Comparison of Hydrogen Certification Schemes–Methodology and Results

Report from the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) Hydrogen Certification Mechanisms (H2CM) Task Force

A working paper prepared by the
IPHE Hydrogen Certification Mechanisms Task Force

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International Partnership for Hydrogen and Fuel Cells in the Economy
Website: www.iphe.net
Contact: media@iphe.net

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IPHE is aware that this framework for certification schemes analysis is being requested by multiple governments particularly during a period when policy makers, industry, and various stakeholders are considering hydrogen and other clean energy technologies to meet their climate goals as well as allocation of incentives and funding to accelerate deployments. Nothing in this report should be construed as an indication of future individual determinations regarding the appropriateness of any specific certification schemes for any specific purpose. The analysis described in this framework should be treated as first version available to be revised as analyses are updated, not a conclusion or direction of the IPHE, nor of its members.

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Executive Summary

This report presents the process, findings, and recommendations of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) Hydrogen Certification Mechanisms (H2CM) task force.

The task force contributed extensively to formulating definitions and descriptions of many terms and concepts relevant for hydrogen certification. This work is reflected in the initial 2023 and the revised 2024 version of the *Hydrogen Certification 101* document, which was published under the auspice of the Hydrogen Breakthrough Agenda.

The principal output of the task force was a comparison of 17 certification schemes and 4 support mechanisms across 11 countries or regions. Of these, 10 were existing certification schemes or support mechanisms for hydrogen and hydrogen derivatives and 11 were certification schemes or support mechanisms at different stages of development for the purpose of compliance (regulatory markets) or for the purposes of disclosure or reporting (voluntary markets).

The comparison considered the following 4 key elements: (1) product attributes, (2) operational setup and procedures, (3) chain of custody model, and (4) the information technology (IT) used for the registry. The comparison showed not only considerable variation in the availability of information but also considerable differences between the analysed certification schemes. The task force expects many of the differences concerning product attributes, operational setup and procedures, and the chain of custody to have adverse impacts on trade of certified hydrogen and hydrogen derivatives between markets relying on different certification systems. Only differences in the setup of registries and IT systems are not expected to negatively affect tradability as technical solutions are expected to help address any such differences.

Regarding product attributes, certification schemes focused on greenhouse gas (GHG) emissions, followed by provisions on electricity sourcing and permissible production technologies. Water and land use were considered by a majority of schemes, though with little detailed information available. Further product attributes were not considered by most certification schemes. Generally, different markets and different jurisdictions relying on schemes with stricter requirements are considered unlikely to treat hydrogen not aligned with those requirements as equivalent, whereby:

- The task force expects differences in GHG emissions accounting methodologies and thresholds, differences in permissible (production) technologies and feedstocks, as well as different provisions regarding electricity sourcing to have a medium to high impact on tradability.
- The task force expects differences in requirements related to water and land use, biodiversity, waste, pollution, and social impacts to have a high impact on tradability if markets or jurisdictions introduce more stringent requirements on these product attributes in the future.

Regarding the operational setup and procedures, the purpose of the certification scheme and whether schemes refer to specific voluntary technical standards for their institutional setup are expected to have an impact on tradability, whereby:

- It is assumed that governments will only regard certification schemes with the purpose of regulatory compliance (compliance schemes) as relevant means for certifying the adherence to regulatory requirements. As a result, only compliance schemes could recognise other compliance schemes as equivalent. However, since most schemes are aimed at compliance and few schemes are aimed at voluntary reporting, the task force expects that differences in the purpose of certification schemes will have a low impact on tradability.
- The task force expects differences in the institutional setup and operational processes between certification schemes to have a high impact on tradability. It is assumed that schemes adhering to voluntary technical standards for their operational setup and procedures will be less willing to recognise schemes that are not aligned to any such standard.

Regarding the chain of custody model, the choice of the model and the specific provisions of schemes applying the same model are expected to affect tradability of certified hydrogen, whereby:

- Mass balancing and book and claim are two fundamentally different models for tracking and tracing products and certificates. It is considered unlikely that the models will be compatible with each other as schemes operating with mass balance will require a "reasonable physical link" to be demonstrated, which book and claim cannot provide, given that the transfer of a certificate is separate from the transfer of the hydrogen.
- Even between schemes applying the same chain of custody model, differences in the level of tracking and tracing, in time periods for reporting, in cancellation rules, and in provisions regarding co-mingling are expected to have a high impact on tradability of certified hydrogen.

Whenever differences between schemes are expected to have a high impact on tradability, the report identifies options to improve tradability of certified hydrogen. Overall, the task force regards progress towards enabling tradability of certified hydrogen not as a continuous trajectory. Rather, progress is envisioned as an incremental process, with the need to achieve a certain degree of commonality within a key element in order to have measurable improvements in tradability. Therefore, this report proposes a modular approach to address the differences between requirements in different markets and jurisdictions applied by certification schemes. The proposed modular approach would entail a number of common modules that jurisdictions or scheme owners agree on and can opt in or opt out, as well as modules that would remain specific to individual jurisdictions or certification schemes.

The report lays out two broad options for a modular approach: (i) a more limited approach with fewer items agreed upon in the common modules and (ii) a more ambitious approach with a more comprehensive agreement on the content within common modules. A more ambitious approach would bring higher benefits for international market development and trade of certified hydrogen and hydrogen derivatives. Both approaches could be implemented in the form of a digital product passport for hydrogen and its derivatives that contains or is linked to the necessary information.

For product attributes, regardless of the level of ambition, this modular approach could be implemented in the form of a digital product passport which contains the necessary information to determine whether a quantity of hydrogen certified under one scheme complies with the requirements of another scheme.

The report suggests starting with GHG emission intensity. A common module could consist of a single agreed-upon methodology for each step of the hydrogen value chain. The standard series being developed by ISO/TC197/SC1/WG1[1] could serve as the base of such a module or number of modules. If jurisdictions and/or scheme owners cannot agree on a common methodology, a less ambitious approach could entail companies along the hydrogen value chain providing all data needed to estimate GHG emissions under all relevant methodologies. The standard series under development by ISO could serve as reference. Once progress has been made on GHG emissions, lessons from that process could be applied to other attributes.

For the operational setup and procedures, jurisdiction or certification scheme owners implementing the regulatory requirements for the certification schemes could agree on a set of voluntary technical standards that certification bodies, issuing bodies, accreditation bodies, and auditors are required to adhere to under the respective certification rules. Certification schemes that currently do not adhere to such voluntary technical standards for their operational setup and procedures should be supported to apply relevant provisions by sharing best practices and by providing practical guidance on implementation.

For the chain of custody model used to track and trace products and certificates, many governments and certification schemes are still in the process of developing the necessary requirements. As a result, little can be said about differences, the impact of these differences on the tradability of certified hydrogen, and options to reduce the adverse impacts. However, the current early stage of development also provides an opportunity. The choice of the chain of custody model used to track and trace products and certificates generally depends on the purpose of the certification scheme, either regulatory compliance or voluntary reporting. Depending on the purpose, jurisdictions or scheme owners could agree on a single chain of custody model, i.e., either mass balancing or book and claim, with a set of common provisions with the aim to prevent substantial future variations among requirements. Many jurisdictions are still in the process of developing the necessary requirements and where requirements exist, scheme owners are still in the process of translating those requirements into practice. This current early stage of development provides an opportunity to design models that integrate features to ensure compatibility across a variety of certification schemes, preventing barriers to mutual recognition of hydrogen certification.

Building on the central recommendation to introduce a digital product passport for hydrogen and its derivatives, the report proposes a common set of information that the passport could

[1] ISO/CD 19870-1.2 - Hydrogen technologies — Methodology for determining the greenhouse gas emissions — Part 1: Emissions associated with the production of hydrogen up to production gate

contain or be linked to in order to be an effective tool to improve tradability of certified hydrogen.

Finally, the report highlights potential interactions between hydrogen certification schemes and other up- and downstream certification schemes, such as schemes for electricity and steel.

The next steps following the publication of this report may include (1) publication of the draft inventory used for the analysis, (2) dissemination of the results of the comparative analysis and discussions of suggestions to improve tradability of certified hydrogen, (3) identification of information gaps within the inventory, (4) expansion of the inventory of certification schemes, and (5) development of recommendations regarding the design and implementation of a digital product passport.

1 Background

The IPHE Hydrogen Certification Mechanisms (H2CM) task force was formed at the 38th IPHE Steering Committee Meeting in San Jose, Costa Rica, in December 2022. Its objective was to provide a deeper understanding of certification mechanisms, as well as a sound basis to support reaching consensus on implementing interoperable certification mechanisms across regions/countries for clean hydrogen, thus contributing to the rapid build-up of international clean hydrogen trade.

At COP 27 (27th Conference of the Parties to the United Nations Framework Convention on Climate Change), the Hydrogen Breakthrough Agenda (BtA) identified the development of voluntary technical standards and certification (H.1. Standards and certification) for clean hydrogen as one priority action. The H2CM task force is part of the setup of this priority action. Under the coordination of the BtA, other organisations, such as the International Energy Agency (IEA) Hydrogen Technology Collaboration Programme's (H2 TCP) Certification Task and the International Renewable Energy Agency (IRENA), also work on hydrogen certification, complementing the work of IPHE. As such, from its inception, the H2CM task force engaged with other relevant organisations contributing to priority action H.1.

2 Overview

This report presents the process behind and the results of the H2CM task force, including:

1. A description of the principles and terminology of product certification with a focus on hydrogen.
2. An inventory of hydrogen certification mechanisms, functioning as a repository for information on and providing a summary of existing and emerging hydrogen certification mechanisms across the world, including their scope and the attributes they consider.
3. A compare-and-contrast analysis of the hydrogen certification mechanisms included in the inventory, highlighting the main similarities and differences between them.
4. An analysis of the ways in which different elements of certification mechanisms either support or obstruct trade of certified hydrogen.
5. An assessment of common information requirements to facilitate trade of certified hydrogen.
6. An analysis of potential interactions between certification mechanisms along the entire value chain for products involving hydrogen.

3 Principles and Terminology

3.1 Process

The document explaining principles and terminology related to hydrogen certification is a joint publication by the IPHE and the IEA H2 TCP. Both organisations had initially started working independently on documents with similar purposes. The H2CM task force developed a short document on principles and terminology while a task within the IEA H2 TCP had developed a similar document over the course of the previous year. However, both organisations refrained from publishing their documents individually in favour of combining the two and publishing them under the auspice of the Breakthrough Agenda. The combined document was officially released on 2 August 2023 under the title *Hydrogen Certification 101*.

3.2 Results

In a concise manner, the *Hydrogen Certification 101* report provides insight into four interrelated aspects of certification:

1. Definitions of many terms and concepts relevant for hydrogen certification, starting at a high level, defining terms such as “certification” and “certification scheme,” down to concepts such as different chain of custody models to track and trace products and/or their certificates.
2. Descriptions of the different purposes and functionalities of hydrogen certification schemes, explaining the differences between (mandatory) certification in compliance markets and (voluntary) certification in reporting markets.
3. Basic information on the design of certification schemes, introducing the different bodies and institutions associated with certification and their role within a certification scheme as well as presenting further key elements of certification schemes, such as the product attributes to be evidenced by a scheme and the chain of custody model employed by a scheme.
4. The concepts of *tradability*, *mutual recognition*, and *interoperability* of certification schemes for hydrogen and derivatives.

The *Hydrogen Certification 101* is meant as a first source of reference for a broader audience with limited prior knowledge on certification. It is not intended as a comprehensive encyclopaedia or technical guidebook for experts.

While the first publication lacked definitions for some common terms, revisions have since been based on the insights the H2CM task force, IEA H2 TCP, and others have since gained. For example, definitions for mutual recognition and interoperability have been added, which are two terms that are increasingly used when talking about hydrogen certification. Some other revisions, which are introduced in the following paragraphs, concern the following terms and concepts:

- Certification system and certification scheme,
- Key elements of certification schemes, and

- Fundamental design principles of certification schemes.

3.2.1 Certification System and Certification Scheme

Certification system refers to the entirety of the legal, institutional, procedural, and technical arrangements to certify a given product or process. It includes the legal and regulatory requirements set by the government and/or competent authority when the purpose of certification is compliance, or a voluntary agreement implemented by a contracted third party when the purpose of certification is reporting (**Figure 1**). The nature of the actor putting in place the requirements and supervising compliance depends on the purpose of the specific certification in question, i.e., whether certification serves for compliance or reporting (see **Box 1**). Within a certification system, one or multiple certification schemes can operate, either nationally or internationally.[2]

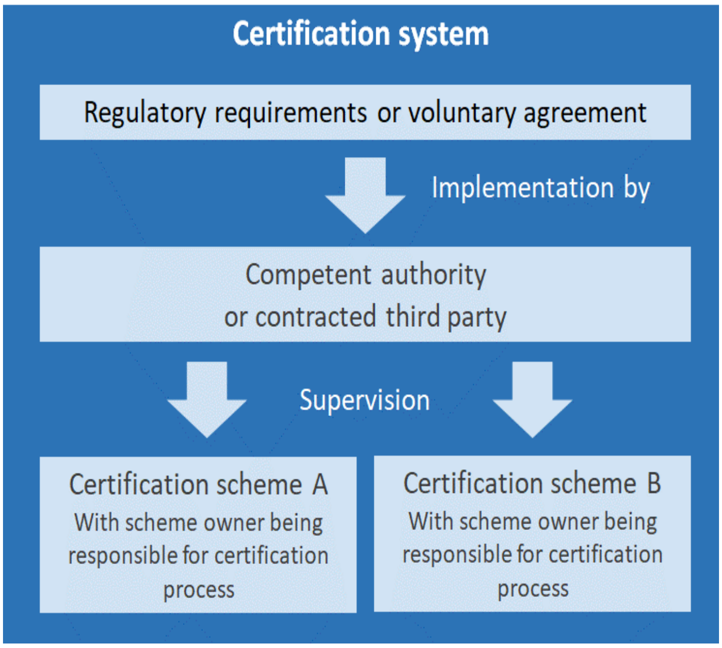

Figure 1: Certification system and certification scheme

Certification scheme (or mechanism) refers to an instrument to confirm that a product or process meets the requirements set by a government, competent authority, or contracted third party (**Figure 1**). A scheme may cover additional attributes beyond those mandated by national legislation. Certification schemes consist of four key elements, which include a set of governance, assessment, and verification processes used to ensure that the considered product (e.g., hydrogen) meets a given set of requirements or criteria (see **Section 3.2.2** Key Elements of Certification Schemes).

Certification schemes may refer to voluntary technical standards, including standards defining their operational setup and procedures as well as the methodologies for assessing the product attributes or processes they are designed to certify.

[2] For example, under a certification system for compliance confirmation with the European Union (EU) regulation (EU renewable energy legislation, in force since 2009), multiple certification schemes operate on an international scale, also outside the EU.

Box 1: Purpose of a Certification Scheme—Compliance or Reporting

Certification schemes can provide (i) a means for compliance with a certain regulation or with criteria to access public funding (regulatory compliance), and/or (ii) a means for voluntary reporting by private companies to inform consumers (disclosure) and investors (corporate reporting).

Certification schemes designed for compliance refer to schemes whose purpose is to ensure legal compliance with requirements established by government authorities for product attributes or processes during production, conversion, storage, transport, and/or use of hydrogen. Among others, these government requirements can be associated with receiving financial support or benefiting from tax credits. For certification schemes with the purpose of compliance, it is the responsibility of government authorities to define the rules for the given certification scheme to meet the compliance requirements. A government may choose to develop and own schemes themselves, or it may recognise schemes of independent organizations to carry out the certification.

Certification schemes designed for reporting refer to schemes whose purpose is to voluntarily disclose information to consumers, investors, or other interested parties regarding product attributes and/or processes during production, conversion, storage, transport, and/or use of hydrogen. Among others, these schemes can be associated with consumer or corporate reporting covering environmental, social, and governance criteria or corporate social responsibility reporting. For certification schemes with the purpose of voluntary reporting, it is the decision of non-governmental actors, including private sector associations, to define the criteria and attributes of the given certification scheme to meet the needs and expectations of consumers, investors, and other market participants.

Schemes designed for compliance markets are mandatory, created and regulated by governments or institutions like the European Commission while voluntary markets are usually neither legally mandated nor enforced, but self-governed. This usually results in different legal frameworks with different requirements. By being mandatory, schemes designed for compliance tend to set stricter conditions for their operational setup and procedures, chain of custody methods, and reporting compared to schemes designed for reporting. Given that many schemes are still under development, detailed information on these three aspects is often scarce.

The distinction between schemes for compliance and schemes for reporting is important for at least two reasons:

- It is an indicator of how similar (or different) individual certification schemes might be, which affects interoperability and the possibility of mutual recognition.
- World Trade Organisation (WTO) rules are likely only applicable to schemes designed for compliance. Schemes designed for reporting are likely not subject to WTO rules. This is expected to affect tradability of hydrogen certified by schemes with different purposes.

3.2.2 Key Elements of Certification Schemes

There are four key elements of certification schemes.

