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Braunschweig und Berlin
National Metrology Institute

INTERNATIONAL COOPERATION

The Quality Infrastructure System for Green Hydrogen

Creating the Basis for the Development of the Emerging Sector

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german cooperation
DEUTSCHE ZUSAMMENARBEIT

On behalf of

Federal Ministry
for Economic Cooperation
and Development

On behalf of the Federal Government of Germany, the Physikalisch-Technische Bundesanstalt promotes the improvement of the framework conditions for economic, social and environmentally friendly action and thus supports the development of quality infrastructure.

Disclaimer:
The views and opinions expressed in this study are those of the author and do not necessarily reflect the official position of PTB.

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Abstract

Green hydrogen plays a crucial role in the net zero scenario because it can store renewable energy for use in sectors that are difficult to electrify, require high energy density, or are remote from power grids. Despite the prioritization awarded to green hydrogen on political and private sector agendas worldwide, actual production and demand are still far off the track to net zero and significant bottlenecks remain.

This compact explains how quality infrastructure[1] creates the basis for the development of the sector by reducing existing risks and supporting the achievement of the intended positive sustainability impacts of investments. It further discusses the existing gaps between the demand, both current and projected, and supply of quality infrastructure services. Based on PTB's experience, key learnings are defined on how policymakers and sector stakeholders can support quality infrastructure to effectively foster the development of the green hydrogen industry.

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1 Quality infrastructure is *the system comprising the organizations (public and private) together with the policies, relevant legal and regulatory framework, and practices needed to support and enhance the quality, safety and environmental soundness of goods, services and processes.* (INetQI, 2023).

1. Green Hydrogen: Key in the Transition to a Carbon-free Economy

Meeting the ever increasing demand for energy while limiting the global rise in temperature is one of the biggest challenges facing our society and requires a complete, or at least deep, decarbonization of our economy. Although green hydrogen[2], produced with renewable energy sources, makes a relatively small contribution to overall reductions in CO_2 emissions compared to other mitigation measures, it does play a crucial role in the net zero scenario[3]. This is because it can store energy for use in sectors that are difficult to electrify, require high energy density, or are remote from power grids. Examples of such sectors include aviation, maritime shipping, and industrial processes requiring high temperatures – for example in the cement and steel sectors.

This explains the high expectations placed in the development of the green hydrogen sector and its prioritization on political and private sector agendas. For instance, affordable renewable and low carbon hydrogen by 2030 is one of the *breakthroughs* adopted in the Breakthrough Agenda launched in 2021 in Glasgow at the Conference of the Parties (COP26)[4]. Green hydrogen also played an important role at the COP27 held in 2022 in Sharm El-Sheikh, where the EU, the World Bank and several national governments announced related plans and agreements.

That same year, the G7[5] launched a Hydrogen Action Pact. On the national level, 26 governments have committed to adopting hydrogen as a clean energy vector in their energy system (IEA, 2022a). A national hydrogen strategy for Germany was published in 2020 and recently updated (BMWi 2020; BMWK 2023). The support of the German Federal Ministry for Economic Cooperation and Development (BMZ) in the areas of renewable energy, green hydrogen and P2X[6] is contributing to the global energy transition while at the same time making local economies less dependent on fossil fuels and fostering a sustainable economic transformation in partner countries.[7] In the private sector, many multinational companies have published objectives and action plans to become carbon neutral. Under such plans, private investment in green hydrogen is increasing.

Despite the strategies, policies and initiatives described above, both production and demand for green hydrogen are far off the track to a net zero scenario. As shown in *figure 1* below, global hydrogen demand totalled 94 million tonnes (Mt) in 2021. This demand was mainly covered by hydrogen production based on fossil fuel technologies (around 77 Mt). Over one sixth of the total consisted of by-products (around 16.5 Mt), mainly from the petrochemical industry. Less than 1 % (0.6 Mt) of global production was based on low-emission technologies[8].

2 A colour code is broadly used to differentiate between methods of hydrogen production. *Grey hydrogen* is produced using fossil fuels, mostly methane or coal. *Blue hydrogen* uses the same fossil energy sources but applies post-combustion carbon capture and storage. *Turquoise hydrogen* also uses natural gas as the energy source, but through pyrolysis the carbon is transformed back into solid carbon, which is easier to store. *Green hydrogen* can be seen as the most suitable option in a decarbonized economy, as it does not produce CO_2 emissions as a by-product. It is mainly produced by means of water electrolysis using renewable energy sources (IRENA, 2020).

3 The net zero scenario refers to the objective of reducing global carbon dioxide (CO_2) emissions to net zero by 2050 to be consistent with efforts to limit the long-term increase in average global temperatures to 1.5 °C (IEA, 2021).

4 COP: Conference of the Parties between countries that signed the United Nations Framework Convention on Climate Change.

5 The Group of Seven (G7) is an intergovernmental political forum consisting of Canada, France, Germany, Italy, Japan, the United Kingdom and the United States. The European Union (EU) is a *non-enumerated member*.

6 The term P2X (Power-to-X) refers to various pathways of electricity conversion, energy storage, and reconversion that use surplus electric power, typically during periods where fluctuating renewable energy generation exceeds load (Lund et.al., 2015).

7 To this end, BMZ supports partner countries in market ramp-up and the establishment of local, competitive value chains.

8 According to the definition of the International Energy Agency, low-emission hydrogen includes hydrogen produced via electrolysis where the electricity is generated from a low-emission source (renewables or nuclear), biomass or fossil fuels with CCUS (carbon capture, utilization and storage) (IEA, 2022b).

Hydrogen production is currently responsible for more than 900 Mt of CO_2 emissions per year (IEA 2022a; IEA 2022 b), or around 2 % of global CO_2 emissions. This amount is equivalent to the emissions of approximately 219 coal-fired power plants, or to the emissions avoided by 222 000 wind turbines in one year (EPA, 2022).

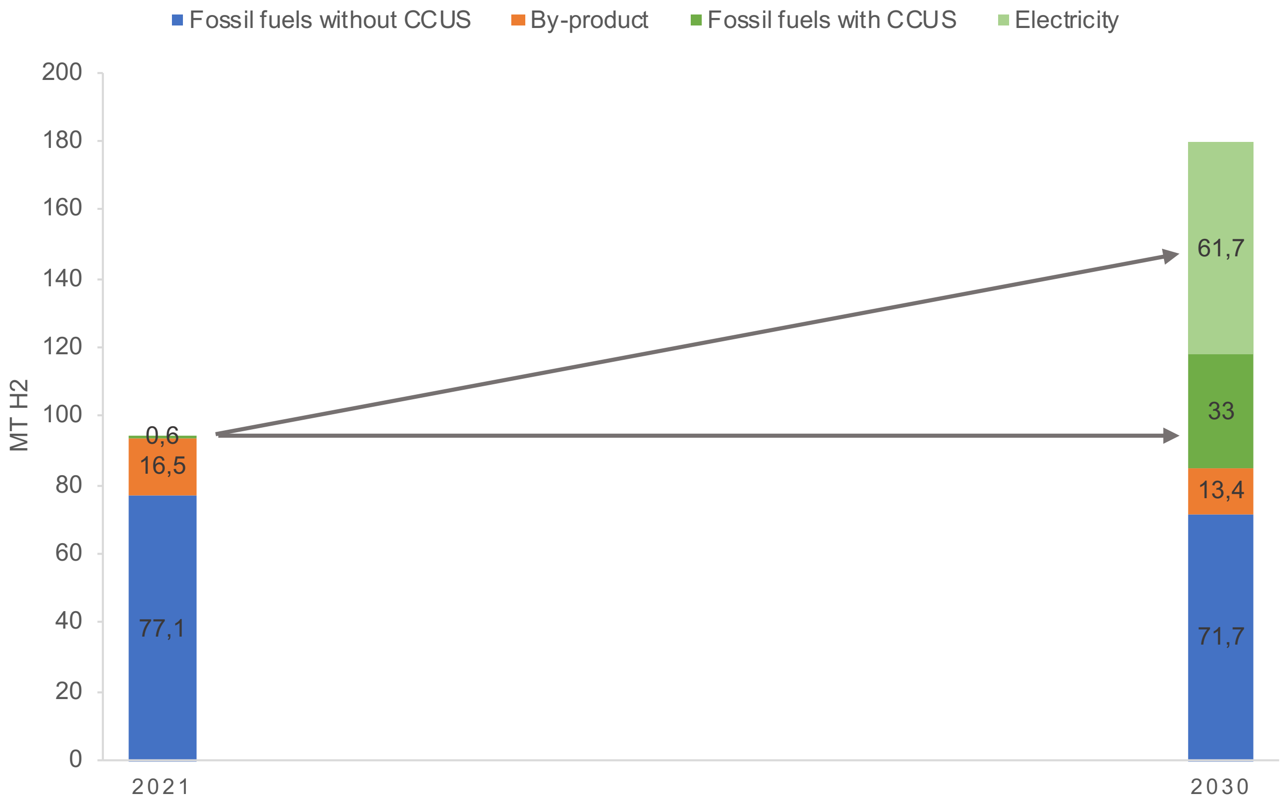

Figure 1: Global hydrogen production by technology in the net zero scenario, 2021–2030 (IEA, 2022)

According to the *Roadmap for the Global Energy Sector* developed by the International Energy Agency (IEA), a net zero scenario foresees more than half of global hydrogen production (95 Mt) being based on low-emission technologies by 2030. Around two-thirds of this production would be based on electrolysis (62 Mt) and the remaining third produced from fossil fuels with carbon capture, utilization and storage (CCUS) (IEA 2021; IEA 2022a), as shown in *figure 1*.

2. The Green Hydrogen Value Chain and its Challenges

From the generation to the use of renewable energy
As shown in *Figure 2* below, green hydrogen is produced using renewable energy such as wind, solar or hydro to power the process of splitting water in electrolyzers.

Regardless of how it is produced, hydrogen can be used directly as a gas or it can be liquified (LH_2) or transformed into various derivatives. To facilitate transport and storage, hydrogen can be converted into chemicals such as ammonia or, using production plants developed over the past years in some countries, liquid organic hydrogen carriers (LOHCs). Moreover, the conversion of hydrogen into methane facilitates transport and storage, as it enables the use of the existing natural gas infrastructure. The same is achieved by mixing hydrogen in low percentages with natural gas.

The demand for hydrogen remains concentrated in traditional applications. The refining sector accounted for around 40 million tonnes (Mt) of global demand and ammonia (mostly for nitrogen fertilizers) for approximately 34 Mt of the total 94 Mt in 2021. The use of hydrogen in new applications, such as transport, power, buildings and high-temperature heat in industry, today only represents 0.04 % of global demand (IEA 2022a; IRENA 2020).

Key challenges in the development of the sector
Several challenges must be considered with respect to the development of green hydrogen as a widely used energy carrier. These include:

- **Renewable energies:** The production of green energy must be substantially and quickly increased to create a surplus – i.e., an amount beyond existing local energy demand – that can be used to produce hydrogen.
- **Infrastructure:** A massive expansion of the existing hydrogen infrastructure is required. This is not limited to the installation of electrolyzers. New infrastructure is also needed for the direct storage, transmission and use of hydrogen. The currently high share of derivatives lowers the efficiency of the hydrogen value chain and in some cases leads to negative environmental impacts.
- **New applications:** To contribute to the decarbonization of heavy industry and long-distance transport, a step-change in the use of green hydrogen in new applications is required.
- **Trade:** In a net zero scenario, green hydrogen is produced in countries with abundant renewable energy sources, especially in Africa and Latin America, and exported to countries with high energy demand in sectors that are difficult to electrify. Internationally recognized criteria and quality assurance mechanisms are required to facilitate trade and prevent technical barriers to trade (TBTs) as well as potential *greenwashing* and unintended negative sustainability impacts (for example, high CO_2 emissions during transport).

- **Just transition:** On the path towards climate neutrality, the emergence of new dependencies for the exporting countries must be avoided. The development of the green hydrogen sector in emerging and developing countries must benefit the local economy, foster sustainable progress and the creation of decent jobs, and improve access to renewable energies, contributing to Sustainable Development Goal 7: *Affordable and Clean Energy* (BMZ 2022; BMWi 2020). Also, potentially negative social and ecological effects must be systematically considered to ensure that the green hydrogen sector contributes to sustainable development in emerging and developing countries. For example, land use conflicts, increased water scarcity or negative biodiversity impacts caused by renewable energy or hydrogen plants must be prevented (Villagrasa, 2022).
- **Finance:** The global development of the green hydrogen sector requires enormous investments. The professional services firm Deloitte estimates a cumulative global investment need of US$ 9.4 trillion by 2050 in the hydrogen value chain, of which US$ 3.1 trillion are required in developing economies (see *figure 2*). These amounts seem more manageable if they are put into relation: US$ 9.4 trillion over a 25-year period corresponds to 23 times the global investment in the production of oil and gas in the year 2022 (Deloitte, 2023; IEA, 2022c).

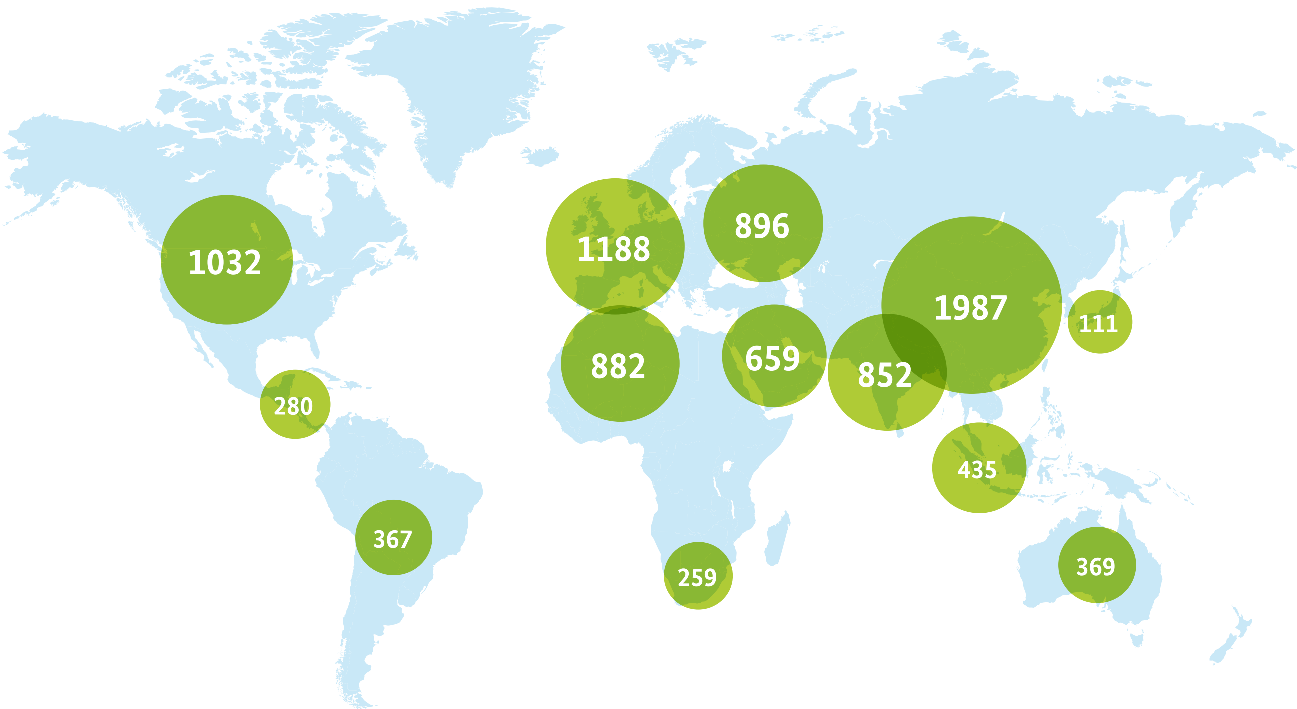

Figure 2: Cumulative investments in the green and blue hydrogen supply chain (US$ billion), 2050 (based on Deloitte, 2023)[9]

9 The estimation includes investments in *green* and *blue* hydrogen (see definitions above).

In light of the experience gained in the development of relatively new technologies such as photovoltaic, the need for addressing these challenges is clear, and the necessary foundations must be laid today if we are to establish the green hydrogen sector as a significant element of the net zero scenario. Clear public and private priorities as well as massive investment will be needed to achieve this objective. The photovoltaic sector took approximately three decades to develop a relatively mature technology with the economies of scale needed to reduce generation prices to economically viable levels without public subsidies.

The next section explores how quality infrastructure helps lay the foundations for, and overcome existing bottlenecks to, the development of the green hydrogen sector, securing its positive reputation and safeguarding investment.

3. Quality Infrastructure: Creating the Basis for the Development of the Emerging Green Hydrogen Sector

Quality infrastructure is *the system comprising the organizations (public and private) together with the policies, relevant legal and regulatory framework, and practices needed to support and enhance the quality, safety and environmental soundness of goods, services and processes.* It relies on the components *metrology, standardization, accreditation, conformity assessment, and market surveillance.* (INetQI, 2023). These components and how they relate to one another are shown in *figure 3*.

Quality infrastructure creates an important technical basis for the development of the green hydrogen sector. It helps to reduce safety, financial and reputational risks in the sector, while supporting the achievement of the intended positive sustainability impacts of investment.

