International PtX Hub

Supported by:

Federal Ministry for Economic Affairs and Climate Action

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LEGAL CONSIDERATIONS OF GLOBAL TRADE IN GREEN HYDROGEN AND POWER-TO-X

IMPRINT

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Berlin, February 2024

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Executive Summary

Principles of transparancy, efficiency, inclusiveness and sustainability could be implemented in a future legal framework for global hydrogen trade but are not sufficiently reflected to date.

UN Sales Law and WTO Law provide an international legal framework for global trade in green hydrogen.

In general, international regulation provides necessary orientation and has an integrative effect.

The main challenge is a global standard and definition for green hydrogen. All efforts should align with existing provisions to further the integration process.

Since renewable energy for hydrogen production is not equally available to all states, global trade of hydrogen will increase significantly with the progressing energy transition: Twelve G20 states and the EU have adopted hydrogen strategies, with some, like the EU, Germany, Japan, and South Korea, committing to future green hydrogen imports. Several economies, notably from the Global South, including Argentina, Chile, Brazil, Uruguay, Morocco, Namibia, South Africa and India, aim to produce and export green hydrogen. Under favourable economic and legal conditions, demand for imports as well as export readiness will drive market growth and trade relations for green hydrogen and its derivatives. Projections suggest a global trade in green hydrogen and derivatives, with an estimated 12-25% share of internationally traded green hydrogen by 2050.

This report examines the legal framework governing global trade in hydrogen with the aim to (1) give a comprehensive overview of the regulation in place and thus (2) to provide a guideline for countries that wish to engage in the global trade of hydrogen from a legal perspective.

In view of the outlined development of global trade in green hydrogen and its derivatives, it becomes clear that a regulatory patchwork would not allow for a transparent, efficient, sustainable, and inclusive trade.

The harmonisation of the legal framework highly depends on the national legislators and their collaboration. First of all, an agreement at the political level on the understanding of the term "green hydrogen" and on the choice of instruments for certification and creditability is crucial. Second, multilateral negotiations on an international level are necessary. Finally, bilateral partnerships and multilateral negotiations on issues of international trade in hydrogen should be initiated by the PtX partner countries, especially with regard to the integration of several of the SDG criteria: transparency, sustainability, efficiency, and inclusiveness. This entails ensuring alignment and consistency in the definitions, certification schemes, and import tariffs for hydrogen and its derivatives.

There are efforts on global governance of green hydrogen. Just recently, the International Hydrogen Trade Forum to Accelerate Global Collaboration (IHTF) was launched during the 14th CEM Meeting by several countries like Australia, Brazil, Canada, Chile, Germany, Japan, Saudi Arabia, South Korea, The Netherlands, United Arab Emirates, United Kingdom, United States, Uruguay and the EU[1] with the aim of expediting international hydrogen trade and serving as a platform for fostering dialogue among exporting and importing

[1] CEM, Launch of the International Hydrogen Trade Forum to Accelerate Global Collaboration, Press Release, 2023, available at: https://www.cleanenergyministerial.org/content/uploads/2023/07/press-release-ihtf.pdf (last access 12 December 2023).

countries, as well as relevant public and private entities.

The IHTF, coordinated by UNIDO[2], intends to contribute to the achievement of the SDG and therefore fosters a Just Transition. With the IHTF the aim is to achieve a non-discriminatory market access and to promote participation in international hydrogen trade of all interested parties, inclusive non-CEM members[3].

In general, the report finds that there is an opportunity to shape the legal framework governing global trade in green hydrogen according to the four principles of transparency, efficiency, sustainability, and inclusiveness. Clear requirements in this regard can already be identified and may serve as a blueprint. As an example, the Green Hydrogen Standard established by the GH2 makes a notable effort to incorporate the four principles by outlining seven additional requirements, besides mere production standards. These requirements include considerations such as social and environmental impact, health and safety, as well as government, transparency, and accountability. For projects to receive accreditation and certification from GH2, they must satisfy all seven requirements. Given that global trade in this sector is still in its nascent stage, implementing sustainable supply chains from the very beginning is particularly advantageous for supplying countries in the Global South.

The report examines the legal framework for global trade under the following aspects:

- Transaction and movement of goods
- Product characteristics
- Production standardisation and certification
- Transportation and storage.

Transaction and movement of goods is mainly governed by sales law and regulation on import and export. The CISG is an international treaty that governs contracts for the sale of goods, including hydrogen, between parties located in different countries, when the states are contracting states, or when the rules of private international law lead to the application of the law of a Contracting State (Art. 1 CISG). In this case, UN Sales Law automatically applies, but parties may exclude the application of this Convention or derogate from or vary the effect of any of its provisions (Art. 6 CISG). This convention offers a consistent framework of rules and principles for the conclusion, interpretation, and execution of international sales contracts. The CISG serves to prevent protracted legal disputes arising from absent or ambiguous contract clauses. Even states that are not contracting parties to the Convention can still choose to apply its provisions. However, the CISG only provides generic provisions. Specific provisions for the global trade of green hydrogen and its derivatives must be negotiated individually. Since methanol and ammonia are already extensively traded commodities, enough experience and blueprints exist in this sector.

International regulation of imports and exports primarily adheres to WTO Law. Of particular importance for the global trade of hydrogen are GATT, ASCM and TBT. WTO law is characterised by a very high level of abstraction and does not provide specific regulations for the trade of green hydrogen. However, WTO rules encompass general principles that are relevant to trade in hydrogen and its derivatives. The decisive factors include the requirement of equal treatment, which prohibits the discrimination of similar or 'like' goods, and the prohibition of quantitative import restrictions. An examination of WTO law reveals that measures discriminating against fossil-based hydrogen in favour of green hydrogen may be in conflict with GATT provisions. The WTO dispute resolution mechanism has not yet addressed the interpretation of WTO law in the context of climate protection. However, it is anticipated that future debates will likely focus on incorporating the environmental impact of production processes. Member states, therefore, must thoroughly examine the conformity of any incentives for green hydrogen with WTO law. In particular, local content requirements are most likely to be inconsistent with WTO law as they often result in discrimination against imported like products.

Given its primary focus on the global alignment of regulation and the standardisation of production processes, the TBT Agreement plays a vital role in advancing international trade in green hydrogen. It does so by advocating the adoption of international

[2] UNIDO, Launch of the International Hydrogen Trade Forum to accelerate global hydrogen flows, Press Release, 2023, available at: https://www.unido.org/news/launch-international-hydrogen-trade-forum-accelerate-global-hydrogen-flows (last access 12 December 2023).
[3] CEM, Launch of the International Hydrogen Trade Forum to Accelerate Global Collaboration, 2023.

standards, which in turn diminishes technical barriers to trade. For green hydrogen and its derivatives, this entails the establishment and utilisation of internationally recognised standards for the production, storage, transport, and utilisation of green hydrogen and PtX products. This standardisation can streamline regulations worldwide, facilitating the trade and utilisation of green hydrogen and PtX products on a global scale.

At the European level, hydrogen and ammonia fall under the scope of CBAM.[4] This means they can only be imported into the customs territory of the EU by an authorised CBAM declarant. Importers or their indirect customs representatives should seek authorisation through the CBAM registry for the import of hydrogen and ammonia. Importers are obligated to report quantities, emissions data for each type of goods, and the carbon price in the country of origin. CBAM does present administrative challenges for the import of green hydrogen into the EU, which may result in additional expenses. However, it also provides the opportunity for supplying countries to establish similar carbon pricing systems that, when recognised by the European Commission, exempt importers from going through the administrative trouble. Additionally, this could help prevent financial outflows to the EU and instead support local economies.