1. **Product Attributes:** The characteristics of the product that the schemes are intended to certify, including the methodologies to measure these attributes.
2. **Operational Setup and Procedures:** The institutional setup and the processes of a certification scheme.
3. **Chain of Custody:** The chain of custody model determines the approach that is applied to track and trace information on product attributes along the supply chain

of a product and the related transactions.

4. **Information Technology:** An IT system is needed for a certification scheme to be operable. The system provides a practical means to participate in the scheme. It is the repository for any information on individual certificates throughout their life cycle, from issuance to transfer to cancellation. As such, the IT system serves as an interface for any party using the certification scheme and is essential to track compliance with the requirements of the certification scheme.

3.2.3 Fundamental Design Principles of Certification Schemes

There are four fundamental design principles for certification schemes.

1. Robustness, i.e., avoidance of fraud and misuse,
2. Transparency, i.e., disclosure of any information in a clear, factual, neutral, and comprehensible manner,
3. Impartiality, i.e., definitions, setups, and procedures without bias or prejudice, and
4. Accuracy, i.e., measurements, estimates, and calculations should neither be systemically over nor under the actual value.

Each of these design principles applies to the key elements of certification schemes (i.e., product attributes, operational setup and procedures, chain of custody model, IT). **Table 1** provides an overview of the practical consequences and benefits when applying the design principles to each of the key elements.

Table 1: Fundamental Design Principles of Certification Schemes

	Robustness	Transparency	Impartiality	Accuracy
Products attributes	Adequacy of definitions and methodologies to measure the product attributes a scheme is intended to certify. Consistent application of accounting approaches, system boundaries, and methodologies. Rationale for methodologies as well as rationale for, and recording of, any changes in methodologies.	Disclosure of information on definitions and methodologies (including processes, procedures, assumptions, and limitations) of determining product attributes in a clear, factual, neutral, and comprehensible manner. Information should be recorded, compiled, and analysed in a way that enables internal and external reviewers to arrive at the same results if provided with the underlying data sources.	Unbiased definitions and methodologies	Measurements, estimates, or calculations of product attributes should neither be systemically over nor under the actual value. Reduction of margin of error in quantifying product attributes as much as practicable.
Operational setup and procedures	Credible and trusted system of checks and balances within certification system. Oversight by supervisory authority.	Clear roles and responsibilities of different actors and bodies within a certification scheme	Certification body and/or auditors are independent third parties. Declaration of any conflicts of interest by the bodies as part of the operational setup.	
Chain of custody model	Strong provisions to ensure trackability and traceability to avoid any kind of fraud, such as false declarations or double counting of certified products, certificates, and product attributes	Clear and publicly available requirements for tracking and tracing of certified products, certificates, and product attributes	Tracking and tracing of products and certificates without bias against any actors or types of transfers	Reliable tracking and tracing of certified products, certificates, and product attributes
IT system	Ensure the integrity of all users' accounts and of all data related to the accounts and certificate and product transactions. Protection of repository from manipulation.	Clear user rights and responsibilities. Free and easy access to the wide public to generic data concerning the product, its certificates, the certification scheme status, annual reports, fraud attempts, etc.	Unbiased information repository, including non-discriminatory memory allocation within the database	Reliable tracking and tracing of certified products, certificates, and product attributes

3.2.4 Tradability, Interoperability, and Mutual Recognition of Certification Schemes

Currently, a number of countries and regions, including some of the European Union (EU) member states, Japan, and Korea, seek to secure imports of hydrogen and derivatives that meet specified product attributes. A number of other countries are focusing primarily on production of certified hydrogen for export or for domestic use.

Producers of hydrogen that meets specified product attributes may need to have their products certified for each purpose or country/region individually according to the respective requirements. Incompatibility of requirements between different markets and different jurisdictions may lead to non-recognition of certification schemes, additional administrative burdens, and barriers for the development of international value chains of certified hydrogen and derivatives.

Fragmented compliance markets with different certification systems would effectively preclude the development of a global hydrogen market.

To better understand how certification supports or inhibits trade, it is useful to distinguish the three concepts of tradability, interoperability, and mutual recognition:

1. **Tradability** represents the extent to which hydrogen that meets specified product attributes can be traded without impediments caused by the differences in the legal and technical requirements of certification schemes. Tradability is regarded as a spectrum, moving from a multitude of independent certification schemes with little to no tradability to a common (global) certification system with complete tradability of certified products and a number of options along that path. In this specific context, tradability has two dimensions: interoperability and mutual recognition (**Figure 2**).
2. **Interoperability** represents the technical dimension of tradability. It refers to the ability of schemes to exchange information and to (mutually or singularly) use the information that has been exchanged to enable them to operate effectively together.
3. **Mutual recognition** represents the intergovernmental and legal dimension of tradability. It refers to the legal framework leading to the acceptance of the equivalency of certification schemes or parts of certification schemes, such as information related to product attributes, their operational setup, and the modalities of tracking and tracing of products by the relevant competent authorities and/or government agencies.

The differences among the key elements within individual certification systems generally touch on both aspects of tradability. For example, while the IT system is regarded as pertaining to interoperability, there are aspects that fall within mutual recognition, e.g., protection against manipulation, prevention of double-counting, data protection, registry ownership. Complementarily, while many aspects of operational setup and procedures are related to mutual recognition, there are operational questions that can be addressed on a technical level (e.g., through ISO standards such as the data transfer protocol) and, therefore, fall within the dimension of interoperability.

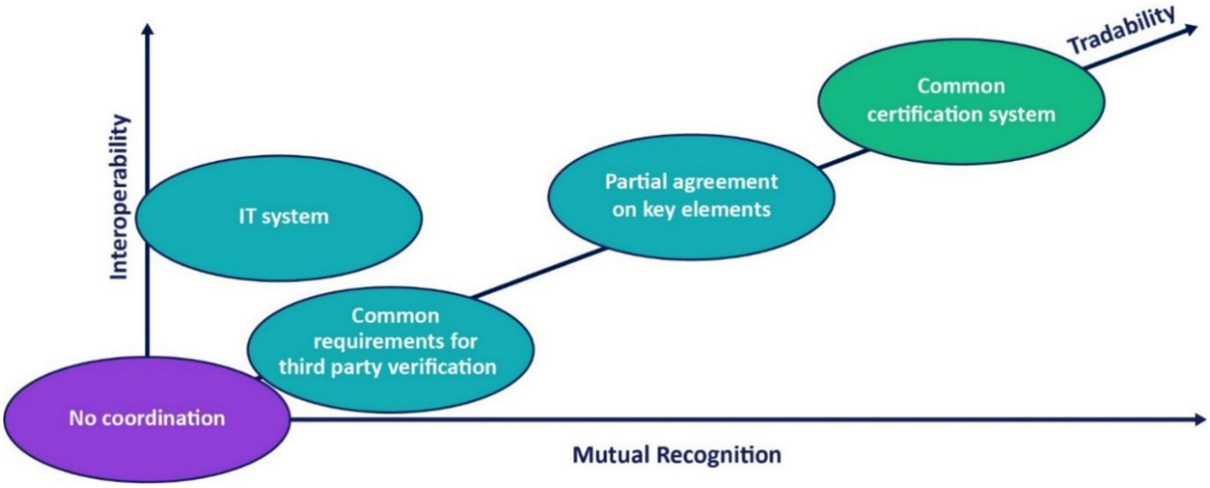

Figure 2: Tradability, interoperability, and mutual recognition
Note: Location of options along the tradability spectrum is illustrative and dependent on design details within each option.

4 Hydrogen Certification Inventory

4.1 Inventory Design

The inventory is an Excel-based repository. Excel was chosen to enable easy access and common usage, not requiring any software or database management skills.

The information contained in the inventory is derived from several different sources, most importantly:

- Input from representatives of IPHE member countries,
- Interviews with scheme developers from both IPHE member countries and non-IPHE member countries, and
- Public documents.

The inventory file is divided into different tabs, reflecting the key elements of certification schemes to facilitate navigation and increase user friendliness. Information sources are provided either in a separate column when concerning the entirety of information on a scheme for an individual key element or as a comment on an individual cell when only concerning the information in that cell. Colour codes are used to broadly mark the reliability of data in an individual cell, with green for reliable, yellow for somewhat reliable, and red for unreliable. Finally, comments on individual cells are used to indicate specific data sources and to provide more detailed information (**Figure 3**).

Country	Designation of scheme		Purpose		Tracking model	Production pathways	Product attributes				
							Summary for GHG emissions		Sumnary for electricity sourcing (Direct line, supply via grid with PPA, supply via grid without PPA)		
	Name	Status	Certification scheme versus support mechanism	If certification scheme, compliance or reporting		eligible technology and fuel options for production	Threshold mass (kg CO2 / kg H2)	Summary system boundary	Direct line	Supply via grid with PPA, REC or similar	Supply via grid without PAA, REC or similar
Australia	Product Guarantee of Origin scheme	Under development	certification scheme	reporting	Mass balancing	all technologies and fuels	None	Well-to-user	direct line but grid connection allowed	supply via grid only with PPA	no supply via grid without PPA permissible
Austria	TUeV AUSTRIA	Operational	certification scheme	reporting	Mass balancing	all technologies and fuels	2.27 kg CO2eq/ kg H2		no information	no information	no information
Canada	Clean Fuels Regulation	Operational	support mechanism		no information	no information	4 kg CO2eq/ kg H2	Well-to-wheel	no information	no information	no information
China	China Hydrogen Aliance's Standard	Operational	certification scheme	reporting	Book and claim	all technologies and fuels	14.51 kg CO2eq /kg H2 4.9 kg CO2eq/ kg H2 4.9 kg CO2eq/ kg H2	Well-to-gate Well-to-gate Well-to-gate	direct line but grid connection allowed	supply via grid only with PPA	no supply via grid without PPA permissible
Germany	dena Biogasregister	Operational	certification scheme	compliance	Mass balancing, book and claim	only electricity from renewable sources	none	no information	with regard to EEG only direct connection	no supply via grid with PPA	supply via grid without PPA permissible
	H2Global	Operational	support mechanism		Mass balance	only electricity from renewable sources	3.04 kg CO2eq/ kg H2	Well-to-gate + partial	direct line and no grid connection allowed	Supply via grid, PPA optional	supply via grid without PPA permissible
	TÜV Süd CMS 70	Operational	certification scheme	reporting	Mass balancing for "Green Hydrogen+"	all technologies and fuels	3.38 kg CO2eq/ kgH2	Well-to-gate	direct line and no grid connection allowed	supply via grid only with PPA	no supply via grid without PPA permissible
Japan	Hydrogen Society Promotion Act (METI)	Under development	Support		TBD	TBD	3.4 kg CO2eq/ kgH2	Well-to-gate	no information	no information	no information
Japan (Chubu Region)	Low-carbon hydrogen	Operational	certification scheme	reporting	Book and claim	no information	no information	Well-to-gate	direct line but grid	Supply via grid, PPA	supply via grid without PPA
Korea	Clean Hydrogen Certification System	Operational	certification scheme	compliance	Mass balancing, book and claim	no information	4kg CO2eq/ kg H2	Well-to-gate	no information	no information	no information
United Kingdom	UK Low Carbon Hydrogen Certificaton	Under delvelopment	certification scheme	compliance and reporting	Mass balancing	only electricity from renewable sources and fossil fuels with CCS	2.4 kg CO2eq/ kg H2	Well-to-gate	direct line but grid connection allowed	Supply via grid, PPA optional	supply via grid without PPA permissible
	UK Renewable Transport Fuel Obligation (RTFO)	Operational	certification scheme	compliance	Mass balancing	no information	3.94 kg CO2eq/ kg H2	Well-to-wheel	direct line but grid connection allowed	Supply via grid, PPA optional	supply via grid without PPA permissible

Figure 3: Illustrative example of inventory layout
Note: This figure is for illustrative purposes only and limited to a small sample of the information contained in the inventory.

The inventory was used to conduct a comparison of the different certification schemes and assess the impact of their differences on the tradability of certified hydrogen.

4.2 Inventory Content

The inventory is a systematic collection and mapping of information about existing hydrogen certification schemes and schemes that are currently under development. The information it contains was collected during the period 2023–2024 and might be updated in the future. It contains information on **17 certification schemes and 4 support mechanisms across 11 countries or regions**.[3] Of these, 10 are existing certification schemes or support mechanisms for hydrogen and hydrogen derivatives and 11 are certification schemes or support mechanisms at different stages of development (for the purpose of compliance [regulatory markets] or for the purposes of disclosure or reporting [voluntary markets]). For a detailed list of certification schemes and support mechanisms covered by the inventory, please refer to **Appendix A:** Certification Schemes and Support Mechanisms Covered by the Inventory.

The inventory contains detailed information on the following four key elements of hydrogen certification schemes (see **Section 3.2.2** Key Elements of Certification Schemes):

1. Product attributes
2. Operational setup and procedures
3. Chain of custody
4. Information technology.

[3] While some of the support mechanisms do not qualify as certification schemes under the definition provided in the *Hydrogen Certification 101*, in this document the term "certification scheme" includes these support mechanisms unless explicitly stated otherwise in order to facilitate readability.
Note that the UK RTFO is not a certification scheme in a traditional sense. Instead, it requires suppliers of relevant transport fuels (petrol, diesel, gas oil, and renewable fuels) in the UK to meet an annual obligation for the supply of renewable fuels using third party certification.
Appendix A provides an overview of all certification schemes and support mechanisms included in the inventory and considered for this report.

The following sections present in more detail the kind of information compiled in the inventory for each of these four key elements.

While similar inventories for information on hydrogen certification have been compiled by other organisations, the inventory developed by the H2CM task force is more comprehensive (i.e., a higher number of schemes included), has a wider scope (i.e., a larger variety of elements covered), and has a higher granularity (i.e., a higher level of detail) than comparable initiatives.

4.2.1 Product Attributes

Product attributes refer to the characteristics of the hydrogen that the certification schemes are intended to verify as well as the methodologies to measure these attributes.

The inventory includes a total of **14 potential product attributes** (**Table 2**). While the inventory is designed to capture information on these attributes for all certification schemes, not all certification schemes consider or provide detailed information about each of these attributes.

Table 2: Attributes Captured by the Inventory by Category

Environmental	Social
Permissible production technologies	Labour standards
GHG emissions	Job creation
Electricity sourcing	Local content requirements
Water use	Professional training
Land use	Gender aspects
Biodiversity	Development of local infrastructure
Generation of waste and pollutants	Sustainable development goals
Sustainable development goals	

Regarding permissible production technologies, the inventory is designed to capture information on the eligible technologies and feedstock options to produce hydrogen under each certification scheme to identify whether there are any restrictions.

Regarding the accounting of GHG emissions, the inventory can capture the following information:

- The GHG emissions accounting methodology used to determine the emission intensity of production and possibly further steps in the value chain of hydrogen. This is relevant to determine whether there are any methodologies that are widely used or if most certification schemes use their specific methodologies to estimate GHG emissions.
- Whether certification schemes identify a specific threshold for the GHG emissions intensity, and where that threshold lies. If the threshold refers to the emissions intensity per amount of hydrogen measured as an energy unit, the information, whether it refers to the higher or lower heating value, is captured.

- The system boundaries considered for estimating GHG emissions. This captures broad definitions such as well-to-gate; well-to-wheel; and life cycle assessment Scope 1, 2, or 3. In addition, the inventory provides information on whether, and to what extent, the following supply chain steps are considered in the GHG emission accounting methodology:
  - Capital goods, referring to the construction of electricity generation plants and hydrogen production plants.
  - Raw material extraction and pre-processing, referring to the extraction, processing, and transport of inputs for hydrogen production.
  - Production, including fuel produced on site and fuel purchased; potential gasification, steam generation, cooling and compression of gases.
  - Conversion, referring to conversion of hydrogen into a hydrogen carrier (e.g., liquid hydrogen, ammonia, and liquified organic hydrogen carriers).
  - Storage, including mainly the electricity used during storage of hydrogen.
  - Transport and distribution, including mainly the fuels used for transport and distribution of hydrogen.
  - Conversion, referring to conversion of a hydrogen carrier into hydrogen.
  - Use, referring to the consumption of hydrogen.
- Whether the GHG emissions accounting methodology includes a threshold below which GHG emissions from a single source are not considered and where that threshold lies.
- How GHG emissions are allocated in case of a production process that not only produces hydrogen but also other co-products, i.e., allocation based on mass, allocation based on energy content, allocation based on economic value.
- Whether carbon capture and storage (CCS) is permissible under the methodology and whether the methodology considers fuel consumption for the CCS process.
- How GHG emissions are measured, specifically asking if only on-site measurements are permissible or if the use of default values is permissible and if so, what the requirements are to use default values.