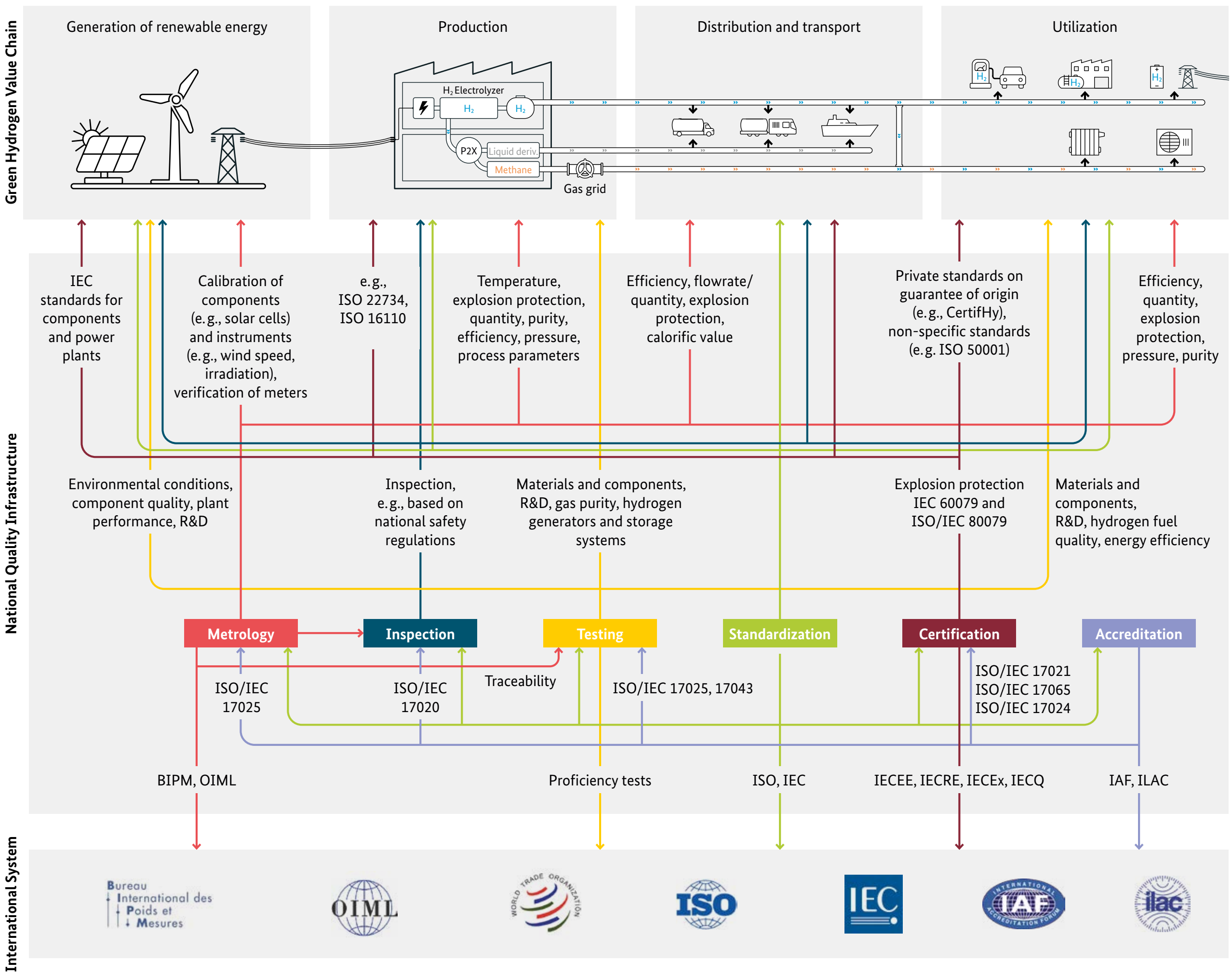

Figure 3: Overview of the green hydrogen value chain and the quality infrastructure required (© Physikalisch-Technische Bundesanstalt, International Cooperation)

The main contributions made by quality infrastructure can be grouped into the following areas:

Safety

Guaranteeing safety along the entire value chain is crucial for the expansion of the green hydrogen sector. There are specific risks along the value chain that must be continuously reduced. As hydrogen is an odourless and colourless gas, detectors are essential to identify possible leaks or spills early on, for instance in hydrogen fuelling stations or pipelines. Due to hydrogen's low volumetric energy density, high pressure is required for transport and storage. This imposes challenges, especially on the transport sector and on new vehicle technologies, such as fuel-cell trucks and – even more so – hydrogen powered aircraft. Additionally, the gas damages certain materials (*hydrogen embrittlement*), so R&D on appropriate infrastructure and close monitoring of possible material fatigue are fundamental.

Quality infrastructure services constitute the basis for effective safety assurance in the sector. Technical regulations and standards establish the common safety criteria to be fulfilled along all parts of the green hydrogen value chain. Testing provides crucial information on the safety of the materials and infrastructure used. It supports the monitoring of the systems, for example, to detect possible leakage. Metrology is required to increase measurement precision and establish traceability, for example of testing services, enabling reliable inspection and certification of safety standards. Reliable measurements, for example of pressures and temperatures in production, storage, transport and use, are also crucial to assure safe operations of the developing sector.

Quality and sustainability

To prevent reputational risks and attract investment as well as policy support, the green hydrogen sector must meet commonly accepted high-quality and sustainability criteria[10] across the involved industries and countries. Such criteria are established in standards, for example on the *guarantee of origin*, which assures that the green hydrogen was produced solely with renewable energy and that greenhouse gas emissions along the value chain are kept to a minimum. Testing and certification by accredited bodies support the international recognition of certificates, creating the basis for international trade with green hydrogen. Metrology services are required to control key quality parameters, for example gas purity in the production process.

Efficiency and innovation

Efficiency in the generation of renewable energy and its conversion into green hydrogen must be continuously improved to make best use of the available resources. Substantial innovations are required to expand the sector and important engineering challenges exist, for example, in the direct distribution of hydrogen to the end user and in increasing the efficiency of electrolyzers.

Quality infrastructure contributes to both efficiency and innovation, among other things by providing reliable testing and exact calibration services for R&D programmes or by establishing commonly recognized standards for efficient distribution. A functional quality infrastructure fosters trust in the new technology – a key success factor for its further development and growth.

10 Germany's National Hydrogen Council defined the following sustainability criteria for hydrogen projects: certified CO_2 footprint along the entire value chain; overall reduction of CO_2 emissions in the atmosphere; impact assessments; reduction of energy poverty; resolution of conflicts on land use; avoidance of water conflicts, water supply must not be jeopardized (Nationaler Wasserstoffrat, 2021).

4. Quality Infrastructure Development Required

The hydrogen sector's demand for quality infrastructure services is nothing new. The production, distribution and utilization of hydrogen have been backed up by quality infrastructure for many years. The same applies to natural gas and renewable energy, where sector developments were accompanied by a continuous improvement in services over the past decades.

However, this demand for services is increasing as more and more green hydrogen is produced, distributed and consumed. Establishing green hydrogen as a relevant part of the low-carbon economy requires additional and improved quality infrastructure services. This also applies to the necessary increase in renewable energy generation, for which the availability and application of state-of-the-art quality infrastructure services are now more important than ever.

Many of the newly demanded services are specific to the green hydrogen sector, where increased safety, quality and sustainability requirements must be met. But other, more generic services are also frequently lacking in developing economies, where the main potential for green hydrogen production exists.

Together, this leads to critical gaps between the current and projected demand for quality infrastructure services. These gaps can be summarized as follows:

Metrology

Advanced national metrology institutes (NMIs) already offer many services that are relevant for the green hydrogen sector. Such services typically exist for quantities such as pressure, temperature and density, or when assessing the efficiency. But certain metrological services that are specific to green hydrogen are currently only offered by a few NMIs worldwide. Such services include the measurement of very high pressures with small measurement uncertainties. These measurements are required for tests on equipment durability and the detection of leaks during the generation, distribution and storage of hydrogen.

The same applies to the determination of the hydrogen gas quantity and gas flow required for gas meters. Calibrated gas meters are important for the correct billing of the end user. Flow measurement with very high accuracy is also required for exact monitoring during all steps of the value chain. It creates the basis for custody transfer, where hydrogen is transferred between two parties. Furthermore, measurements of the chemical composition, the modelling of entire green hydrogen systems, and the validation of procedures to determine the calorific value – especially important if hydrogen is mixed with natural gas – are currently only offered by the most advanced NMIs (PTB, 2021).

In this context, measurement standards and metrology services remain to be developed by more NMIs to fulfil the most important demands of the green hydrogen sector. This applies especially to NMIs in developing economies, where priority should be given to the development of basic services in magnitudes also required by other sectors (for example, temperature and pressure).

However, improved and additional NMI services only constitute the very top of the metrology hierarchy. High exactitude is required and the relation to specified reference standards (*traceability*) must also be established along the entire value chain in order to generate the benefits described. This requires a coordinated approach involving the different levels of the metrology system, including secondary and industry calibration laboratories. An example is seen in the hydrogen sensors that can be used for remote sensing and the early detection of leaks. The information generated by these sensors is only reliable if they are correctly installed and calibrated by laboratories providing exact measurements that are traceable to national and international standards.

Standardization

A lack of standards along the green hydrogen value chain currently constitutes a major obstacle to the development of the sector. New standardization is especially needed in the areas of hydrogen distribution, storage and transfer to the end user. Also not covered by international standards are liquid hydrogen and derivatives such as synthetic fuels. As material and equipment must tolerate higher hydrogen concentrations to enable direct storage and distribution, related requirements must be defined in new or adapted standards.

In light of this demand for standardization, several technical committees (TCs) of the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) are working on new and updated standards relevant for the hydrogen sector. Such TCs include IEC TC 105 *Fuel cell technologies*, IEC TC 31 *Equipment for explosive atmospheres* and ISO/TC 197 *Hydrogen technologies*.

The development of new standards by these international standardization organizations takes time – a typical timeline for a new standard is three years. In order to close the standardization gaps quickly, various private and public standard setters as well as NGOs have over the past years developed their own standards for the sector. This has led to important progress in the definition of well-defined criteria by organizations such as CertifHy and the Green Hydrogen Organization, but also to a lack of international recognition and, in many cases, to duplication.

Areas still requiring internationally recognized criteria include life cycle assessments (LCAs) for estimating the emissions released in the hydrogen value chain (e.g., fugitive emissions) and other unintended environmental impacts. Another important area is the *guarantee of origin* required to differentiate green hydrogen from other hydrogen types.

To establish commonly accepted criteria for international trade with green hydrogen, a harmonization of requirements is necessary. Such requirements should be defined in standards developed by internationally recognized organizations that involve the relevant stakeholders. In particular, the participation of developing and emerging economies in the relevant technical committees must be fostered, as they are currently largely underrepresented.

Testing

The services provided by public and private testing laboratories have supported safe operations in the hydrogen industry over the past decades. An example of such services is the testing of tanks, which must be robust to allow safe and efficient storage. Standards and regulations define very stringent requirements for these tanks and their components, which are therefore subject to a wide range of tests under extreme conditions.

As a result of the expansion of the green hydrogen sector, new tests are needed, and the requirements are becoming more demanding. For example, the quality of hydrogen must be tested at refuelling stations (HRSs), as fuel cell vehicles in particular are very sensitive to impurities. In addition, research and development programmes have, for instance, increased their testing specifications to support the development of highly efficient electrolyzers or to establish reliable remote sensing systems for storage and distribution.

Certification and inspection

International trade with green hydrogen requires not only internationally recognized standards but also effective and efficient quality assurance based on such standards. In this context, certification and inspection schemes play a crucial role in the reduction of barriers to trade. The application of internationally recognized schemes increases efficiency and reliability since products or processes (a gas tank, for example, or green hydrogen generated in an exporting country) only have to be tested and certified once to be accepted internationally.

Subgroups of the International Electrotechnical Commission (IEC), such as IECx (IEC System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres), are currently working on applying existing schemes for the certification of equipment, services and persons to the requirements of the green hydrogen value chain (Arnhold, 2021).

Regulation
Regulations are required to guarantee safety along the green hydrogen value chain in order to protect the customer and prevent possible negative environmental effects. In this context, national and supranational regulators (e.g., the European Commission in the revised Renewable Energy Directive) (European Commission, 2021) have in recent years published new and updated legal requirements relevant for the green hydrogen sector.

To facilitate international trade with green hydrogen and prevent technical barriers to trade, it is important that such regulations apply internationally accepted criteria where possible, especially by referring to existing international standards. Currently, the criteria defined in existing national and supranational regulations still differ substantially, for example concerning the permitted carbon thresholds for hydrogen.

5. Learnings from PTB's International Projects Supporting the Development of Quality Infrastructure

For 60 years, the International Cooperation group at PTB has supported developing and emerging countries worldwide in the development and use of a needs-based and internationally recognized quality infrastructure.

Based on PTB's experience, the following key learnings can be defined on how policymakers and sector stakeholders can support quality infrastructure to effectively foster the development of the green hydrogen industry.[11]

Support quality infrastructure while developing the green hydrogen sector

Experience from sectors that developed quickly, such as photovoltaics, shows that countries typically undergo a learning curve, with investment opportunities leading to a boom in development. After this introductory phase, quality, safety and sustainability issues are identified in installations and components. Problems related to such issues are especially frequent when inexperienced professionals are involved in rapidly developing new sectors. The identification of these issues leads to higher quality awareness and the improvement of quality assurance mechanisms as the sector matures.