As hydrogen and its derivatives can exhibit variations in admixtures and aggregate states due to their physical properties, production methods, and other factors, there is a need for internationally harmonised standards. Harmonisation ensures that the molecules produced possess consistent physical properties and qualities, can be easily blended, and are suitable for their intended uses and technical applications. ISO 14687:2019 establishes voluntary basic criteria for the physical properties of hydrogen as a product, defining the minimum quality standards for hydrogen fuel. This standard specifies the minimum quality characteristics, setting limits for impurities, moisture content, and hydrocarbons that hydrogen fuel must meet to ensure safe and efficient use. While voluntary, it is advisable to adhere to internationally harmonised standards, as all energy systems need to be coordinated and operate at a similar level. This ensures that exported hydrogen can be used in all systems, thereby enhancing its market value.

The report highlights that within the realm of standardisation and certification, significant progress is taking place on international level. Several definitions and standards with cross-border applicability already exist or are in the process of being developed. However, at present, most definitions and standards for green hydrogen have a geographically limited scope. They may not be directly applicable to cross-border situations without additional adaptation or transposition. The creation of a universally harmonised definition for green hydrogen and its derivatives on a global scale is unlikely at this point due to the diverse interests involved. As a result, under the current legislative framework, suppliers are required to thoroughly assess the standardisation and certification schemes of each recipient country. Therefore, any national standardisation initiatives should align with the pre-existing international production standards to accelerate the integration process.

At international level, the IPHE has formed the Hydrogen Production Analysis Task Force (H2PA TF) to develop a methodology and analytical framework for evaluating greenhouse gas emissions linked to hydrogen production on a unit basis.[5] The aim of the IPHE is to develop a globally harmonised standard for determining the greenhouse gas emissions associated with the production of hydrogen, that is internationally accepted.

In the European market, the definition of green hydrogen is primarily governed by the RED II (now RED III) and its corresponding Delegated Acts (DA 27 and DA 28). These regulations establish new standards with the central aim of preventing an increase in fossil fuel-generated electricity in various sectors resulting from an increasing demand for green hydrogen. The primary focus is on the first DA (DA 27), which includes specific criteria such as additionality and temporal correlation, aiming to establish a close link between the production

[4] International PtX Hub, Öko Institute, adelphi & ecologic, 2023, Explaining the new EU Carbon Border Adjustment Mechanism (CBAM), available at https://ptx-hub.org/publication/explaining-the-new-eu-carbon-border-adjustment-mechanism-cbam-implications-for-ptx-imports-to-the-eu/

[5] International PtX Hub & Öko Institute, 2023, Introduction to the IPHE Methodology: Determining the greenhouse gas emissions associated with the production of hydrogen via electrolysis of water, available at: https://ptx-hub.org/wp-content/uploads/2023/08/International-PtX-Hub_202308_IPHE-methodology-electrolysis.pdf (last access 12 December 2023).

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of renewable energy and hydrogen.[6] It is crucial to note that both Delegated Acts apply not only to hydrogen production within EU Member States but also to imports. As a result, compliance with these standards is vital for countries interested in exporting hydrogen to the EU. The DA 27 essentially shapes the European legal framework for defining green hydrogen and its derivatives, especially considering the now adopted RED III broadening the scope of the definition of renewable fuels non biological origin (RFNBOs). On its side, DA 28 further elaborates the RED II mandate, which demands a minimum greenhouse gas emission reduction of 70% from the use of electricity-based fuels against fossil fuels. It also sets out a methodology for calculating emission reductions for these fuels as well as for recycled carbon fuels. Compliance with the DAs seems crucial when supplying the European market. The narrow requirements may present challenges for some supplying countries.

The criteria set out in the DAs also serve as the criteria for the initial funding window of the H2 Global funding scheme. H2 Global's objective is to create a stable market platform that connects supply and demand by employing both intermediate funding and long-term offtake contracts. Through the intermediary, a cost difference compensation is established between the expected higher purchase prices and lower selling prices. It is therefore an important tool for suppliers of green hydrogen and PtX seeking entry into the European market. Suppliers interested in utilising H2Global's first funding window as a facilitative tool for accessing the European market must, therefore, adhere to these requirements, irrespective of the intended end-use of the products.

Certification stands as a fundamental and essential element in the realisation and facilitation of global trade in green hydrogen and its derivatives. To implement a certification process, standards or regulations to which the certification scheme adheres need to be established. Thus, certification is the tool to demonstrate compliance with these standards or regulations. The development of standards and the consequent certification process can be either driven by legal obligations or by consumers' demand.[7]

Voluntary or policy driven certification

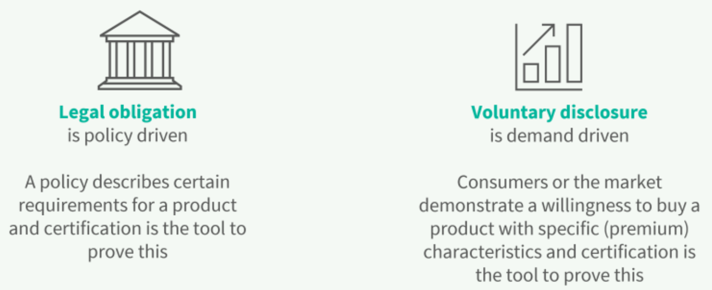

Figure 1: Own illustration

In the EU, the RED II (III) and its DAs are a regulatory framework that sets certain product requirements for green hydrogen which need to be certified. So called certification schemes or, in the EU context also called voluntary schemes, interpret this regulation and set up a certification framework under which companies and

[6] International PtX Hub, ecologic, Öko-Institute & adelphi, 2023, EU Requirements for Renewable Hydrogen and its Derivatives. Analysis of the two delegated acts adopted by the European Commission in February 2023 specifying the conditions under which electricity used to produce renewable fuels of non-biological origin (RFNBO) may be counted as fully renewable & the methodology to assess the greenhouse gas emissions savings from RFNBO, available at: https://ptx-hub.org/wp-content/uploads/2023/04/International-PtX-Hub_EU-Requirements-for-green-hydrogen-and-PtX.pdf (last access 12 December 2023).
[7] IPHE, Hydrogen Certification 101, 2023, available at: https://www.iphe.net/_files/ugd/45185a_fe8631bbe2ad496c9da93711935f7520.pdf (last access 13 December 2023).

producers are then audited by third-party certification bodies. The schemes need to be recognised by the EU Commission. Currently, a few schemes have handed in their certification approach for H2 and RFNBOs to the EU Commission, but none has been officially recognised yet.[8] Often, the schemes offer different certification approaches – one for the regulatory market (e.g., RED II) and one for the voluntary market – so companies can choose whether they would like to get certified under a certain regulatory framework or on a more voluntary basis. For example, the certification scheme ISCC offers ISCC EU certification for the regulatory market and ISCC Plus certification for the voluntary market[9].

In summary, each certification scheme offers advantages for different purposes. Hence, suppliers must carefully evaluate their targeted market and determine which certification scheme(s) would be most advantageous for their product. This decision should be taken by producers and developers at very early stages of the respective project.

