Publishable Summary for 24GRD07 CryoMet
Metrology for reliable liquefied energy gases measurement

Overview

The fit for 55 package of legislation requires an increased usage of liquefied energy gases to reach 55 % net greenhouse gas emissions reduction by 2030. However, reliable measurement methods for (bio-)LNG and liquefied hydrogen (LH_2) are not yet fully developed. Bio-LNG is defined here as (predominantly) liquefied methane originating from biomethane and/or biogas and traceable measurements for both it and LH_2 are urgently needed across the supply chain. In order to address this issue, this project will develop reference data sets and technical evidence to support the acceptance of measurement methods for (bio-)LNG and LH_2. This will include verification of the results and datasets under in-field conditions and by SI-traceable intercomparisons. The project's outcomes should enable the European liquefied gas metrological framework to be expanded, and new SI-traceable calibration procedures to be developed. The project's liquefied gas measurement methods and good practice guidance will also be disseminated and promoted to standardisation bodies, the measurement supply chain, and end-users to support their wide uptake.

Need

The European climate law means that reaching the EU's climate goal of reducing EU net greenhouse gas emissions by at least 55 % in 2030 is a legal obligation. To meet this goal, the fit for 55 package legislation was adopted by the EU in 2023. Regulations in this package require an increased usage of liquefied energy gases. However, current measurement uncertainty for flow, composition, and temperature measurements in liquefied gas in-field conditions are relatively large with respect to gaseous energy gases. A liquefied gas metrology project is therefore urgently needed to facilitate a safe, secure, affordable, and sustainable energy system for the near future. Accurate LH_2 isomer composition and temperature measurements are also urgently needed for safe usage and technology development.

(Bio-)LNG and renewable hydrogen are required to make Europe's energy supply secure now and by 2050 when 10 % of renewable hydrogen is projected to be transported in liquid form. Bio-LNG is an immediate (drop-in) and affordable decarbonised fuel option and renewable LH_2 is a key element in decarbonised aviation. Currently the accepted measurement methods for (bio-)LNG and LH_2 are lacking verified accuracy under in-field process conditions at sufficiently low uncertainties. Verified and representative accuracy claims for quantities transferred, and for measurement composition for (bio-)LNG and LH_2 are also needed. In in-field conditions down to -253 °C, systematic temperature measurement errors occur, but these have yet to be quantified to assess concomitant uncertainty. Further to this, SI-traceable calibration procedures need to be developed, and inter-comparisons between (scarce) standards are needed to corroborate uncertainty claims. Finally, reference data sets are needed to support the adoption of accepted measurement methods by relevant standardisation technical committees such as ISO/TC28, OMIL/TC8, CEN/TC282, CEN/TC408, and IEC/TC65/SC65B and stakeholders across the supply chain.

Objectives

The overall goal of this project is to (1) determine the accuracy of (bio-)LNG measurement systems under in-field custody transfer process conditions and to (2) reliably establish achievable accuracy for LH_2 measurement systems. The objectives are:

1. To determine the measurement reliability and uncertainty of (bio-)LNG flow meters in-field, including 2-phase flow, meter insulation type, reproducibility, and temperature cycles. In addition, to develop

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.

The project has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.

traceable (bio-)LNG and LH_2 meter diagnostics and to demonstrate, using reference data sets, a target accuracy of 0.5 % for (bio-)LNG flow meters.

2. To determine the reliability of (bio-)LNG composition measurements under in-field conditions, including sampling errors, and the achievable accuracy of LNG composition measurement equipment. Then to demonstrate, using reference data sets, a target uncertainty of less than 0.3 % (k = 2) for the online determination of LNG density.
3. To determine the accuracy of (bio-)LNG in-field temperature measurements, including the impact of static and dynamic effects on the temperature measurement system. Then to demonstrate, using SI-traceable reference data sets, a target uncertainty up to 0.5 °C (k = 2), for in-field conditions and for cryogenic temperatures down to -253 °C (LH_2).
4. To perform SI-traceable flow and temperature measurements in LH_2 conditions and to develop SI-traceable calibration procedures for LH_2 flow, composition, and temperature measurement systems. In addition, to verify the performance of the (bio-)LNG and LH_2 metrological infrastructure developed, including through inter-comparisons of the SI-traceable calibration systems.
5. To 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 (OMIL/TC8, ISO/TC28, CEN/TC408, IEC/TC65/SC65B), the EMN for Energy Gases and end users (e.g. research institutes, plant operators, Transmission System Operators/Distribution System Operators (TSOs/DSOs)).

Progress beyond the state of the art and results

Liquefied gas flow metering reliability (objective 1)

Using the standards and models from previous projects ENG03 LNG, ENG60 LNG II, 16ENG09 LNG III, and 20IND11 MetHyInfra, this project will go beyond the current state of the art by (I) making a directly traceable assessment of the installation effects on the LNG flow meter at an LNG terminal, and (II) quantifying in-field uncertainty from key LNG flow meter measurement influencing variables. The project aims to show that improved accuracy classes of (bio-)LNG flow meters to 0.5 % are possible (and when they are not). In-field LH_2 flow meter uncertainty will also be quantified using numerical meter models (digital twin), traceable machine-learning meter diagnostics, and the above reference data (from the traceable assessment).

