Physikalisch-Technische Bundesanstalt
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Summary of "QI for GH2" findings from Desk Research Study Report

IRENA's World Energy Transitions Outlook states that a combination of technologies is needed to keep the world on a 1.5°C climate pathway. By supporting the production and use of renewable-based hydrogen it is possible to advance the deep decarbonisation of the energy sector. Renewable-based hydrogen is hydrogen produced from renewable electricity and it is commonly known as green hydrogen (GH2). GH2 links renewable electricity with a range of end-use applications acting as a complement of electrification, bioenergy, and direct renewable energy use (IRENA, 2023a).

The use of GH2 as a low-carbon vector is now recognised as a key element to address the decarbonisation of large energy use sectors, such as industry and transport. As a result, an increasing number of countries across the globe are defining ambitious plans and strategies for the production, trade, and use of GH2.

The production and trade of GH2 will entail the development of sophisticated technology and infrastructure. Furthermore, it is also imperative that the attributes - e.g., safety, performance, sustainability- of the GH2 being produced and traded conforms with international, regional, and national market requirements. To this extent, it is equally important that countries invest in developing the complementary and required quality infrastructure (QI) to assure those attributes along the GH2 value chain, thus creating the basis for the sustainable development of the sector. QI will be an important pillar that will be required for countries to ensure that they can successfully implement their national and international GH2 strategies.

IRENA with support from PTB and BMZ are currently implementing a project with the main goal of developing a tangible roadmap that can be used by global policymakers and stakeholders on the required steps to be taken to ensure a robust QI system for GH2 can be established. To start this process, IRENA has prepared this report synthesising the desk research undertaken on the quality infrastructure required to support the sustainable development of the GH2 value chain

Some of the key findings of the desk research study for each elements of the QI are listed below:

Standardization:

- There are plenty of international standards that focus on the production of hydrogen however, new standardisation is especially needed in the **areas of distribution, storage, and transfer of hydrogen to the end user**. Furthermore, liquid hydrogen and derivates such as synthetic fuels are currently not sufficiently covered by international standards.

- There is also a need to **develop recognized and robust Life Cycle Assessments (LCA), to estimate the emissions** caused in the hydrogen value chain (e.g. fugitive emissions) and other unintended environmental impacts.

Testing:

- In advanced quality infrastructure systems, the available testing services mostly cover the current demand of the hydrogen industry for the assurance of quality and safety. **Services for hydrogen generators; purity of gas; efficient electrolyzers, and cryogenic components are still lacking these ecosystems**.

- In medium and basic quality infrastructure systems, the development of tests for e**nvironmental conditions; electricity metering; quality of renewable energy components; and distribution infrastructure reliability** is highly necessary.

Metrology:

- In developed countries, advanced national metrology institutes **already offer many services that are relevant for the green hydrogen sector**. Such services typically exist for quantities such as pressure, temperature, density, or efficiency. The measurement of **very high pressures** (with small measurement uncertainties) and **high flow rates** (and of different gas mixtures) still pose challenges to be addressed.

- In developing countries, the priority for less advanced national metrology institutes should be the **development of basic services in magnitudes** also required by other sectors (for example, temperature and pressure).

Certification:

- The existing certification schemes relevant for the green hydrogen value chain are based on different private, national, or international criteria and standards. There is an important need for the **development of unified criteria on the quality, safety, and sustainability** in international standards, as basis for internationally recognized certification and inspection schemes.

- In developing markets, **product, process, and personnel certification required** to assure the quality of renewable energy components and plant are **not available. Inspection capabilities** for commissioning and decommissioning **are not fully developed**.

Accreditation:

- Advanced quality infrastructure systems normally have internationally recognized accreditation bodies, but such organizations **must expand their accreditation scope** to fulfill the newly developing requirements

- In less developed quality infrastructure systems, often the accreditation bodies **are not internationally recognized.** Also, additionally to the aspects mentioned above, accreditation requirements in the **renewable energy sector are often lacking.**

Transversal considerations:

- **Regulations** are required to guarantee safety along the green hydrogen value chain, to protect the customer and prevent possible negative environmental effects. To facilitate international trade with green hydrogen and prevent technical barriers to trade, it is important that such regulations apply internationally **accepted and harmonized criteria** where possible, especially by referring to existing **international standards.**

Summary of Survey Results Responses

The summary of findings from the survey are as follows:

Standards:

Kindly refer to list below with regards to the key **standards** that are essential for the green hydrogen value chain as noted by the respondents.

The survey responses on standards clearly show that there are many standards for the design; installation/infrastructure; and O&M however, not many responses were given for safety; testing; and inspection facets.

Certification:

It was noted that the most appropriate certification schemes of hydrogen equipment are being developed by IECEx conformity assessment services that now include both electrical and mechanical (pressure gas) components. However, a hydrogen certification system as a product would still need to be developed. It was suggested that the future ISO/TS 19870 for the Methodology of GHG footprint assessment being developed by ISO/TC 197/SC 1 could serve as a basis for this endeavour.