Regarding the sourcing of electricity, the inventory differentiates three possibilities:

- Electricity is generated at the same facility where hydrogen is produced or is directly connected to the hydrogen production facility (i.e., behind the meter). As such, the inventory aims to capture:
  - Whether a parallel grid connection of the hydrogen production facility is allowed.
  - Whether there are any requirements on the temporal correlation between electricity generation and hydrogen production.
  - Whether an electricity generation and demand forecast is required.
- The hydrogen production facility is connected to the electricity grid and procures electricity via power purchase agreements (PPA), renewable electricity certificates, or similar energy attribute certificates. As such, the inventory can capture the

following details:

  - If there are any requirements for the minimum share of electricity generated from renewable sources and the threshold of that share.
  - If there are any requirements for the maximum emissions intensity of electricity generation and the threshold of that emissions intensity.
  - If there are any requirements for the additionality of electricity generation assets, i.e., if the generation asset needs to be built in addition to existing assets. If such a requirement exists, the inventory is designed to capture its provisions, including the timing of its phase in.
  - If there are any requirements for the temporal correlation between the generation of electricity used for hydrogen production and the hydrogen production process (i.e., to what extent the electricity generation and consumption must match). If such a requirement exists, the inventory is designed to capture its provisions, including the timing of its phase in.
  - If there are any requirements for the geographical correlation between the generation of electricity used for hydrogen production and the hydrogen production process (i.e., to what extent existing transmission infrastructure is considered). If such a requirement exists, the inventory is designed to capture its provisions, including the timing of its phase in.
  - If there are any restrictions on electricity generation assets that have received (public) financial support in the past, independent of their relevance for generating electricity for hydrogen production.
  - If and how use of excess electricity, i.e., electricity from generation assets that would have to be curtailed, is considered.
  - If and how the use of electricity from battery storage is considered.
- The hydrogen production facility is connected to the electricity grid without a PPA or renewable electricity certificate with any utilities. If that is the case, the inventory can provide the same details as listed above for hydrogen production facility connected to the electricity grid with a PPA.

Regarding further environmental and social attributes (see **Table 2** for the complete list), the inventory is designed to capture any dedicated provisions that might be part of the hydrogen certification as well as to indicate whether relevant provisions exist as part of other legislation or regulations.

Finally, the inventory also includes information on whether any sustainable development goals (SDGs) are considered and if so, which goals are applicable.

4.2.2 Operational Setup and Procedures

Operational setup and procedures refer to the institutional framework and the processes of a certification scheme. It includes the purpose for which a certification scheme has been developed, the different actors and bodies that are part of the certification scheme, and the processes for designing, operating, overseeing, and changing the certification scheme. Transparent and clearly defined operational structures and processes are essential for the functioning of a certification scheme and to demonstrate credibility and trustworthiness of a scheme towards its stakeholders.

To capture information on the purpose of a certification scheme, the inventory distinguishes between (mandatory) schemes for compliance and (voluntary) schemes for reporting (see **Box 1**). The inventory is also designed to include information on whether a certification scheme serves any regulatory framework and if so, which framework.

Regarding a scheme's operational setup, the inventory focuses on capturing information on whether bodies and actors associated with a certification scheme meet the requirements of relevant voluntary technical standards and guidelines. For that purpose, the inventory aims to capture whether a scheme appears consistent with the requirements of any of the following ISO standards:[4]

- ISO/IEC 17065:2012 (ISO 17065 [Conformity assessment — Requirements for bodies certifying products, processes and services])
- ISO/IEC 17029:2019 (ISO 17029 [Conformity assessment — General principles and requirements for validation and verification bodies])
- ISO/IEC 17011:2017 (ISO 17011 [Conformity assessment — Requirements for accreditation bodies accrediting conformity assessment bodies])
- ISO 14065:2020 (ISO 14065 [General principles and requirements for bodies validating and verifying environmental information])
- ISO 19011:2018 (ISO 19011 [Guidelines for auditing management systems]).

These voluntary technical standards were identified based on an iterative process in which standards mentioned by specific certification schemes were noted and it was verified for all other schemes whether they also refer to the same standards. The current list includes the standards most referred to by certification schemes.

In addition, the inventory provides the possibility to complement this general information with more details on individual bodies or actors within a certification scheme, capturing:

- The designation of the certification body or conformity assessment body[5] and whether the body meets any requirements set out in a voluntary technical standard, in particular ISO 17065 (Conformity assessment: Requirements for bodies certifying products, processes and services) and/or ISO 17029 (Conformity assessment: General principles and requirements for validation and verification bodies),
- The designations of auditors accredited within the certification scheme and whether these auditors meet any requirements set out in a voluntary technical standard, in particular ISO 19011 (Guidelines for auditing management systems),
- The designation of the issuing body and whether the issuing body meets any requirements set out in a voluntary technical standard, in particular ISO 17065 (Requirements for bodies certifying products, processes and services), and

[4] Many of the certification schemes reviewed do not explicitly state compliance with given ISO standards. These schemes were reviewed for general consistency with the requirements of those standards.

[5] In case of certification according to a specific standard, the certification body is considered a conformity assessment body.

- The designation of the accreditation body and whether the accreditation body meets any requirements set out in a voluntary technical standard, in particular ISO 17011 (Requirements for accreditation bodies accrediting conformity assessment bodies).

4.2.3 Chain of Custody

The chain of custody model determines the approach that is applied to track and trace information on product attributes along the value chain and the related transactions. While there are fundamental conceptual differences between chain of custody models, there can also be differences in approaches following the same chain of custody model, concerning definitions, methodologies, and implementation, such as title transfer and cancellation rules.

The inventory is designed to capture the following information regarding the chain of custody model:

- The unit used to measure certified amounts of hydrogen. For the schemes measuring amounts of hydrogen based on energy content, the inventory is designed to capture information on whether the higher heating value (gross energy, upper heating value, gross calorific value, higher calorific value) or lower heating value (net energy, net calorific value, or lower calorific value) is used.
- The type of chain of custody model allowed under the certification, i.e., book and claim or mass balancing (See **Box 2**).
- For certification schemes using book and claim as the chain of custody model:
  - The geographic coverage of the certification scheme.
  - Whether certificates have a specified maximum lifetime after which they expire and if so, the duration of that lifetime.
  - Whether the chain of custody model considers any voluntary technical standards for the tracking and tracing of product attributes, and if so, the designation of these standards.
  - Provisions concerning cancellation (i.e., retirement) of certificates.
  - Whether certificates are limited to hydrogen or can be transferred to other fuels (e.g., hydrogen blended with natural gas).
- For certification schemes using mass balancing as the chain of custody model:
  - The level at which the system operates (e.g., site, batch, group).
  - The permissible maximum time that can be considered for mass balancing.
  - Whether certificates have a specified maximum lifetime after which they expire, and if so, the duration of that lifetime.
  - Provisions concerning cancellation (i.e., retirement) of certificates.
  - The approach towards consignment, in particular, whether consignment of hydrogen can be co-mingled with other consignments of hydrogen with different GHG specifications or even comingled with other fuels.

Box 2: Chain of Custody Models–Mass Balancing versus Book and Claim

The chain of custody model within a scheme determines the process associated with the change of ownership and legal responsibility of a certificate and/or the underlying physical product for tracking and tracing of product attributes along the supply chain. There are two types of chain of custody models commonly used in certification of energy products: (1) mass balancing and (2) book and claim. A comparison is made in **Table 3**.

The mass balancing model is designed to track and trace the total amount of certified products along the supply chain, while ensuring an appropriate allocation of this certified quantity to the products reaching the end users. This requires that the product and the certificate have a reasonable physical link.[6]

Co-mingling of consignments of certified and non-certified products within a defined boundary (spatial unit) is possible under a mass balancing approach in some certification schemes. Spatial units may be a container, a logistical facility or a (future) hydrogen pipeline network.

The book and claim model allows tracking and tracing of the electronic certificates containing the information of product attributes from their issuing to their cancellation (for disclosure). The model allows for completely separating the physical product from the certified product attributes, so that during any physical or commercial transactions after production, the certificate for the product attributes can be traded separately from the physical product. As a result, by purchasing a certificate, customers can claim the use of certified hydrogen without the need to physically transport the hydrogen.

The book and claim model is widely used for certification of electricity generated from renewable sources. In the electricity market, use of a book and claim model affects the product attributes of customers in the same market that are not using any certificates. To prevent double counting or double accounting, the product attributes claimed by a customer of a certificate for electricity from renewable sources often need to be subtracted from the attributes of the remaining electricity mix. This residual mix is calculated as the average “renewables content” of the remaining electricity consumption by the market. As a result, other parameters remain the same, increasing the use of renewable electricity certificates decreases the renewable content of remaining residual electricity mix.

The declaration of the residual mix is needed to avoid double counting (i.e., the amount of electricity from renewable sources consumed by a user based on a certificate cannot be claimed by other users in the remaining residual mix). Two (theoretical) alternatives are to either not declare any renewables content of electricity sold to customers that are not using a certificate, or to oblige the allocation of all renewable electricity certificates in a market among electricity consumers. As of now, it remains to be seen whether and how this residual mix is considered in the case of tracking and tracing product attributes of hydrogen via a book and claim model.[7]

[6] The definition of what constitutes a “reasonable physical link” often differs between jurisdictions.

[7] Given the comparatively small share of electricity currently used by hydrogen producers via book and claim systems, some schemes that use the book and claim model do not require calculation of a residual mix.

Table 3: Comparison of Tracing Models

Chain of Custody Model	Mass Balancing	Book and Claim
Description	Product attributes are linked to the physical product consignment. Both are tracked and traced along each step in the supply chain, from producer to the final customer. Co-mingling of products with different parameters for product attributes is allowed.	The certificates are issued at the production gate; they can be traded separately from the physical product and purchased by the customer to claim the use of certified product.
Link to physical product	Physical product and product attributes are linked, while co-mingling of products with different parameters for product attributes is allowed.	No link between physical product and product attribute.
Need to calculate the residual mix	No	Yes, depending on how the scheme is administered
Need to physically transport hydrogen	Yes	No
Examples of regulations or guidelines[8]	U.S. California Low Carbon Fuels Standard (LCFS), RED II RFNBO (and recognised voluntary schemes), Australian GO scheme for hydrogen, CBAM, H2Global	RED II GO, Australian GO scheme for renewable electricity, CertifHy GO scheme, U.S. California LCFS

4.2.4 Information Technology

Information technology refers to setup and operation of a database that serves as the registry (or ledger) for all transactions along the supply chain (i.e., issuance, transfer, cancelation) for every participant in a certification scheme (i.e., account holder). The IT system is the central instrument to track and trace a product consignment and the associated product attributes (in a mass balancing chain of custody model) or the certified product attributes (in a book and claim chain of custody model). The specific design of an IT system is subject to the purpose, the chain of custody model, and the regulatory environment (e.g., data protection).

Many of the certification schemes analysed in this report are still in development. Therefore, there was insufficient information available for the IT system to be included in the inventory. In the future, the following aspects might be of interest:

- Layout of registry, referring to whether there are separate registries for (1) the proofs of product attributes (e.g., proof of sustainability); (2) the transactions of proofs of product attributes and the accounts of sellers and purchasers; and (3) the certificates given to companies producing, converting, transporting, and storing the hydrogen fulfilling the required product attributes, or all relevant information is compiled in a single registry.
- Registry ownership, referring to whether the registry (or registries) is owned and operated by a public entity or a private company.
- IT architecture, referring to whether there is a centralised database (or databases)

[8] The regulations shown may utilize mass balancing and/or book and claim to track hydrogen, or to track its feedstock (e.g. electricity). Tracking of electricity specifically is commonly done through book-and-claim.

serving as the registry or a decentralised database with relevant information stored on the users’ computers.

- The file format, referring to the format in which data is stored in the registry (or registries).
- Data transfer protocols and user interface.
- User rights and responsibilities, referring, among other things, to the information required from account holders.
- Technology solutions to ensure uniqueness of certificates, referring, among other things, to means chosen to prevent double counting and fraud (e.g., blockchain).

5 Comparison and Interoperability Assessment

5.1 Methodology

The comparison and the tradability assessment were developed based on the information collected in the inventory.

The methodology used to conduct the comparison and tradability assessment included the following five steps:

1. Determination of available information,
2. Categorisation of differences,
3. Explanation of differences,
4. Explanation of impact on tradability, and
5. Identification of enablers for tradability.

First, to determine the available information, the share of schemes with any information was calculated for each item in the inventory.

Second, to categorise the difference between the schemes, a quantitative comparison was applied, assessing for each item within the inventory whether:

1. Provisions within the schemes were identical (or similar),
2. Some schemes had additional requirements,
3. Differences between schemes were administrative only, or
4. Differences were substantial.

Third, a qualitative comparison was applied, identifying the similarities and differences between schemes in more detail, grouping those that showed similarities, and justifying the choice made in the quantitative comparison (in the second step).

Fourth, when differences between schemes had been identified (i.e., Options 2, 3, or 4 had been selected in the quantitative comparison), a description for the expected impact on tradability was given.

Fifth, when differences between schemes were expected to have a negative impact on tradability, options to enable tradability were identified where possible.

5.2 Results

5.2.1 Overview

5.2.1.1 Results of Comparison and Impact on Tradability

Certification schemes showed **considerable variation in the information available**. Information availability was generally higher for the product attributes and operational setup compared to very little information being available for the chain of custody model provisions of individual schemes, as well as their IT systems. There was also considerable variation in available information within single key elements. For example, while the information available for GHG emissions accounting and requirements towards electricity sourcing generally came at a medium to high level of detail, information on other environmental and social attributes showed a low level of detail with many relevant legal provisions being outside of the specific requirements of the certification schemes.

Regarding product attributes, **certification schemes focused on GHG emissions, followed by provisions on electricity sourcing and permissible production technologies**. Water and land use were considered by a majority of schemes, though with little detailed information available. Further product attributes received little attention in certification schemes.

- The task force expects differences in **GHG emissions** accounting methodologies and thresholds to have a high impact on tradability.
- Markets and jurisdictions relying on schemes with stricter requirements (e.g., lower thresholds, wider system boundaries, stricter cut-off criteria) are considered unlikely to treat hydrogen not aligned with those requirements as equivalent. Similarly, differences in the allocation method in case of co-production will also reduce tradability, as different allocation methods will result in different GHG emission intensities, even when using identical data.
- Differences in **permissible (production) technologies and feedstocks**, including eligibility of CCS are also expected to have a medium impact tradability. In particular, for markets and jurisdictions that do not allow for CCS, supply options of hydrogen will be reduced, as any producer relying on CCS is excluded. However, only a few schemes have in place such restrictions.
- Different provisions regarding **electricity sourcing** are expected to have a medium to high impact on tradability. Markets and jurisdictions relying on schemes with stricter requirements (e.g., necessity for PPAs or similar contractual arrangements, additionality, temporal and geographic correlation) are considered unlikely to treat hydrogen not aligned with those requirements as equivalent.
- Requirements related to **water and land use, biodiversity, waste, pollution, and social impacts** are expected to have a low impact on tradability at this point. Currently, most schemes do not have dedicated provisions on these attributes. Rather, these attributes are subject to legislation and regulation outside of the certification schemes. Should schemes include dedicated provisions on these attributes in the future and these provisions show considerable difference, the impact on tradability could be high (i.e., similar to the current high impact of difference in GHG emissions accounting on tradability).

Regarding the **operational setup and procedures**, two aspects are of particular importance for tradability: (1) the purpose of the certification scheme and (2) whether schemes refer to specific voluntary technical standards for their institutional setup.

- Almost two thirds of the schemes for which information is available operate as compliance schemes or aim at becoming compliance schemes. The remaining schemes are voluntary reporting schemes. It is assumed that governments will only regard compliance schemes as relevant means for certifying the adherence to regulatory requirements. As a result, only compliance schemes could recognise other compliance schemes as equivalent. However, since most schemes are aimed at compliance, it is expected that differences in the **purpose of certification schemes** will have a low impact on tradability.
- Of the schemes that provide information, **almost all meet the requirements of at least one of the following voluntary technical standards** for their institutional setup and procedures: ISO 17065, ISO 19011, ISO 14065, or ISO 17029. Differences in the institutional setup and operational processes between certification schemes are expected to have a high impact on tradability. It is assumed that schemes adhering to voluntary technical standards for their operational setup and procedures will be less willing to recognise schemes that are not aligned to any such standard.

Of the schemes providing information on their chain of custody model to track and trace hydrogen and its derivatives, almost three quarters use mass balancing, with only 20% relying on book and claim, and one scheme allowing for both chain of custody models to track and trace hydrogen. Mass balancing and book and claim are two fundamentally different models for tracking and tracing products and certificates. While not impossible, it is considered as unlikely that the models will be compatible with each other as schemes operating with mass balance will require a “reasonable physical link” to be demonstrated, which book and claim cannot provide, given that the transfer of a certificate is separate to the transfer of the hydrogen.

- **Differences in tracking and tracing** hydrogen and certificates are expected to have a high impact on tradability. Even schemes applying the same chain of custody model show considerable differences, such as in the level of tracking and tracing, in time periods for reporting, in cancellation rules, and in provisions regarding co-mingling. All of these differences are likely to substantially reduce tradability of certified hydrogen.
- There is **insufficient information for a more systematic and detailed assessment**. While nearly three quarters of the analysed schemes provide information on the chain of custody model used, the share of schemes providing detailed information on specific requirements is considerably lower. However, such information should become available once schemes have been fully developed.

