure hydrogen and/or hydrogen-enriched natural gas (HENG).

As a result of this study a robust flow transfer calibration standard has been designed to be used for inter-comparisons measurements with renewable gases. This includes measurements with hydrogen, nitrogen, methane and air. The flow rate ranges covered by this inter-comparison are 25 l/h up to 9,000 l/h, which are commonly used flow rates of domestic gas meters.

After checking the CMCs of the involved partners, 5 different flow rates and 4 test gases were defined which have been then investigated in the inter-comparison procedure. This study concludes in using a laminar flow element, a critical nozzle and a rotary meter as the transfer package. The transfer package has been designed, realised and sent to five different laboratories (4 NMIs and 1 manufacturer). This inter-comparison process lead globally to a good agreement between the results of the participants,

Type testing for meters with hydrogen (second part of objective 3)

Laboratories in PTB and NEL have tested domestic gas meters with air and hydrogen gas flows with two different flow meter types using critical nozzles or rotary meter as references. The uncertainty of the reference nozzles operating with either nitrogen or hydrogen is approximately 0.3 % (k=2). Tests have been performed in both laboratories with diaphragm meters at different flowrates 0.6, 1.2 and 10 m3/h and also with thermal mass meters at 0.6, 1.2 and 6 m3/h.

These tests conclude to the possibility to carry out tests needed for the conformity assessments of gas meters with hydrogen. Uncertainty requirements for such tests given in OIML R137 have been fulfilled by both partners. For diaphragm meters no systematically difference was observed between nitrogen and hydrogen as test gas. For other gas meter technologies nevertheless, further specific investigation is needed. Moreover, experience showed the need to package carefully gas meters for such comparisons and to fit them with shock sensors to log mechanical stress like severe shocks and vibrations.

At the same time laboratory VSL, supported by manufacturers have performed tests with a rotary gas meter at elevated pressure (9 and 16 bar) with HENG using a piston prover. Tests have been performed at 7 different flow rates from 5 to 160 m^3/h, with both natural gas and hydrogen-15% enriched natural gas according to EN 12480 standard for rotary displacement gas meters.

Different accuracy tests have demonstrated that G100 rotary meter at high pressure has similar behaviour at all calibration conditions, for natural gas and mixture with hydrogen. Regarding more precisely the results, analysis led to the underreport observation which can be explained by leakage effect with hydrogen mixture. As a result, it is expected that meters with 100% hydrogen will lead to larger differences with natural gas especially with lowest flowrates. Calibration with air also indicated a systematic drift and the need to calibrate meters at process conditions as far as possible.

Regarding the test bench these tests showed the oil piston prover of VSL can be used by 20 % hydrogen content of the test gas.

5 Impact

The project has built a wide stakeholder committee to spread this knowledge to research organisations and industrial users. NEWGASMET's objectives and conclusions from the bibliography study were presented at different national and international meetings such as CEN, Working Group Measuring Instruments (WGMI European Commission), Energy Gases EMN and Welmec. Then a strong relationship was built with the TC237 standardisation group in order to present the analysis of different standards and their necessary evolutions to include use of renewable gases.

Impact on industrial and other user communities

The results from the bibliographic study have been considered as useful for the industrial and standardisation communities. The consortium created a relevant dissemination network comprising active actors in the gas sector and authorities with a stakeholders committee and discussion with TC237 technical committee in CEN organization. In addition, a training session was organised with over 50 interested parties from Europe and even US.

To promote new knowledge about the flow metering of renewable gases, and to broadly share the data generated during the project with scientific and industrial end-users, different partners participated in conferences organised by standardisation bodies and industry associations like CIM 2021 in Lyon, the Italian Gas Forum or ENLIT Europe 2021.

Meetings with the stakeholders have been held in continuation of the project meetings to spread progress and to ensure that the project is in line with the expectations from the industry. Furthermore, the stakeholders' meeting has been used as an opportunity to present the conclusions of the French DSO's project about the injection of hydrogen into the gas network in 2020.

Impact on the metrology and scientific communities

In relation to the development of traceable methods for renewable gases, a setup was developed by a National Metrology Institute to assess leaky gas meters; this development could become an exploitable result for use in the technical standards that are used to prove the hydrogen tightness of gas meters. This issue is crucial as existing gas meters can be tight with natural gas, but not with hydrogen.

The partners have also developed durability test setups for hydrogen and biogas. Using their expertise, these setups will be used for further durability test services, which would be of interest to gas meter manufacturers, DSOs and TSOs.

Impact on relevant standards

Contacts have been made with regulation authorities at national and European levels. The CEN/TC237 secretary was chief stakeholder and the other committee members have included gas manufacturers and TSO/DSO. The results from the literature study and the outcome from the study of the EN-standards and OIML recommendations were presented at the CEN/TC 237 plenary meetings in 2021.

Furthermore, the chief stakeholder was regularly invited to the project meetings to give recommendations and to take part in the stakeholder committee meeting.

Several partners were also involved in regular standardisation working groups such as Welmec (Measuring Instrument Directive harmonisation) or WGMI (European Commission Working Group for MID) to create harmonization between different standardisation groups in Europe.

Longer-term economic, social and environmental impacts

The EU strategy plan aims to reduce greenhouse gas emissions by 40 % by 2030 compared to the 1990 level, and to increase the renewable share of total energy consumption to at least 27 %. This major change aims to decarbonise energy production and to avoid energy imports from countries outside Europe. These renewable energies are produced using natural processes that are constantly replenished such as electricity produced by solar, wind or biomass resources. A new process called P2G or P2X aims to transport this potential power to end-users using the existing European gas network by converting electricity into hydrogen, or Synthetic Natural Gas (SNG) when hydrogen is combined with carbon dioxide. Another way to develop energy bio-sources is to install biogas/biomethane facilities that are supplied by agricultural by-products or by bio-waste which can be burned or injected into the gas network.

By investigating the effect on gas meters and delivering solutions to industry and to standards bodies, this project improved the confidence of consumers and suppliers in the billing of renewable gases. This will help to develop renewable resources in Europe, in order to reduce fossil fuel consumption according to the European Union Directive for Renewable Energy.

6 List of publications

There are no peer-reviewed publications.

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

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