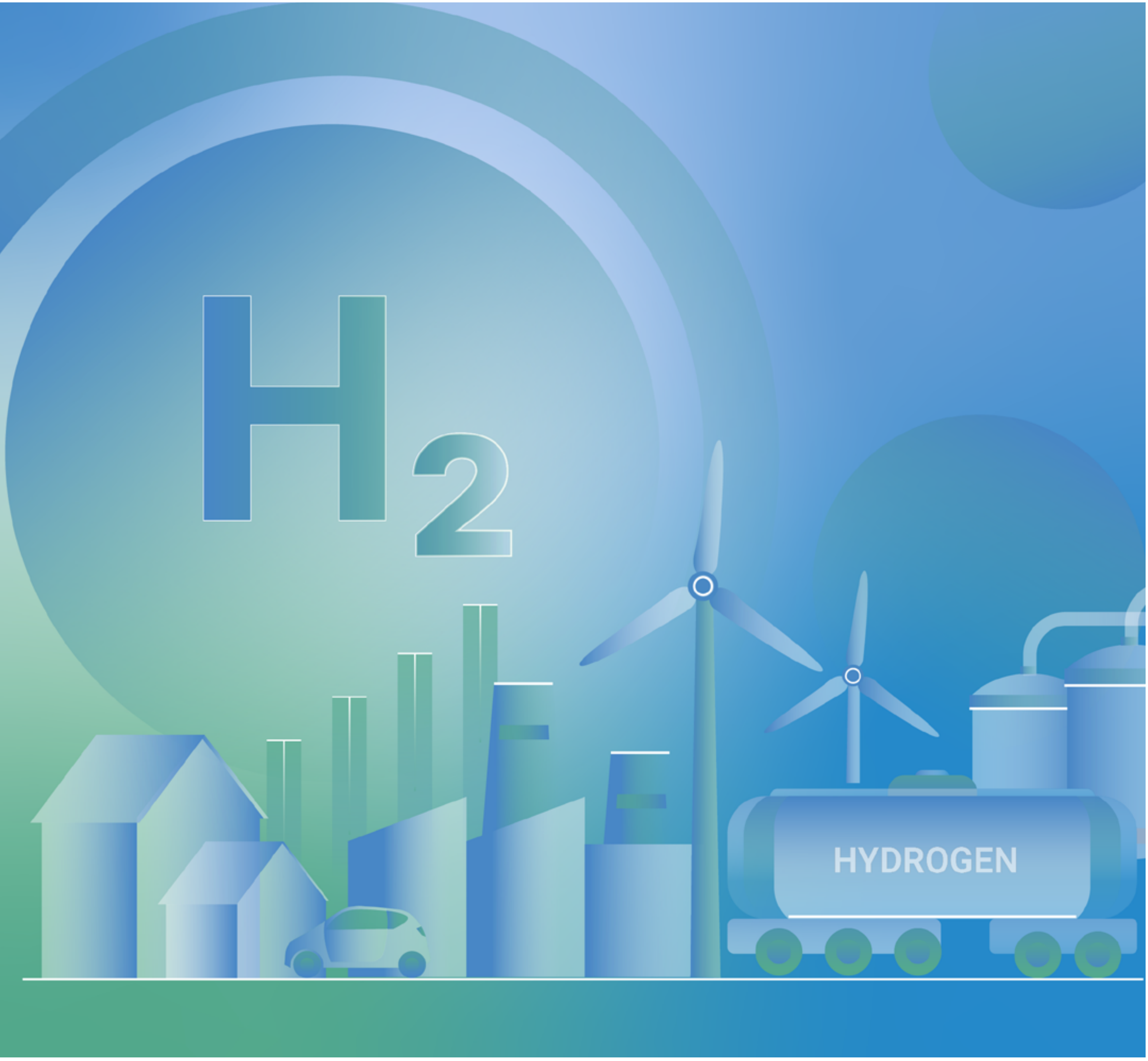
UNECE

Towards a Hydrogen Economy in the UNECE Region



UNITED NATIONS

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Towards a Hydrogen Economy in the UNECE Region

ECE ENERGY SERIES No. 79

UNITED NATIONS
Geneva, 2023

United Nations Publications
405 East 42nd St
S-09FW001
New York, NY 10017
United States of America
Email: permissions@un.org
Website: https://shop.un.org

United Nations publication issued by the United Nations Economic Commission for Europe.

ECE/ENERGY/151

UNITED NATIONS PUBLICATION
eISBN: 978-92-1-358563-4

Foreword

Hydrogen is a versatile energy carrier with the potential to decarbonize economies in our region, promoting sustainable economic growth, bolstering system resilience, and facilitating a just energy transition.

Over the past two years, numerous supportive policies have been implemented, and numerous low-emission hydrogen projects have been announced, both in the UNECE region and beyond. Yet, according to the International Energy Agency, a mere 4% of these projects have reached a final investment decision, while low-emissions hydrogen still constitutes less than 1% of overall hydrogen production and use. Achieving the scale and pace of hydrogen deployment necessary to bridge the gap between the current status quo and our climate objectives requires more decisive actions from policymakers and the emerging hydrogen industry.

To accelerate this process, the crucial first step is the establishment of an internationally agreed-upon classification system that is clear, scientifically rigorous, and easy to implement. This publication analyses one facet of such hydrogen classification: greenhouse gas emissions associated with its production and use. It provides an overview of global technical standards for hydrogen safety and sustainability, along with reporting standards for investors and financial markets. This sets the stage for the development of a global regulatory framework for a hydrogen certification system.

UNECE and its Hydrogen Task Force will continue to explore the role of hydrogen in the energy transition, including the use of the United Nations Framework Classification as a tool for evaluating the sustainability of hydrogen projects.

Tatiana Molcean

Tatiana Molcean
United Nations Under-Secretary-General
Executive Secretary, United Nations Economic
Commission for Europe

Acknowledgements

The authors of this United Nations Economic Commission for Europe's publication are Daria Nochevnik, Hydrogen Council's Director for Policy and Partnerships, and Andrei Tchouvelev, Hydrogen Council's Director Safety & Regulatory, in collaboration with Branko Milicevic, the Secretary of the UNECE Hydrogen Task Force.

Main findings of the publication were presented at the meeting of the Hydrogen Task Force in Geneva and to interested UNECE member States, as well as shared with the Groups of Experts under the UNECE Committee of Sustainable Energy.

Contents

Figures

Tables

Acronyms and Abbreviations

AHJs	Authorities Having Jurisdiction
CAPEX	Capital expenditure or capital expense
CCUS	Carbon capture, utilization and storage
CDP	Carbon Disclosure Project
CFP	Carbon footprint
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
FCEV	Fuel cell electric vehicles
FID	Final investment decision
GCA	Global Conformity Assessment
GHG	Greenhouse gas
GRF-H2Cert	Global Regulatory Framework for Hydrogen Certification System
GRI	Global Reporting Initiative
Gt	Billion tons
GTR	Global Technical Regulation
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IECEx	International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres
IFRS	International Financial Reporting Standards Foundation
ISO	International Organization for Standardization
ISSB	International Sustainability Standards Board
ITC	Inland Transport Committee
LCA	Life cycle assessment
LOHC	Liquid organic hydrogen carrier
Mt	Million tonnes
NFPA	National Fire Protection Association
NSS	National standards system
SC 1	Technical subcommittee
SCC	Standards Council of Canada
SDOs	Standards Development Organisations
TC	Technical committee
TCFD	Task Force on Climate-related Financial Disclosures
UNIDO	United Nations Industrial Development Organization

Chapter 1: Status quo and outlook for the hydrogen industry and pathway towards a global hydrogen economy

Hydrogen is a versatile energy carrier that can enable deep decarbonisation of economies worldwide, supporting just transition and sustainable economic growth. Projections indicate that renewable and low carbon hydrogen[1] can help abate between 60 and 80 billion tons (Gt) of carbon dioxide (CO_2) by 2050.[2] Going hand in hand with direct electrification and other clean energy pathways, hydrogen deployment can also improve system resilience, cost-efficiency, optimization of energy systems, energy security, and diversification of supplies thanks to cross-border trade flows in hydrogen and its derivatives.

Over the past two years, there has been significant and sustained growth in the development and execution of hydrogen projects throughout the entire value chain. Simultaneously, there has been a notable increase in public policies and legislative initiatives designed to streamline the adoption of hydrogen across various regions within the UNECE region. However, governments and industry stakeholders now confront an unprecedented challenge: to expedite and scale up real-world deployment of hydrogen to meet our global climate objectives, in alignment with the goals of the Paris Agreement.

A. Hydrogen industry today

Today, hydrogen is used primarily in industry, in particular ammonia, methanol, and steel, as well as in oil refining with global demand for hydrogen at 94 million tonnes (Mt).[3] Today, most of the hydrogen is produced from fossil fuels. This means that industry and governments are faced with the double challenge of accelerating fuel switching to renewable and low carbon hydrogen in existing hydrogen end use sectors on the one hand, as well as expanding the use of renewable and low carbon hydrogen to other sectors and applications on the other. The latter include heavy industry, transport, power generation and buildings.