5.2.1.2 Options to Improve Tradability

Regarding suggestions to improve tradability, this analysis aims to focus on the politically most feasible and technically most pragmatic options. For most of the key elements of certification, a modular approach is regarded as a way to meet both criteria. Such a modular approach would entail a number of common modules that different jurisdictions or scheme owners agree on and can opt into or opt out of, as well as modules that would remain specific to individual jurisdictions (or certification schemes). Different modular approaches can be envisioned, with the main difference being the level of ambition (i.e., whether to follow a rather incremental approach with fewer items agreed upon in the common modules or whether to be more ambitious with a more comprehensive agreement on the content within common modules).

Overall, progress towards improving tradability trajectory is not regarded as a continuous trajectory as **Figure 2** might suggest. Rather, progress should be envisioned as an incremental process with the need to achieve certain thresholds of commonality within a key element in order to have a measurable improvement in tradability.

For **product attributes**, a modular approach could take two different forms:

1. A less ambitious approach could translate into certified entities along the hydrogen value chain providing the data needed to calculate GHG emissions (and potentially other product attributes) using methodologies specific to individual jurisdictions. In this case, the common module would consist of agreement on the data that would need to be provided to calculate emissions for all relevant methodologies. This could entail companies opting to provide only the data necessary for some methodologies and thereby accepting that their hydrogen would not qualify for certain markets.
2. A more ambitious approach could entail developing a common methodology for each product attribute. In that case, individual modules would consist of a single agreed-upon methodology for each step of the hydrogen value chain. Individual certification schemes (or individual companies) could then choose to opt into or opt out of individual modules. ISO TC197/SC1/WG1 is developing a series of voluntary technical standards providing a methodology for determining the GHG emissions associated with the production, conversion, conditioning and transport of hydrogen. This standard series could serve as a set of modules for GHG emissions accounting. Other standards would need to be developed for other product attributes.

Both approaches could be implemented in the form of a **digital products passport for hydrogen and its derivatives** that contains or is linked to the necessary data and methodologies (see **Box 3**). For more details on the information that could be contained in a hydrogen passport, please refer to **Section 6** Information Requirements for Certification Equivalency.

Box 3: Digital Product Passport for Hydrogen and its Derivatives

A digital product passport is a structured collection of product and process-related data along the entire value chain (or parts of the value chain) on top of a token assigned to a specific volume of hydrogen or its derivative. Ideally, a digital product passport contains or is linked to all relevant data points for all relevant certification schemes. Relevant data is compiled and provided to authorities or entities along the value chain when needed and informs whether the hydrogen or derivative adheres to the relevant product requirements of a specific jurisdiction or market.

A digital product passport for a volume of hydrogen and hydrogen derivatives could be established in the form of a unique ID connected to a data repository accessible to entities along the value chain, including trading partners and end users.[9] The data could include information on (i) the product attributes, (ii) the operational setup and procedures of the certification schemes via which the attributes have been assessed, and (iii) the chain of custody model used to track the specific volume. For each of those, the associated standard, regulation, institution or methodology should be included (see **Section 6** Information Requirements for Certification Equivalency). Information in a digital product passport could be accessible from a chip, or by scanning a watermark or quick response (QR) code.[10]

Digital product passports have been suggested in various jurisdictions[11] for a variety of applications. For example, the Global Battery Alliance proposes a battery passport. The passport establishes a digital twin of an electric vehicle's physical battery carrying information on that battery about a number of sustainability and lifecycle requirements.[12]

The IEA, market participants, and software developers expect that challenges such as co-mingling (i.e., mixing) of volumes of hydrogen from different sources with possibly different attributes (e.g., GHG emissions intensities) can be addressed by technical solutions, as long as different jurisdictions or scheme owners agree on the fundamental principles.[13]

For an intermediate energy product like hydrogen, a digital product passport should be developed in a manner that is compatible with products upstream and downstream in the value chain (**Section 7** Certification Along the Entire Value Chain).

An example of a digital passport is illustrated in **Figure 4.**

[9] UNECE 2024, Critical Raw Materials. https://uncefact.github.io/project-crm/docs/about/purpose
[10] UNECE 2023, White Paper Digital Product Conformity Certificate Exchange. White Paper
[11] For example, in North America (IRA, UFLPA, TSCA, CARB2, Lacey Act, Dodd-Frank Act), Europe (Green Deal, ESPR, Battery Pass, EUDR, REACH, CRM, NZIA, CBAM), and Japan (Carbon Footprint Regulation for EV batteries, Act on the Promotion of Effective Utilization of Resources).
[12] Global Battery Alliance 2024, Battery Passport. Battery Passport (globalbattery.org)
[13] International Energy Agency (IEA) 2023, Towards hydrogen definitions based on their emissions intensity. Towards hydrogen definitions based on their emissions intensity – Analysis - IEA
H2Global Foundation and Hydrogen Europe 2023, Standardizing Hydrogen Certification: Enhance Traceability, Transparency, and Market Access. H2Global-Stiftung-Policy-Brief-05_2023-EN.pdf (hydrogeneurope.eu)
SAP 2023, Solutions for Regulatory Requirements and Customer Needs.
Siemens Energy 2023, CertaLink™ Zertifikate für Energiemärkte.

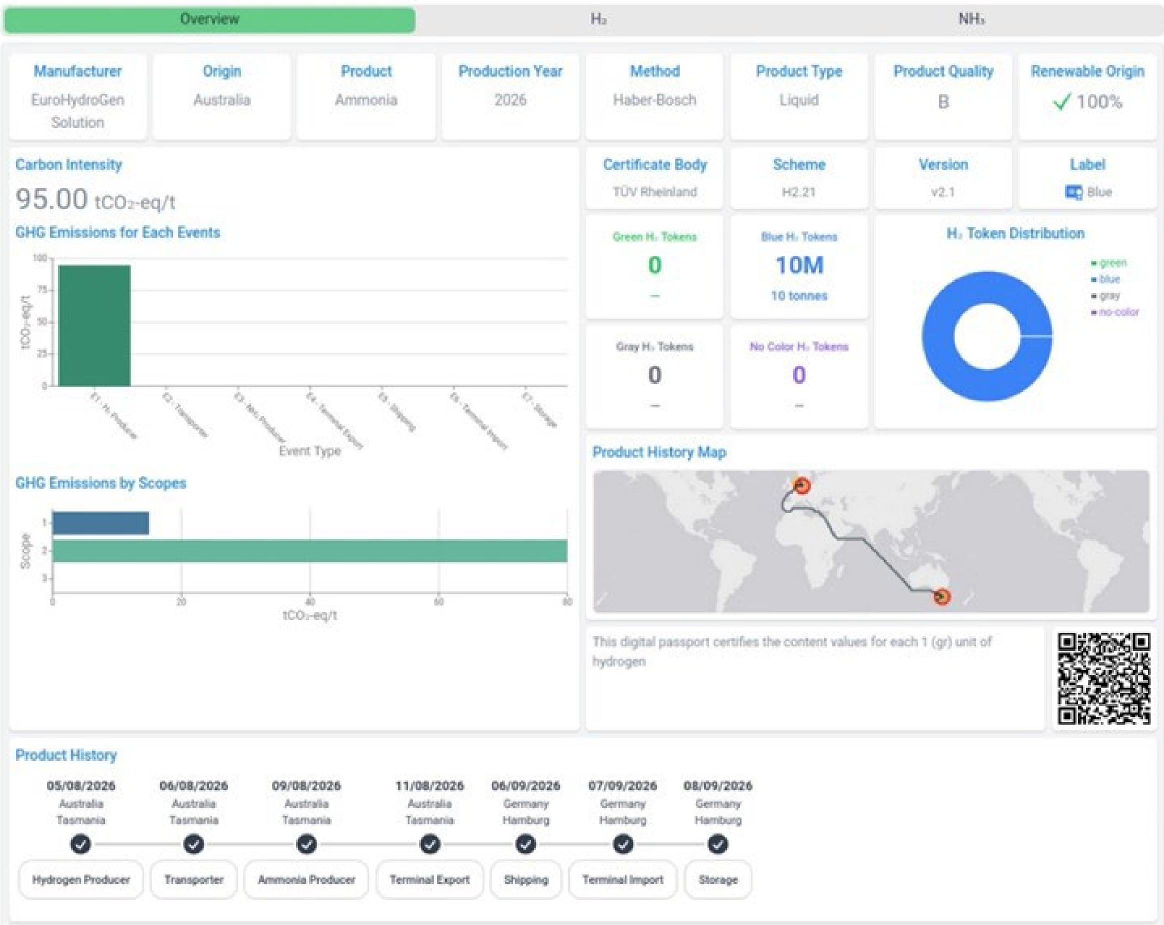

Figure 4: Illustrative example of a digital product passport for hydrogen and its derivatives
Source: Standards United AG 2024

For the **operational setup and procedures**, an agreement on a set of voluntary technical standards that certification bodies, issuing bodies, accreditation bodies, and auditors must adhere to is regarded as a pragmatic and effective step to facilitate tradability of certified hydrogen. Either certification scheme owners themselves or the governments putting in place the regulatory requirements for the schemes could agree on which standards should be adhered to.

Practical steps towards such a common set of agreed-upon technical standards for the operational setup and procedures could be to:

- Encourage all certification schemes to disclose their adherence to relevant voluntary technical standards for their operational setup and procedures.
- Support and assist schemes that currently do not adhere to voluntary technical standards for their operational setup and procedures to adopt relevant provisions by sharing best practices and to provide practical guidance on implementation, either bilaterally or through multilateral fora.

For the **chain of custody model** used to track and trace products and certificates, mass balancing and book and claim represent two fundamentally different approaches with little space for common solutions to bridge that gap. Many jurisdictions are still in the process of developing the necessary requirements, and where requirements exist, many scheme owners are still in the process of translating those requirements into practice. As a result, little can be said about differences between schemes using the same chain of custody model and options to reduce the possible impacts on tradability. However, the current early stage of development also provides an opportunity to agree on a single chain of custody model, i.e., either mass balancing or book and claim, with a set of common provisions to prevent substantial future differences between requirements. Absent such an agreement, once detailed provisions are in place, schemes with stricter requirements are considered as unlikely to recognise schemes with less strict requirements (see **Table 4**).

Table 4: Summary of Comparison and Tradability Assessment by Key Element

Key element	Available information	Quantitative comparison	Options to enable tradability
Product attributes	Mixed level of detail Medium to high level of detail for GHG emissions and electricity sourcing Low level of detail for other environmental and social attributes, where many provisions outside of scope	Some schemes have additional or stricter requirements	Introduction of a hydrogen passport Less ambitious: Agreement on a common set of data and information to be provided for each product attribute More ambitious: Agreement on modules with common methodology for each product attribute and each step of the hydrogen value chain that schemes can opt into or opt out of
Operational setup and procedures	Mixed level of detail Ambiguity of terminology	Some schemes have additional or stricter requirements	Agreement on a set of voluntary technical standards for certification bodies, issuing bodies, accreditation bodies, and auditors
Chain of custody	Only broad information with low level of detail	Substantial differences	Agreement on a set of common provisions concerning schemes using the same chain of custody model to prevent substantial differences between schemes in the future
IT	Only broad information if any	Insufficient information for systematic comparison	Insufficient information for assessment of options

5.2.2 Product Attributes

Information availability for product attributes was generally higher compared to other key elements, particularly chain of custody models and IT systems. However, there was considerable variation in available information for individual product attributes. For example, while the information available for GHG emissions accounting and requirements towards electricity sourcing generally came at a medium to high level of detail, information on other environmental and social attributes showed a low level of detail with many provisions assumed to be outside of the scope of hydrogen certification.

Overall, the 21 analysed certification schemes focused on GHG emissions, followed by provisions on electricity sourcing and permissible production technologies, both of which are often considered in relation to GHG emissions. Water and land use were considered by a majority of schemes, though with little detailed information available. Further product attributes received little attention by certification schemes. See **Table 5** for details.

Table 5: Summary of Product Attributes

Product attribute	Share of schemes considering the attribute	Share of schemes with detailed provisions	Share of schemes with threshold	Expected impact on tradability
Permissible production technologies	60%	60%	25%	Low impact
GHG emissions	100%	50%	80%	High impact
Electricity sourcing	75%	50%	N/A	High impact
Water use	60%	40%	N/A	Low impact
Land use	60%	40%	N/A	Low impact
Biodiversity	40%	15%	N/A	Low impact
Waste and pollutants	30%	5%	N/A	Low impact
Labour standards	60%	25%	N/A	Low impact
Job creation	40%	10%	N/A	Low impact
Local content requirements	33%	15%	N/A	Low impact
Professional training	30%	15%	N/A	Low impact
Gender	30%	15%	N/A	Low impact
Development of local infrastructure	30%	15%	N/A	Low impact
Sustainable development goals			N/A	Low impact

5.2.2.1 Permissible Production Technologies

About half of the analysed certification schemes provide information on eligible technology and feedstock options for producing hydrogen. Of the schemes for which information is available, approximately three quarters consider all technologies and fuels as eligible, while one quarter has restrictions on which technologies and feedstocks are eligible.

In theory, stricter requirements for the technology and feedstocks used to produce hydrogen reduces tradability. In particular, it reduces quantities of hydrogen for import, as there are likely fewer producers meeting those stricter requirements. In practice, the effect on tradability is likely limited as the specific schemes in question are either aimed at domestic production or operate with long-term contracts with producers abroad to import hydrogen.

5.2.2.2 GHG Emissions

All analysed schemes consider GHG emissions intensity as a product attribute. A large majority (81%) provide information on the emissions accounting methodology used. While some schemes (29%) base their calculation of GHG emissions on methodologies that were developed jointly, such as the accounting provisions under the EU Renewable Energy Directive and the methodology initially developed by IPHE, or keep the option open to align their methodology with a future ISO standard, most schemes (52%) use their own specific methodologies to estimate GHG emissions.

Almost all analysed schemes (>85%) provide information on whether the certified hydrogen needs to meet a specific **threshold for the GHG emissions intensity**. This threshold is defined as a permissible amount of carbon dioxide equivalent emitted per unit of hydrogen, either measured in mass or in energy content. The differences in GHG emission thresholds between certification schemes are substantial, ranging from 1 kg CO_2e per kg H_2 to 14.51 kg CO_2e per kg H_2. Only one scheme does not require the certified hydrogen to meet any specific threshold. Instead, this scheme certifies that the hydrogen produced has the estimated GHG emissions intensity.

All but one of the analysed schemes provide a broad definition of the **system boundary** (see **Table 6**) that they consider for estimating GHG emissions. Two thirds of the schemes consider well-to-gate as their scope, while approximately a quarter considers a wider well-to-user scope. However, differences still exist among schemes following one of these two approaches.

Table 6: System Boundaries

Country/Scheme	Raw material extraction and pre-processing	Production	Conditioning (on site)	Conversion (on site)	Storage (on site)	Transport and distribution	Conditioning	Conversion	Storage	Use
Australia, Product Guarantee of Origin scheme										
TÜV Austria										
Canada, Clean Hydrogen Investment Tax Credit										
China Hydrogen Alliance's Standard										
EU, CertifHy										
EU, ISCC										
EU, REDCert										
France, Guarantees of origin										
France, Guarantees of traceability										
Germany, dena Biogasregister										
Germany, H2Global										
TÜV Süd										
Japan, Hydrogen Society Promotion Act (METI)										
Japan, Low-carbon hydrogen certification										
Korea, Clean Hydrogen Certification Scheme										
UK Low Carbon Hydrogen Certification Scheme										
UK Renewable Transport Fuel Obligation										
US (California), Low Carbon Fuel Standard										
US, Clean Hydrogen Production Tax Credit (45V)										
US, Colorado clean hydrogen tax credit										
GH2 Green Hydrogen Organisation										
Percentage of schemes considering this step as part of the GHG emission accounting	67%	86%	67 %	52 %	57%	48%	38%	38%	33%	14%

Note: lighter colour indicates partial consideration of GHG emissions generated in a specific step in the value chain

Most schemes consider raw material extraction and pre-processing (67%), the production process of hydrogen in their GHG emissions accounting (86%), as well as the conditioning (67%) and storage (57%) of hydrogen prior to transport and distribution. Approximately half the analysed certification schemes also include the conversion of hydrogen into carriers (52%) and the transport and distribution of hydrogen (48%). A minority of the analysed schemes include conditioning and conversion (38%) as well as storage after transport and distribution (33%). While very few certification schemes include GHG emissions from the use of hydrogen

(14%), none consider GHG emissions from constructing the hydrogen production facilities (capital goods emissions) (**Table 6**).[14]

Cut-off criteria refer to thresholds, either as a specified absolute amount or a share, of material or energy flow or GHG emissions below which GHG emissions from a single source are not considered. Approximately a third of the analysed certification schemes provide information about cut-off criteria as part of their GHG emissions accounting methodology. Of the schemes which provide information, all but one define cut-off criteria. However, the thresholds of the cut-off criteria show considerable differences between schemes, generally falling in the range of 1% to 5% of total GHG emissions for the applicable system boundary.

