



## Publishable Summary for 22NRM03 MetHyTrucks Metrology to support standardisation of hydrogen fuel sampling for heavy duty hydrogen transport

#### Overview

Hydrogen can significantly contribute to reducing emissions from the transportation sector as it is particularly well suited as a fuel for long-haul heavy-duty (HD) vehicles. The uptake of hydrogen for heavy-duty transport requires further standardisation to support Europe's green energy future. Sampling systems and methods have already been developed for use at hydrogen refuelling stations (HRS) for light-duty (LD) vehicles, however there is a lack of technical evidence for heavy-duty transport. This project will deliver the evidence needed for the standardisation of hydrogen fuel sampling for heavy-duty applications. This will include the development of dedicated sampling systems for contaminants (gaseous species and particulate matter), methodologies for the validation of sampling methods, guidelines for the evaluation of sampling representativeness, uncertainty budgets, safety considerations and venting protocols. The outputs will be directly fed into ongoing standardisation activities in CEN/TC 268 and ISO/TC 197.

#### Need

With increased interest in using hydrogen and fuel cells in medium and heavy-duty applications, the need for dedicated standards for these applications has increased. Currently the number of hydrogen-fuelled buses, trucks and trains in Europe is around 500 units, but this is expected to increase at a very high pace. At least 60,000 hydrogen-fuelled trucks are expected to be in operation by 2030 which will require a large infrastructure comprising truck-suitable hydrogen refuelling stations.

Hydrogen-powered vehicles require extremely pure hydrogen as some contaminants can reduce the performance of the fuel cell even at very low levels. Previous metrology projects have paved the way for the development of the European quality infrastructure for hydrogen conformity assessment. However, the reliability of a measurement is intrinsically linked to the representativeness and reliability of the sampling itself. Poor sampling may lead to a fleet of HD vehicles being damaged. Moreover, standardisation is required as the HD-HRS network will be shared between operators (e.g. BP, Air Liquide, MotiveFuels). Also, sampling practices should not create a source of discrepancies in quality within the emerging network.

Within ISO/TC 197/WG 33, a new standard is being developed to support hydrogen sampling at hydrogen refuelling stations. Sampling is not currently standardised, and only good practice information is available in Annex K of ISO 19880-1. The new draft ISO 19880-9 standard is focussing on sampling for passenger LD-HRS due to the lack of technical evidence and sampling systems for HD-HRS. The main barrier is the lack of sampling systems, which are adapted for heavy-duty applications. Reliable specific sampling systems for HD-HRS need to be developed for both gaseous and particulate phases (Objective 1).

New or adapted sampling approaches, for HD-HRS applications, will need to be trialled in real conditions to assess the performance of the sampling approach. Without this data and evidence, standardisation documents for HD-HRS applications cannot be progressed. This will require a standardised protocol to meaningfully demonstrate sampling system performance (Objective 2).

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An additional challenge will be to create the uncertainty budget associated with the sampling. This will be needed to assess the total uncertainty budget for the hydrogen quality assessment. This uncertainty budget will be directly linked to the representativeness of the sample collected (Objective 3).

Finally, the sampling of hydrogen at HRS is performed within an explosive atmosphere area. Therefore, there are associated safety risks. Consequently, the safe performance of hydrogen sampling needs to be considered (Objective 4).

#### Objectives

The specific objectives of the project are:

- 1. To develop three reference methods/systems based on new hardware for interfacing relevant nozzle geometries for hydrogen heavy duty applications. This includes addressing methods for both gaseous and particulate phases. In addition, method comparison with existing methods for sampling for light duty applications will be documented to demonstrate equivalence or identified bias.
- 2. To develop methodologies for the validation of sampling systems. This includes method validation, including evidence of the impact of physical parameters (e.g. pressure and flow) on sampling representativeness. Gas sampling validation includes accurate gas contamination and an assessment of the recovery yield. The system will be laboratory based for flexibility in fluid physical parameter control and gas composition.
- 3. To develop guidelines for the evaluation of the uncertainty of the sampling and for the sampling representativeness including the minimum sample size (target uncertainties of 10 %), and sample volume/gravimetric requirements by performing repeated samplings under varying conditions.
- 4. To support the standardisation of the safe heavy-duty sampling of hydrogen: including the venting of hydrogen, risk assessment and the training of stakeholders.
- 5. To contribute to the standards development work of the technical committees CEN/TC 268 and ISO/TC 197 to ensure that the outputs of the project are aligned with their needs, communicated quickly to those developing the standards and to those who should use them, and in a form that can be incorporated into the standards at the earliest opportunity.

#### Progress beyond the state of the art and results

# Methods for sampling hydrogen for quality assessment (gaseous species and particulates) at heavy-duty HRS (Objective 1)

This project will adapt existing, or develop new, sampling systems for HD applications. This is the first step that will be needed to enable the collection of a representative sample of hydrogen at these emerging stations. Several engineering companies (e.g. ENGIE, ZBT) will develop sampling systems to fill the market gap and the NMIs will ensure that the metrological aspects needed for the validation of these systems have been considered. The new sampling systems will be tested and validated leading to the development of guidance on the metrological testing and validation of systems for heavy-duty HRS sampling.