Policymakers and stakeholders can learn from this experience and support the necessary quality infrastructure as an integral part of green hydrogen sector development. The systematic consideration of quality infrastructure at an early stage increases the efficiency of investment, improves sustainability impacts, increases acceptance for this technology, and reduces its risks.

11 Adapted from Ferdinand et.al. (2021)

Take a holistic approach to the development of quality infrastructure

A national quality infrastructure is an interrelated system in which the various components complement one another. Consequently, they should be developed together in order to be coherent and functional. Moreover, a national quality infrastructure should not be developed in isolation but always linked to the international system by establishing the respective relations: to ISO and IEC for standardization; to BIPM and OIML for metrology and legal metrology; to IAF and ILAC for accreditation; and to the various regional organizations.

This holistic approach creates the basis for the development of the specific quality infrastructure services required by the green hydrogen sector and for their recognition in international markets.

Develop an appropriate policy framework

Policy and regulatory frameworks are an integral part of the quality infrastructure system and influence both the availability of quality infrastructure services and their use by the green hydrogen sector. Public policies and programmes should include objectives and criteria on quality, safety and sustainability in the green hydrogen sector. Related requirements and the relevant standards, guided by international specifications and practices, should be specified in public tenders, contracts and government programmes in order to foster their application.

At the same time, the inclusion of detailed quality criteria in technical regulations should be avoided. Mandatory requirements that go beyond safeguarding human health and safety or the environment are not in line with international best practices and WTO-TBT agreements. Moreover, experience shows that mandatory requirements often fail to be implemented due to a lack of enforcement, while an inclusion of quality criteria in tenders, contracts and government programmes leads industry actors to proactively demonstrate compliance.

Foster exchange and cooperation between the green hydrogen sector and quality infrastructure organizations

Exchange and cooperation among the green hydrogen sector and quality infrastructure stakeholders should be fostered to create awareness and encourage the joint development of applied approaches to quality assurance. Representatives of the relevant renewable energy sectors should be involved in this dialogue, as they are an essential part of the green hydrogen value chain. Broad engagement processes are common practice, especially in the area of standardization, where industry and quality infrastructure stakeholders work together in the relevant ISO and IEC technical committees. Such approaches are also required in the other components of the quality infrastructure in order to share information about current and future supply and demand, align related programmes and strategies, foster innovative approaches, and create productive relations over the long-term.

Define specific priorities within the national context

The development of quality infrastructure should be aligned with the concrete national needs. These differ depending on the development status of the quality infrastructure itself, as well as on the country's current situation and plans for the development of the green hydrogen sector. To assess priorities, current and potential users of quality infrastructure services in the sector should be consulted regularly. Also, consideration should be given to both the financial viability and the potential impact of services to be developed. Close coordination with neighbouring countries and on the regional level is advisable in this context, as not all quality infrastructure services required by the green hydrogen sector are needed on a national level but may be obtained abroad as a result of regional development strategies.

Base quality infrastructure on existing international standards

Given the global nature of the future green hydrogen market, international standards are the best basis to foster global compatibility, facilitate trade, and use existing resources efficiently. Existing international standards in the green hydrogen sector consider worldwide experience and result from a broad agreement amongst relevant stakeholders.

Taking this into account, international standardization processes and reference to existing standards are crucial. Standardization processes that are, by contrast, limited to the national level increase the disparity of criteria and hamper the development of the green hydrogen sector.

Participate in regional and international forums and organizations

Especially for emerging and developing economies planning to generate green hydrogen in the future, it is essential to engage actively in regional and international quality infrastructure forums and organizations where related criteria, procedures and strategies are defined. Examples in the area of standardization include the technical working groups of the international organizations IEC and ISO, as mentioned above (IEC TC 105 *Fuel cell technologies*, IEC TC 31 *Equipment for explosive atmospheres* and ISO/TC 197 *Hydrogen technologies*). But also regional standardization, metrology and accreditation organizations can provide a valuable forum to foster and coordinate the development of services required by the green hydrogen sector.[12] The participation of emerging and developing economies in such organizations allows their specific requirements and conditions for the development of related services to be taken into greater consideration. Currently, the relevant processes tend to be dominated by industrialized countries. The recent push induced by the Covid-19 pandemic towards more digital and virtual processes in these organizations represents an opportunity for developing economies to increase their participation on the regional and international levels.

12 Examples of such regional organizations are the African Organisation for Standardisation (ARSO), the Inter-American Metrology System (SIM), and the Asia Pacific Accreditation Cooperation Incorporated (APAC).

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