Early awareness of certification

- Include certification in the beginning of project design
- Know the markets you want to sell your product in and identify where which certification is required

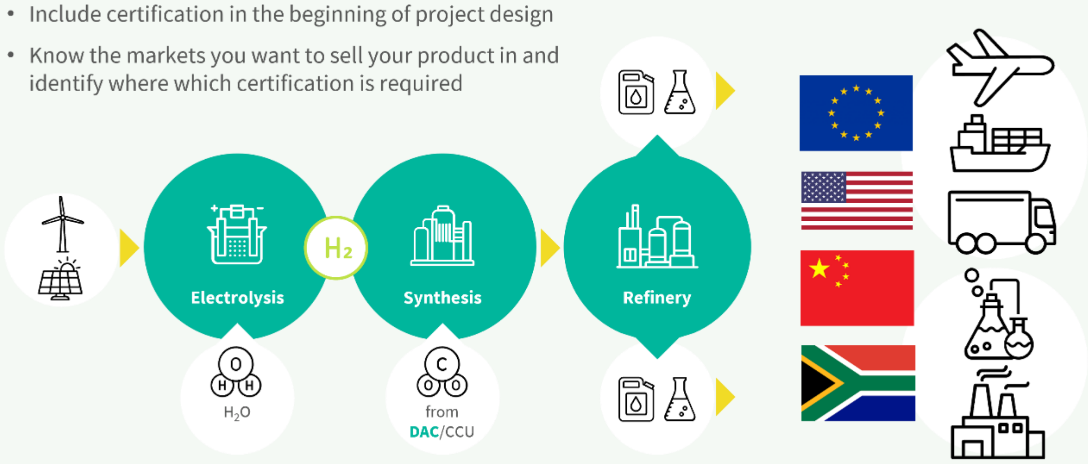

Figure 2: Own illustration

Since all schemes are in early stages, ongoing monitoring is essential for the successful development of a project. The importance of the establishment of a standardised, harmonised, and transparent market for (low carbon and renewable) hydrogen and its derivatives has already been recognised by the leaders of the G7[10] and the G20[11]. Additionally, at the COP 28 the international community launched the "Declaration on Hydrogen and Derivatives"[12] aiming at achieving a system for the mutual recognition of certification systems. It is one of the topics currently occupying the top list of the international political agenda.

Concerning safety and transportation, the report observes a substantial level of international harmonisation and standardisation. States that have

[8] A current list of the schemes is available at: European Commission, Voluntary schemes, 2023, available at: https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/voluntary-schemes_en (last access 14 Dezember 2023).
[9] ISCC Certification Schemes, ISCC System, available at: https://www.iscc-system.org/ (last access 14 December 2023).
[10] G7 2023 Hiroshima Summit, G7 Hiroshima Leaders' Communiqué, 2023, available at: https://www.g7hiroshima.go.jp/documents/pdf/Leaders_Communique_01_en.pdf?v20231006 (last access 12 December 2023).
[11] European Council , G20 New Delhi Leaders' Declaration, 2023,available at: https://www.consilium.europa.eu/media/66739/g20-new-delhi-leaders-declaration.pdf (last access 12 December 2023).
[12] COP28 UAE, Declaration on Hydrogen and Derivatives, 2023,available at: https://www.cop28.com/en/cop28-uae-declaration-on-hydrogen-and-derivatives (last access 12 December 2023).

not adopted the global legal framework are advised to do so, as it ensures a high degree of safety and legal certainty for investors.

The report recommends that national stakeholders adhere to established international regulations when crafting the legal framework for green hydrogen trade. This approach ensures consistency and mitigates the risk of conflicts with overarching laws. However, it is equally important that national regulators and stakeholders consider regional specifics such as energy and human resources, availability of water and land as well as the local economy. When crafting the legal framework for a hydrogen economy, these regional specifics should be imbedded into the internationally given blueprint.

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1 INTRODUCTION

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Among the numerous scenarios drawing ways to reduce global greenhouse gas emissions, there is broad scientific consensus that the use of green hydrogen[13] and its derivatives[14] such as green ammonia and green methanol will play a crucial role in decarbonising the energy system and industrial production processes.[15]

Projections differ, but it is estimated that in a climate neutral world by 2050, 12 - 30 % of the total final energy demand could be met through the utilisation of green hydrogen and its derivatives.[16] Apart from serving as energy carriers and storage, various production processes in industries like fertiliser, chemicals, steel, or cement will require green hydrogen, ammonia, and methanol as feedstock. This substitution is crucial to replace current fossil-based equivalents and achieve climate targets.

Since reliable preconditions and sufficient renewables are not equally available across the globe for meeting the demand for domestic production of green hydrogen and its derivatives in all states, global trade will be necessary. It is estimated that by 2050, the share of internationally traded green hydrogen will reach 12 – 25 %.[17] Economical approaches for stimulating the development of a global trade in green hydrogen and its derivatives have been subject to various studies[18], whereas its legal requirements and regulatory design still raise a number of questions.[19] They relate, in particular, to socially, politically, and economically widely desired aspects such as **transparency, efficiency, sustainability and inclusiveness** of trade.

This report focuses on the legal aspects of the emerging global trade in green hydrogen and its derivatives. Its purpose is to offer an overview and understanding of requirements, international trade related rules, standards, and certification. Additionally, it uncovers remaining regulatory challenges. Methodologically, the findings are, based on desk research conducted on publicly available secondary literature and relevant legal sources. They also derive from the results of an online expert survey, where experts in hydrogen trade responded to standardised questions about their ideas and suggestions for the development of global trade in green hydrogen and its derivatives. The report assesses the international and supranational trade rules affecting global trade in green hydrogen and its derivatives, as those provisions may constitute a relevant baseline for legal harmonisation.

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[13] The term *green hydrogen* is not ubiquitously applied for hydrogen produced by electrolysis using 100% renewable energy and could have a different (narrower) meaning depending on the context. Other terms are for instance renewable hydrogen. However, this report uses the term as generic term for hydrogen produced by electrolysis using 100% renewable energy.

[14] Hydrogen derivatives are molecules based on hydrogen molecules.

[15] The report focuses on hydrogen itself as the basis for any hydrogen derivative. To the extent that derivatives are directly scrutinized, the focus is primarily on hydrogen-derived products, eg green ammonia and green methanol. This emphasis stems from the fact that green ammonia is already being manufactured through direct synthesis, and there is a strong likelihood that green methanol will follow suit soon. This direct connection to the hydrogen value chain establishes them as especially compelling candidates for extensive production and trade, in Sachverständigenrat für Umweltfragen, Wasserstoff im Klimaschutz: Klasse statt Masse, 2021, para. 67.

[16] Agora Energiewende, Agora Industry, Fundación Torcuato di Tella & International PtX Hub, 12 Insights on Hydrogen, 2021, 11; Deloitte, Green hydrogen: Energizing the path to net zero, 2023, 3; Energy Transitions Commissions, Making the Hydrogen Economy Possible, 2021, 22; Hydrogen Council, McKinsey & Company, Hydrogen for Net-Zero, 2021, 13; International Energy Agency, Global Hydrogen Review 2021, 2021, 20; International Renewable Energy Agency, World Energy Transitions Outlook 2022, 2022, 235, Figure 5.10; International Renewable Energy Agency, Global hydrogen trade (Part I), 2022, 17.

[17] Deloitte, Green hydrogen: Energizing the path to net zero, 2023, 3; International Energy Agency, Global Hydrogen Review 2022, 2022, 261; International Renewable Energy Agency, Global hydrogen trade (Part I), 2022, 7.

[18] Deloitte, Green hydrogen: Energizing the path to net zero, 2023; Deloitte Finance, IFP Énergies Nouvelles (IFPEN), Carbon Limits, Stiftelsen for industriell og teknisk forskning (SINTEF), Hydrogen4EU, Charting pathways to enable net zero, (Ed. 2022); A. *Nuñez-Jimenez* et al., MIGHTY: Model of International Green Hydrogen Trade, 2022; European Commission, Joint Research Centre, The role of hydrogen in energy decarbonization scenarios, 2022; Hydrogen Council, Mc Kinsey & Company, Hydrogen Insights 2022, 2022; International Energy Agency, Global Hydrogen Review 2022, 2022; Agora Energiewende, Agora Industry, 12 Insights on Hydrogen, 2021; Energy Transitions Commission, Making the Hydrogen Economy Possible, 2021; International Energy Agency, The Future of Hydrogen, Seizing today's opportunities, 2019.

[19] International Partnership for Hydrogen and Fuel Cells in the Economy, International Trade Rules for Hydrogen and its Carriers, 2022.

2 OVERVIEW OF A GREEN HYDROGEN AND PTX ECONOMY

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Hydrogen, ammonia, and methanol have been synthetically produced on an industrial scale for quite some time, serving various purposes.[20] They are primarily utilised as feedstock in the fertiliser industry, reducing agents, solvents, synthetic materials, and cleaning agents, among other applications. Currently, the hydrogen needed for these processes is mainly derived from fossil sources like natural gas, coal or oil, leading to significant greenhouse gas emissions during production processes. As of 2021, hydrogen was predominantly sourced from fossil sources, including natural gas (47%), coal (27%), and oil (22%).[21] Besides their role as feedstock, hydrogen, ammonia, and methanol are suitable as energy carriers in the context of sector coupling, aiming to reduce greenhouse gas emissions in challenging-to-electrify sectors such as marine transport, long distance road cargo, and aviation. Hydrogen and its derivatives can also serve as energy storage, optimising the possible uses of volatile renewable energy generation and offering flexibility to the grid.

Against this backdrop, numerous states and supranational institutions, like the European Union, have crafted strategy papers outlining possible needs, roles, development measures, and corresponding actions to boost a green hydrogen and PtX economy. Among the G20 members, twelve states and the European Union have already published hydrogen strategies.[22] Many explicitly state that, due to local conditions, they will not be able to entirely meet their future demand for green hydrogen and its derivatives domestically. Consequently, governments of highly industrialised G20 economies like Germany[23], Japan[24], and South Korea[25] are already pledging to import hydrogen in the future. Other countries, which are likely to be able to produce more hydrogen than their domestic demand requires, thanks to their favourable geographical and climatic conditions, express willingness to produce and export green hydrogen and its derivatives in the future. This includes highly industrialised states like Australia, Canada, and the USA, as well as several nations of the Global South, including Argentina, Chile, Brazil, Uruguay, Morocco, Namibia, South Africa and India. These countries are already actively pursuing concrete hydrogen trade projects up to the year 2030.[26] Given suitable economic and legal conditions, the combination of import needs and export willingness is likely to lead to the development of markets and corresponding trade relations for green hydrogen and its derivatives. Various forecasts therefore assume the emergence of a global trade in green hydrogen and its derivatives.[27]

Most likely due to their relative geographical proximity, significant trade flows are expected to develop by 2030 primarily between Australia and the Middle East as export regions and Asia as import region. Similarly, Northern and Southern Africa are likely to serve as export regions with Europe as an import region, while North America may act as export region with East Asia as an import region. By 2050, trade flows are expected to have diversified significantly and virtually most regions of the world being in trade relations with each other through the trade of green hydrogen, ammonia, and methanol. The projected estimate suggests that the volume of traded hydrogen could reach 110 MtH_{2eq} by 2050.[28]

In view of the projected increase in demand for green hydrogen imports, especially in the European Union, and considering the ongoing cooperation and associated development progress, there is a significant development opportunity for many countries to actively participate in the global trade of green

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[20] J. Shi, Y. Zhu, Y. Feng et al., in: Atmosphere, A Prompt Decarbonization Pathway for Shipping, 2023; Oxford Institute for Energy Studies, Global trade of hydrogen: what is the best way to transfer hydrogen over long distances?, 2022.
[21] International Energy Agency, Global Hydrogen Review 2022, 2022, 71; International Renewable Energy Agency, Hydrogen Overview, available at: https://www.irena.org/Energy-Transition/Technology/Hydrogen (las access 14 February 2024); *A. Nicita, G. Maggio,* in: International Journal of Hydrogen Energy, Green hydrogen as feedstock: Financial analysis of a photovoltaic-powered electrolysis plant, 2020.
[22] Ecologic Institute, Advancing a green hydrogen agenda in the G20, 2023, Table 1, 5.
[23] German Federal Government, The National Hydrogen Strategy, 2020, 3.
[24] Ministerial Council on Renewable Energy of Japan, Basic Hydrogen Strategy, 2017, para. 4.2.
[25] Stangarone*,* in: Clean Technologies and Environmental Policy*,* South Korean efforts to transition to a hydrogen economy, 2021.
[26] International Energy Agency, Global Hydrogen Review 2022, 2022, 170.
[27] Deutsche Gesellschaft für Internationale Zusammenarbeit, The structures of the emerging international hydrogen trade, 14; International Renewable Energy Agency, Global hydrogen trade (Part I), 2023, 16.
[28] Deloitte, Green hydrogen: Energizing the path to net zero, 2023, 38.

hydrogen and its derivatives.[29] However, in order to avoid fostering one-sided trade relations that primarily cater to the interests of the importing economies, the framework conditions for global trade in green hydrogen and its derivatives should be developed and implemented with a focus on sustainability, transparency, inclusiveness and efficiency.[30]

Overview of a PtX economy

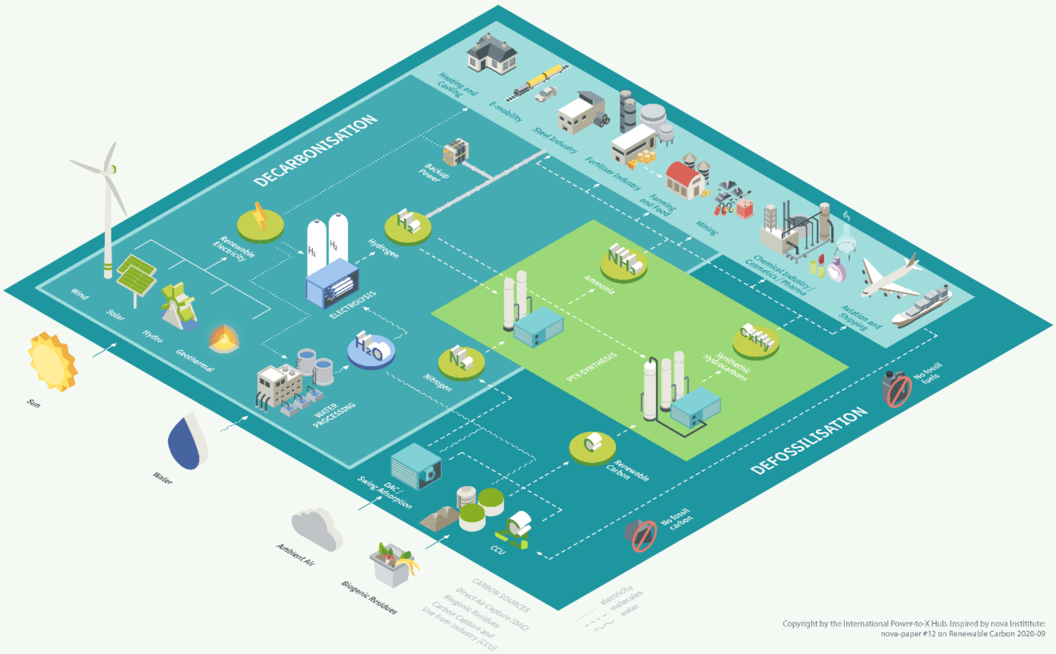

Figure 3: International Power-to-X Hub (2020)

[29] Mischler, Interview "Everyone benefits from hydrogen as an energy source", 2022, available at: https://www.giz.de/en/mediacenter/110676.html (14 February 2024).
[30] Villagrasa, Brot für die Welt / Heinrichs Böll Stiftung, Green hydrogen: Key success criteria for sustainable trade & production, 2022, 26 ff.

It is crucial to enable and emphasise a design and development of global trade in green hydrogen and its derivatives in a transparent, efficient, sustainable, and inclusive manner. The general requirements for a socially just and fair global trade in green hydrogen and PtX products as a basis for the subsequent legal analysis are hence the following principles.

Four guiding principles for global trade according to the International PtX Hub

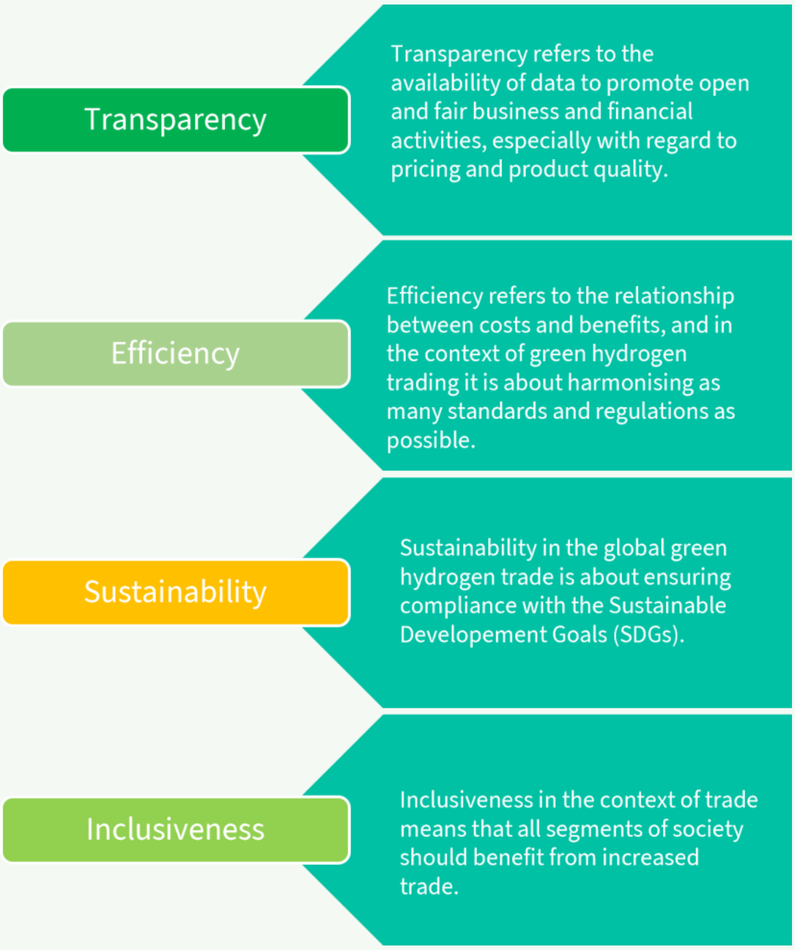

Figure 4: Own illustration

3 GLOBAL LEGAL FRAMEWORK

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Regulations that apply generally or specifically to the trade of hydrogen exist at different levels, under different legal regimes in different jurisdictions.[31] In view of the outlined development of global trade in green hydrogen and its derivatives, the expected international trade flows and the large number of economic entities involved, a ‘regulatory patchwork’ would not allow for a transparent, efficient, sustainable and inclusive trade. An unmanageable number of non-harmonised national regulations would significantly hamper the ramp up and scale up of global trade in green hydrogen and its derivatives. Hence, only international, and supranational regulation should provide the necessary orientation and integrative effect for the realisation of global trade in green hydrogen and its derivatives. This report thus focuses on existing and emerging international and supranational regulation in this area to outline the basis from which next steps should follow.

The scope entails regional supranational agreements and regulation such as on the European Union level, as well as international and worldwide agreements and standards on the World Trade Organisation (WTO) level. In addition to the public law, non-governmental actors, organisations, associations, and institutions such as national standardisation bodies, technical associations, technical testing organisations or other specialised scientific associations (e.g., the International Organisation for Standardization [ISO]) issue private law rules and standards for the trade in hydrogen and its derivatives. Such standards have no direct binding legal effect but become binding either through unilateral or bilateral voluntary commitments or by incorporation into the public law by (dynamic or static) reference. They are nonetheless crucial for a comprehensive legal framework for a global trade in green hydrogen.

Against this backdrop, the report first sheds light on the ongoing developments on the international stage regarding international collaboration on a global hydrogen economy (3.1). The subsequent chapters are following different trade elements defined in chapter (3.2), starting with UN Sales Law (3.3) followed by import and export regulation (3.1), regulation on product characteristics (3.5), standardisation and certification (3.6), safety requirements (3.7), legal metrology (3.18) and regulation governing transportation (3.9).

[31] International Partnership for Hydrogen and Fuel Cells in the Economy, International Trade Rules for Hydrogen and its Carriers, 2022, para. 5.

3.1 Global governance for hydrogen trade

The global community generally has recognised the need for a harmonised regulatory framework for global trade in hydrogen that aligns as many national interests as possible and taken first steps towards a global cooperation.

The International Hydrogen Trade Forum (IHTF) was launched on July 22, 2023, during the 14th Clean Energy Ministerial (CEM14) meeting in India. The governments of 14 states issued a joint declaration to accelerate international hydrogen trade and provide a platform to promote dialogue among a group of governments on the international hydrogen market. The IHTF intends to bring together hydrogen importing and exporting countries to accelerate international hydrogen trade, promote cooperation and remove barriers to the emerging hydrogen market.[32]

Launched during the 14th Clean Energy Ministerial (CEM) Meeting by several countries like Australia, Brazil, Canada, Chile, Germany, Japan, Saudi Arabia, South Korea, The Netherlands, United Arab Emirates, United Kingdom, United States, Uruguay, and the EU[33] with the aim of expediting international hydrogen trade and serving as a platform for fostering dialogue among exporting and importing countries, as well as relevant public and private entities. The IHTF also intends to contribute to the achievement of the Sustainable Development Goals (SDG) and therefore foster a Just Transition. The United Nations Industrial Development Organization (UNIDO) is the entity coordinating the IHTF.[34] The IHTF aims to achieve a non-discriminatory market access and to foster participation in international hydrogen trade of all interested parties, also of non-CEM members. The IHTF members include Australia, Brazil, Canada, Chile, Germany, Japan, the Netherlands, Saudi Arabia, South Korea, the United Arab Emirates, the United Kingdom, the United States, Uruguay, and the European Commission on behalf of the European Union. The UNIDO will assume the role of coordinator. Within this role, UNIDO will facilitate collaboration between government officials and industry leaders and provide the perspective and considerations of developing and emerging countries. Forum members also plan to collaborate with existing complementary organisations such as the World Trade Organization, Mission Innovation, G20, Asia-Pacific Economic Cooperation, International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), and the Hydrogen Council.[35]

The IPHE is a global initiative that promotes clean and sustainable energy solutions through hydrogen and fuel cell technologies.[36] IPHE was created to foster collaboration among its member countries and organisations, with a focus on advancing the adoption of hydrogen and fuel cells in various sectors, including transportation, industry, and power generation.[37] Its core objectives encompass research and development, policy coordination, market expansion, education and outreach, and knowledge sharing. IPHE's collaborative efforts, carried out through Task Forces, Work Groups[38], and other initiatives, address specific challenges and opportunities in the hydrogen and fuel cell sector, making it a pivotal platform for international cooperation and knowledge exchange that drives the development and implementation of these environmentally friendly energy technologies.[39]

[32] Quintaernum, Launch of the International Hydrogen Trade Forum, 2023, available at quintaernum.de (last access 15 December 2023).
[33] Clean Energy Ministerial, Launch of the International Hydrogen Trade Forum to Accelerate Global Collaboration, 2023, available at https://www.cleanenergyministerial.org/launch-of-the-international-hydrogen-trade-forum-to-accelerate-global-collaboration/ (last access 15 December 2023).
[34] UNIDO, Launch of the International Hydrogen Trade Forum to accelerate global hydrogen flows, 2023, available at https://www.unido.org/news/launch-international-hydrogen-trade-forum-accelerate-global-hydrogen-flows (last access 15 December 2023).
[35] Press release International Hydrogen Trade Forum, 2023, available at p. press-release-ihtf.pdf (cleanenergyministerial.org) (last access 15 December 2023).
[36] IPHE, Terms of Reference for the International Partnership for Hydrogen and Fuel Cells in the Economy, 2023, para 1, available at: https://www.iphe.net/_files/ugd/45185a_d2b2a065310f42fbb4d4103c080143ae.pdf (last access 15 December 2023).
[37] IPHE, Terms of Reference for the International Partnership for Hydrogen and Fuel Cells in the Economy, 2023, paras. 2.1 – 2.6.
[38] IPHE, Terms of Reference for the International Partnership for Hydrogen and Fuel Cells in the Economy, 2023, para. 3.6.
[39] IPHE, Mission & Purpose, 2023, available at: https://www.iphe.net/about (last access 15 December 2023).

IPHE recognises the critical importance of establishing accounting standards for different hydrogen sources along the supply chain to create a market for green hydrogen. These standards should be agreed upon internationally. To this end, IPHE has established the Hydrogen Production Analysis Task Force (H2PA TF) to propose a methodology and analytical framework for assessing the greenhouse gas emissions associated with hydrogen production on a unit basis.[40] The Task Force published its first version of the methodology in October 2021 and the third updated version in July 2023[41], which is currently being developed into an ISO standard. This framework can serve as a basis for a certification scheme. However, it's important to clarify that the H2PA TF does not provide specific guidance on greenhouse gas emission intensity thresholds which remains at the discretion of each country, although having common terminology and thresholds can facilitate international hydrogen trade.[42] The methodology adheres to the key principles: inclusiveness (ensuring that all potential primary energy sources are considered), flexibility (allowing adaptability to specific circumstances), transparency (clearly stating the approach and assumptions to build confidence), comparability (allowing meaningful emissions comparisons with other technologies) and practicality (making the methodologies user-friendly and conducive to industry adoption).[43] This methodology serves as a reference, allowing each country to develop its own methodology tailored to its specific national circumstances and regulatory framework.

3.2 Structure of trade elements

As global trade is complex and entails many different aspects and elements, the following chapter tries to structure trade elements for the further legal assessment. It determines the areas of trade and their specific elements for the following analysis of this report. Although the terms trade and market are sometimes used synonymously, this report distinguishes between *trade* meaning the structures and activities within a market that link production and consumption of goods and services,[44] and *market* as the generic term for supply and demand as such in addition to trade.[45] In this sense, trade is the necessary condition for the realisation of markets and will be of main focus for this report. The report differentiates between the following four trade areas as a basis notably for the subsequent legal analysis as each trade area requires specific regulation.

[40] IPHE, Task Forces, (H2PA), 2023, available at: https://www.iphe.net/working-groups-task-forces (last access 15 December 2023).
[41] IPHE, Methodology for Determining the Greenhouse Gas Emissions Associated With the Production of Hydrogen, Working Paper, 2023, available at https://www.iphe.net/_files/ugd/45185a_ef588ba32fc54e0eb57b0b7444cfa5f9.pdf (last access 15 December 2023).
[42] IPHE, Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen, 2023, 12.
[43] IPHE, Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen, 2023, 13.
[44] Schröder, Gabler Wirtschaftslexikon, 2004, 1334.
[45] Duden Wirtschaft von A bis Z (2016).

Areas of trade

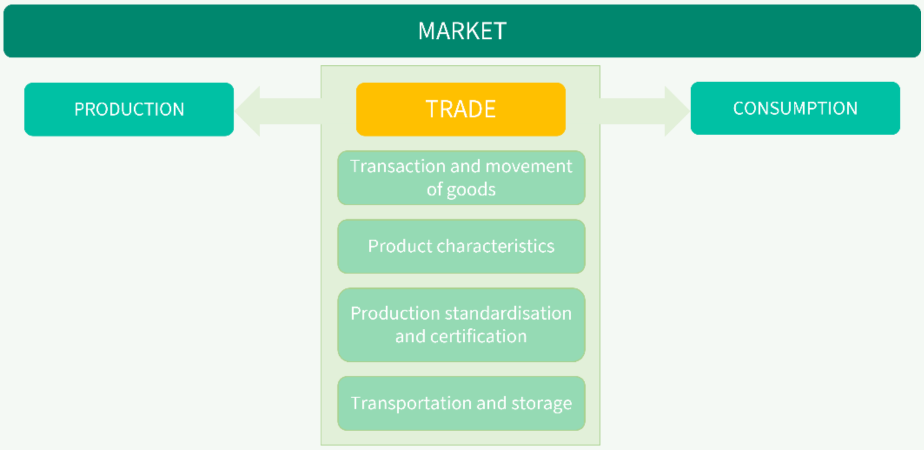

Figure 5: Own illustration

- The area of Transaction and movement of goods concerns aspects of the conclusion of contracts. Transaction and movement of goods furthermore involves aspects regarding export and import between countries, custom duties, dispute resolution, measuring and pricing. Both, international and national law partially covers this trade area with rules on obstruction of free trade and the freedom of contract, mainly trying to ensure a free trade on any (non-discriminating) terms.
- The physical properties of the traded products, such as their composition, quality, and aggregate state, concern the area of Product characteristics. Without a qualitative, abstract distinction between green and non-green hydrogen and its derivatives, there can be no explicit trade in green hydrogen and its derivatives.
- Since the distinction is linked to the production conditions, *Production standardisation and certification* is to be qualified as a further area of trade.
- *Transportation and storage* concerns above all the aspects of infrastructure and safety and is a crucial element when it comes to establish a global green hydrogen trade. Regulation in this area must adhere to the specific risks posed by hydrogen and other PtX-Products.