Allocation refers to the method used to allot GHG emissions in cases of hydrogen production processes that also produce other co-products, such as oxygen, chlorine, steam or electricity. There are multiple allocation methods, including allocation based on mass, on molar ratio, on energy content, and on the economic value of the individual co-products (see **Box 4**).

Approximately half of the analysed certification schemes provide information about their allocation method. Of these schemes, six allow for allocation based on energy content and economic value (29%), four allow for allocation based on energy content alone (19%), and one scheme allows for allocation based on the molar ratio. Of the six schemes allowing for allocation based on energy content and economic value, only three provide a clear hierarchy for the order in which those two options should be applied. While in those three schemes the hierarchies are similar, they are not identical.

Box 4: Allocation Methods

There are various methods to allocate GHG emissions in cases of hydrogen production processes that also produce other co-products. These include allocation based on physical properties of products (such as energy content, mole, and mass) and allocation based on economic value. Subdivision and system expansion are methods to avoid allocation.

Physical Allocation

Physical allocation refers to assigning GHG emissions to valorised co-products based on physical properties of these products, such as the ratio between their energy contents, between their masses, or between their molar masses. The different allocation options are relevant for different production processes and sets of co-products, while the results show considerable differences in the GHG emission intensities allocated to the co-products. For example, allocation based on the energy content of the co-products—usually their lower heating value—can be suitable for processes where all or most of the co-products contain energy, such as steam cracking. However, it can be problematic for processes in which some co-products do not contain energy, such as chlorine and oxygen in the chlor-alkali and electrolysis processes. (see **Table 7**) Allocation based on mass or molar mass ratios can affect emissions values for hydrogen considerably, since hydrogen has a very high energy to mass ratio compared to other co-products, resulting in a very low emissions intensity in the case of mass allocation and a very high emissions intensity in case of allocation based on the molar ratio.

[14] Conditioning refers to changing the physical conditions (temperature, pressure, purity) of hydrogen. Conversion refers to changing the chemicals conditions of hydrogen and transforming it into a carrier, such as liquid hydrogen (LH_2), ammonia (NH_3), and liquid organic hydrogen carriers (LOHCs).

Economic Value

Allocation based on the economic value of the co-products is based on the price of these products and can be understood as reflecting the generation of revenue as the motivation behind their production. Allocation based on economic value can help to capture differences between regions and markets for similar products. It also carries the potential to differentiate between similar products with different quality attributes. However, market prices tend to change over time, between different regions, and between different steps along the value chain. Allocating GHG emissions based on economic value depends on having market prices for all co-products at the stage of co-production. In the case of hydrogen, there are currently no liquid markets, resulting in a lack of price information. In addition, future prices are subject to high uncertainty which undermines estimating GHG emissions for future hydrogen projects. In some jurisdictions, the levels of subsidies and thus the price of hydrogen, depend on the GHG emissions level. This could lead to potential conflicts of interest or to market distortions. Finally, allocation based on cost or revenue might not reflect the physical causalities of producing or purchasing a specific product.

Subdivision and System Expansion

Subdivision and system expansion are approaches to avoid allocation, rather than allocation methods. Subdivision refers to dividing a process into two or more sub-processes and estimating GHG emissions separately for each of these sub-processes. System expansion refers to extending the scope of the GHG emissions calculation by considering co-products from hydrogen production as alternatives to other production methods on the market and assigning the co-products the same GHG emissions intensity as the products they replace. However, system expansion involves developing counterfactual scenarios and it requires a thorough understanding of the market for the relevant co-products, the alternative production methods, and the impacts of this substitution on the market and the industries. This method is more reliable when there are limited and mature alternative production pathways for the relevant co-products. When there are many possible alternatives or only technologically immature alternatives, this method is less reliable.

Table 7: Exemplary Results of Allocation Methods for Hydrogen as a Co-Product from Chlor-Alkali and Steam Cracking Production Pathways

Allocation method	Chlor-alkali ($kg\ CO_2e$ / $kg\ H_2$)	Steam cracking ($kg\ CO_2e$ / $kg\ H_2$)
Energy content (physical property)	33.8	2.6
Mass (physical property)	1.4	1.0–3.0
Molar mass (physical property)	16.1	-
Economic value	4.1–7.1	1.0–3.0
Subdivision or system expansion	6.8–16.1	8.5–10.0

Source: IPHE 2023, Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen

Approximately, three quarters of the analysed certification schemes provide information about whether **carbon capture and storage** is permissible, with approximately half the schemes regarding CCS as permissible while approximately a quarter not allowing for the technology. These latter schemes include the ones that limit technology and feedstock options for the production of hydrogen to renewable sources. However, it also includes several schemes that do not put any limitation on eligible production technologies and feedstocks.

Finally, regarding the **measurement of GHG emissions**, less than half of the analysed certification schemes (41%) provide information on whether only on-site measurements are permissible, or the use of default emission factors is also permissible. Of those schemes, all allow for the use of default emission factors, though some schemes put conditions on their usage.

The task force expects for **differences in GHG emissions accounting methodologies and thresholds to have a high impact on tradability of certified hydrogen**. Jurisdictions relying on schemes with stricter requirements (e.g., lower thresholds, wider system boundaries, stricter cut-off criteria) are considered unlikely to treat imports of hydrogen not aligned with those requirements as equivalent. However, a remedy that could reduce the obstacles of different methodologies is to opt for a modular approach. Such a modular approach could take different forms:

1. Following a less ambitious approach, companies could either provide the data needed to calculate GHG emissions under each methodology, or companies opt to only provide the data necessary for some methodologies and thereby accept that the hydrogen does not qualify for certain markets.
2. Following a more ambitious approach, a common methodology to estimate GHG emissions could be developed with individual modules for each step along the hydrogen value chain. Individual certification schemes (or individual companies) could then opt into or opt out of individual modules. ISO TC197/SC1/WG1 is developing a series of voluntary technical standards providing a methodology for determining the GHG emissions associated with the production, conversion, conditioning and transport of hydrogen. This standard series could serve as a base of such a common set of modules for GHG emissions accounting.

Both approaches could be implemented in the form of a digital product passport that contains the necessary information (see **Box 3**). For more details on the information that could be contained in a hydrogen passport, please refer to **Section 6** Information Requirements for Certification Equivalency in this report.

Similarly, the task force also expects that **differences in the allocation method in cases of co-production will have a high impact on tradability of certified hydrogen**, as different allocation methods will result in different GHG emission intensities, even when using identical data. The obstacles for tradability arising from differences in emission allocation are considered as even more difficult to address than other methodological differences. Two possible options—neither of them ideal—are:

1. Hydrogen producers could provide the necessary data to calculate GHG emissions using the different allocation methods. With the help of a digital product passport, GHG emissions would then be calculated according to the allocation method of the different certification schemes. However, this option would put a heavy burden on producers by asking them to provide a considerable amount of data.
2. Jurisdictions and/or certification schemes could agree on an approach to handle allocation with a clear hierarchy between different methods. However, such a hierarchy would likely need to be technology specific and even then, arriving at such

an agreement is regarded as a challenge (see **Box 4)**. While the emissions accounting methodology being developed by ISO TC197/SC1/WG1 provides useful guidance, it does not completely resolve the issue.

Similar to restricting production technologies and fuels, the task force expects **different provision by certification schemes on the eligibility of CCS as part of the production process to have a high impact on tradability of certified hydrogen**. For jurisdictions that do not allow for CCS, import options of hydrogen will be reduced, as any producer relying on CCS is excluded. Information on the usage of CCS could be included in the above-mentioned digital product passport, allowing for transparency and easy access to the information.

5.2.2.3 Electricity Sourcing

Approximately three quarters of the schemes included in the inventory consider **electricity sourcing** as a product attribute. The analysis distinguishes three cases of electricity sourcing, namely electricity supply via:

1. A direct connection between the hydrogen production facility and the electricity generation plant.
2. The transmission and distribution network while requiring a PPA, electricity certificates or a similar guarantee of origin.
3. The transmission and distribution network without requiring a PPA, electricity certificates or a similar guarantee of origin.

About two thirds of the analysed certification schemes provide information about provisions concerning a **direct connection** between the hydrogen production facility and the electricity generation plant. Of those, approximately one quarter do not allow for a grid connection if electricity supply occurs via a direct line. In contrast, 11 of the 15 schemes on which information is available allow for a network connection in addition to a direct line.

Almost two thirds of the analysed certification schemes provide information on whether temporal correlation in case of a direct line is required. Most of the schemes that allow for a grid connection in case of a direct connection between the electrolyser and the electricity generation plant do have requirements on temporal correlation. Requirements for temporal correlation show considerable differences, ranging from 30-minute to annual intervals, though few schemes provide that information. Only one of the schemes allowing for a grid connection in case of a direct line has no requirements regarding temporal correlation. Schemes that do not allow for a grid connection in case of a direct connection between the electrolyser and the electricity generation plant have no requirements on temporal correlation.

The large majority (75%) of schemes on which information is available do not require PPA or electricity certificates in case of electricity supply via the grid. Instead, PPA and electricity certificates are optional to prove use of electricity from specific electricity sources or to demonstrate GHG emissions below a certain threshold. However, about one quarter of schemes for which information is available require a PPA or electricity certificate when hydrogen production facilities are connected to the grid.

In case of a **grid connection and a PPA, electricity certificate or similar being in place**, many schemes put in place requirements regarding the following aspects:

- Source of electricity generation
- Additionality
- Temporal correlation
- Geographic correlation
- Financial support
- Consideration of excess electricity
- Consideration of electricity from battery storage.

About half of the certification schemes provide information on whether there are specific requirements regarding additionality of the electricity generation capacity used for the production of hydrogen. About half of the schemes on which information is available have requirements in place regarding additionality. Specific requirements differ, but most ask for generation assets having been built in the range of 1–3 yrs prior to the start of the hydrogen production plant. About one quarter of the schemes on which information is available encourage additionality within the same range, but do not have in place any mandatory requirements. Finally, another quarter of the schemes on which information is available have no requirements in place regarding additionality.

Similarly, about half of the certification schemes provide information on whether there are specific requirements regarding the temporal correlation of electricity generation and hydrogen production. The large majority (>80%) of the schemes on which information is available have requirements in place regarding temporal correlation. As with additionality, specific time periods differ between schemes, but most fall within the range of 15 min to 1 hr. Two of the schemes on which information is available have no requirements in place regarding temporal correlation.

In line with additionality and temporal correlation, about half of the certification schemes provide information on whether there are specific requirements regarding geographic correlation of electricity generation and hydrogen production. Almost three quarters of the schemes on which information is available have requirements in place regarding geographic correlation. However, it is unclear to what extent these requirements match. One quarter of the schemes on which information is available have no requirements in place regarding geographic correlation.

Only about a third of the certification schemes provide information on how they consider use of electricity that would have been curtailed (excess electricity) for hydrogen production and use of electricity from (battery) storage. Most schemes on which information is available allow for excess electricity generated from renewables to be counted as electricity generated from renewable sources, with only one scheme not allowing for such an approach. In contrast, there is an even split regarding how electricity from storage is considered. Half of the schemes on which information is available allow for electricity from battery storage to be counted as electricity generated from renewable sources—often with the condition that the stored electricity was initially generated from renewable sources. The other half of the schemes does not allow for electricity from battery storage to be counted as electricity generated from renewable sources.

Finally, few certification schemes (40%) provide information on whether financial support for electricity generation (via a different support mechanism than the one for hydrogen production) is permissible. The limited information available seems to indicate that differences between schemes are substantial. While three quarters of the schemes on which information is available allow for such financial support for electricity generation, one quarter does not allow for it.

The last case of electricity sourcing captures provisions for hydrogen production **facilities being connected to the grid and not relying on PPAs or similar contractual arrangements**. Relevant aspects include:

- Minimum share of renewables within the electricity mix of the grid
- Threshold for GHG emissions intensity of the electricity mix of the grid
- Geographical correlation.

Almost three quarters of the certification schemes provide information on whether a minimum share of electricity from renewables is required in the grid supplying a hydrogen production facility. About 60% of the schemes on which information is available do not set any threshold. Instead, they consider the share of electricity generated from renewables in the network mix when evaluating the GHG emissions of the hydrogen production facility. Two schemes have explicit thresholds for the share of renewables. The remaining schemes do not allow for grid electricity to be used to produce hydrogen without a PPA or similar arrangement.

Similarly, about two thirds of the certification schemes provide information on whether they define a maximum threshold for GHG emissions intensity of the electricity supplied via the grid. Almost 60% of the schemes on which information is available do not set any threshold. They assign the average GHG emissions intensity of the electricity supplied via the grid, thereby determining an implicit maximum threshold for GHG emissions intensity of the electricity supplied via the grid through the GHG emission threshold of the hydrogen. Most of the remaining schemes do not allow for grid electricity to be used to produce hydrogen without a PPA or similar arrangement. No scheme explicitly determines a maximum threshold for GHG emissions intensity of the electricity supplied via the grid.

About three quarters of the certification schemes provide information on whether there are any requirements regarding geographical correlation in case of a hydrogen production facility receiving electricity via the grid without having a PPA or similar contractual arrangements in place. About 60% of the schemes on which information is available have requirements for geographical correlation in place. However, it is unclear to what extent these requirements match. The remaining schemes do not allow for grid electricity to be used to produce hydrogen without a PPA or similar arrangement, or they have no requirements for geographical correlation in place.

The task force expects different provisions regarding electricity sourcing to have a **medium to high impact on tradability of certified hydrogen**. Jurisdictions relying on schemes with stricter requirements, e.g., necessity for PPAs or similar contractual arrangements, additionality, temporal and geographic correlation—are considered unlikely to treat imports of hydrogen not aligned with those requirements as equivalent. However, there is uncertainty as to the extent provisions of different schemes are equivalent to one another. Given this uncertainty, there are a few options of how to reduce the impact and facilitate tradability.

Similar to the provisions on GHG emissions, these options can be less or more ambitious:

1. Following a less ambitious approach, certification schemes could explicitly state key provisions associated with electricity sourcing, covering all the three of the above-mentioned cases. The provisions for each case would not need to be identical. However, all certification schemes having explicit provisions in place would facilitate comparing them and assessing their equivalency.
2. Following a more ambitious approach, regulatory authorities or certification schemes could agree on a set of common modules for provisions across different certification schemes. Certification schemes (or companies) could then be allowed to opt in or opt out of individual modules. For example, building on the first option, all schemes could establish provisions on the three electricity sourcing options identified. Within each option, individual modules could be agreed on for additionality, temporal correlation, geographic correlation, excess electricity, and electricity from storage. Individual certification schemes (or regulating authorities) could then decide which of these agreed modules they will adopt.

In line with the options outlined with regard to the GHG emissions accounting methodology, both approaches for electricity sourcing could be implemented in the form of a digital product passport that contains the necessary information (see **Box 3**). For more details on the information that could be contained in a hydrogen passport, please refer to **Section 6** Information Requirements for Certification Equivalency.

5.2.2.4 Other Product Attributes

In addition to permissible production technologies, GHG emissions, and electricity sourcing, the comparison considered the following product attributes:

- Requirements for water use,
- Requirements for land use,
- Impact on biodiversity,
- Generation of waste and pollutants,
- Requirements for labour standards,
- Creation of jobs,
- Requirements for local content,
- Professional training offered,
- Requirements for gender representation,
- Development of local infrastructure, and
- Contribution towards the SDGs.

For each of these attributes, the comparison considered whether and what specific provisions individual schemes consider as well as whether provisions on any of these attributes are part of other legislation or regulatory requirements but outside the scope of the specific scheme.

Overall, few schemes provide information on the product attributes listed above. While about 60% of the schemes make reference to water use, land use, and labour standards, few schemes mention any other environmental or social product attributes. However, it is assumed that most jurisdictions have legislation and regulatory provisions that would include many of these attributes and be relevant to the construction and operation of hydrogen infrastructure.

While nearly two thirds of the certification schemes provide information on whether not they consider the amount of **water** used, only four schemes provide any details on how the amount of water consumed is considered. Of those four, three consider amounts of water for their GHG emissions accounting. Similarly, while about half of the certification schemes provide information on whether they consider the source of the water used, only two schemes provide any details on how the source of water is taken into account. Half of the certification schemes provide information on whether water consumption is addressed within other legislation or regulation. Of those schemes providing information, all state that water consumption is addressed within provisions beyond the hydrogen certification scheme. It is assumed that most jurisdictions have provisions on water use/consumption of industrial facilities, which would also apply to hydrogen production plants.

Nearly two thirds of the certification schemes provide information on whether they consider **land use**. Of the seven schemes that provide any details, three consider land use only for GHG emissions accounting. Less than half of the certification schemes provide information on whether land use is addressed within legislation or regulation unrelated to the specific requirements for the hydrogen certification scheme, all of which state that land use is addressed within other legislation or regulation.

About 40% of the certification schemes provide information on whether they consider **biodiversity**. However, only three schemes provide any details on how the biodiversity is considered. A third of the schemes state that biodiversity is addressed within other legislation or regulation. It is assumed that most jurisdictions have provisions on biodiversity for the construction of industrial facilities that would be relevant for hydrogen infrastructure.