So far, two sampling systems for gaseous species have been adapted to the HD conditions by ENGIE and ZBT. A third sampling system has been designed and built, but some issues need to be addressed before it is fully functional. Key information regarding current and future specifications and operations of HD-HRS have been acquired via a questionnaire that was sent out to several stakeholders. Five completed questionnaires were received and collated. Another questionnaire was sent out to stakeholders to enable the review of LD sampling systems and what would be needed to adapt these to HD conditions. An open-access report was written, which discusses the parameters that affect the material compatibility of the sampling vessels. A general conclusion is that more studies are needed in order to better understand the effects of all of these parameters, specifically for the filling pressure and the temperature.

#### Methodologies to validate the sampling systems to ensure sample representativeness (Objective 2)

This project will develop a protocol to validate sampling systems. The first version will take advantage of all of the knowledge that has been gathered during previous projects (EMPIR projects 16ENG01 MetroHyVe and 19ENG04 MetroHyVe 2, and FCH-JU HYDRAITE). The outcome of this project will allow the consortium to



finalise the protocol using feedback from the activities conducted throughout this project. Finally, to enable the validation of all of the performance parameters of the sampling system, the project will provide a recommendation that can be used to assess the performance of sampling systems with regards to recovery in an environment where accurate gas contamination can be prepared. This will allow the consortium to establish documented evidence which proves that a given sampling method meets the requirements for its intended purpose.

The consortium published an open-access report summarising the literature and publications on existing protocols and guidelines related to the validation of the hydrogen sampling systems that are used for off-line quality control at HRS, including those developed in EMPIR JRPs 16ENG01 MetroHyVe and 19ENG04 MetroHyVe 2, and in other relevant projects. Key information, regarding the protocols used and the experiences gained during sampling, has been acquired via a questionnaire that was sent out to several stakeholders and participants. Six completed questionnaires were received and collated.

#### Guidelines for sample representativeness and measurement uncertainties arising from sampling (Objective 3)

The current practice for assessing hydrogen purity, according to ISO 14687, involves sampling. The measurement uncertainty associated with the sampling is the single most important parameter that describes the quality of the measurements and it must inevitably contribute to the uncertainty associated with the reported result. While existing guidance identifies sampling as a possible important contribution to the uncertainty of a result, procedures for estimating the resulting uncertainty are not well developed and further specific guidance will be developed in this project.

The consortium published an open access report summarising the most relevant information from the Eurachem/EUROLAB/CITAC/Nordtest Guide on measurement uncertainty arising from sampling. Two main approaches for estimating the uncertainty associated with sampling are described; the empirical approach which uses some level of replication of the whole measurement procedure to give a direct estimate of the uncertainty for the final result of the measurement, and a modelling approach which identifies all of the sources of uncertainty.

#### Good practice guide for hydrogen venting during a sampling exercise (Objective 4)

The sampling of hydrogen fuel at a HRS is an operation within an explosive atmosphere (ATEX) area involving safety risks, which include a venting step. The sampling exercise is not part of the normal procedure that occurs at a HRS. As HD-HRS operate at high flowrates and downtime has to be minimised (to reduce the impact on the refuelling of trucks), safety is a key element for the standardisation of sampling. To reduce the risk to an acceptable level, a reliable risk assessment methodology will be prepared so that appropriate control measures can be planned and required safety standards can be established.

The consortium published an open access report regarding the safety and venting requirements for the different hydrogen sampling strategies which gathers the main sampling techniques and the venting procedures that are being used in the field during a HRS. It also provides guidelines for performing safe venting after the sampling.

#### Outcomes and impact

To promote the uptake of the sampling systems that are being developed in this project, and to share insights generated throughout the project, results were shared with scientific and industrial end-users. Two presentations were made at conferences, an oral presentation and a poster at the International Conference on Measurements of Energy in Germany in September 2023 and a poster presentation at the Gas Analysis Event in January 2024. The project was introduced to the ISO/TC 197 Hydrogen technologies WG27/28 and WG33. The project was also introduced to the GERG network. One paper has been submitted to Energy Reports.

#### Outcomes for industrial and other user communities

This project's outcomes will enable fit-for-purpose hydrogen sampling services to be used by industries, testing laboratories, research organisations and other end-users. End-users will be able to rely on hydrogen purity assessments, which will in turn contribute to preventing serious damage to hydrogen-powered trucks and buses and it will secure and improve the overall European quality infrastructure for hydrogen conformity



assessment. Considering the existing fleet of 500, and a future fleet of 60000, vehicles, it is critical to ensure that hydrogen fuel will not reduce vehicle lifetime, increase the cost of ownership significantly and the availability of the service for the early adopter communities. Maintaining a high level of service will be key for the successful energy transition towards green energy and lower  $CO_2$  emissions.