(Bio-)LNG composition and density measurements reliability (objective 2)

The project will go beyond the current state of the art by using techniques based on novel Raman-based probes for (bio-)LNG composition measurement (independent of the vaporisation of the (bio-)LNG). The results will be compared with metrologically validated Gas Chromatography (GC)-based methods (where vaporisation is needed). The applicability of the Raman technology to bio-LNG will be determined, which should aid smaller scale bio-LNG plant operators.

The in-field (bio-)LNG density measurement uncertainty will be demonstrated with a target of 0.3 % (k = 2), improving it from the currently decade-long accepted uncertainty of 0.45 % (k = 2). The project will achieve this by quantitatively verifying sampling uncertainty from direct (densitometer) methods and indirect (GC/Raman & EoS) LNG-density determination methods. From the results, good practice guides on improved (bio-)LNG sampling, composition measurements and density determination will be created.

SI-traceable liquefied energy gases temperature measurement accuracy (objective 3)

The project will develop new and unique SI-traceable methods for in-field industrial temperature sensor calibration at temperatures down to -253 °C. It will also characterise the uncertainty of temperature measurements in LNG conditions, using the best in-field installation conditions of VSL's LNG facility combined with static and dynamic effects modelling. The target temperature measurement uncertainty at in-field LH_2 conditions is within 0.5 °C (k = 2). The project will also evaluate the extrapolation of the temperature-resistance characteristic of the industrial sensors based on newly developed calibration procedures at temperatures below -200 °C.

SI-traceable liquefied energy gases calibration procedures (objective 4)

The project will go beyond the current state of the art by developing novel methods for SI-traceable measurements of the ortho- and para-spin isomer composition of LH_2, based on (I) Raman spectroscopy and (II) sound-speed measurements. These new methods will fill an important scientific knowledge gap on LH_2 composition measurements and the determination of their uncertainty, as well as an engineering knowledge gap related to safe and efficient upscaling of LH_2 production. The project will also undertake highly needed (inter-)comparisons between scarce LH_2 flow and isomer composition (Raman) measurement standards.

Publicly available SI-traceable reference data sets (all objectives)

The project will openly publish its SI-traceable reference data sets according to the FAIR principles. The datasets are intended to be used to demonstrate in-field (I) LNG flow meter error and uncertainty, (II) LNG and bio-LNG composition measurements including an assessment of sampling error, and (III) SI-traceable (bio-)LNG and LH_2 temperature measurements.

Outcomes and impact

Key dissemination and communication activities

Outcomes for industrial and other user communities

The improved in-field (bio-)LNG density measurement uncertainty from 0.45 % ($k = 2$) to 0.3 % ($k = 2$) and the project's reference data sets, will be crucial for improving LNG transport and distribution value chains, as LNG terminals and dispensing stations can accept smaller uncertainties in their custody transfer or legal compliance obligations. The project's good-practice guide for LNG and bio-LNG sampling will support TSOs/DSOs, (bio-)LNG plant operators, and (liquefied) natural gas traders in the reduction of systematic vaporisation and sampling errors, and hence a reduction in concomitant uncertainty. The project's reference data sets will also facilitate agreement between (industrial) parties about the uncertainty of liquefied gas measurement results.

Improved LH_2 temperature measurement accuracy together with the project's novel and verified approach for calibrating Raman spectroscopy as a tool for hydrogen isomer measurements will support the upscaling of LH_2 production plants and long-haul LH_2 transport systems by enabling improved explosion and pressure (boil-off) risk assessments as well as improved engineering solutions based on more accurate thermodynamic property determination.

In addition, the project will engage with industrial and other user communities via articles in trade journals and magazines, a biannual e-newsletter, social media, and webinars.

Furthermore, the project will benefit from input from industrial stakeholders in its stakeholder committee. The project's stakeholder committee includes representatives from industry (gas operators, (bio-)LNG terminals, EU associations), standardisation (ISO/IEC, OIML, CEN), the scientific community (Oil and Gas research, aviation & space research), and the measurement supply chain (equipment manufacturers, accredited laboratories). The results of the project will also be provided via the GERG network to industrial and other user communities (i.e. there are more than 200 experts involved in GERG working groups and committees on a permanent basis, and its social media has an audience of over 3500 subscribers on LinkedIn).

Outcomes for the metrology and scientific communities

The project's development of SI-traceable isomer composition (para- and ortho-hydrogen) determination of LH_2 at low uncertainty (1.0 %, $k = 2$) will be groundbreaking for the scientific community. It will enable scientists to perform consistent LH_2 composition measurements, which in turn will stimulate the much-needed development of accurate thermodynamic (EoS) property measurements and modelling.