Less than a third of the certification schemes provide information on whether they consider **waste and pollution**. Only one scheme provides details on how the waste and pollution are considered. Also, less than a third of the schemes state that waste and pollution are addressed within other legislation or regulation. It is assumed that most jurisdictions have provisions on waste treatment and disposal as well as the emission of pollutants that would apply to hydrogen production and distribution.

Regarding **social impacts**, except for labour standards (60%), less than half of the certification schemes provide information on whether they consider job creation (40%), local content (33%), training (30%), gender (30%), or the development of local infrastructure (30%). Only a small minority of schemes (10%–15%) provide details on these product attributes, with the exception of labour standards, for which about one quarter provides details. However, available information is considered insufficient to undertake any representative comparison.

Less than half of the schemes state that social impacts are addressed within other legislation or regulation. However, as with the environmental attributes, it is assumed that most jurisdictions have provisions on at least some of the social aspects during the construction and operation of the relevant hydrogen infrastructure.

Less than half of the certification schemes provide information on whether they consider the **sustainable development goals**. Of the schemes that provide information only one considers the SDGs.

The task force expects product attributes including water and land use, biodiversity, waste, pollution, and social impacts to have a **low impact on tradability of certified hydrogen** at this point. Currently, most schemes do not have dedicated provisions on these attributes. Rather, these attributes are subject to legislation and regulation outside of certification schemes for hydrogen and its derivatives. While those provisions apply to domestically produced hydrogen, they likely do not apply to hydrogen produced in another jurisdiction. Should schemes include dedicated provisions on these attributes in the future and these provisions show considerable difference, the task force expects the impact on tradability to become high (i.e., similar to the current high impact of the difference in GHG emissions accounting on tradability).

5.2.3 Operational Setup and Procedures

The operational setup and procedures are a key element of certification schemes, encompassing their purpose, institutional setup, and procedural framework.

For most of the analysed certification schemes, data is available regarding their purpose, specifically whether they serve for compliance or for voluntary reporting. For most compliance schemes, data is equally available on the regulatory frameworks to which schemes are creditable.

Most schemes also provide data on their institutional setups and procedural frameworks. However, completeness and level of detail of that information show considerable differences between schemes. These setups and frameworks typically involve various bodies, including a certification body, an issuing body, and an accrediting body. Most schemes explicitly name the institutions and entities within their jurisdiction responsible for each of these roles. Schemes that do not specify these operational bodies are generally in an early stage of development. As these schemes mature, it is expected that they will define and disclose their operational structures.

There is less information regarding the adherence of schemes’ operational setups and procedures to voluntary technical international standards. For the schemes that do provide such information, the following ISO standards play a prominent role: ISO 17065, ISO 19011, and ISO 14065 (**Table 8**).

Table 8: Summary of Certification Schemes' Adherence to ISO Standards for their Operational Setup and Procedures

	Purpose	Certification Body	Auditors	Issuing Body	Accreditation Body
Australia **Product Guarantee of Origin Scheme**	Reporting	Expected to adhere to ISO 17029 and ISO 17065	ISO 19011 ISO 14064	ISO 17065	N/A
Austria **TUeV AUSTRIA Green Hydrogen Certification Scheme**	Reporting	ISO 17029 or ISO 17065	ISO 19011	ISO 17065	ISO 17011
Canada **Clean Hydrogen - Investment Tax Credit**	Compliance	N/A	N/A	N/A	N/A
China **China Hydrogen Alliance's Standard**	Reporting	Expected to adhere to ISO 17065	Expected to adhere to ISO 19011	Expected to adhere to ISO 17065	No information
EU **CertifHy**	Aimed at compliance	ISO/IEC 17065	ISO 19011	No information	No information
EU **ISCC EU**	Aimed at compliance	ISO 17021 ISO 17060 ISO 14065 ISO 14064-3 ISO 17065	ISO 19011	ISO 17065	No information
EU **RedCertEU**	Aimed at compliance	ISO 17065 ISO 14065	ISO 19011	ISO 17065	No information
France **Guarantees of Origin**	Aimed at compliance	No information	No information	No information	No information
France **Guarantees of Traceability**	Aimed at compliance	No information	No information	No information	No information
Germany **dena Biogasregister**	Compliance	No information	No information	No information	No information
Germany **H2Global**	Compliance	ISO 17065	ISO 19011	ISO 17065	No information
Germany **TÜV Süd CMS 70**	Reporting	ISO 17065 or ISO 17029	ISO 19011	ISO 17065 or ISO 17029	ISO 17011
Japan **(METI) Japan Basic Hydrogen Strategy [tentative name]**	No information	No information	No information	No information	No information
(Japan, Chubu Region) **Low-Carbon Hydrogen Certification**	Reporting	No information	No information	No information	No information
Korea **Clean Hydrogen Certification Scheme**	Compliance	ISO 17029 ISO 17065 ISO 14065 ISO 14064-3 ISO 14067 ISO 17025 ISO 17020	ISO 14066	N/A	N/A
UK **Low Carbon Hydrogen Certification**	Compliance and reporting	No information	No information	No information	No information

UK **Renewable Transport Fuel Obligation (RTFO)**	Compliance	No information	ISO 19011	No information	ISO 17011
United States (California) **Low Carbon Fuel Standard (LCFS)**	Compliance	ISO 14064-3 ISO 14065	No information	ISO 14064-3 ISO 14065	ISO 14064-3 ISO 14065
United States (nation-wide) **Inflation Reduction Act Credit for production of clean hydrogen**[15]	Compliance	ISO 14065	N/A	N/A	N/A
United States (Colorado-tax) **Colorado Clean Hydrogen Tax Credit**	Compliance	N/A	N/A	N/A	N/A
GH2 Green Hydrogen Organisation	Reporting	No information	No information	No information	No information

5.2.3.1 Purpose of Schemes

All certification schemes and support mechanisms provide information on their purpose (i.e., whether certification schemes function as compliance mechanisms or as voluntary reporting tools). Almost half of the schemes (48%) are intended to serve for **compliance**, being designed to ensure adherence to specific regulations. While participation can be mandatory, in most cases, certification is required to receive public funding or demonstrate fulfilment of quotas or other requirements (see **Box 1**). Almost one third of the schemes (29%) serve as **voluntary reporting tools**. These schemes typically focus on providing consumers, investors, and other interested parties with information about product attributes and/or processes during production, conversion, transport and/or use of hydrogen. Approximately a quarter of schemes (24%) do not qualify as certification schemes under the definition provided in *Hydrogen Certification 101* but are support mechanisms to implement specific policies and have features identical or similar to certification schemes (**Figure 5**).

[15] Standard states that verifiers must be accredited as validation and verification bodies by the American National Standards Institute National Accreditation Board. Proposed rules do not explicitly identify the relevant ISO standard. However, ISO 14065 is assumed to be relevant, given that it is the ISO standard that prescribes requirements for emissions validation and verification bodies.

Differences in the purpose of certification schemes are expected to have a **low impact on tradability**. It is assumed that governments will only regard compliance schemes as relevant means to certify adherence to regulatory requirements. As a result, only compliance schemes could recognise other compliance schemes as equivalent. If a reporting scheme is recognised within a jurisdiction as a means to verify compliance with regulatory requirements, by definition, that scheme would cease to be a reporting tool and become a means to assess compliance. Reporting schemes could unilaterally recognise compliance schemes and other reporting schemes as equivalent, but only between reporting schemes could such a recognition be mutual.

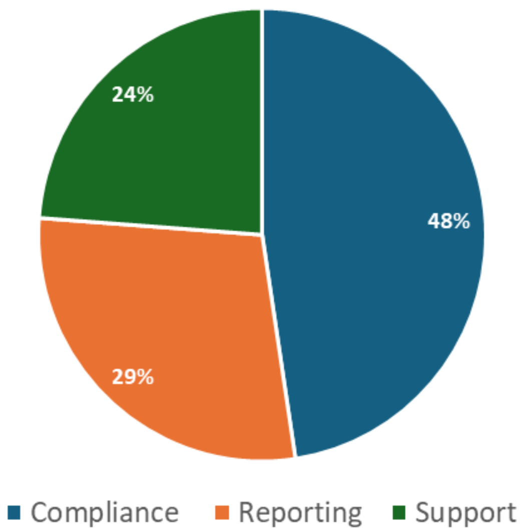

Figure 5: Share of Certification Schemes by Purpose

5.2.3.2 Institutional Setup and Procedural Framework

The institutional setup and procedural frameworks of certification schemes were compared by determining their adherence to the following set of voluntary technical standards:

- ISO 14065:2020 – General principles and requirements for bodies validating and verifying environmental information,
- ISO/IEC 17011:2017 – Requirements for accreditation bodies accrediting conformity assessment bodies,
- ISO/IEC 17029:2019 – General principles and requirements for validation and verification bodies,
- ISO/IEC 17065:2012 – Requirements for bodies certifying products, processes and service, and
- ISO 19011:2018 – Guidelines for auditing management systems.

These standards were identified based on an iterative process in which standards mentioned by specific certification schemes were noted. It was then verified for all other analysed schemes whether they also refer to these standards. The current list includes the standards most referred to. For more information on individual standards, please refer to **Appendix C**: Background to Voluntary Technical Standards Relevant to the Operational Setup and Procedures of Certification Schemes.

Nearly two thirds of the certification schemes (62%) **provide information** on whether their institutional setup and processes adhere to at least one of the listed voluntary technical standards. Of the schemes that provide information, **almost all** (92%) meet the requirements of at least one of the specified standards. Only one out of the twelve schemes that provided information does not meet the requirements of any of the listed standards. Most schemes providing information meet the requirements of ISO 17065, ISO 19011, ISO 14065 and ISO 17029 for their institutional setup and operational procedures (**Figure 6** and **Appendix B**: Overview of Certification Schemes' Adherence to Selected Voluntary Technical Standards for their Operational Setup and Procedures).

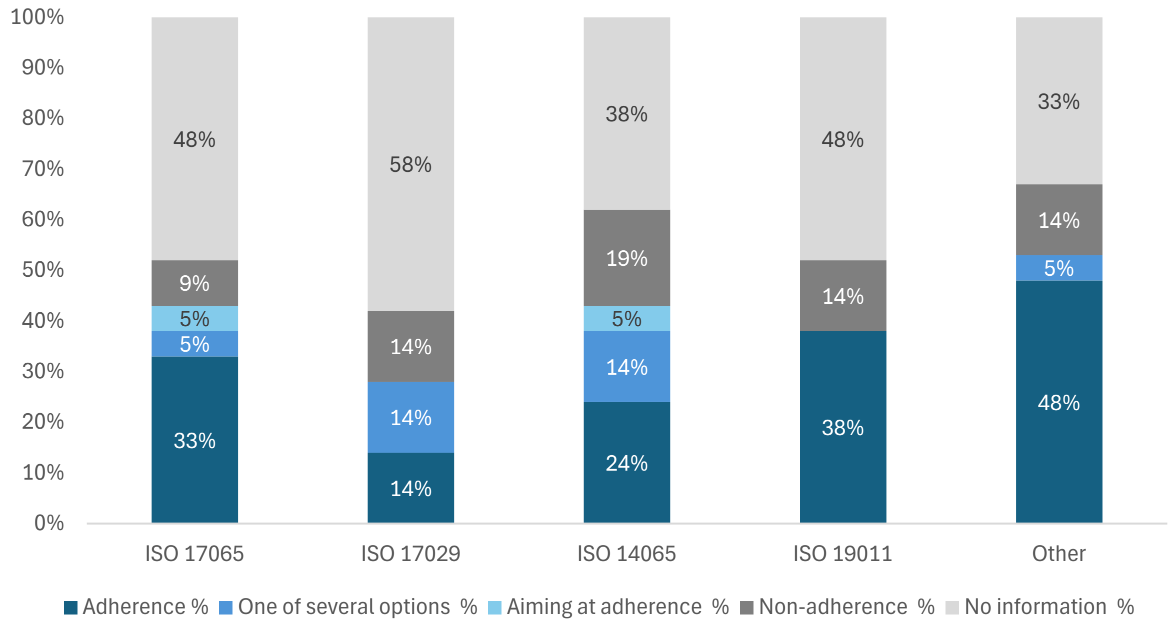

Figure 6: Adherence of schemes' operational setup and procedures to selected voluntary technical standards

Certification bodies are independent third parties that carry-out conformity assessment activities with the purpose to validate or verify the requirements of the certification scheme and the actual determination of the attributes according to a specific methodology. Certification schemes define the qualifications required from certification bodies.[16]

The large majority of the analysed certification schemes (90%) provide information on whether the scheme includes a designated certification body. Almost two thirds of the certification schemes (62%) provide information on whether the certification body meets the requirements of a voluntary technical standard. Just over two thirds (69%) of schemes that provide information on this category refer to such a standard. The standard that is most often referred to is ISO 17065, followed closely by ISO 14065.

To assess whether a user complies with the certification scheme, a certification body can employ **auditors** who conduct in-depth assessments. Similar to certification bodies, the large majority of the analysed certification schemes (90%) provide information on whether or not the scheme includes designated auditors. All but one of the schemes that provide information on this category list their auditors. Almost two thirds (62%) of the certification schemes provide information on whether their auditors meet the requirements of a voluntary

[16] Conformity assessment bodies are a particular type of certification bodies that carry-out conformity assessment activities with the purpose to validate or verify both the conformity of a given product or facility with a voluntary technical standard.

technical standard. Approximately two thirds (69%) of schemes that provide information refer to such a standard. All but two of the schemes that refer to a standard refer to ISO 19011. One of the schemes that currently does not refer to ISO 19011 for its auditors is planning to do so in the future. In addition to ISO 19011, one scheme also refers to ISO 14064 regarding requirements that its auditors need to fulfil. Finally, one scheme that does not refer to ISO 19011 refers to ISO 14066.

Issuing bodies ensure, considering the validation or verification processes established by the certification bodies, that the information evidenced by the certificate is correct and complies with the requirements of the scheme. Where the judgement of the issuing body is positive, it issues the related certificates. The issuing body may be a separate body, or the certification body may additionally take that role.

The large majority (86%) of the analysed certification schemes provide information on whether the scheme includes a designated issuing body. More than half (57%) of the schemes provide information on whether their issuing body meets the requirements of a voluntary technical standard. Equally, more than half (58%) of schemes that provide information refer to such a standard. The most referenced standard is ISO 17065, with one scheme planning to refer to ISO 17065 in the future. In addition to ISO 17065, one scheme also refers to ISO 14064-3 and ISO 14065 regarding requirements that its issuing body needs to fulfil.

Accreditation bodies assess and regularly monitor the technical competence, reliability, independence, and integrity of certification bodies in the public interest. National accreditation bodies act as a regulatory authority, when empowered by the respective state to do so.

The vast majority (86%) of the analysed certification schemes provide information on whether the scheme includes a designated accreditation body. However, less than half (43%) of the schemes provide information on whether their accreditation body meets requirements of a voluntary technical standard. Equally, less than half (43%) of schemes that provide information refer to such a standard. One additional scheme aims to refer to a standard in the future. The standard most referred to—namely by three schemes—is ISO 17011.

Differences in the institutional setup and operational processes between certification schemes are expected to have a **high impact on tradability of certified hydrogen**. It is assumed that schemes adhering to voluntary technical standards for their operational setup and procedures will be less willing to recognise schemes in which operational setup is not aligned to any relevant standard. The considerable share of schemes adhering to voluntary technical standards underscores the importance of these standards for the operational setup and processes. It also provides a pragmatic solution for how to increase tradability of certified hydrogen as there are already existing procedures and best practices to follow. Agreement of scheme owners (or regulating authorities setting the requirements for the schemes) on a set of technical standards that certification bodies, issuing bodies, accreditation bodies, and auditors have to adhere to is regarded as a pragmatic and effective step to facilitate mutual recognition.

Practical steps towards such a common set of standards could be:

- Encourage all certification schemes to disclose their adherence to relevant ISO standards for their institutional setup and operational procedures.

- Support and assist schemes that currently do not adhere to any voluntary technical standards for their operational setup and procedures to adopt relevant provisions by sharing best practices and providing practical guidance on implementation, either bilaterally or through multilateral fora.

5.2.4 Chain of Custody

The chain of custody model determines the approach that is applied to track and trace information on product attributes along the value chain of a product and the related transactions.

Information availability for chain of custody models used by the analysed certification schemes was mixed. While nearly three quarters of the analysed schemes provided information on whether they use book and claim or mass balancing to track and trace products and certificates, the share of schemes providing detailed information on specific requirements was considerably lower. Information availability was generally higher for schemes using book and claim than for schemes using mass balancing.

Of the schemes providing information almost three quarters use mass balancing, with only 20% relying on book and claim, and one scheme allowing for both chain of custody models. Mass balancing and book and claim are two fundamentally different models for tracking and tracing products and certificates (see **Box 2**). While not impossible, it is considered as unlikely that both models will be compatible with one another.