---

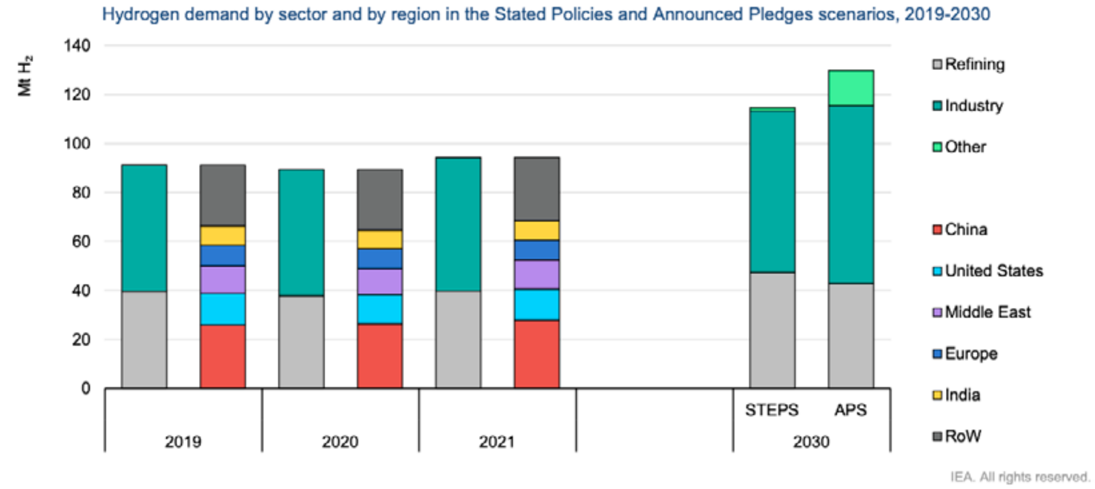
[1] As explained in detail in Chapter 6, there is currently no common global classification system with common GHG emissions thresholds/ranges and qualifications for defining renewable and low carbon hydrogen. In this report we use the terms renewable and low carbon whereby 'renewable hydrogen' refers to hydrogen produced from energy sources of renewable origin including i) hydrogen produced through water electrolysis with electricity of renewable origin used as feedstock; and/ or ii) hydrogen produced through the gasification of sustainable biomass which is then reformed or pyrolyzed (if the CO_2 is sequestrated the hydrogen produced can be qualified as carbon-negative), while 'low carbon hydrogen' refers to hydrogen produced from energy sources of non-renewable origin, including i) hydrogen produced using natural gas as a feedstock with SMR or ATR coupled with CCS; ii) hydrogen produced through pyrolysis of natural gas into hydrogen and solid carbon; iii) hydrogen produced through gasification of coal with CCS; iv) hydrogen produced through electrolysis using electricity of non-renewable origin as feedstock.

[2] Global Hydrogen Review, IEA, 2022; Hydrogen for Net Zero, Hydrogen Council, 2021.

[3] Global Hydrogen Review, IEA, 2022.

Figure 1

Hydrogen demand by sector and outlook for demand increase in line with policy announcements



Notes: Mt H_2 = million tonnes of hydrogen; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario. *Other* includes transport, buildings, power generation sectors and production of hydrogen-derived fuels and hydrogen blending.

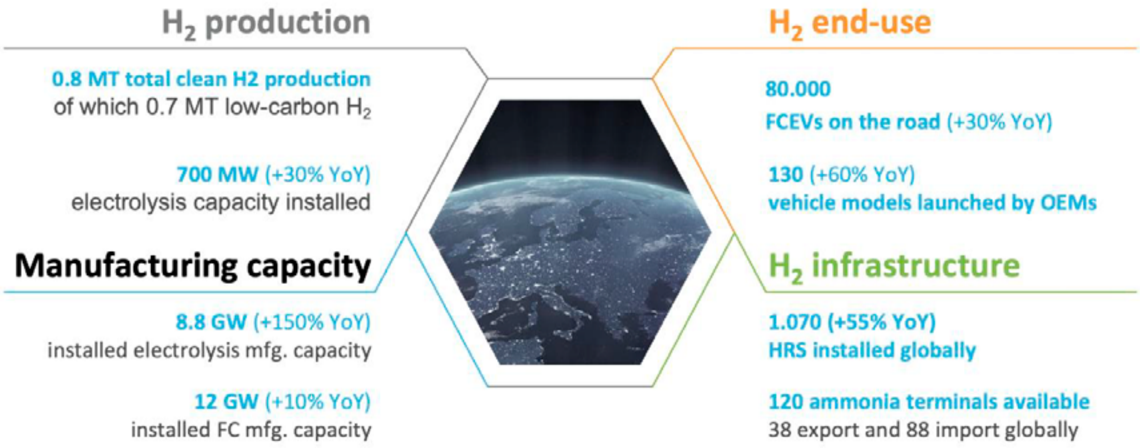
Source: Global Hydrogen Review, IEA, 2022.

Considering the IEA Announced Pledges Scenario - which assumes that all climate commitments made by governments around the world, including Nationally Determined Contributions and longer-term net zero targets, will be met in full and on time - the outlook for hydrogen demand is expected to be at 130 Mt by 2030. New hydrogen end uses, and applications would account for some 25% of that total demand and the traditional end use sectors would switch to renewable and low-carbon hydrogen in traditional applications.

While deployment of renewable and low carbon hydrogen and fuel cells has been growing steadily in the last two years (Figure 2), closing the gap between the status quo and our climate goals and policy targets will require bold actions by both decision-makers and industry to enable hydrogen deployment at pace and scale.

Figure 2

Hydrogen deployment growing steadily: status as of January 2023



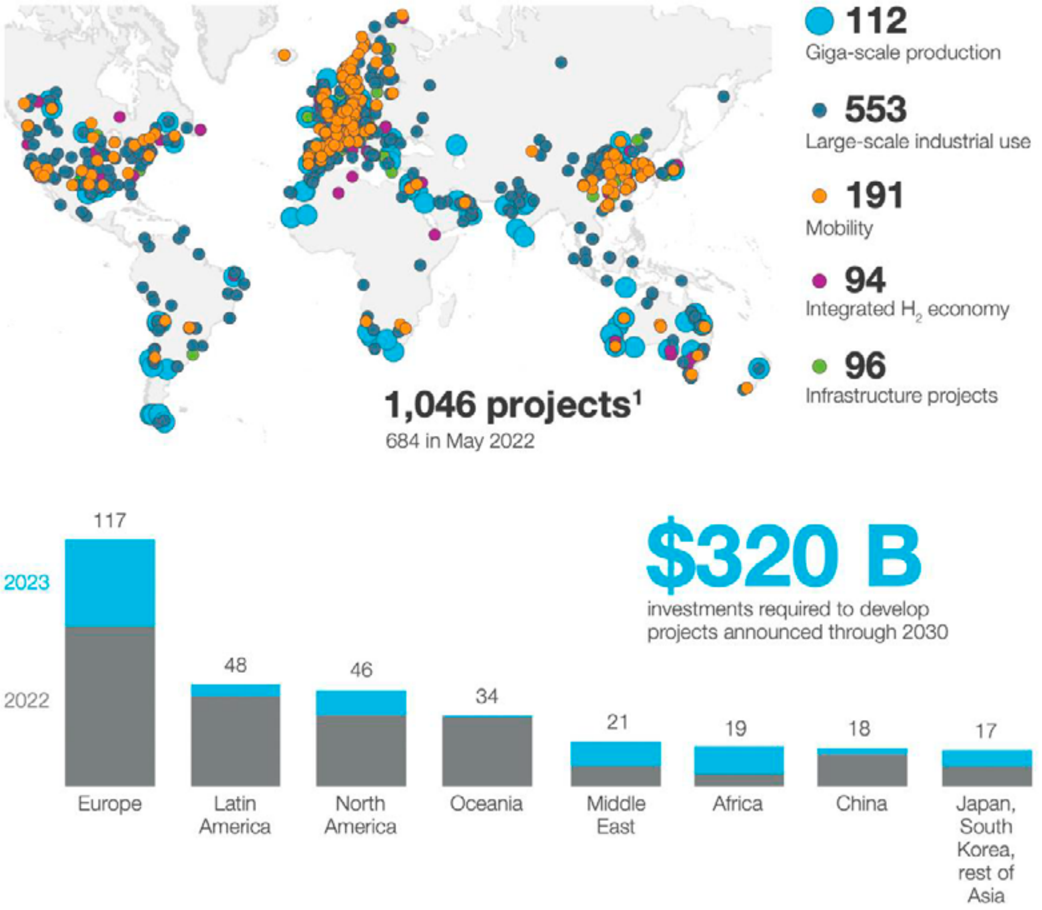
Source: Hydrogen Council, 2023.

Status of renewable and low-carbon hydrogen projects worldwide: project pipeline continues to grow, yet pace and scale of deployment needs to increase exponentially.

More than 1,000 mature large-scale renewable and low-carbon hydrogen project proposals were put forward by industry globally by beginning of 2023 (Figure 3).[4] Nearly 80% of these projects aim to be fully or partially commissioned through 2030 and represent total investments of USD 320 billion of direct investments into hydrogen value chains through 2030 (up from USD 240 billion). However, to deliver our 2050 net zero targets, the volume of announced projects needs to double by 2030 – and these projects need to be subsequently matured and deployed on the ground.[5]

Figure 3

Global snapshot: more than 1,040 hydrogen projects announced in 2023



Source: Hydrogen Insights 2023, Hydrogen Council, 2023.

---

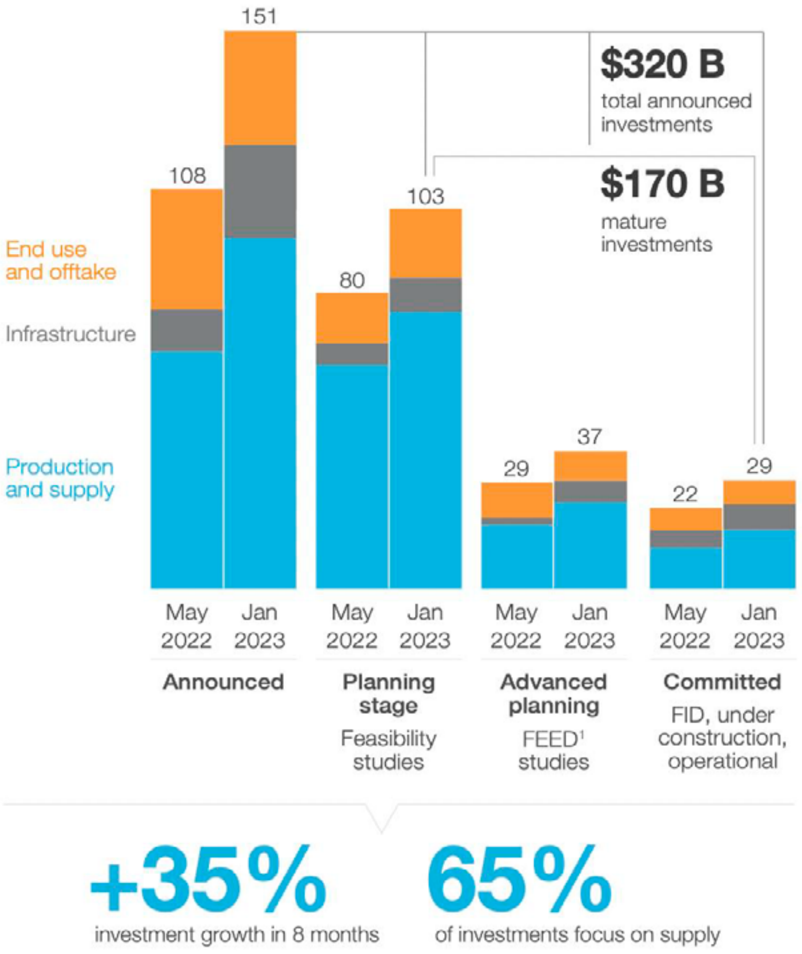
[4] Hydrogen Insights 2023, Hydrogen Council, 2023

[5] Ibid.

Notably, last year saw a substantial increase in final investment decisions (FIDs) – the total amount of committed investments grew from USD 22 billion in 2022 to nearly USD 30 billion in 2023 (see Figure 4). At the same time, this figure represents only 10% of the total USD 320 billion in announced projects through 2030. Global industry is currently facing several challenges from strained supply chains and labour shortages to increasing inflation and interest rates, as well as the **risk of market fragmentation due to lack of harmonised global regulatory frameworks for hydrogen and derivatives.** All the above may slow project deployment on the ground and create barriers for projects to cross the FID line. Yet, by 2030, the volume of committed capital must increase more than twentyfold to stay on track with net zero.

Figure 4

Breakdown of projects across main development stages and committed investments in hydrogen across the value chain by 2030, in USD billion



Source: Hydrogen Insights 2023, Hydrogen Council, 2023.

B. Towards a global hydrogen market

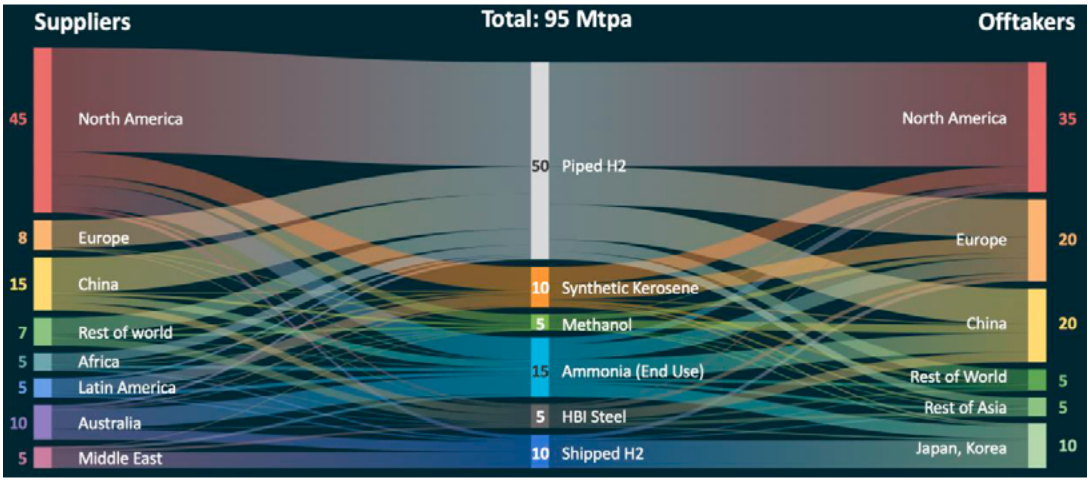
Global renewable and low carbon energy and infrastructure endowments are not distributed near major demand pools. Hydrogen and its derivatives will therefore become a critical enabler for moving clean electrons and molecules across long distances, creating new value chains between the Global North with the Global South (Figure 3).

Developing countries and emerging markets are putting forward ambitious hydrogen strategies that are set to contribute to global decarbonisation goals, while at the same time, unlock in-country value and socio-economic benefits of hydrogen boosting green industrialisation and sustainable economic growth.

By 2040, the main hydrogen and derivative products shipped over long distance are expected to be ammonia, followed by synthetic kerosine and liquid hydrogen (LH2), while more than half of the total volumes on the global market is expected to be transported by pipelines in the US, Europe, and China (Figure 5).

Figure 5

Outlook for global trade flows in hydrogen and derivative over long-distance (exceeding 1000km) by 2040, MT H2 equivalent



Source: Hydrogen Trade Flows, Hydrogen Council, 2022.

Developing a truly global hydrogen economy requires not only large-scale deployment of the enabling physical infrastructure across the value chain but also the enabling regulations, codes and standards at international level. The latter play a critical role in enabling transparency, reliability, and interoperability of the infrastructure systems for hydrogen and derivatives, helping build consumer and investor trust.

The next chapter of this report offers a snapshot of the status quo and outlook for the development of key safety and sustainability standards for hydrogen globally.

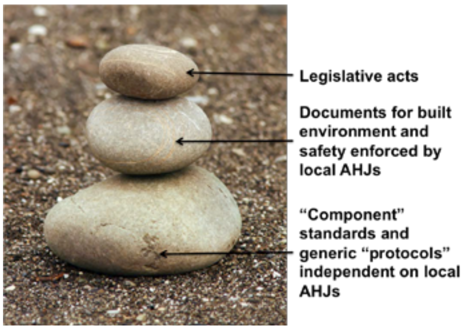
Chapter 2: Introduction into Global Technical Standards for Hydrogen Safety and Sustainability

A. Hierarchy of elements within a Regulatory Framework – Pyramid of RCS (Regulations, Codes & Standards)

Visually and simplistically the hierarchy of hydrogen safety regulations, code and standards could be presented as a pyramid consisting of three main segments (Figure 6 below).[6] "Component standards" form the foundation of any national standards system (NSS), which in turn informs the regulatory framework. "Component" is a cumulative generic term for individual components (like valves, hoses, etc.), more complex components (like a dispenser) and component systems (like an electrolyser, reformer, storage unit, PSA etc.). "Protocol" is a cumulative generic term for protocols and procedures. Documents for built environment and safety that are enforced by local Authorities Having Jurisdiction (AHJs) occupy the middle segment of the pyramid. Those normally include installation codes and building and fire codes (sometimes called "model codes") adopted by local regulations and thus have the force of law. More details on the relationship between codes and standards are provided in section 2.0 Best Practices and RCS below.

Figure 6

Hierarchical pyramid of RCS



Source: Hydrogen Council.

The top of the pyramid is taken by "legislative acts". Those include a wide variety of legally binding documents issued by local (provincial), national (federal) or regional (like in the European Union) acts of various levels of government. Such documents may be called "Regulations", "Code of Regulations", "Directives", "Acts" or similar. Such documents may and often do refer to codes and / or standards regarding specific requirements. Once those codes and standards are explicitly mentioned in a legislative act, they themselves part of the legislative act and have the force of law. Otherwise, standards are voluntary compliance documents.

---

[6] A.V. Tchouvelev et al, Chapter 6 in Science and Engineering of Hydrogen-Based Energy Technologies, November 2018, ISBN: 978-0-12-814251-6. Stone pyramid image Copyright: snolligoster / 123RF Stock Photo.

B. Key terms and definitions

Best practices and RCS play a critical role in ensuring public safety. It is thus useful to examine the meaning and purpose of each one in the society.

(Hydrogen) Best Practices

Out of many available original definitions for "best practices", the one developed by Hydrogen Tools (www.h2tools.org) stands out: "***A best practice is a technique or methodology that has reliably led to a desired result***. *Using best practices is a commitment to utilizing available knowledge and technology to achieve success."*

We should just add here that key attributes for safety best practices include Safety Culture, Safety Planning, Incident Procedures and Communications.

