Publishable Summary for 24GRD10 SmartGasNet
Metrology for smart metering in gas networks

Overview

Partial replacement of natural gas with renewable alternatives, e.g., biomethane and hydrogen is essential to mitigate climate change. However, the introduction of these renewable gases in gas grids gives rise to increasing fluctuations in gas flow rates and properties. This project will provide the necessary methods, algorithms, datasets and good practice guides to enable gas grid operators to adapt their data processing for fiscal metering, custody transfer and billing. This measurement infrastructure for gas supply will support the envisaged increase in the use of renewable energy gases.

Need

The European Commission aims at having a carbon-neutral energy supply in Europe by 2050. For this to happen, the dependence on natural gas must be reduced by upscaling biomethane and hydrogen utilisation. However, the gas infrastructure must be prepared for larger fluctuations in supply and demand, gas properties and flow rates, and an increased number of entry points in the grids. The successful increase in the use of renewable energy gases depends partly on these developments, including changes to measurements.

Current practices for fiscal metering underrate uncertainty by some 35 %. Additionally, it is known that quantifying measurement errors of flow meters are challenging yet essential to obtain metrologically traceable results. Models that describe the dynamics in gas grids are therefore urgently needed, and their development requires flow metering data obtained under well-understood conditions. However, suitable data from gas grids are generally not publicly available.

Distribution System Operators (DSOs) and Transmission System Operators (TSOs) are contemplating to introduce machine learning (ML), a well-known branch of Artificial intelligence (AI), in gas grids to improve their operation, ensure safety and potentially also for gas allocation and billing. Current practices for fiscal metering presume transparency of the measurement models employed and ignore any prior knowledge. The use of prior knowledge (i.e. “training data”) is a key feature in ML-models, however and it is unclear what their impact is on the metrological traceability and uncertainty of the measurement results.

Consequently, guidance documents such as OIML R140 and ISO 15112 for evaluating gas allocation and fiscal metering data require urgent improvement, so that measurement results are metrologically traceable and coherent. Underrated uncertainties are detrimental to this coherence and cause that risks cannot be reliably assessed, let alone be efficiently managed.

Objectives

The objective of the project is to prepare the measurement infrastructure of gas grids in Europe for the take-up of renewable energy gases, to ensure that measurement results are metrologically traceable, gas grids can be operated reliably and safely, and that billing is fair. The project will enhance European expertise in modelling and forecasting of grid properties, including the role that AI and ML can play in achieving this goal. The specific objectives of the project are:

1. To create datasets for time-resolved gas flow measurements, including temperature, pressure and gas composition using state-of-the-art methods and techniques, mimicking changes in gas grid flow

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rate, pressure, temperature and gas composition typically seen in real world scenarios in order to enable studying and modelling of time-correlation effects. These reference datasets should be made FAIR and published with their full context (meta data).

2. To develop methods for the evaluation of time correlation in gas metering data, as well as uncertainty evaluation for time averages of gas quantity and calorific value, and link these with models used to operate gas grids. The methods should be applicable to grids for hydrogen, natural gas and hydrogen-enriched natural gas (enriched to the most common level), and fully validated. Synthetic datasets should be created with known features (e.g., correlated measurement errors) for validating data processing methods used in the operation of gas grids, including fiscal metering.
3. To assess the possibility of integrating machine learning, as a type of artificial intelligence, in smart metering and monitoring systems used in gas grids with respect to its applicability to produce measurement results that meet the requirements of ISO/IEC 17025, OIML R140 and ISO 15112, and ISO/IEC Guide 98.
4. Using results from Objectives 1-3 and liaising with industry to get feedback on applicability, to develop and validate an integrated package of methods for the evaluation of measurement data to support gas allocation and the fiscal metering of the most commonly used blends of natural gas with renewable gases (e.g., hydrogen and biomethane) as well as renewable hydrogen.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (GERG and MARCOGAZ), standards developing organisations (ISO/TC 193, ISO/TC 197, CEN/TC 234, EURAMET TC-F and TC-MC), legal metrology organisations (WELMEC, OIML) and end users (e.g., gas network operators).

Progress beyond the state of the art and results

Objective 1: Datasets for time-resolved gas flow measurements, mimicking real world scenarios

The project will provide well-documented, FAIR (findable, accessible, interoperable and reusable), time-resolved measurement datasets that will be published with open access. The datasets will comprise measurement data of the flow rate, pressure, temperature and where appropriate other quantities, such as gas composition. Datasets will be developed with different dynamic scenarios in mind, using state-of-the-art measurement facilities. The datasets will be large enough for statistical modelling and used as training data for AI/ML. The datasets will be curated and enriched with metadata describing the dynamic features that were included in the scenario creating them. A range of different fluids will be targeted in the measurements.

Objective 2: Methods for the evaluation of time-correlation in gas metering data, as well as uncertainty evaluation for time averages of gas quantity and calorific value

This project will deliver data-driven, validated models for assessing serial correlation in gas metering data. These methods will identify statistically different sections in the data to provide appropriate models for these sections. The experimental datasets will be supplemented by artificial (synthetic) datasets generated using said models to explore other scenarios, which will be based on computational fluid dynamics (CFD) modelling. The uncertainty evaluation of aggregating data into time averages will be explored, as well as their impact on the uncertainty calculated for total quantity or energy.