3.3 UN Sales Law

- **UN Sales Law (CISG) provides a uniform set of rules and principles for the conclusion, interpretation and performance of international sales contracts**
- **The CISG thus helps provide legal certainty and reduces the risk of disputes arising from inconsistencies in contract terms and interpretations increasing the reliability and enforceability of the agreements**
- **UN Sales Law automatically applies when the concluded contract falls within the sphere of application**
- **Contracting Parties should examine if they are subject to UN Sales Law and whether its application is in their best interest. It is advisable to refer at least to the provisions of the UN Sales Convention for guidance**

Trading in green hydrogen and its derivatives requires the conclusion of at least one contract between the legal entities involved. The **United Nations Convention on Contracts for the International Sale of Goods (CISG)** is an international treaty that governs contracts for the sale of goods between parties located in different countries and provides a uniform set of rules and principles for the formation, interpretation, and performance of international sales contracts.[46]

The CISG applies to contracts of sale of goods between parties whose places of business are in different States, when the states are contracting states, or when the rules of private international law lead to the application of the law of a Contracting State (Art. 1 CISG).[47] In this case, UN Sales Law automatically applies,[48] but parties may exclude the application of this Convention or, subject to Art. 12, derogate from or vary the effect of any of its provisions (Art. 6 CISG). The CISG has been ratified by currently 97 states, among them Germany and Uruguay but not Namibia[49], thus making it one of the most widely accepted international treaties governing commercial transactions and covering an estimated 80 % of worldwide trade[50].

The CISG does not expressly regulate whether the concept of goods covers gases such as hydrogen or especially ammonia, so this question must be determined by way of interpretation. The interpretation of the CISG must have regard to its international character and to the need to promote uniformity in its application and the observance of good faith in international trade, Art. 7 I CISG. The interpretation of an international uniform law such as the CISG requires an autonomous interpretation independent of national law.[51]

Goods in the sense of Art. 1 I CISG are, first and foremost, movable objects, which is sufficient if the goods are movable at the time of delivery.[52] Hydrogen can be used in liquid or gaseous form.[53] In this context, hydrogen is movable in both liquid and gaseous states since it can be transported from one place to another in both aggregate states.[54] Liquid hydrogen is a tangible substance, thus, the CISG applies to contracts for the sale of liquid hydrogen.[55] Same goes for other liquids like methanol, LOHC or liquid synthetic natural gas (SNG).

The crucial question therefore is whether goods within the meaning of Art. 1 I CISG covers only goods with a solid body. However, the term goods do not allow such a narrow interpretation. In the literature, certain incorporeal objects (e.g., standard computer software) are also regarded as goods, which leads to the conclusion, that CISG is not only applicable to tangible objects.[56]

Art. 2 lit. f CISG explicitly excludes the application of the CISG to the purchase of electricity. This exclusion is a consequence of the special features of electricity supply contracts, for which special rules apply in national and international trade.[57] However, no analogy may be drawn from this exemption to the effect that other energy sources - such as gas - are also not covered by the CISG[58] as exemptions are to be applied restrictively.

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[46] United Nations Commission On International Trade Law, Key provisions, available at: https://uncitral.un.org/en/texts/salegoods/conventions/sale_of_goods/cisg (last access 14 February 2024).
[47] United Nations Commission on International Trade Law, Legal Guide to Uniform Instruments, 2021, para. 106.
[48] Herdegen, Internationales Wirtschaftsrecht, 2023, § 23 para. 19.
[49] United Nations Commission On International Trade Law, Status, available at: https://uncitral.un.org/en/texts/salegoods/conventions/sale_of_goods/cisg/status ().
[50] Hoekstra, in: Uniform Law Review, Political barriers in the ratification of international commercial law conventions, 2021, 61.
[51] Güllemann, Internationales Vertragsrecht, 166 f.
[52] Magnus, in: Staudinger BGB, CISG, Art.1 para. 50.
[53] Demaco Hydrogen, Alles über flüssigen Wasserstoff, available at: https://demaco-cryogenics.com/de/blog/alles-ueber-fluessigen-wasserstoff/ (last access 15 December 2023).
[54] Universität Augsburg, Transport von Wasserstoff, available at: https://www.uni-augsburg.de/de/forschung/einrichtungen/institute/amu/wasserstoff-forschung-h2-unia/h2lab/h2-sp/transport/ (last access 15 December 2023).
[55] Saenger, in: Internationales Vertragsrecht, Kommentar, Art. 1 CISG para. 6.; Magnus, in: Staudinger BGB, CISG, Art.1 para. 45.
[56] Saenger, in: Internationales Vertragsrecht, Kommentar, Art. 1 CISG para. 6.; Plitz, in: NJW 1994, Neue Entwicklungen im UN Kaufrecht, 1102; Magnus, in: Staudinger BGB, CISG, Art. 1 para. 44; Herdegen, Internationales Wirtschaftsrecht, § 1 para 20.
[57] Saenger, in: Internationales Vertragsrecht, Kommentar, Art. 2 CISG para. 12.
[58] Magnus, in: Staudinger BGB, CISG, Art.2 para. 50; P. Schlechtriem, in: AJP 1992, Anwendungsvoraussetzungen und Anwendungsbereich, 347.

Instead, it seems more convincing to not set requirements too high on the physicality of the goods within the meaning of the CISG, so that at least bottled or otherwise transportable gas is covered by the concept of goods in the Convention.[59] The objective of the CISG to eliminate legal obstacles in international trade and the uniform application required by Art. 7 I CISG when interpreting the convention also speaks in favour of hydrogen being a commodity under the CISG in its gaseous state. It seems contradictory and not in the sense of a uniform application of the CISG if hydrogen as a liquid gas is to be covered by the scope of the CISG and hydrogen in its gaseous state is not. As a result, the CISG should be applied to contracts of sale of hydrogen between parties domiciled in different Contracting States.

The substantive sphere of application governs only the formation of the contract of sale and the rights and obligations of the seller and the buyer arising from such a contract. In particular, except as otherwise expressly provided in this Convention, it is not concerned with the validity of the contract or of any of its provisions or of any usage as well as the effect which the contract may have on the property in the goods sold (Art. 4 CISG).

Within its sphere of application, the CISG provides a set of standardised rules and principles applicable to the formation, interpretation and performance of international sales contracts entailing detailed rights and obligations of the seller and the buyer. Within the scope of the CISG, parties can benefit from a widely recognised and accepted framework for resolving disputes and enforcing contractual obligations. The CISG helps provide legal certainty and reduces the risk of disputes arising from inconsistencies in contract terms and interpretations increasing the reliability and enforceability of the agreements.

3.4 Regulation on import and export

The following chapter draws an overview of the existing regulation affecting import and export of green hydrogen. While the analysis shows that most of the existing legal framework is rather general and more specific regulations for the trade of green hydrogen will be necessary, it also finds that there is a baseline for the development of a global hydrogen and PtX economy.