(Hydrogen) Codes & Standards on Safety, Built Environment and Fire Protection

There are a significant number of generic definitions of codes and standards. When it comes to those pertaining to the Hydrogen Economy, the reference organizations that have been developing codes and standards at global level for almost a century are ISO and NFPA. The latter is focusing in particular on built environment and fire protection.

Standard

The International Organization for Standardization **(ISO)**[7] defines a standard as "***a document, established by a consensus of subject matter experts and approved by a recognized body that provides guidance on the design, use or performance of materials, products, processes, services, systems or persons***."

In the context of hydrogen:

- A safety standard can set the requirements for manufacturing and testing a hydrogen storage container, while
- A standard for assessment of a sustainability attribute of hydrogen can define, for example, a methodology for calculating a given certain sustainability attribute, e.g., CFP (carbon footprint) of hydrogen production, conditioning, and transport and for establishing the renewable content of hydrogen.

Code

With a reference to NFPA's (National Fire Protection Association)[8] "***A Reporter's Guide to Fire and the NFPA***", the earliest building code is thought to have been developed sometime between 1955 B.C. and 1913 B.C., during the reign of King Hammurabi of Babylon. The code didn't specify how to build a building – but laid out the consequences of not building well. If a house fell and killed the owner or his child, then the builder, or his child, would be slain in retaliation.

Today's codes are more elaborate, and less punitive. But like Hammurabi's code, they express society's will on a particular technical issue, *specifying a desired outcome*.

---

[7] https://www.iso.org/sites/ConsumersStandards/1_standards.html

[8] https://www.nfpa.org/News-and-Research/News-and-media/Press-Room/Reporters-Guide-to-Fire-and-NFPA/About-codes-and-standards.

Difference between codes and standards: the what and the how

A code is a model, a set of rules that experts recommend following. It is not a law but can be adopted into law.

A standard is a more detailed elaboration, the "nuts and bolts" of meeting a code; in other words, it describes practical aspects pertaining to a given process or product rather than general rules.

One way of looking at the differences between codes and standards is that a *code tells you what you need to do*, and a *standard tells you how to do it*. A code may say that a building must have a fire-alarm system. The standard will spell out what kind of system and how it must work, often using best practices and lessons learned as the source of practical knowledge (in addition to fundamental and applied science research).

There is strong connection between regulations, codes, standards, and best practices.

Borrowing NFPA's "nuts and bolts" expression, safety and sustainability standards could be described as *voluntary* ***field-tested and proven-to-work*** *nuts and bolts of installing and establishing safe and sustainable operation of equipment or process or developing a system of mutual recognition of testing and certification of hydrogen equipment or hydrogen itself as a product.*

C. Role of ISO and IEC

Standards Development Organisations (SDOs), such as the International Organisation for Standardisation (ISO), are organizations focused on developing, publishing, or disseminating technical standards to meet the needs of an industry or field. Due to their nature, global SDOs such as ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) focus their activities on the development of component standards and generic protocols.

International (ISO and IEC) component standards (i.e., for safety and performance) and standards for assessment of sustainability attributes of hydrogen (e.g., for GHG footprint/ renewable content assessment) are being developed to foster transparency, help build consumer trust and alleviate barriers to the development of cross-border value chains and international trade. This way, a hydrogen component (such as a hose or breakaway device), or an assembly (such as electrolyser or reformer or dispenser), can meet the same design and testing criteria and thus can be sold across the globe without any additional requirements. While installation requirements of those components or assemblies (such as, e.g., separation distances) may differ from jurisdiction to jurisdiction, their design and testing requirements should not.

In a similar fashion, the determination GHG emissions footprint of hydrogen production pathways across jurisdictions can be based on the same methodology globally, while the specific GHG emissions thresholds differ jurisdiction to jurisdiction based on countries' policy choices.

Since ISO and IEC standards are developed by the broadest spectrum of international stakeholders, they become "super" standards and thus can complement and ultimately replace existing similar/analogous national component standards. Legislators at national level can proactively contribute to greater harmonisation of the global safety standards and help avoiding fragmentation and duplication of jurisdiction-specific and supra-national standards by way of

- Harmonising national standards including those that served as seed documents for the development of international standards with the established international standards. National standards may include certain deviations related to some jurisdiction-specific regulations pertaining to jurisdiction-specific climate, social or market conditions, where justified.

- Having national legislation and installation codes recognize international standards or their national versions harmonised with the international standard as the only / preferred product standard.
- Removing from national installation codes any design and testing requirements related to components and assemblies and focus solely on their installation requirements. They should also explicitly reference available international component standards or their national harmonized adoptions for design and testing requirements.

ISO/TC 197 Hydrogen Technologies

The scope of this technical committee (TC) established in 1990 is *"Standardization in the field of systems and devices for the production, storage, transportation, measurement and use of hydrogen".*

The secretariat of this TC is held by the Standards Council of Canada (SCC). ISO/TC 197 is composed of 34 Participating and 14 Observing member countries, including active participation from all G7 and 90% of G20 countries. Thus, ISO/TC 197 global participation covers the biggest world economies. ISO TC/197 has also been cooperating with the United Nations Industrial Development Organization (UNIDO) to facilitate knowledge sharing and capacity building on global standard development paving the way for greater engagement of emerging markets and developing countries in global standard development initiatives.

ISO/TC 197 develops standards for core hydrogen technologies across the hydrogen value chain from production to end use applications. These include hydrogen production by water electrolysis and reforming technologies, as well as stationary storage and hydrogen applications in transport.

ISO/TC 197 has been collaborating closely with the European CEN/CENELEC technical committees under the umbrella of the Vienna Agreement. This is a streamlined mechanism for ISO/TC 197 standards adoption within the European Union (via CEN/TC268/WG5 that acts as a CEN ISO/TC 197 mirror committee). The most recent example of such collaboration was the adoption of ISO/TC 197 work products onto European standards related to the deployment of hydrogen fuelling infrastructure per EU Alternative Fuel Infrastructure Directive that came in full force in November 2017.

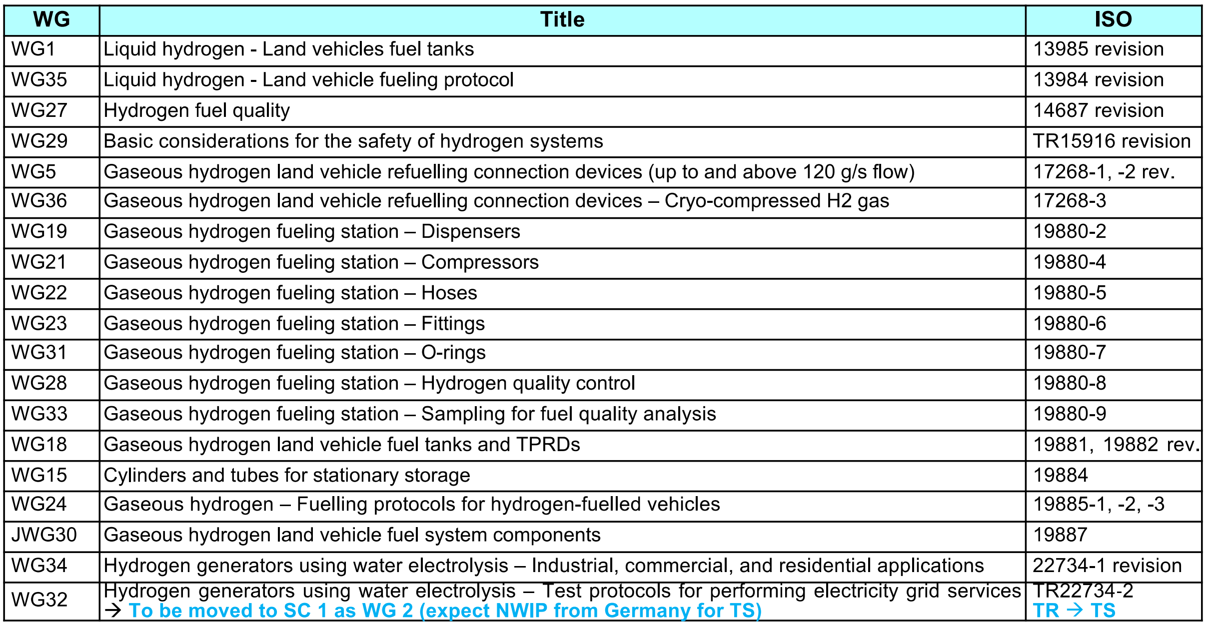
The current work program of ISO/TC 197 for the development of safety standards is shown on Figure 7. For convenience of the reader, the Working Groups are arrangement in the ascending order of the standard numbers[9].

---

[9] A.V. Tchouvelev, presentation at UNECE 10th Session of the Group of Experts on Gas, March 23, 2023.

Figure 7

ISO/TC 197 Working Groups and Standards



WG	Title	ISO
WG1	Liquid hydrogen - Land vehicles fuel tanks	13985 revision
WG35	Liquid hydrogen - Land vehicle fueling protocol	13984 revision
WG27	Hydrogen fuel quality	14687 revision
WG29	Basic considerations for the safety of hydrogen systems	TR15916 revision
WG5	Gaseous hydrogen land vehicle refuelling connection devices (up to and above 120 g/s flow)	17268-1, -2 rev.
WG36	Gaseous hydrogen land vehicle refuelling connection devices – Cryo-compressed H2 gas	17268-3
WG19	Gaseous hydrogen fueling station – Dispensers	19880-2
WG21	Gaseous hydrogen fueling station – Compressors	19880-4
WG22	Gaseous hydrogen fueling station – Hoses	19880-5
WG23	Gaseous hydrogen fueling station – Fittings	19880-6
WG31	Gaseous hydrogen fueling station – O-rings	19880-7
WG28	Gaseous hydrogen fueling station – Hydrogen quality control	19880-8
WG33	Gaseous hydrogen fueling station – Sampling for fuel quality analysis	19880-9
WG18	Gaseous hydrogen land vehicle fuel tanks and TPRDs	19881, 19882 rev.
WG15	Cylinders and tubes for stationary storage	19884
WG24	Gaseous hydrogen – Fuelling protocols for hydrogen-fuelled vehicles	19885-1, -2, -3
JWG30	Gaseous hydrogen land vehicle fuel system components	19887
WG34	Hydrogen generators using water electrolysis – Industrial, commercial, and residential applications	22734-1 revision
WG32	Hydrogen generators using water electrolysis – Test protocols for performing electricity grid services → To be moved to SC 1 as WG 2 (expect NWIP from Germany for TS)	TR22734-2 TR → TS

Source: Hydrogen Council.

Driven by the need for global relevance to support the deployment of fuel cell electric vehicles (FCEV) for road mobility, ISO/TC 197 has been developing many international standards related to the hydrogen refuelling infrastructure as well as critical components of the compressed hydrogen storage system on-board hydrogen-fuelled vehicles. The standards developed by ISO/TC 197 contribute to the harmonization of safety aspects and equipment requirements around the globe.

The centrepiece of its work program is the so-called Fuelling Family that includes all standards directly related to hydrogen fuelling stations. Many of the standards that are being developed by ISO/TC 197 have direct relevance to the UN GTR #13 and R134, Global technical regulations on hydrogen and fuel cell vehicles developed under UNECE WP.29 The World Forum for Harmonization of Vehicle Regulations, which is a working party of the Inland Transport Committee.

ISO/TC 197/SC 1 Hydrogen at Scale and Horizontal Energy Systems

In response to the ongoing global effort to accelerate and expand *application* of hydrogen technologies across the economies worldwide, ISO/TC 197 established a new subcommittee *Hydrogen at scale and horizontal energy systems*. This subcommittee covers a wide range of new hydrogen applications as well as the challenging issues associated with scaling up of core technologies. This also allows to preserve the high level of expertise and focus on core hydrogen technologies including road mobility and its infrastructure at the parent committee level, which is paramount in ensuring the continuation of the development of high-quality safety standards.

The scope of work of this technical subcommittee (SC 1) established in 2022 is "*Standardization of large-scale hydrogen energy systems and applications including aspects of testing, certification, sustainability and placement, and coordination with other relevant standardization bodies and stakeholders*".

Key words from the above description of the Scope of SC 1 that constitute the current primary focus of SC 1 are underscored reflect the priority focus areas of the subcommittee. SC 1 is coordinating the work on relevant technical standards for applications and horizontal energy systems where hydrogen plays a central role and serves as a link in the energy chain enabling system integration and sector coupling. These areas for coordination also include but are not limited to renewables and energy storage / grid balancing, multifuel stations and systems, such applications as rail, maritime and aviation, commercial and residential sectors for heat and power, testing and certification of hydrogen equipment/components and as a product, and multitude of sustainability aspects of hydrogen economy including climate, environment, and SDG dimensions.

Methodology for Determining GHG Footprint of Hydrogen Technologies

The centrepiece of SC1 work program is the development of the uniform *Methodology for determining the greenhouse gas (GHG) emissions associated with the Production, Conditioning and Transport of Hydrogen to Consumption Gate*. It is initially developed as a Technical Specification (ISO/TS 19870) for expediency (publication in December 2023)[10]. Starting in 2024, this work will be split into three separate streams to develop individual international standards for production, conditioning and conversion, and transport of hydrogen.

Climate change mitigation initiatives worldwide rely on robust quantification, monitoring, reporting and verification of GHG emissions and/or removals. International standards that support scientific knowledge transfer into practical assessment tools can help provide transparency, ensure credibility and robustness of these tools, and ultimately contribute to achievement of the climate targets set by the Paris Agreement.

ISO 14040 and ISO 14044 define the principles, requirements and guidelines identified in existing International Standards on life cycle assessment (LCA).

ISO 14067 is based on the principles, requirements, and guidelines on LCA identified in ISO 14040 and ISO 14044 and aims to set specific requirements for the quantification of a carbon footprint (CFP) and a partial CFP of a given product. It also defines the principles, requirements, and guidelines for the quantification of the carbon footprint of products. Its aim is to quantify GHG emissions associated with the lifecycle stages of a product, beginning with resource extraction and raw material sourcing, and extending through the production, use and end-of-life stages of the product.

Hydrogen can be produced from diverse sources including renewables, nuclear and fossil fuels using carbon capture, utilization and storage (CCUS) to reduce the emissions associated with its production. Hydrogen can be used to decarbonize numerous sectors including transport, industrial manufacturing, and power generation.

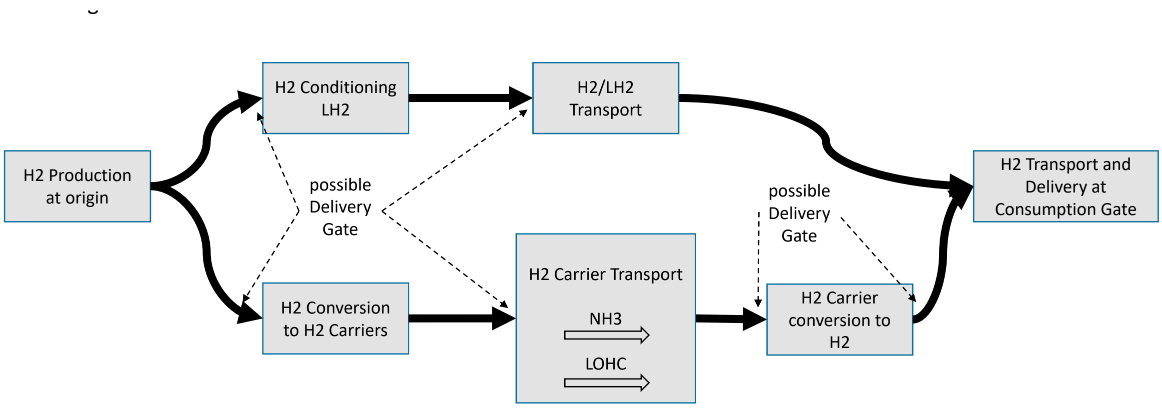
ISO/TS 19870, in line with ISO 14067, thus addresses the specific case of the hydrogen value chain, covering different production processes and other parts of the value chain, such as conditioning hydrogen in different physical states, conversion of hydrogen into different hydrogen carriers and transport up to the consumption gate, as shown on Figure 8.

---

[10] https://www.iso.org/standard/65628.html

Figure 8

Examples of hydrogen supply chain considered in ISO/TS 19870

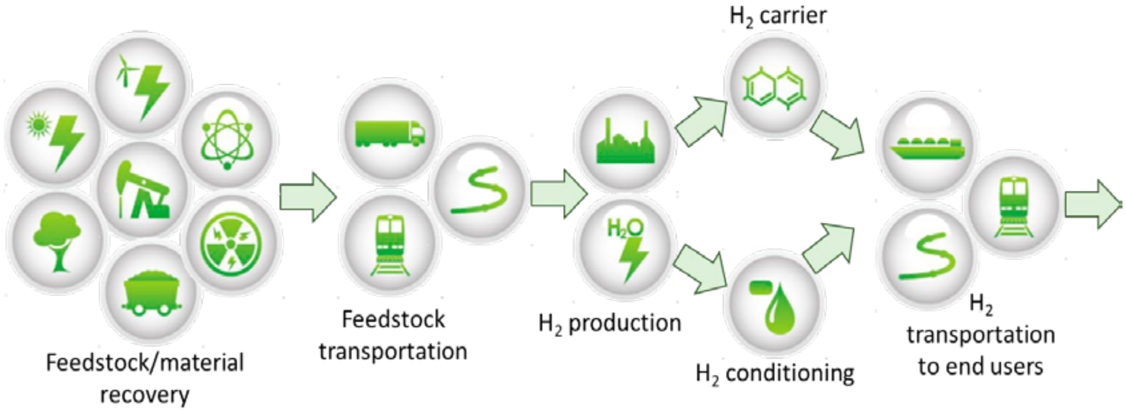


Source: Hydrogen Council.

ISO/TS 19870 also considers indirect emissions including those associated with the upstream activities in the raw material acquisition phase, raw material transport phase, etc. GHG emissions contributions are defined in terms of carbon dioxide equivalent (CO_2e), as shown on Figure 9.

Figure 9

Schematic of "well-to-consumption gate" system boundary adopted for ISO/TS 19870



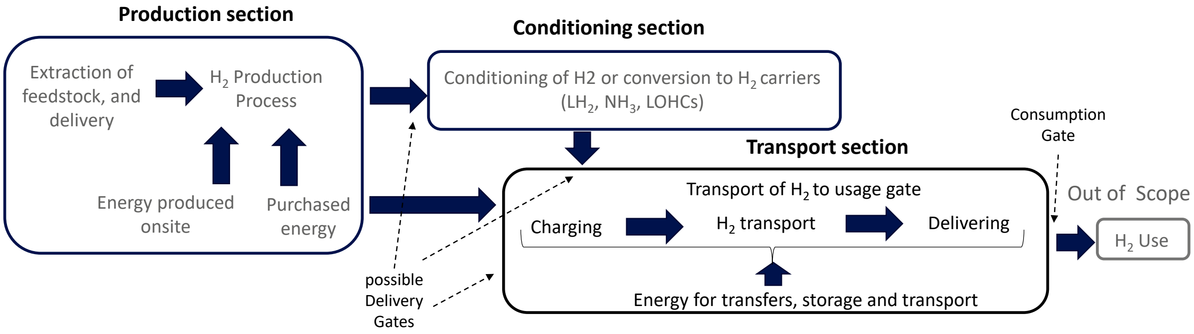
Source: Hydrogen Council.

GHG emissions from the construction, manufacturing, and decommissioning of the capital goods (including hydrogen production device, etc.), business travel, employee commuting, and upstream leased assets are not considered in the well-to-consumption gate system boundary (see Figure 9). However, in some cases these emissions can be significant. Therefore, ISO/TS 19870 requires quantification of capital goods emissions, or "CAPEX" emissions, to have them provided in a transparent manner using relevant values taken from literature or evaluated by calculations following relevant ISO documents (e.g., ISO 14044).

The “well-to-consumption gate” system boundary used in ISO/TS 19870 is divided in three sections considering hydrogen i) production, ii) conditioning/conversion and iii) transport, as described in Figure 10.

Figure 10

“Well-to-consumption gate” system boundary divided in three sections (production, conditioning/conversion and transport)



Source: Hydrogen Council.

In conclusion, ISO/TS 19870 specifically describes the requirements and GHG emissions assessment methods applied to the following hydrogen production pathways: electrolysis, steam methane reforming (with carbon capture and storage), co-production and coal gasification (with carbon capture and storage), auto-thermal reforming (with carbon capture and storage), hydrogen as a co-product in industrial applications and hydrogen from biomass waste as feedstock. It is anticipated that its future revisions will consider additional pathways. The document also considers the GHG emissions from conditioning or conversion of hydrogen into different physical forms and chemical carriers:

- Hydrogen liquefaction.
- Production, transport and cracking of ammonia as a hydrogen carrier.
- Hydrogenation, transport, and dehydrogenation of liquid organic hydrogen carriers (LOHCs).

ISO/TS 19870 also considers the GHG emissions due to hydrogen and/or hydrogen carriers’ transport up to the consumption gate. Finally, ISO/TS 19870 applies to and includes every delivery along the supply chain up to the final delivery to the consumption gate (as shown on Figure 8).

Chapter 3: Sustainability disclosures and reporting standards for investors and financial markets

In the world of finance and sustainability disclosures, the landscape of voluntary sustainability-related standards and requirements has been very diverse and fragmented.

Sustainability disclosure standards are used as a basis for sustainability reporting – they require companies to disclose information about their sustainability-related risks and opportunities, including their governance arrangements, actual and potential impacts of sustainability risks, risk management processes, and metrics and targets. Examples of the most widely used sustainability disclosure standards include the Global Reporting Initiative (GRI), the Carbon Disclosure Project (CDP) and the Task Force on Climate-related Financial Disclosures (TCFD).

The reference body dealing with financial reporting standards internationally is the International Financial Reporting Standards Foundation (IFRS) - a non-profit organization responsible for the development of global accounting and sustainability disclosure standards otherwise known as IFRS Standards. In response to the growing need for harmonisation of sustainability disclosures, the Trustees of the IFRS Foundation established the International Sustainability Standards Board (ISSB) on 3 November 2021 at COP26 in Glasgow. In June 2023 the International Sustainability Standards Board (ISSB) issued its first two IFRS® Sustainability Disclosure Standards, IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information and IFRS S2 Climate-related Disclosures. The issuance of these two standards marks an important step towards globally consistent disclosures, providing a common language on sustainability-related disclosures in capital markets and helping tackle duplicative reporting.

The ISO standards can play an important role in informing reporting and disclosure frameworks and sustainability disclosures, in particular for investors and funds investing in hydrogen as an asset class. For example, the EU Taxonomy for Sustainable Finance refers to ISO standards (i.e., ISO 14064:2018[11]and ISO 14067:2018[12]) in its guidelines for hydrogen production to be qualified as a sustainable economic activity.

Indeed, ISO 14067:2018 being widely used as a generic standard for assessment of the carbon footprint of products. As discussed in the previous section of the report, ISO/TS 19870 which will be published in December 2023, specifies methodologies that can be applied to determine the carbon footprint of a product (CFP) or partial CFP of a hydrogen product in line with ISO 14067.

Going forward, in the field of hydrogen and beyond, collaboration between the global SDOs to explore synergies and pursue consistency between technical standards on the one hand and financial reporting standards on the other will play an increasingly important role.

---

[11] ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification.

[12] ISO 14064-1:2018 Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.

Chapter 4: Role of Certification Solutions

Market valuation of hydrogen and derivatives is determined not only by the energy content of the physical product but also by its sustainability attributes (e.g. GHG footprint, renewable origin and other attributes) evidenced by a certificate. Hydrogen certification is complex topic which has been gaining increasing importance in the past two years as it is critical for both policy and project implementation. In order to help creating a common language on this critical topic, IPHE[13] and IEA H2 TCP[14] with support from IRENA[15] and contributions from the Hydrogen Council[16] and the International Power-to-X Hub[17], released the Hydrogen Certification 101 paper developed under the Breakthrough Agenda's[18] Hydrogen Breakthrough priority action H.1 Standards and Certification. This paper offers the basic information on

- Terminology and concepts used in hydrogen certification.
- Purposes and functionalities of hydrogen certification schemes.
- Basic information on certification scheme design; and
- Concept of mutual recognition of certification schemes for hydrogen and derivatives.

Below is an extract from the introductory section of the paper on the purpose and the functionalities of certification schemes for hydrogen and derivatives.

- In the emerging global hydrogen economy, robust tradeable certification schemes for hydrogen and derivatives are due to play a key role to:
- Enable the implementation of government policies as certification can constitute an integral element of policy measures such as targets, quotas, and tax credits.
- Evidence their sustainability attributes, such as carbon footprint (CFP) - meaning greenhouse gases (GHG) – as well as the use of land and water, and social impacts – in a reliable and consistent manner internationally.
- Create transparency for consumers and enable consumer choice.
- Allow consumers to signal demand for hydrogen based on its sustainability credentials.
- Create trust between prospective importers and exporters, fostering global, cross-border trade in hydrogen and derivatives based on their sustainability credentials.

---

[13] International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), see here

[14] International Energy Agency's Technology Hydrogen Collaboration Platform (IEA H2 TCP) & Task 47 Certification R&D, see here

[15] International Renewable Energy Agency (IRENA), see here

[16] Hydrogen Council, see here

[17] Power-to-X Hub, see here

[18] Breakthrough Agenda, see here

Certification allows evidencing that a unit of hydrogen or a derivative product has been produced, transported, and delivered with specific sustainability attributes. This commonly results in the issuance of electronic certificates, which may then be transferred either with or separately from the underlying physical hydrogen or a derivative product. The need for and types of attributes evidenced by certification schemes, as well as design features of schemes are largely driven by demands of the end-consumer, in line with mandatory (imposed by a regulatory obligation) or voluntary requirements (imposed by the consumer itself or its peers, driven by ESG reporting and disclosure requirements).

As certification schemes are currently largely regional or national, this may constitute a barrier to global, cross-border trade in hydrogen and derivatives between regions or countries. Mutual recognition of certification schemes will be instrumental to overcome this barrier, ensuring that the end-consumer in each import country can trust in the veracity of the production and certification process in the given export country.

Chapter 5: Towards a Global Regulatory Framework for a Hydrogen Certification System

To facilitate cohesion between various national certification schemes for hydrogen and derivatives, a Global Regulatory Framework for Hydrogen Certification System (GRF-H2Cert) could be envisaged based on learnings from existing frameworks.

GRF-H2Cert will rest on two pillars:

- Global Technical Regulation, GTR, and
- Global Conformity Assessment, GCA.

Global Technical Regulation. GTR for hydrogen certification system can build on the established experience with GTR 13 for hydrogen and fuel cell vehicles. The development of the GTR 13 occurred within the World Forum for Harmonization of Vehicle Regulations (WP.29) of the Inland Transport Committee (ITC) of UNECE. The key driver for GTR 13 was the identified need for global harmonization of national crash test requirements (e.g., in North America, Asia and EU) and agreement upon maximum allowable level of hydrogen leakage, basic performance tests and acceptance criteria for on-board hydrogen storage system as well as common minimum requirements for end of life of critical components.

GTR 13 was developed by the cooperative effort of contracting parties – UN Member States signatories to a (specific) Agreement and led by co-sponsors, i.e., Member States – proponents of specific scope and actions. National acceptance of the GRT 13 requirements opens the pathway for mutual recognition of performance tests and thus facilitates global trade of hydrogen fuel cell vehicles.

Similarly, a GTR for hydrogen certification can be developed under the umbrella of the Sustainable Energy Division of UNECE. G7 or G20 countries can be the initial signatories of the Global Hydrogen Certification System Agreement with the invitation of other nations to join. Recognizing that independent nations may be using their own hydrogen certification schemes and setting GHG footprint thresholds for their own compliance markets, the key objectives of the GTR will be to a) agree on the common methodology for GHG footprint assessment of hydrogen production, conditioning and delivery to the consumption gate and b) establish minimum common requirements for conformity assessment (auditing) of hydrogen certificates (see below). ISO standards will serve the basis for and will be directly referenced in the GTR.

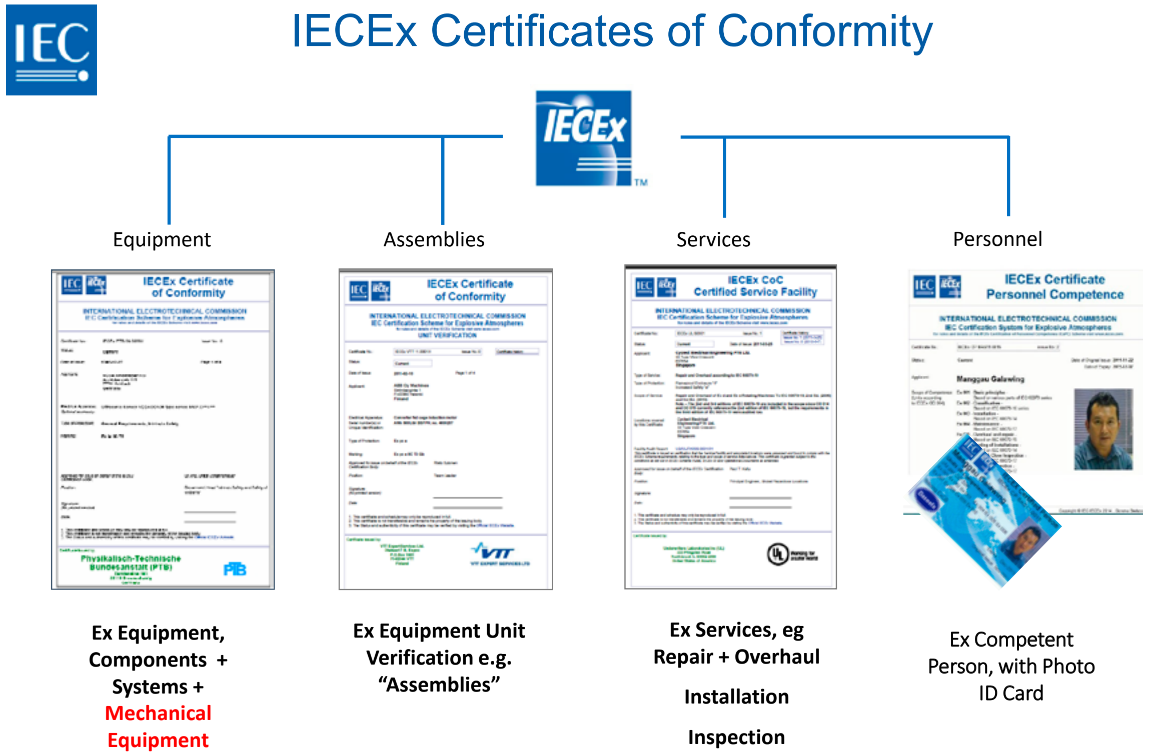
Global Conformity Assessment. Conformity assessment is an established way of verification of product and services standards' requirements as well as personnel competence via a set of tests and protocols. At the end of such verification a conformity assessment agency issues a certificate of conformity (which indicates compliance with stipulated requirements). Such certificate assures the user of acquired products and services as well as of the employed personnel that they meet specific requirements stipulated in a standard or minimum required qualifications. This ensures trust between the supplier and the customer.

A well-established system developed by IECEx could be used as the basis for Global Conformity Assessment mechanism. IECEx is a conformity assessment arm of the International Electrotechnical Commission, IEC, a global international standardization body established in 1904. (Note: IEC established ISO in 1947). IECEx is a global organization with 95 certification bodies worldwide. Since 1996 IECEx has issued over 140,000 certificates and reports certifying compliance of products, services, and personnel. Their specific focus is on industries that use flammable / combustible materials.

Figure 11 below illustrates the current conformity assessment services of IECEx.

Figure 11

Conformity assessment services of IECEx



Source: Hydrogen Council.

In 2021 IECEx has established a Working Group on Hydrogen Economy for the purposes of certification of hydrogen equipment based on ISO/TC 197 standards. They are fully equipped to expand their conformity assessment portfolio to hydrogen certification by developing specific procedures for hydrogen certificates' auditing based on future ISO standards for GHG footprint assessment methodology and hydrogen certification.

Combination of the above two pillars will ensure truly global transparent mechanism for harmonized implementation of a global certification system for hydrogen and derivatives.

Chapter 6: Hydrogen Classification

Note: This section considers Hydrogen Classification only from the climate impact perspective.

A. Classification and its purposes

Merriam-Webster dictionary defines Classification as "*systematic arrangement in groups or categories "**according to established criteria***". [19] The established criteria may differ depending on the nature and the purpose of the given classification system. Similarly, a label or certification mark signals that certain defined requirements or criteria are fulfilled.

In the world of energy, one of the most well-known classification and labelling systems is the EU system for labelling energy efficiency of appliances in line with energy efficiency classes from A to G on the label, A being the most energy efficient, G the least efficient. The labels offer useful information to the customer and facilitate consumer choice between various models.

Zooming in on hydrogen, while the chemical properties of hydrogen molecules may be identical, hydrogen production, conditioning and transport pathways may have different GHG intensities.

Countries across geographies have been introducing national legislation on hydrogen making different policy choices on the types of hydrogen that they intend to deploy and support, in particular, based on different GHG emissions intensity thresholds (in $kg\ CO_2$*-equivalent (eq)/kg* H_2), considering different national circumstances.

In other words, national classification systems and thresholds for qualifying hydrogen as "clean" "sustainable" or "low carbon" are introduced in national legislation to reflect and serve the policy choices of countries relating to the types of the hydrogen they seek to produce/ incentivise and and/ or import.

IEA highlights that "*the imposed emissions intensity levels for well-to-gate system boundaries vary widely between… regulations, reflecting different regional circumstances. For systems with a well-to-gate boundary, the range goes from 0.45kilogramme of* CO_2 *equivalent per kilogramme of hydrogen (kg* CO_2*-equivalent (eq)/kg* H_2*) in the US Clean Hydrogen Production Tax Credit to 14.5 kg* CO_2*-eq/kg H2 in China Hydrogen Alliance's standard.*"

Examples of actual ranges in GHG emissions footprint of hydrogen production pathways which would vary depending on the scope of the assessment and technology considered are provided in Table 1.[20]

---

[19] https://www.merriam-webster.com/dictionary/classification

[20] Figures borrowed from *Towards hydrogen definitions based on their emissions intensity, IEA, 2023.*

Table 1

Examples of ranges in GHG emissions footprint of hydrogen production pathways

Production pathway	CO_2 footprint range
H2 production from PV electricity (LCA)	0.9-2.5 kg CO_2-eq/kg H_2
H2 production from wind (LCA)	0.4-0.8 kg CO_2-eq/kg H_2
H2 production from coal gasification, without CCS	22-26 kg CO_2-eq/kg H_2
H2 production from coal gasification, with CCS (capture rate at 93%)	2.6-6.3 kg CO_2-eq/kg H_2
H2 production from natural gas (SMR) with CCS (capture rate at 93%) – considering direct emissions	0.7 kg CO_2-eq/kg H_2
H2 production from natural gas (SMR) with CCS (capture rate at 93%) – including the upper and lower end of global upstream and midstream emissions for natural gas supply today	1.5-6.2 kg CO_2-eq/kg H_2

B. Hydrogen Classification Beyond Colours

The UNECE Committee's on Sustainable Energy document released in August 2022 *"A comprehensive and science-based terminology, classification and taxonomy for hydrogen"* [21] concluded the following:

*"**A hydrogen classification based on colour has limited value in international trade*** because the life cycle emissions of a given hydrogen production pathway can vary widely based on deployment-specific variables, such as upstream emissions or rate of carbon capture. ***The colour-based classification does not take into account the entire value chain*** when calculating carbon footprint and focuses only on the method of hydrogen production. Furthermore, there are often other production facilities in the value chain to which no colour code is or can be assigned."

The IEA report *"Towards hydrogen definitions based on their emissions intensity"* [22] released in April 2023 echoed and reinforced a similar conclusion: ***"Using colours to refer to different production routes, or terms such as "sustainable", "low-carbon" or "clean" hydrogen, obscures many different levels of potential emissions.*** This terminology has proved impractical as a basis for contracting decisions, deterring potential investors. ***By agreeing to use the emissions intensity of hydrogen production in the definition of national regulations about hydrogen, governments can facilitate market and regulatory interoperability."***

Indeed, the use of colour coding system for hydrogen can be considered untransparent and impractical.