The project's dissemination activities will enable the uptake of the outcomes by industrial stakeholders including HRS operators, fuel cell electric heavy duty vehicles, fleet operators, hydrogen producers, testing laboratories, research institutes and other end-users as well as standardisation committees.

The project's outcomes will contribute to lowering the detrimental impact of transport-related air pollution on the climate and health via extended implementation of hydrogen mobility.

As outlined above, it is anticipated that a major outcome of this project will be the widespread uptake and use of the sampling systems developed in the project throughout Europe and globally. Another outcome will be the increase in new services for hydrogen quality monitoring using the new solutions developed in this project. Due to the close collaboration between the participants and industrial stakeholders, the industry will be able to use the services developed in this project (new capabilities to sample hydrogen at HD-HRS) to demonstrate that the hydrogen they deliver has the required quality. Eventually, the industry will also be able to use the design of the sampling systems developed in this project to build their own sampling systems for internal use.

#### Outcomes for the metrology and scientific communities

This project will deliver protocols and guidelines to enable the metrological community to obtain an insight into the actual challenges associated with representative sampling. This will allow tailored sampling systems to be developed and validated.

The successful delivery of the project will significantly advance the scientific state-of-the-art by providing newly developed sampling systems that will be capable of collecting representative and thus reliable samples of the hydrogen delivered at the station. This will be a key tool for the hydrogen quality assessment chain. These developments will be brought to the metrological communities through workshops, webinars and other dissemination activities.

Gas metrology and commercial gas analysis laboratories will be able to use suitable sampling strategies at heavy duty refuelling stations to ensure that representative samples of hydrogen can be taken and transported to their laboratory.

NMIs having developed traceable and reliable methods for hydrogen quality assessment will be able to expand their services to the sampling of hydrogen at HRS. Whilst these new capabilities will support industry, the science community such as universities or laboratories will also benefit from the outcomes regarding the representativeness of a sample. The NMIs and DIs will provide metrological traceability from the nozzle at the HRS to the laboratory for hydrogen quality assessment as required for safe and reliable distribution of hydrogen at the HRS. This will address the demand for renewable energy and it will enable society to prepare for the energy transition.

#### Outcomes for relevant standards

The project's outcomes will provide direct input to several working groups within TC 197: WG 24, WG 29, WG 27, WG 28 and WG3 3. This project is of most relevance for ISO/TC 197/WG 33 "Sampling for fuel quality analysis" as it will provide direct input on the results of the project to be considered for use in the development of the first revision of ISO 19880-9. This project will also liaise with the standards developing organisations that are responsible for EN 17124, EN 17127, ISO 19880-8, ISO 19880-1, ISO21087 and ISO 14687.

This project will also provide input to the activities of other technical committees, such as BIPM WGFF, EURAMET/Metchem SC-GAS, and national working groups and mirror committees. In addition, the project's outputs will be disseminated to the European Metrology Network (EMN) for Energy Gases as several participants are active members of this EMN. Sampling representativeness and the evaluation of uncertainties, due to sampling, will also be important for gases other than hydrogen and some of the outcomes (for example the guidelines on sample representativeness) of this project will be used in other fields (e.g. biomethane).

#### Longer-term economic, social and environmental impacts

In addition to supporting long-term climate change targets, hydrogen buses and heavy-duty vehicles will improve air quality and provide health benefits as only water is emitted from the tailpipes; this will prevent people from breathing in carbon dioxide and carbon monoxide emissions and it will reduce the frequency of



pollution peaks. As more heavy-duty HRS are built, the number of Fuel Cell Electrical Vehicles (FCEVs) will increase. Then they will become more visible to society. However, as for any new market, public safety needs to be guaranteed and acceptance needs to be obtained. These can only be achieved by minimising operational problems, which will in turn be achieved by confidence and assurance that the hydrogen fuel has the required quality. Performing representative sampling is of paramount importance for the quality assessment. As enhanced acceptance of FCEVs is achieved, these vehicles will be more and more regarded as normal road vehicles rather than as a prototype or a small fleet. Societal acceptance of hydrogen fuel is essential to achieve the energy transition towards a greener society. As mentioned in the strategic agenda from the EMN for Energy Gases, it is clear that the electricity grid alone cannot support user energy demands. Moreover, diversification by the development of hydrogen technology would allow society to absorb a shock in a major energy input.

### List of publications

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

Project start date and duration:		1 June 2023, 36 months				
Coordinator: Karine Arrhenius, RISE	Tel: +46 70 567 5728		E-mail: karine.arrhenius@ri.se			
Project website address: https://www.ri.se/en/methytrucks						
Chief Stakeholder Organisation: ITM Pow	ver Plc	Chief Stakeholder Contact: Nick Hart				
Internal Beneficiaries:	External Beneficiaries:		Unfunded Beneficiaries:			
1. RISE, Sweden	6. ENGIE, France		-			
2. Cesame, France	7. GERG, Belgium					
3. CMI, Czechia	8. SINTEF, Norv	vay				
4. PTB, Germany	PTB, Germany 9. ZBT, German					
5. VSL, Netherlands						
Associated Partners: 10. NPL, UK						