5.2.4.1 Measuring Units for Hydrogen

Almost two thirds of the analysed certification schemes provide information on the measuring unit used for hydrogen. Just over half of the schemes measure amounts of hydrogen in mass, nearly one third uses energy content, and two schemes measure both mass and energy content. Of the schemes measuring the energy content, the large majority relies on the lower calorific value (lower heating value), with only one scheme using the higher calorific value, and one scheme indicating both lower and higher calorific value. The use of different measuring units is not expected to represent an obstacle for tradability of certified hydrogen as conversion between units should be simple and based on agreed conversion factors.

5.2.4.2 Book and Claim

Three of the 21 analysed certification schemes and support mechanisms use book and claim as their chain of custody model, with an additional scheme allowing for its optional use, i.e., dena Biogasregister (**Table 9**).

Table 9: Summary of Certification Schemes using Book and Claim

	Expiration period of certificates	Associated standard	Cancellation of certificates	Transfer of certificates across different fuels
China **China Hydrogen Alliance's Standard**	12 months	No	Upon reported consumption	No information
France **Guarantees of Origin**	12 months	EN 16325	Upon reported consumption	Possible
Germany **dena Biogasregister**	No expiration	No	Possible at any time	Possible
United States (California) **Low Carbon Fuel Standard (LCFS)**	No expiration	No information	Upon verification or compliance issues	No information

All four certification schemes that use book and claim as their chain of custody model provide information on the **expiration of certificates** (i.e., whether certificates have a specified maximum lifetime). For two of the schemes, certificates expire after 12 months while for the other two there is no expiration period of certificates. Different provisions on the lifetime of certificates are considered to have a substantial impact on the tradability of certified hydrogen, as it is regarded as unlikely that schemes with limited lifetimes for certificates will recognise schemes with no expiration of certificates as equivalent.

Three of the four certification schemes that use book and claim as their chain of custody model provide information on whether provisions are associated with any (voluntary) **technical standard**. Only one scheme's provisions are associated with such a standard. The absence of a (voluntary) technical standard is regarded as an indicator that there are likely considerable differences between schemes of how book and claim models are implemented. Differences in the provisions concerning tracking and tracing via book and claim are considered to have a substantial impact on tradability of certified hydrogen. This is exemplified by the differences in the two following aspects.

All four certification schemes that use book and claim provide some information regarding **cancellation** (i.e., retirement) of certificates. However, the provided information is considered to be incomplete. Therefore, no assessment of the differences (or compatibility) can be made. However, it is expected that differences in cancellation rules and procedures would likely have a substantial impact on the tradability of certified hydrogen.

Only two of the four certification schemes using book and claim as their chain of custody models provide information on whether **certificates are limited to hydrogen or can be transferred to other fuels** (e.g., hydrogen blended with natural gas). The available information is insufficient to assess differences (or compatibility) of the provisions. However, as with cancellation rules, it is expected that differences in the provisions concerning the transfer of certificates to fuels other than hydrogen would likely have a substantial impact on the tradability of certified hydrogen.

5.2.4.3 Mass Balancing

Eleven of the 21 analysed certification schemes and support mechanisms use mass balancing as their chain of custody models, with an additional scheme allowing for its optional use (see **Table 10**).

Three quarters of the analysed certification schemes using mass balancing as their chain of custody models provide information regarding the **level at which the schemes track and trace products and certificates** (e.g., site, batch). Of the nine schemes providing information, five rely on a site-level mass balance system while four have tighter requirements and track and trace at batch level. It is unclear what impact differences in the operational level of mass balance systems would have on the tradability of certified hydrogen. In principle, batch and site level systems could recognise each other as equivalent. However, it is uncertain whether the schemes tracking and tracing at batch-level would recognise schemes operated at site-level as equivalent and whether schemes with different batch sizes would recognise one another.

Table 10: Summary of Certification Schemes using Mass Balancing

	Mass balance level (batch/site)	Time period for mass balancing	Expiration period of certificated	Cancellation of certificates	Approach to consignments
Australia **Product Guarantee of Origin scheme**	Batch	No information	12 months	No information	No information
EU **CertifHy**	No information	No information	No information	No information	No information
EU **ISCC EU**	Site	3 months	12 months	No information	Co-mingling of hydrogen with different GHG specifications allowed
EU **RedCertEU**	Site	3 months	12 months	No information	Co-mingling of hydrogen with different GHG specifications allowed
France **Guarantees of traceability**	Batch	No information	No information	Upon arrival at end-consumer	No information
Germany **dena Biogasregister**	Batch	No information	No expiration period	Upon reported consumption	Co-mingling of hydrogen and other gases with different specifications allowed
Germany **H2Global**	Site	3 months	No information	Upon reported consumption	Co-mingling of hydrogen with different GHG specifications allowed
(Germany) **TÜV Süd CMS 70**	Site	No information	12 months	No information	Co-mingling of hydrogen with different GHG specifications allowed
Korea **Clean Hydrogen Certification Scheme**	Batch	12 months	No information	Upon reported consumption	Co-mingling of hydrogen with different GHG specifications allowed
UK **Low Carbon Hydrogen Certification**	No information	No information	No information	No information	No information
UK **Renewable Transport Fuel Obligation (RTFO)**	Site	3 months	12 months	No information	Co-mingling of hydrogen with different GHG specifications allowed
GH2 Green Hydrogen Organisation	No information	No information	No information	No information	No information

Half of the analysed certification schemes using mass balancing as their chain of custody models provide information regarding the **maximum time period for balancing** that can be considered. Two thirds of the schemes providing information have a 3-month reporting period. One scheme has a considerably longer period of 12 months. Differences in the maximum reporting periods are considered to have a substantial impact on tradability, as schemes with shorter periods might not recognise schemes with longer periods.

Similarly, half of the analysed certification schemes using mass balance as their chain of custody model provide information regarding the **expiration period of certificates**. Five out of the seven schemes providing information have an expiration period of 12 months for their certificates. The remaining two schemes do not have any expiration period for their certificates. Differences in expiration periods of certificates are considered to have a substantial impact on the tradability of certified hydrogen, as schemes with shorter periods might not recognise schemes with longer or no expiration periods.

Half of the analysed certification schemes using mass balancing also provide information on modalities concerning the **cancellation** (i.e., retirement) of certificates. Provisions from the schemes that provide information appear similar, though not identical, with certificates being cancelled upon reported consumption of the product or arrival at the end-consumer, respectively. Given the similarity between provisions, cancellation does not seem to have a substantial impact on tradability of certified hydrogen. However, this assessment is based on only a small number of schemes providing information with very limited details.

Just over half of the analysed certification schemes using mass balancing provide information on whether **consignments of hydrogen can be co-mingled** (i.e., physically mixed) with other consignments of hydrogen with different GHG specifications or even blended with other fuels. Most of the schemes that provide information allow for co-mingling consignments or aggregation of individual batches with different GHG specifications, under certain conditions (86%). However, these conditions are not identical. At least one scheme also allows for the co-mingling of hydrogen with other fuels. A more detailed analysis is required to assess the impact of different requirements regarding co-mingling on the tradability of certified hydrogen. Among others, provisions regarding co-mingling are relevant for requirements for storage and for transport of hydrogen. If there are substantial differences concerning the conditions under which co-mingling is permissible, this would likely have a substantial impact on tradability, as schemes with stricter requirements are considered unlikely to recognise schemes with less strict requirements.

In addition, **accounting for losses** is also particularly relevant during storage and transport of hydrogen. Two thirds of the analysed certification schemes provide information on provisions to account for losses during storage and transport. However, that information is in many cases incomplete or lacks detail for a systematic comparison.

Three of the eight schemes state that losses are accounted for based on delivered quantities of hydrogen. Another five of the eight schemes mention that storage sites and means of transport must track inputs and outputs of hydrogen, with two of these schemes explicitly requiring storage facilities to be certified. While only one scheme explicitly limits the transport modes that can be used for hydrogen, this does not preclude that more schemes have similar restrictions.

There is insufficient information to assess the impact of differences concerning requirements for storage and transport on the tradability of certified hydrogen. If requirements showed considerable differences, it is assumed that the impact would be substantial, as schemes with stricter requirements are considered as unlikely to recognise schemes with less strict requirements.

Overall, differences in tracking and tracing hydrogen and certificates are expected to have a **high impact on tradability of certified hydrogen**. Mass balancing and book and claim represent two fundamentally different chain of custody models with little space for common solutions to bridge that gap. Even schemes applying the same chain of custody model show considerable differences in the level of tracking and tracing, in time periods for reporting, in cancellation rules, and in provisions regarding co-mingling which are expected to substantially reduce tradability. There is insufficient information for a more systematic and detailed assessment as many governments and certification schemes are still in the process of developing the necessary requirements and the modalities of how to implement these requirements, respectively. Such information should become available once schemes have been fully developed.

As a result, little can be said about differences between schemes using the same chain of custody model and options of how reduce the possible impacts of these differences on the tradability of certified hydrogen. However, the current early stage of development also provides an opportunity to agree on a set of common provisions between governments and/or certification schemes with the aim to prevent substantial future differences between schemes using the same chain of custody model. Absent such an agreement, once detailed provisions are in place, schemes with stricter requirements are considered as unlikely to recognise schemes with less strict requirements.

5.2.5 Information Technology

Many of the certification schemes analysed in this report are still in development. The collected data shows that the certification schemes rely on digital certificates and a “conventional” database, whiteout any further details. As a result, the information concerning the IT framework is insufficient for a proper assessment of the IT system. Therefore, instead of relying on the inventory for the analysis, the task force based its analysis on European guarantees of origin (GOs) IT framework, as an example of how different national registries can exchange information.

The EU GOs scheme stems from Article 19 of the EU’s renewable energy directive (RED), which applies to the EU’s member states. However, EU neighbouring third countries (e.g., United Kingdom, Norway, Switzerland, Iceland, and Liechtenstein) may join the EU GOs certification scheme by adopting the provisions set by the RED. Each EU member state and third country that implements EU GOs is a GO scheme owner. As such, the government designates an issuing body that also handles all the technical details, including the national GO registry and the corresponding IT framework. To date, the hydrogen EU GOs schemes are not yet fully implemented. However, there is a functional digital framework for electricity EU GOs, which would be most likely replicated for hydrogen.

The unit base of the digital framework for EU GOs is the national registry, also called a GO domain. The hardware part (i.e., the server) is located in the respective EU member state and the EU's neighbouring country that decided to join EU's GO certification. The software part is based on a database, owned by the government, and an interface software, which can be privately owned (e.g., under private license) or owned by the respective government.

The GO certificate is an xml formatted file which contains all the information regarding the certified quantity of energy.[17] The database contains all the information related to the accounts (e.g., administrator, competent authority, producer, supplier/end-user) and the status of the GOs in each account.

The interface software allows account holders access to their accounts registered in the database. The issuing body records in the database the operations among account holders, as well as the issuance of GOs, through the interface software.

The GOs import/export operations (GOs transfer between national registries) are performed through a hub set by the European Association of Issuing Bodies (AIB), thus jointly operated by the issuing bodies. **Figure 7** depicts schematically the principle of this hub.

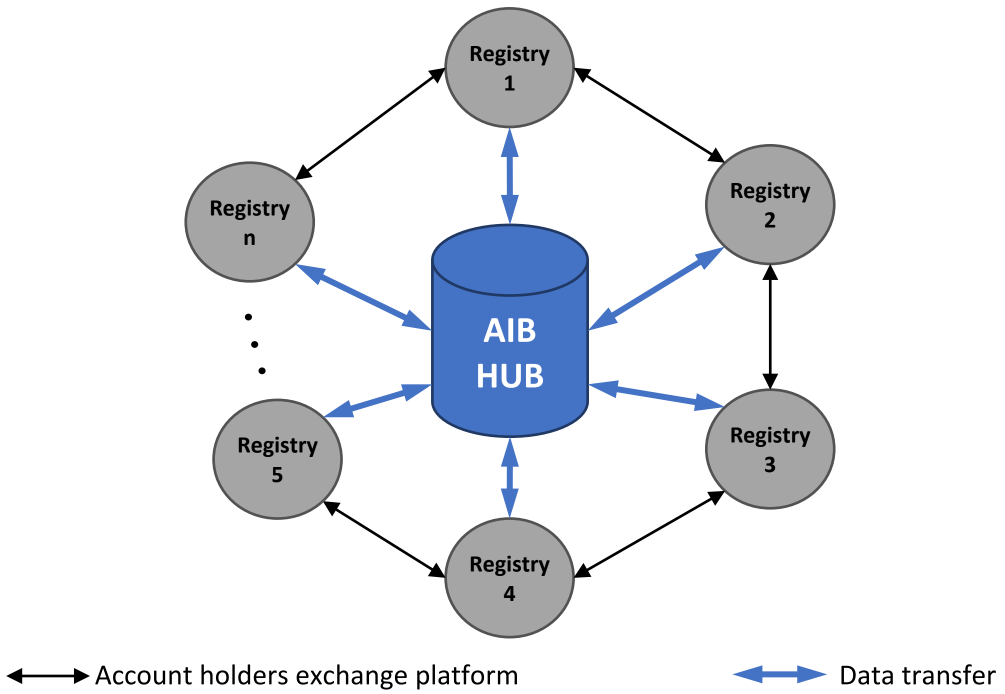

Figure 7: EU's GO system IT framework

The hub consists of a server and a data transfer protocol software running on this server, such as file transfer protocol secure (FTPS) or secure file transfer protocol (SFTP), that allows the xml file (i.e., the GO) to be transferred between registries. This means a cancelling operation on the exporting side and an issuance operation on the importing side. The hub also hosts a digital platform to enable the account holders from different registries to interact directly. Once the account holders strike a deal, they ask the issuing body of the concerned registry to perform the necessary import/export operations to complete the transaction. The Article 19

[17] The minimum required information is set by the art. 19 of the EU's RED.

provisions of RED are setting the rules for GOs transfer between national registries. The AIB website[18] provides further information concerning the European Energy Certification System.

The EU GOs IT framework is a practical example of a working system involving more than one registry, each registry being under a different jurisdiction. However, this is just an example, and more existing IT frameworks would be helpful.

6 Information Requirements for Certification Equivalency

6.1 Methodology

One of the results of the tradability assessment was that a **digital product passport** (see **Box 3**) could constitute a useful tool to facilitate tradability of certified hydrogen between jurisdictions using different certification schemes. Information requirements for certification equivalency refers to the common information that a digital product passport could contain.

The information that would need to be gathered in a digital product passport was identified based on:

1. The information gathered by the task force in the inventory, and
2. The information gaps that the task force identified conducting the comparison of certification schemes and the tradability assessment.

6.2 Results

6.2.1 Overview

The digital product passport could contain information on three of the four key elements of certification schemes: (1) the product attributes, (2) the operational setup and procedures, and (3) the chain of custody model.[19] For a digital product passport to be useful, it would need to contain a considerable amount of information regarding product attributes and the modalities of the chain of custody model, but less information on operational setup and procedures would be needed.

6.2.2 Product Attributes

Relevant product attributes could include both environmental and social aspects, such as:

- Permissible production technologies,
- GHG emissions,
- Electricity sourcing,
- Water use,
- Land use,
- Biodiversity,

[18] https://www.aib-net.org/aib

[19] Information on IT would not be contained in the digital product passport, as the passport itself would be part of the IT infrastructure.

- Generation of waste and pollutants,
- Labour standards,
- Job creation,
- Local content requirements,
- Professional training,
- Gender aspects, and
- Development of local infrastructure.

Given that most existing certification schemes and schemes under development focus on GHG emissions, electricity sourcing, permissible production technologies, and water use, the product passport should also initially focus on these product attributes.[20]

The information on product attributes the hydrogen passport would contain depends on whether a common methodology for the calculation of an individual product attribute exists.

1. If a common methodology for estimating a specific product attribute is in place, it could be sufficient for the product passport to contain the relevant indicator (e.g., GHG emissions intensity) for the individual steps along the hydrogen value chain (e.g., production, conditioning, conversion, storage, and transport) calculated used the common methodology.
2. If no common methodology for estimating a specific product attribute is in place, the product passport would need to contain considerably more information, as it would need to include all data needed to calculate a specific product attribute (e.g., GHG emissions) for the specific steps of the value chain according to the different methodologies required by different certification schemes.

For **GHG emissions**, the required information for each individual steps along the hydrogen value chain could include:

- Production pathway, technologies, and equipment used (e.g., production technology, carbon dioxide treatment, water treatment technology, means of transport),
- Amount of hydrogen,
- Hydrogen temperature and pressure,
- Hydrogen purity level at the gate,
- Specification of contaminants,
- Quantities of all inputs, outputs and waste,
- Sources of input,
- Emission intensities of all inputs and outputs,
- Cut-off criteria,

[20] While land use is considered by 60% of the analysed certification schemes, only 40% provide any information on how land use is assessed. Of the seven schemes that provide any details, three consider land use only for GHG emissions accounting. This is regarded as insufficient to assess what information might be required for a digital product passport.

- Allocation rules when a unit process yields multiple valorised co-products, and
- Permissible methods of metering.

For **electricity sourcing**, the passport would need to be designed to distinguish between three options electricity supply:

1. A direct connection between the hydrogen production facility and the electricity generation plant,
2. The transmission and distribution network while requiring a PPA, electricity certificates or a similar proof of origin, or
3. The transmission and distribution network without requiring a PPA, electricity certificates or a similar proof of origin.