To deliver on our global climate targets, decarbonisation initiatives should be anchored in robust and transparent solutions for assessing and evidencing the GHG emissions footprint and other sustainability attributes of energy products on an LCA basis. Enabling transparency on the GHG emissions footprint of hydrogen is necessary to facilitate informed consumer choices and ultimately to allow the least carbon intensive products reveal their GHG emissions footprint in a consistent manner.

As discussed in chapter II, ISO/TS 19870 - using IPHE Guidelines as a seed document - is currently working on such a global benchmark methodology, which will play a critical role in delivering on the above-mentioned objectives.

---

[21] ECE/ENERGY/2022/8, GE.22-11023(E).

[22] https://www.iea.org/reports/towards-hydrogen-definitions-based-on-their-emissions-intensity

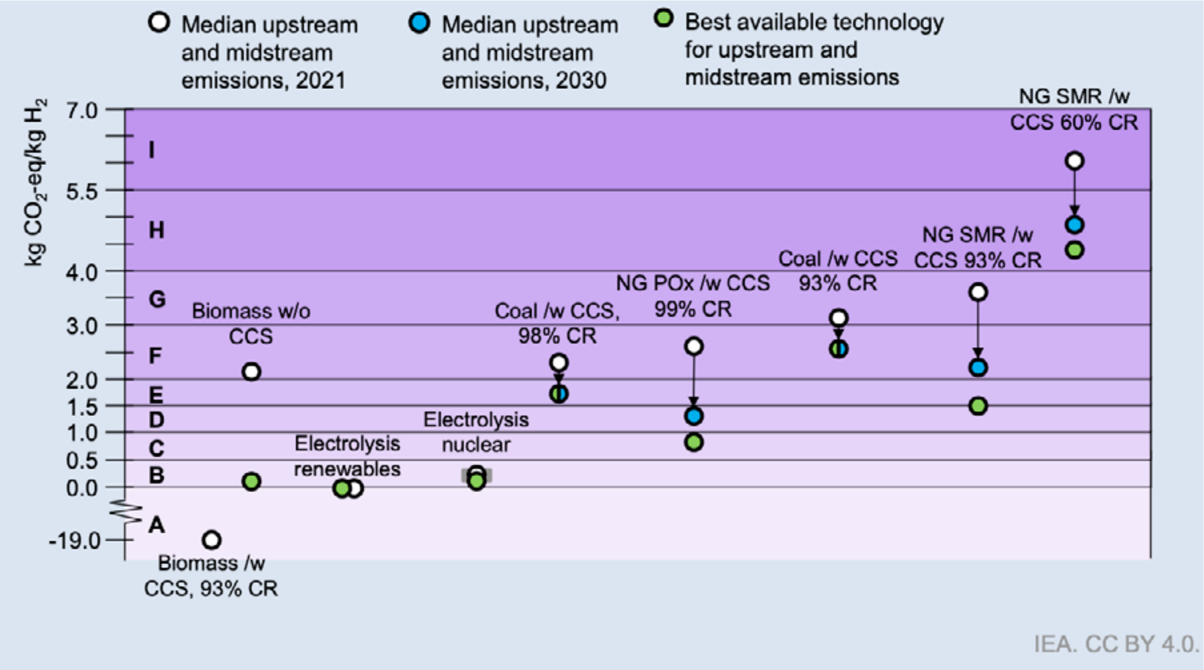
C. Hydrogen Classification Options

While the importance of transparency on GHG emissions footprint calculation is clear for policymakers, regulators and industry, the challenge is to find a simplified way to communicate the differences in the possible range of GHG emission footprint across all hydrogen production, conditioning and transport pathways.

IEA proposes to consider a set of nine distinct, technology-neutral levels, ranging from emissions intensities below zero (level "A") to an upper value of 7 kg CO_2-eq/kg H2 (level "I"), highlighting that some stakeholders, such as the investment community and general public, may appreciate the simplicity of quoting the aggregated "level" of emissions intensity. Such system would cover all production pathways, including those from unabated fossil fuels to renewable power, nuclear and others. See the IEA example of a potential quantitative system for emissions intensity levels of hydrogen productions in Figure 12.

Figure 12

IEA example of a potential quantitative system for emissions intensity levels of hydrogen productions



Source: Towards hydrogen definitions based on their emissions intensity, IEA, 2023.

Agreeing a common global classification system, based on a benchmark standard methodology for GHG emissions assessment offered by ISO/TS 19870 would make a material difference for the development of the global hydrogen economy and cross-border value chains. It would help creating a common language for international investors, providing transparency for consumers, and ultimately reducing transaction costs for the industry.

D. Hydrogen Classification vs Certification

In the conclusion of this section, it is important to clarify the confusion between Hydrogen Classification and Certification.

As explained above, classification is essentially labelling of a product to provide transparency for investors and customers and facilitate the establishment of cross-border supply chains. In this context, the label provides the information on GHG footprint and may include other relevant parameters such as, for example, renewable origin.

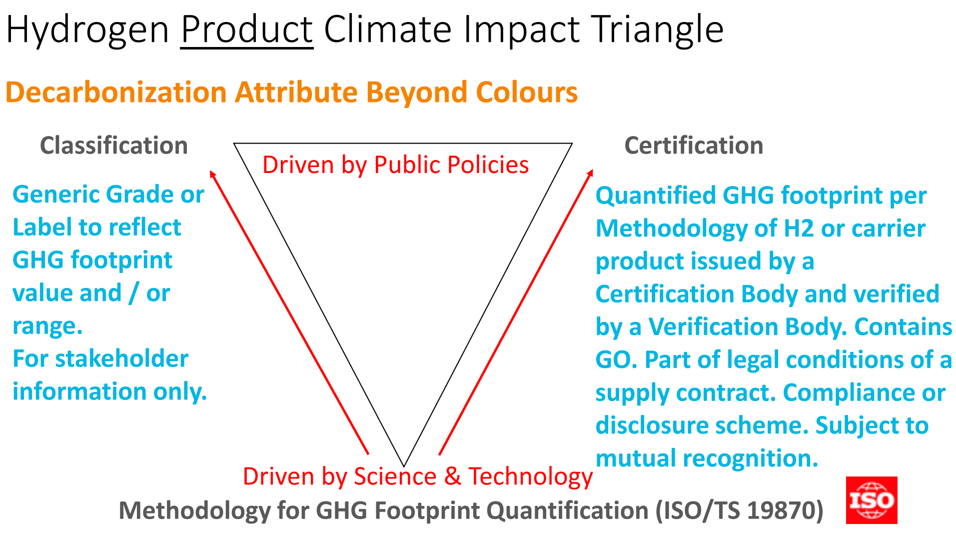
Hydrogen certification, as explained in Part III.2, is completely different mechanism or rather an instrument that provides for evidencing (sustainability) attributes of hydrogen production, transport and delivery of hydrogen or derivative products. It involves at various stages accreditation, certification, and verification bodies as part of the global regulatory framework explained in Part III.1. Thus, certification mechanism or scheme has legal connotations, is subject to disclosure as well as mutual recognition.

It should be noted that although Classification and Certification may rely on the Methodology for GHG footprint quantification explained in Part II.4.2.1 for accuracy of information, they are fundamentally driven by public policies, while the Methodology itself is based on science and independent assessment.

The above text is visually summarized on Figure 13.

Figure 13

Hydrogen Product Climate Impact Triangle



Hydrogen Product Climate Impact Triangle

Decarbonization Attribute Beyond Colours

Classification

**Generic Grade or Label to reflect GHG footprint value and / or range.
For stakeholder information only.**

Driven by Public Policies

Certification

Quantified GHG footprint per Methodology of H2 or carrier product issued by a Certification Body and verified by a Verification Body. Contains GO. Part of legal conditions of a supply contract. Compliance or disclosure scheme. Subject to mutual recognition.

Driven by Science & Technology

Methodology for GHG Footprint Quantification (ISO/TS 19870)

Source: Hydrogen Council.

Towards a Hydrogen Economy in the UNECE Region

Hydrogen is an energy carrier that can decarbonize economies and promote sustainable economic growth and system resilience. Although many low-emission hydrogen projects have been announced over the past two years, a mere 4% of them have reached a final investment decision. This indicates that achieving the scale and pace of hydrogen deployment requires more decisive actions from policymakers and the emerging hydrogen industry.

The crucial first step is the establishment of an internationally agreed-upon classification system that is clear, scientifically rigorous, and easy to implement. Both the UNECE Committee on Sustainable Energy and the International Energy Agency determined that a hydrogen classification based on colour lacks practical value in international trade, as does the use of terms such as "sustainable", "low carbon" or "clean" hydrogen. By agreeing to use the emissions intensity of hydrogen production in the definition concerning hydrogen, member States can facilitate market and regulatory interoperability.

A proper hydrogen classification can have many facets. This publication analyses one of them: greenhouse gas emissions associated with its production and use. It provides an overview of global technical standards for hydrogen safety and sustainability, along with reporting standards for investors and financial markets. This sets the stage for the development of a global regulatory framework for a hydrogen certification system.

Information Service
United Nations Economic Commission for Europe

Palais des Nations
CH - 1211 Geneva 10, Switzerland
Telephone: +41(0)22 917 12 34
E-mail: unece_info@un.org
Website: http://www.unece.org

Layout and Printing at United Nations, Geneva – 2325832 **(E)** – March 2024 – 46 – **ECE/ENERGY/151**