The aerospace research community will also benefit from improved accuracy LH_2 (and LNG) standards for flow, composition, and temperature. As this will support their development of prototype components for sustainable aviation and aerospace applications.

The project's inter-comparisons for (bio-)LNG and LH_2 flow, composition, and temperature measurement standards can be used to create a foundation for a European liquefied gas measurement metrological framework. Indeed participants Cesame and VSL will extend their existing calibration services for the

SI-traceable flow measurement of liquefied (energy) gases for temperatures applicable to (bio-)LNG (-162 °C / 111 K), and LH_2 (-253 °C / 20 K) using their cryogenic laser doppler velocimetry (LDV) flow meter and calibrated Coriolis flow meter (CFM), respectively. This service will likely be used by meter manufacturers and their end-users (e.g., TSOs/DSO, bio-LNG plant and terminal operators, aerospace/aviation research).

The results of the project will be provided via the EMN for Energy Gases for promotion to their stakeholders in the metrology and scientific communities. It is intended that the consortium will regularly and closely interact with the EMN and co-organise joint events, to use its already established stakeholder base. The consortium will also provide information about its new services and products to the EMN in order to be added into the EMN's service platform.

Finally, the project will disseminate its outcomes to the metrology and scientific communities through peer-reviewed journal papers, 3 webinars including training for traceable cryogenic measurements, and 2 stakeholder workshops.

Outcomes for relevant standards

The consortium already has well established links to relevant standardisation committees such as ISO/TC28 Petroleum and related products, ISO/TC193 Natural gas, OMIL/TC8, CEN/TC282 Installation and equipment for LNG, CEN/TC408 Biomethane, IEC/TC65/SC65B Measurement and control devices, and are in close contact with the International Group of LNG Importers (GIIGNL) Custody Transfer Handbook (CTH) Task Force. The project outcomes and importantly the SI-traceable and publicly available reference data sets could contribute to standards' development as follows:

- ISO 21903 and OIML R117 can benefit from the flow reference data set with verified accuracy information for in-field process conditions and the quantified effects affecting the flow meter measurements.
- EN 16723 under CEN/TC408, ISO 6974 under ISO/TC193/SC 1 and standards under ISO/TC193 WG17 can benefit from having (bio-)LNG composition reference data sets available, including an assessment of (bio-)LNG composition and density measurement uncertainty as established from direct (Raman/densitometer) and indirect (EoS) methods.
- IEC 60751, OIML R81 can benefit from reference data sets at liquefied gas temperatures to define achievable accuracy under liquefied gas process conditions, in particular for thin film sensor calibration for temperatures below -200 °C. Additionally, IEC 60584-1, IEC 61152, IEC 61515, IEC 61520 could benefit from the characteristics for measuring points at process conditions.

All of the above could also apply to the custody transfer methods of the GIIGNL CTH, which is widely used by stakeholders.[1].

Longer-term economic, social and environmental impacts

In the long-term this project will help to support the EU's uptake of (bio-)LNG and LH_2 as set out by the fit for 55 package legislation. The project will support the achievability of reliable liquefied gas measurements across the entire supply chain. Cost-effective composition measurements will help to support the proliferation of replacing fossil LNG by drop-in bio-LNG fuel, leading to immediate decarbonisation in the heavy-duty transportation sector. Accuracy of LH_2 isomer composition and temperature measurements will also lead to robust risk assessments of LH_2 use, thereby helping to improve public trust in using LH_2 at increased scales of the future. For aviation, the projects' LH_2 SI-traceability will help to improve the testing of sensors, the performance of tests, and, ultimately, the development of operational aircraft using hydrogen as a fuel (supplied as LH_2).

LNG imports currently account for approx. 37 % of the EU's natural gas imports. The volatility in energy prices seen in recent years illustrates the need for a diverse, secure energy supply system. This project will support the uptake of and transitioning to bio-LNG and LH_2, helping to mitigate the risk of energy price increases. In addition, by facilitating a secure and affordable energy system the project will help to improve the EU's economic competitiveness.

[1] The GIIGNL CTH is not a standard and the GIIGNL CTH Task Force is impartial with respect to the project consortium.

List of publications

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>1st August 2025, 36 months</td></tr>
<tr><td colspan="3">Coordinator: Menne Schakel, VSL E-mail: mschakel@vsl.nl
Project website address:</td></tr>
<tr><td>Internal Beneficiaries:
1. VSL, Netherlands
2. Cesame, France
3. CMI, Czechia
4. FSB, Croatia
5. NEL, United Kingdom
6. NPL, United Kingdom
7. PTB, Germany
8. RISE, Sweden
9. TUBITAK, Türkiye</td><td>External Beneficiaries:
10. EffecTech, United Kingdom
11. GERG, Belgium
12. IC, United Kingdom
13. IFE, Norway
14. LUH, Germany
15. NLR, Netherlands
16. TU-IL, Germany
17. UL, Slovenia</td><td>Unfunded Beneficiaries:
18. E + H, Germany
19. EHFL, Germany
20. Emerson M, Netherlands</td></tr>
</table>