For all three of those options and a mix of these options, the following information would need to be captured by the digital product passport for each individual steps along the hydrogen value chain:

- Quantity of electricity consumed, broken down into quantity of electricity generated on-site, quantity of purchased grid electricity associated with a PPA, electricity certificates or a similar proof of origin, quantity of purchased grid electricity not associated with a PPA, electricity certificates or a similar proof of origin,
- Source of electricity generation (i.e., the mix of electricity used for each of the three supply options),
- Emission factors for on-site generation, purchased grid electricity with a PPA, electricity certificates or a similar proof of origin, and purchased grid electricity not associated with a PPA, electricity certificates or a similar proof of origin (residual mix factor),
- Type of PPA, electricity certificates or a similar proof of origin,
- Location-based emission factor used,
- Additionality (i.e., whether generation asset needed to be built in addition to existing assets and, if so, within what period),
- Temporal correlation between the generation of electricity used for hydrogen production and the hydrogen production process (i.e., time period for which electricity generation and consumption match),
- Geographic correlation between the generation of electricity used for hydrogen production and the hydrogen production process (i.e., whether the existing transmission and distribution infrastructure is considered),
- Whether the electricity generation received public financial support,
- The amount of electricity used for hydrogen production coming from generation assets that would have to be curtailed otherwise, and
- The amount of electricity used for hydrogen production coming from battery storage.

For **water use**, the required information for each individual steps along the hydrogen value chain includes:

- Production pathway, technologies, and equipment used (e.g., production technology, water and wastewater treatment technology, means of transport),
- Amount of hydrogen,
- Hydrogen temperature and pressure,
- Hydrogen purity level at the gate,
- Specification of contaminants,
- Quantities of water input and output by source,
- Cut-off criteria,
- Allocation rules when a unit process yields multiple co-products, and
- Permissible methods of measurement.

6.2.3 Operational Setup and Procedures

Concerning the operational setup, the digital product passport should contain the designations of the voluntary technical standards that certification bodies, issuing bodies, accreditation bodies, and auditors are required to adhere to.

6.2.4 Chain of Custody Model

The digital product passport should contain the following information related to the chain of custody model:

- The unit in which amounts of hydrogen are measured, including whether the higher or lower heating value is used for schemes that measure amounts of hydrogen based on energy content, and
- Which chain of custody model is used (i.e., book and claim or mass balancing).

For certification schemes using **book and claim** as their chain of custody model, the digital product passport should contain the following information:

- The designation of any voluntary technical standard that the provisions regarding the chain of custody model might be associated with,
- The expiration period of certificates (i.e., the specified maximum lifetime of certificates),
- The cancellation rules of certificates (i.e., a checklist of cases where certificates would be cancelled), and
- Whether or not certificates only apply to hydrogen or can be transferred to different fuels (e.g. hydrogen blended with natural gas).

For certification schemes using **mass balancing** as their chain of custody model, the digital product passport should contain the following information:

- The level at which the schemes track and trace products and certificates (e.g., site, batch),
- The maximum time period for reporting in the mass balance system (e.g., beginning and end date of batch),

- The expiration period of certificates (i.e., the specified maximum lifetime of certificates),
- The cancellation rules of certificates (i.e., a checklist of cases where certificates would be cancelled), and
- The approach to consignments, including whether co-mingling of hydrogen with different GHG specifications (i.e., aggregation of individual batches with different GHG specifications) is allowed, whether co-mingling of hydrogen with other fuels is allowed, the reporting requirements for transport and storage infrastructure.

7 Certification Along the Entire Value Chain

Since hydrogen is produced (except for geological hydrogen) and used as feedstock or fuel, it is in the center of the value chain. Its certification should account for this and assess all the implications that might arise in this wide context.

Figure 8 depicts a simplified view of the global value chain involving low-emissions hydrogen and the certification across this value chain.

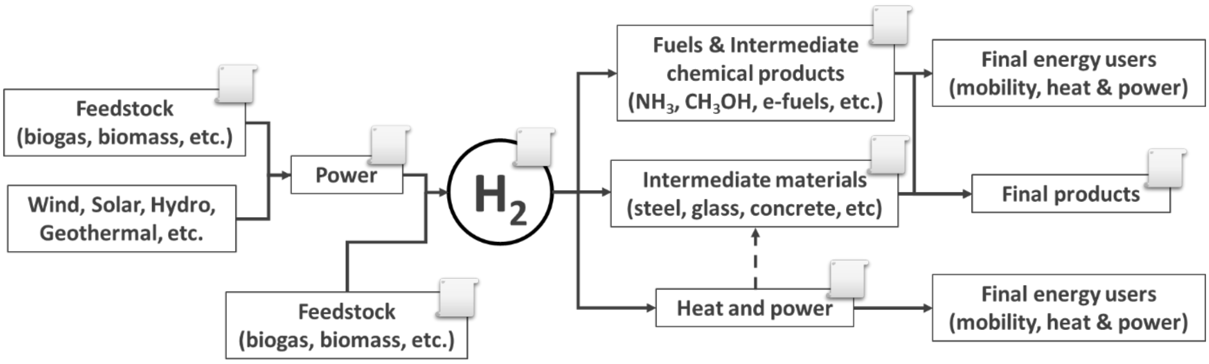

Figure 8: Simplified diagram of the whole value chain and certification

Hydrogen certification requires information related to the inputs used to produce it. From a global perspective, the input may be electricity or a feedstock, such as solid (e.g., biomass, solid waste) or gaseous (e.g., natural gas, gas of biological origin) fuels. In the case of electricity, it may be generated by converting natural energy (e.g., wind, solar, hydro, waves, geothermal) or using a feedstock (*e.g.* biomass, solid waste, biogas, uranium, natural gas). These inputs may already be subject to certification in certain jurisdictions. For example, in the EU, the use of biomass requires a “proof of sustainability,” renewable electricity and biogas are already subject to certification under the book and claim chain of custody model or other voluntary schemes relying on mass balance chain of custody model.

On the downstream side, hydrogen certificates will be used to certify the products (e.g., ammonia, synthetic fuels, fertilizers, steel, and concrete) that are manufactured using hydrogen (as a feedstock and as a mean to generate the required energy), as well as any form of energy generated using hydrogen (mainly for mobility, heat and power). Furthermore, the products mentioned above may be used as fuels (mainly for mobility, power and heat) or raw materials to manufacture products that reach final consumers (e.g., food, cars, houses, toys).

In the latter case, the certificates of the intermediate products and energy will be used to certify the final products. However, some of these downstream flows may already be subject to certification.

The main question that arises is **how the hydrogen certification would fit in?** Jurisdictions that do not have a certification mechanism implemented for the upstream steps, the hydrogen certification should embed the information up to the first step of the value chain. However, some jurisdictions, even if they have implemented a certification mechanism, for instance for electricity, they may decide to set other rules. This is the case in the EU, where the electricity taken from the power grid needs to be contracted under a PPA with a renewable power generation facility located in the same biding zone[21] and the electrolysis facility must operate at the same time[22] as the renewable power generation facility mentioned in the PPA (space-time correlation). These requirements are implicitly introducing the mass balance chain of custody model for electricity. Where there is no certification mechanism for electricity based on the mass balance chain of custody model, the consequence is that the proof of compliance with these provisions must be embedded in the hydrogen certification. This raises another question: "**What is the impact if the chain of custody models are different between hydrogen certification and the upstream and downstream existing certification schemes?**" This question is fundamental, and the EU example would suggest that the same (or equivalent) chain of custody model should be applied across the value chain.

Concerning the question of hydrogen certification within the wider framework, in order to avoid any duplicates and reduce the complexity, the hydrogen certification would require a link with existing certification mechanisms upstream and downstream that **preserves the integrity of the data across the whole value chain**. This is crucial with respect to the final consumer that is entitled to accurate and reliable information. The practical side of this points to the IT, and more explicitly to the data format and data transfer protocols between the certificate mechanisms upstream of the hydrogen production facility and the hydrogen certification. The same applies for the downstream side. While a full assessment to address this is out of the scope of this (edition of the) report, it is important to flag this aspect.

Manufactured hydrogen certification must properly account for the existing situation upstream and downstream of the hydrogen production facility. If there are certification mechanisms already in place either for the inputs needed to produce hydrogen or for the products made using hydrogen, they may be used to convey the information across the value chain following the flux of energy and materials. In order to avoid any duplication of work and reduce complexity, the chain of custody models should not be in contradiction and the data integrity should be secured at any point within the value chain. This particular topic could be object of a normative pre-research action.

[21] Within EU, a bidding zone is the largest geographical area within which market participants are able to exchange energy without capacity allocation.
[22] On hourly basis starting 2030.

8 Conclusion and Next Steps

This report presented the process behind and the results of the IPHE Hydrogen Certification Mechanisms task force.

Based on an inventory used to systematically collect and map information of 17 certification schemes and 4 support mechanisms across 11 countries and regions, the report compared these schemes along the following 4 key elements: (1) product attributes, (2) operational setup and procedures, (3) chain of custody model, and (4) the IT used for the registry.

The comparison showed not only considerable variation in the availability of information but also considerable differences between the analysed certification schemes. Substantial differences regarding product attributes, operational setup and procedures, and the chain of custody model can all have adverse impacts on tradability of certified hydrogen between jurisdiction relying on different certification schemes. Only differences in the setup of registries and IT systems are not expected to negatively affect tradability as technical solutions are expected to help address any such differences.

Overall, progress towards enabling tradability of certified hydrogen is not regarded as a continuous trajectory. Rather, progress should be envisioned as incremental, with the need to achieve certain thresholds of commonality within a key element in order to have a measurable improvement in tradability.

This report proposes a modular approach to address the differences between certification schemes and enable tradability of certified hydrogen. Such a modular approach would entail a number of common modules, that different jurisdictions agree on and can opt into or opt out off, as well as modules that would remain specific to individual jurisdictions. The report lays out two broad options for a modular approach: a more limited approach with fewer items agreed upon in the common modules and a more ambitious approach with a more comprehensive agreement on the content within common modules. Both approaches could be implemented in the form of a digital product passport that contains the necessary modules for the data and the methodologies. This report also provides suggestions for the information that could be contained in a digital product passport.

The next steps following the publication of this report could include the following:

1. Publication of the draft inventory used for the analysis, to make the analysis more transparent, and could be regularly updated as the schemes reviewed evolve.
2. Dissemination of the results of the comparative analysis and discussions of suggestions to improve tradability of certified hydrogen with other initiatives, scheme developers, and industry representatives. This includes regular exchanges with the IEA H2 TCP Task 47 and International Hydrogen Trade Forum. Such exchanges and discussions would allow for identification of the challenges perceived by each of these actors. Based on their input, priorities towards improving tradability of certified hydrogen should be identified and a common set of recommendations should be formulated. Each of these recommendations should also identify who is responsible for addressing and implementing it.

3. Identification of information gaps within the inventory. Such gaps could include relevant certification schemes for hydrogen that are not included at this point as well as further, more detailed, information on specific aspects of certification schemes.
4. Based on such a gap analysis, expansion of the inventory of certification schemes and the analysis to include additional schemes as well as more detailed information on specific aspects.
5. Building on this report and other inputs, development of recommendations regarding the design and implementation of a digital product passport.

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10 Appendices

10.1 Appendix A: Certification Schemes and Support Mechanisms Covered by the Inventory

Country	Designation	Purpose	Status
Australia	Product guarantee of origin	Certification scheme for reporting	Under development
Austria	TÜV Austria green hydrogen certification scheme	Certification scheme for reporting	Operational
Canada	Clean Hydrogen Investment Tax Credit	Support mechanism	Operational
China	China Hydrogen Alliance's Standard	Certification scheme for reporting	Operational
European Union	CertifHy (Biofuels and renewable fuels of non-biological origin, RFNBO)	Certification scheme for compliance	Not yet implemented
	ISCC EU (RFNBO)	Certification scheme for compliance	Not yet implemented
	RedCert EU (RFNBO)	Certification scheme for compliance	Not yet implemented
France	Guarantees of origin scheme	Certification scheme for compliance	Not yet implemented
	Guarantees of traceability scheme	Certification scheme for compliance	Not yet implemented
Germany	Dena Bioregister	Certification scheme for compliance	Operational
	H2 Global	Support mechanism	Operational
	TÜV Süd CMS 70	Certification scheme for reporting	Operational
Japan	Hydrogen Society Promotion Act (METI)	Support	Under development
	Low-carbon hydrogen certification (Chubu Region)	Reporting	Operational
Korea	Clean Hydrogen Certification Scheme	Certification scheme for compliance	Operational
United Kingdom	UK Low Carbon Hydrogen Certification Scheme	Certification scheme for compliance and reporting	Under development

	UK Renewable Transport Fuel Obligation	Certification scheme for compliance	Operational
United States	Low Carbon Fuel Standard (California)	Certification scheme for compliance	Operational
	Inflation Reduction Act – tax credit for production of clean hydrogen	Support mechanism	Under development
	Colorado clean hydrogen tax credit	Support mechanism	Under development
	Green hydrogen (Green Hydrogen Organisation)	Certification scheme for reporting	Under development

10.2 Appendix B: Overview of Certification Schemes' Adherence to Selected Voluntary Technical Standards for their Operational Setup and Procedures

Country/Scheme	Meets requirements of ISO 17065	Meets requirements of ISO 17029	Meets requirements of ISO 14065	Meets requirements of ISO 19011	Meets requirements of another ISO standard
Australia, Product Guarantee of Origin scheme	Adheres	Adheres	Adheres	Adheres	Adheres
TÜV Austria	Adheres	Adheres	Does not adhere	Adheres	Does not adhere
Canada, Clean Hydrogen Investment Tax Credit					
China Hydrogen Alliance's Standard	Aims for adherence	Does not adhere	Aims for adherence	Does not adhere	Adheres
EU, CertifHy	Adheres			Adheres	
EU, ISCC	Adheres	Adheres as one of several options	Adheres	Adheres	
EU, REDCert	Adheres		Adheres	Adheres	Does not adhere
France, Guarantees of origin					Adheres
France, Guarantees of traceability					Adheres
Germany, dena Biogasregister	Does not adhere	Does not adhere	Does not adhere	Does not adhere	Does not adhere
Germany, H2Global	Adheres	Does not adhere	Does not adhere	Adheres	Adheres
TÜV Süd	Adheres	Adheres	Does not adhere	Adheres	Adheres
Japan Basic Hydrogen Strategy					
Japan, Low-carbon hydrogen certification					
Korea, Clean Hydrogen Certification Scheme	Adheres as one of several options	Adheres as one of several options	Adheres as one of several options	Does not adhere	Adheres as one of several options
UK Low Carbon Hydrogen Certification Scheme					
UK Renewable Transport Fuel Obligation			Adheres	Adheres	Adheres
US (California), Low Carbon Fuel Standard			Adheres		Adheres
US, Clean Hydrogen Production Tax Credit (45V)	Does not adhere		Adheres as one of several options		Adheres
US, Colorado clean hydrogen tax credit					
GH2 Green Hydrogen Organisation		Adheres as one of several options	Adheres as one of several options		Adheres
% of schemes with information	52%	43%	62%	52%	67%
% of schemes with information, that adhere to the listed voluntary standards	73%	67%	62%	73%	79%

Key of Table 10: *Scheme adheres to this voluntary standard,*
Scheme aims for adherence to this voluntary standard
Scheme adheres to this voluntary standard as one of several options
Scheme does not adhere to this voluntary standard
No information

10.3 Appendix C: Background to Voluntary Technical Standards Relevant to the Operational Setup and Procedures of Certification Schemes

ISO 14065:2020 – General principles and requirements for bodies validating and verifying environmental information
ISO 14065 is a sector application of ISO/IEC 17029:2019, which contains general principles and requirements for the competence, consistent operation and impartiality of bodies performing validation/verification as conformity assessment activities.

ISO/IEC 17011:2017 – Requirements for accreditation bodies accrediting conformity assessment bodies
ISO 17011 is a voluntary technical standard that specifies requirements for the competence, consistent operation and impartiality of accreditation bodies assessing and accrediting conformity assessment bodies.

ISO/IEC 17029:2019 – General principles and requirements for validation and verification bodies
ISO 17029 is a voluntary technical standard regarding general principles and requirements for the competence, consistent operation and impartiality of bodies performing validation/verification as conformity assessment activities. It is applicable to validation/verification bodies in any sector, providing confirmation that claims are either plausible with regards to the intended future use (i.e. validation) or truthfully stated (i.e., verification).

ISO/IEC 17065:2012 – Requirements for bodies certifying products, processes and service
ISO 17065 is a voluntary technical standard that specifies the criteria for the impartial, consistent, and competent operation of certification bodies responsible for assessing products, processes, and services.

ISO 19011:2018 – Guidelines for auditing management systems
ISO 19011 is a voluntary technical standard that provides guidelines for auditing management systems, including quality management systems (ISO 9001) and environmental management systems (ISO 14001). It outlines the principles of auditing, managing audit programs, and conducting management system audits.