General thoughts for the required certifications of a H2 Production Plant in the EU were provided as a reference example:

- It was noted these plants would need to comply to Best Available Techniques (BAT) Reference Documents appointed by the EU Commission.
- H2 production will have to comply with at least two reference documents: the Common Wastewater and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW) and Common Waste Gas Treatment in the Chemical Sector (WGC). Both reference documents require that an environmental management system be set up.
- Many of the existing companies complying with the environmental management system requirement chose to acquire an ISO 14001 Environmental Management Systems certification.
- Companies storing more than 5 tons of hydrogen would have to comply with the Seveso Directive. Storage of more than 50 tons of hydrogen will require a company to set up a risk management system.
- If the company already has an ISO 9001 or ISO 14001 system it is possible to use these management systems. It is also possible to set up an actual risk management system (ISO 31000).
- ISO 9001 Quality Management System is also highly relevant.

Some of the most recognized hydrogen certification schemes in the market include (but not limited to):

- EU's CertifHy;
- UK's H2 Certification Scheme based on Low Carbon Hydrogen Standard;
- Green Hydrogen Organisation Green Hydrogen Standard;
- TÜV SÜD CMS 70

A key challenge to be addressed is the lack of consensus on the correct approach for GHG calculation as several of them reference common standards such as ISO 14067:2018 and ISO 14064 but, yield different results. Harmonization of these certifications where applicable will be crucial.

Metrology:

Some of the standards especially relevant in the area of metrology for the green hydrogen sector that should be considered are as follows:

- OIML R137 – Gas Meters
- OIML R139 - Compressed Gaseous Fuel Measuring Systems for Vehicles
- OIML R140 – Measuring Systems for Gaseous Fuels
- Many standards of ISO/TC193 and ISO/TC193/SC1 (a task group is creating an inventory, which is due by June 2023)
- ISO 14687 - Hydrogen fuel quality
- ISO 21087 - Analytical methods for hydrogen fuel

For the calibration of RE components that produce electricity, it was noted that metrology for energy rating of PV Modules; and Wind turbines (efficiency of entire systems – from drive chain to inverter/elect. output) are available in industrialized economies but, not prevalent in developing countries. It was also stated that metrological services for current, voltage and frequency can be programmed through the realisation of net profiles caused by different regenerative energy generation paths

For the metrological services for RE related instruments (wind speed, irradiation etc.) it was noted these services are lacking across many countries especially systems for monitoring of long term RE performance on site and for site assessment. Providing metrological services to Pyranometers, pyrheliometers, spectroradiometers, imaging-based metering of irradiance, anemometers for wind vector (LIDAR) will be crucial.

For process parameters for H2 production it was noted that metrology covering high resolution measurement methods and reference standards for electrolysers covering the following aspects are required:

- Inline sensors that monitor quality of hydrogen and specifically the capability of measuring the separation of hydrogen from other by-products (cross-over) and impurities
- measurement of quantity of hydrogen produced to monitor the operational efficiency and the delivered amount to the user (trade)
- hydrogen leak detection (for safety) and hydrogen release (for emissions)
- Cell and stack material degradation at electrolysers (electrolyte and materials),
- Validated digital and modelling solutions to monitor cell/stack degradation.

For H2 purity and chemical composition it was stated that metrology covering high resolution measurement methods and measurement standards are required for the following:

- calibration and validation of online and inline sensing technologies that measure hydrogen (gas, liquified, LOHC, etc.) purity. These technologies are at the moment not specific, not sensitive, and not stable in hydrogen environments.
- hydrogen concentration when mixed in other energy fuels.
- hydrogen odorization

On calorific services it was noted that the accurate determination of calorific value and modelling the uncertainty of the calorific value are particularly relevant when hydrogen is mixed with other energy fuels (Natural gas and biomethane).

On flowrate services it was stated that there is a critical role of metrology to develop reference standards for hydrogen to enable certification, regulation, fair trade among countries and billing (consumer protection)

Metrology was noted to have a key role in the modelling of green hydrogen systems. The complex mix of RE entering the energy market, their fluctuations, and the need to allow fast conversions (P2G and G2P) demands development of accurate modelling and digitalisation of the entire hydrogen supply chain – the development of relevant metrological services can support these endeavours.

Testing:

With regards to **testing**, it was noted that in industrialized economies there is a lack of services for large scale, high pressure and cryogenic components, services in the training of workers to handle new safety considerations, and calibration services and traceability to SI units. It was also noted that testing protocols for pressure ranges up to 100 bar are getting some focus, however, there is still a lack of test infrastructure for wide range (quantity measurement H2). Testing for some specific applications addressed like dispensers or domestic meters are available in industrialized economies.

These aforementioned limitations also exist for developing countries but, there is a significant need to address the knowledge and capacity building gaps for relevant stakeholders to take advantage of the existing QI elements present in their country or region.