Objective 3: Potential integration of AI and ML in smart metering and monitoring systems used in gas grids

The use of AI/ML will be explored in this project, including the requirements for the necessary “training data”. Experimental and synthetic data will be used for this purpose and their influence on the outputs of the ML models will be assessed in terms of transparency, explainability, uncertainty quantification and sustainability. The “trustworthiness” of these methods will be assessed in view of applicable requirements. In particular, the capabilities of these techniques in providing measurement results that are metrologically traceable and meet the requirements such as laid down in ISO/IEC 17025, OIML R140, ISO 15112 and ISO/IEC Guide 98 will be explored, as a stepstone to the wider use of these techniques.

Objective 4: Integrated package of methods for the evaluation of measurement data to support gas allocation and fiscal metering

The software framework of Partnership project 21GRD05 Met4H2 will be upgraded by including full-featured methods for dealing with correlated measurement data based on maximum permissible errors. The data-driven methods for assessing and describing the serial correlation in fiscal metering will also be implemented. The novel methods and code will be accompanied by a guidance document that can be used alongside existing standards and recommendations for fiscal metering.

Outcomes and impact

Key dissemination and communication activities

A stakeholder committee (SC) will be formed to support the project consortium in carrying out the project. A first meeting is planned in the first months of the project and where appropriate guidance and advice will be sought in implementing the project activities. A project website will be created and launched that will present an outline of the project plans and in due course reports, deliverables and other project outputs. In Zenodo, a community will be created to deposit data sets. Standards development organisations, such as ISO/TC 193 Natural gas, OIML TC8/SC7 and JCGM WG1 (GUM) will be informed about the project and arrangements will be made for the dissemination of project outputs, as well as for obtaining the necessary input for, e.g., the scenarios to be considered that are relevant to modelling gas metering data.

Outcomes for industrial and other user communities

The datasets and statistical methods together with the accompanying documentation will enable grid operators to assess their measurement systems and adapt these as necessary. The assessment of the use of AI/ML and the software framework will provide grid operators with the knowledge on where and how to integrate AI/ML into their systems. The data driven models will not only support gas grid operators but will also other industries, such as carbon capture and storage, and water supply. Calibration and testing laboratories for flow measurement will benefit from these methods too, as the assessment of the performance of flow meters under dynamic conditions will be more reliable. The guidance and practical examples provided will enable rapid adoption of these methods in the laboratory community. The novel services being developed will aid the take-up of these methods, also by small organisations. To further promote uptake of the project outputs by these communities and therefore maximise the outcomes and generation of impact, the consortium will publish open access and promote the datasets and statistical methods. The methods will also form the basis for novel consultancy services aimed at supporting industry in implementing the outputs of the project.

Outcomes for the metrology and scientific communities

The FAIR datasets will foster research and development and will enable metrology institutes to revisit their calibration and measurement capabilities and, where necessary, make adaptations. The novel methods for dealing with serial correlations in measurement data will assist the metrology community in their understanding and use of these models in various areas e.g., flow measurement, use of dynamic methods in gas mixture preparation and electrical measurements, etc. The assessment of the AI/ML methods will foster further research in the application of these technologies in systems that produce, among others, measurement results. This applies to the whole metrology community. To further promote uptake of the project outputs by these communities and therefore maximise the outcomes and generation of impact, the consortium will disseminate the outputs through associations like GERG, ERIG and MARCOGAZ and share these with ISO/TC 193 and OIML TC8/SC7. Those organisations will be approached at an early stage to support the work to be carried out in the project and to enhance uptake throughout the project. Dissemination activities will include providing reports, examples and methods, supported by workshops and training courses. These activities will be prepared in close collaboration with the Stakeholder Committee.

Outcomes for relevant standards

This project will contribute to the revision of ISO 15112, EN 1776 and OIML R140 that deal with fiscal metering and custody transfer. These contributions will extend to underlying standards, such as ISO 6974 and ISO 6976, widely used for the volume conversion and the calculation of the calorific value. The outputs will fully embrace the needs of the legal metrology community so that also in this framework the practices can be

adapted so that they are fit for purpose. To further promote uptake of the project outputs by these communities and therefore maximise the outcomes and generation of impact, the consortium will present the project and its results to different standards developing bodies e.g., ISO/TC 193, ISO/TC 193/SC1, JCGM WG1, OIML TC8/SC7.

Longer-term economic, social and environmental impacts

This project will stimulate and foster the decarbonization of the gas grid by preparing the measurement infrastructure to deal safely and reliably with the increased dynamics in these grids due to the injection of renewable energy, such as biomethane and hydrogen from renewable sources. Thereby it will contribute to investments cost saving by enabling the repurposing of the existing gas infrastructure. The project will contribute to a reduction in carbon dioxide emissions as well as to savings in energy transmission and distribution. It will contribute to meeting Europe's targets of being carbon neutral by 2050. The proposed research will foster a non-disruptive change from fossil fuel to renewable energy by industry and end-users. The outputs related to AI/ML will foster further research and a greater understanding of how these can be applied in measurement systems.

List of publications

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Project start date and duration:		1 August 2025, 36 months
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Internal Beneficiaries: 1. VSL, Netherlands 2. CMI, Czechia 3. LEI, Lithuania 4. PTB, Germany	External Beneficiaries: 5. DTU, Denmark 6. ERIG, Belgium 7. GERG, Belgium 8. NORCE, Norway 9. TNO, Netherlands 10. UL, Slovenia	Unfunded Beneficiaries: