European Partnership on Metrology
Call 2024 –Digital Transformation, Green Deal, Normative and Research Potential

Selected Research Topic number: **SRT-v16**
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Title: Metrology to support ammonia use in emerging applications

Abstract

The European (EU) 2040 climate target aims for reducing the EU's net greenhouse gas emissions by 90 % by 2040 relative to 1990. Initiatives like REPowerEU, REFuelEU, and FuelEUmaritime advocate reducing CO_2 emissions using sustainable routes. Green hydrogen is crucial in this context, but its potential is hindered by limited wind and solar energy production, and a significant part of the demand must be imported to the EU. To overcome this, suitable hydrogen carriers like ammonia present promising opportunities for end-case applications (e.g., ammonia cracking, shipping, power generation). The central focus of submitted proposals should be to ensure that the metrology infrastructure and relevant services are in place to facilitate using ammonia as an energy carrier.

Keywords

Ammonia, Hydrogen energy carrier, primary reference materials, impurity, gas and liquid phase flow, custody transfer, material compatibility, sensor degradation, leakage and emissions quantification, life-cycle assessment

Background to the Metrological Challenges

Ammonia is used directly or indirectly in the agricultural sector as fertilisers and traded globally between geographical locations. With the recent development of policies such as the European Green Deal along with numerous hydrogen strategies from European nations, ammonia has long been considered a carbon-free energy carrier for hydrogen. Hydrogen can be released on demand from ammonia through catalytic decomposition and, if needed, consumed in a proton exchange membrane (PEM) fuel cell. Also, ammonia plays a significant role in long-term energy storage due to its most advantageous feature – higher volumetric energy density than hydrogen. Ammonia (NH_3) undergoes thermal conversion in the presence of air/oxygen, producing NO_x and N_2O, the latter being a potent greenhouse gas. This raises the question of whether the relevant infrastructures (i.e., fundamental and legal metrology, safety, monitoring leakage and emissions) are in place. Previous projects have focused on ammonia uses, but the approaches, applications, and measurement ranges differ widely. MetNH3 (ENV55) initiated work on gas cylinder standards and the generation of gas standards for laser spectroscopy while also addressing the selection of inert material. MetAMC (IND63), which catered to airborne molecular contamination in a manufacturing environment (e.g., semiconductor manufacturing), targeted ammonia amount fractions below 1 nmol/mol level. 16ENV08 IMPRESS2 addressed reference measurement methods for ammonia emissions (µmol/mol level) concerning industrial regulatory limits. The ongoing 21GRD10 quantiAGREMI focuses on traceable techniques for quantifying ammonia from agricultural and livestock emissions. These projects provide an excellent basis to start from but require further investigations to apply to new applications.

Similar to green hydrogen (i.e., sustainably produced), ammonia also falls under a similar categorisation based on the production source, leading to impurities from their respective processes (e.g., H_2O, CO_2, H_2S, CH_4). The knowledge and detection of impurities are essential during ammonia applications and for preparing gaseous-certified reference materials. Therefore, there is a need for accurate, cost-effective techniques to be deployed at ports and at the point of usage to monitor the impurities in ammonia and subsequent value chains. An increase in ammonia consumption is expected because of its extended use in emerging applications as an energy vector, which would require fair billing. Currently, there is no metrological infrastructure to calibrate flow

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meters directly with ammonia (gas or liquid), and little is known about how calibrations with alternative (surrogate) fluids translate to use with ammonia.

From the perspective of the entire ammonia life cycle, it is central to look into emissions and ensure the right measurement techniques are available for various end-cases with increased accuracy and traceability to SI units. Additionally, the regulation and policies (EU-Emission trading system) demand mass-based emission measurements or estimates (i.e., top-down | bottom-up calculations); therefore, having both the traceability chain in emission parameters and flow measurements is necessary. In emerging end-use scenarios, standard methods should also investigate the emission flow rate of pollutant mixtures (approx. 500 kg/hr single cylinder test engine) in the stacks (NH_3, NO, NO_2, N_2O). Although methods for measuring stack flow rates, and emissions are available (e.g, ISO 16911-1, ISO 10849), the transfer of methods have to be validated for different gas matrices and emission ranges for ammonia as a primary energy source. The systems for thermo-chemical conversion of ammonia are scaling up, and more ammonia power plants are to be built. Furthermore, most sectors demand reduced emissions in their product life cycle. It is essential to consider the emissions along the different steps of the value chain, including the thermo-chemical conversion of ammonia, and how they impact the climate by performing a life cycle assessment on this pathway. Accurate and traceable measurements are needed in end-use cases (e.g., power generation) to generate realistic estimates.

To summarise, sustainable solutions in energy, transportation, and industry require ammonia as an energy carrier for existing and emerging applications. However, there is still a lack of metrological infrastructure to support the deployment of ammonia in these sectors. Although some developments have been initiated in previous and ongoing projects by considering it as a pollutant in trace, a holistic approach to the ammonia value chain has not been explored. The need recognised in the proposal is prioritised by EMN Energy Gases and stakeholders working towards implementing ammonia in emerging fields.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on metrology research necessary to support the for deployment in the ammonia value chain.

The specific objectives are

1. To develop new traceable reference materials and gas analysis method for ammonia (NH_3) as an energy carrier, including analysing different groups of impurities (e.g. H_2O. CO_2, CH_4, H_2S) arising from various production process value chains. Furthermore, to develop static and dynamic reference gas materials of priority air pollutants (e.g., NH_3, N_2O) for ammonia leakage measurement and emission monitoring during thermo-chemical conversion processes of ammonia.
2. To develop calibration and validation procedures for flow meters used for gas and liquid ammonia flow measurement beyond the state of the art and investigate the use of surrogate fluids and optical methods (e.g., laser-Doppler-velocimetry) for calibration of ammonia flow meters beyond the state of art.
3. To determine traceable monitoring methods for accurately quantifying ammonia leaks in its value chain and establish capabilities for SI-traceable and controlled releases of ‘mimicking leaks’ to support the development of the metrological infrastructure necessary for ammonia leak detection. Additionally, to quantify material compatibility of sensors and instruments (e.g., temperature, pressure, flow meters) in an ammonia-enriched environment by investigating performance degradation, ageing, and adsorption/desorption effects to evaluate the material compatibility of long-term ammonia storage.
4. To develop traceable real-time online emission (e.g. NH_3, N_2O, NO, NO_2) monitoring techniques and to understand the effect of impurities on pollutants formation (e.g., SO_x, CO, CO_2) during thermo-chemical conversion of ammonia in emerging applications. Furthermore, to provide validated methods for quantifying emissions supported by rigid uncertainty analysis related to stack flow and emission species measurements and to conduct ammonia life-cycle analysis for a set of specific applications, focusing on environmental impact (e.g. pollutants, GHG emissions, eco-toxicity) by providing realistic estimates and assessing key uncertainties, with deployment of blockchain tools (e.g., Hyperledger solutions) for traceability of life-cycle assessment.

5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (e.g. instrument manufacturers and accredited calibration laboratories), standards developing organisations (e.g. ISO, CEN, BIPM), and end users (e.g. H_2 users, shipping and power generation sectors, sensor manufacturers, policymakers).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented needs, in particular those supporting the European Green Deal. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP, EMPIR and Metrology Partnership projects ENV55 MetNH3, IND63 MetAMC, 16ENV08 IMPRESS2, 16ENV05 METNO2, 19ENV09 MetroPEMS, ENV60 IMPRESS and 21GRD10 quantiAGREMI and how their proposal will build on those.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.8 M€ and has defined an upper limit of 3.5 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the energy sector.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.