List of standards identified as especially relevant for the green hydrogen sector

According to the responses received from IRENA's survey, the following standards are especially important for the development of the green hydrogen sector:

Design:

- ISO 22734-1 Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications — Part 1: General requirements, test protocols and safety requirements.
- ISO TR 22734-2 Hydrogen generators using water electrolysis — Part 2: Testing guidance for performing electricity grid service.
- ISO 17268 Gaseous hydrogen land vehicle refuelling connection devices ISO 19884 Gaseous hydrogen — Cylinders and tubes for stationary storage.
- ISO 16111 Transportable gas storage devices — Hydrogen absorbed in reversible metal hydride.
- ISO 19880-1 Gaseous hydrogen — Fuelling stations — Part 1: General requirements
- ISO 19880-3 Gaseous hydrogen — Fuelling stations — Part 3: Valves
- ISO 19880-5 Gaseous hydrogen — Fuelling stations — Part 5: Dispenser hoses and hose assemblies ISO 19880-6 Gaseous hydrogen — Fuelling stations — Part 6: Fittings
- ISO 19880-7 Gaseous hydrogen — Fuelling stations — Part 7: O-rings

- ISO 19880-8:2019 Gaseous hydrogen — Fuelling stations — Part 8: Fuel quality control
- ISO/CD 19880-9 Gaseous hydrogen — Fuelling stations — Part 9: Sampling for fuel quality analysis
- IEC 60079-10 series on Area Classification
- IEC 60079-14 Installation
- IEC 60079-17 Inspection
- IEC 60079-19 Repair and Overhaul of Equipment
- ISO/TR 15916, Basic Safety considerations for safety of hydrogen systems.
- ISO 16110 series Hydrogen generators
- ISO 17268 - Gaseous hydrogen land vehicle refuelling connection devices.
- ISO 19880 series- Gaseous hydrogen — Fuelling stations
- ISO 19882 Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers
- ISO 26142 Hydrogen detection apparatus — Stationary applications
- IECEx Certification System via IECEx OD 290 Standardised approach to Testing and Certification of Hydrogen dispensing Equipment and Systems

Installation and infrastructure:

- ISO 19880-x series – Gaseous hydrogen — Fuelling stations
- IEC 60079-x series - General requirements for construction, testing and marking of Ex Equipment and Ex Components intended for use in explosive atmospheres.
- ISO 22734-1 Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications — Part 1: General requirements, test protocols and safety requirements.
- ISO TR 22734-2 Hydrogen generators using water electrolysis — Part 2: Testing guidance for performing electricity grid service.
- ISO 19884 Gaseous hydrogen — Cylinders and tubes for stationary storage
- ISO 16111 Transportable gas storage devices — Hydrogen absorbed in reversible metal hydride ISO.
- CEN Standard EN16325
- ISO/TR 15916, Basic Safety considerations for safety of hydrogen systems.
- ISO 16110 series Hydrogen generators
- ISO 17268 - Gaseous hydrogen land vehicle refuelling connection devices.
- ISO 26142 Hydrogen detection apparatus — Stationary applications
- IEC 80069

Operation and maintenance:

- ISO 19881 Gaseous hydrogen — Land vehicle fuel containers
- ISO 19882 Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers
- ISO 19885-1 Gaseous hydrogen — Fuelling protocols for hydrogen-fuelled vehicles — Part 1: Design and development process for fuelling protocols
- ISO 19885-2 Gaseous hydrogen — Fuelling protocols for hydrogen-fuelled vehicles — Part 2: Definition of communications between the vehicle and dispenser control systems

- ISO 19885-3 Gaseous hydrogen — Fuelling protocols for hydrogen-fuelled vehicles — Part 3: High flow hydrogen fuelling protocols for heavy duty road vehicles.
- ISO 19887 Gaseous Hydrogen — Fuel system components for hydrogen fuelled vehicles.
- ISO 21087:2019 - Gas analysis — Analytical methods for hydrogen fuel — Proton exchange membrane (PEM) fuel cell applications for road vehicles
- IEC 60079-10 series – Area classification (needs to form part of routine inspection plan)
- IEC 60079-17 – Inspection
- IEC 60079-19 Repair and Overhaul
- IEC 62990 series – Gas detectors
- IEC 60079-29-2 Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen.
- IEC 60079-29-3 Gas detectors - Guidance on functional safety of fixed gas detection systems
- IEC/IEEE 60079-30-1 Electrical resistance trace heating - Application guide for design, installation, and maintenance
- IEC 60079-32-1 Electrostatic hazards, guidance
- IEC 60079-43 Equipment in adverse service conditions
- ISO 26142 Hydrogen detection apparatus — Stationary applications
- IEC 62282 series, Fuel cell technologies (currently 29 standards in the series) via IEC TC 105

Safety:

- ISO/TR 19516
- ISO 26142
- IEC 60079-29 series
- ISO 16110-1 Hydrogen generators using fuel processing technologies — Part 1: Safety
- ISO/TR 15916 - Basic considerations for the safety of hydrogen systems
- ISO/IEC 80079