3.4.1 WTO Law

WTO Law is the superstructure that governs trade relations between its current 164 Member States. They account for 98% of world trade and WTO law thus is almost ubiquitous.[60] WTO law entails no specific rules for the trade of hydrogen or even the trade of energy products.[61] The agreements and arrangements concluded within the framework of the WTO (e.g., GATT, GATS, TBT, WTO Subsidies Agreement) do, however, include important general rules on the trade of goods and have an impact on EU law and thus will be relevant for the trade of hydrogen among the Member States. Between 2009 and 2021, 44 WTO Member States notified hydrogen-related policies among which were 34 notifications under the Subsidies Agreement and 10 notifications under the TBT.[62]

In general, international trade should take place in a non-discriminatory manner between the contracting states of the WTO.[63] To achieve these goals, the parties agreed to eliminate tariffs and other barriers to international trade, to simplify the import and export of goods and to establish a process for resolving disputes. The WTO agreements do not contain any specific provisions for climate protection measures and the

[59] Magnus, in: Staudinger BGB, CISG, Art.1 para. 45.
[60] World Trade Organization, WTO in brief, 2023, available at: https://www.wto.org/english/thewto_e/whatis_e/inbrief_e/inbr_e.htm#:~:text=The%20WTO%20has%20164%20members,This%20is%20typically%20by%20consensus (last access 13 December 2023).
[61] Marceau, in: Proceedings of the Annual Meeting (American Society of International Law), The WTO in the Emerging Energy Governance Debate, 2012, 385.
[62] IRENA/WTO, International trade and green hydrogen. Supporting the global transition to a low-carbon economy, 2023, p. 27.
[63] Marrakesh Agreement Establishing the World Trade Organisation, Preamble para. 3, available at: https://www.wto.org/english/docs_e/legal_e/04-wto_e.htm (last access 13 December 2023).

negotiation of new explicit provisions has failed so far.[64] The preamble of the Marrakech Agreement Establishing the World Trade Organisation (Marrakech Agreement) contains the goals of sustainable development and the protection and preservation of the environment.[65] This also includes climate protection albeit it is not explicitly mentioned. The dispute settlement mechanism has also not led to any consolidated rulings on climate protection measures.

The following chapters examine the three most important agreements for global trade in hydrogen: GATT (3.4.1.1), ASCM (3.4.1.2) and TBT (3.4.1.3).

3.4.1.1 General Agreement on Tariffs and Trade (GATT)

- **In general, domestic products and imported like products must be treated equally.**
- **Green hydrogen and fossil-based hydrogen may be considered like products under WTO law.**
- **Favourable treatment of green hydrogen in relation to fossil-based hydrogen could be challenged under GATT.**
- **Local content requirements to enhance domestic production are likely to be non-compliant with GATT.**

The objective of the General Agreement on Tariffs and Trade[66] (GATT) is to direct the trade and economic relations of the contracting parties towards raising the standard of living and achieving full employment, steadily increasing the level of real income and demand, fully tapping the world's sources of aid and increasing production.[67]

Most importantly, GATT sets out the clear requirement of non-discrimination entailing two aspects: First, any advantage, favour, privilege, or immunity granted by any contracting party to any product originating in or destined for any other country shall be accorded immediately and unconditionally to the like product originating in or destined for the territories of all other contracting parties (Art. I 1 GATT). Second, products of the territory of any contracting party imported into the territory of any other contracting party shall not be subject, directly, or indirectly, to internal taxes or other internal charges of any kind in excess of those applied, directly or indirectly, to like domestic products (Art. III 2 GATT). As a general rule, Art. III 4 GATT requires that imported products shall be treated no less favourable than according to like products of national origin.

Especially certain local content requirements that tie e.g. tax reduction or exemptions openly or in fact to domestic products and exclude imported like products are highly likely to be inconsistent with Art. III 4 GATT as the WTO Appellate Body has found for a Brazilian tax programme providing tax exemptions and reductions for the sale of information technology goods in *Brazil - Certain Measures Concerning Taxation and Charges*. In this case the programme required an accreditation of

[64] World Trade Organization, The multilateral trading system and climate change, para. I., available at: https://www.wto.org/english/tratop_e/envir_e/climate_change_e.pdf (last access 13 December 2023).
[65] Marrakesh Agreement, Preamble para. 1.
[66] The General Agreement on Tariffs and Trade, Geneva, July 1986, available at: https://www.wto.org/english/docs_e/legal_e/gatt47_e.pdf (last access 15 December 2023).
[67] GATT, Preamble.

the companies. For being eligible for accreditation the following requirements had to be met:

- Develop or produce goods and services in compliance with the relevant Basic Productive Processes (PPB).
- Invest in information technology research and development activities in Brazil.

PPBs indicated the minimum stages or steps of the manufacturing process of a product that must be performed in Brazil.[68] They essentially required the use of domestic components and subassemblies.[69] Furthermore, products considered *developed in Brazil* were subject to additional tax reductions. Products were considered *developed in Brazil* when they complied with Brazilian legislation and specifications, projects and developments had been carried out in Brazil by technicians who were residents and domiciled in Brazil. The Appellate Body upheld the panels finding[70] that the tax programme treated imported and domestic products differently based on the origin of the product.[71] It equally upheld the finding[72] that the accreditation requirements restricting access to the tax incentives only to domestic products modify the conditions of competition to the detriment of imported products and result in less favourable treatment being accorded to imported products than to *like* domestic products, therefore being inconsistent with Art. III 4 GATT.[73]

GATT does not define the term *like products* but the term has been shaped by WTO Case law.[74] Since WTO law is on a highly abstract level, the task of providing more concrete provisions and definitions falls to the WTO Case Law. The dispute settlement according to WTO Law follows the Annex 2 of the WTO Agreement (Understanding on rules and procedures governing the settlement of disputes, DSU[75]). Member states must bring forward their cases (see Art. 3 No. 7 DSU). However, for diplomatic reasons, Member States can refrain from doing so and questions regarding WTO Law remain unsolved.[76]

For purposes of Art. III 4 GATT, the WTO Appellate Body has clarified that the assessment of whether products are *like* involves an assessment of the extent of the competitive relationship or substitutability between these products, taking into account all relevant evidence, including:

- the physical properties of the products, including the nature and quality of the products
- the end-uses of the products
- consumers' tastes and habits
- the international classification of the products for tariff[77]

The Appellate Body has further explained that panels must examine all the relevant evidence and determine whether that evidence indicates that the products in question are like.[78] According to WTO case law, the assessment of the issues of likeness for purposes of Art. I 1 GATT should also be informed by the approach taken by the Appellate Body in respect of likeness under Article III 4 GATT.[79]

Regarding global trade in green hydrogen, the question arises under two aspects. First, whether fossil-based hydrogen and green hydrogen are like products and

[68] WTO, Reports of the Panel, Brazil – Certain Measures Concerning Taxation and Charges, WTDS472/R, 30 August 2017, para. 2.62.
[69] WTO, Reports of the Appellate Body, Brazil – Certain Measures Concerning Taxation and Charges, WT/DS472/AB/R, 13 December 2018, para. 6.25.
[70] WTO, Reports of the Panel, Brazil – Certain Measures Concerning Taxation and Charges, WTDS472/R, 30 August 2017, para. 7.223.
[71] WTO, Reports of the Appellate Body, Brazil – Certain Measures Concerning Taxation and Charges, WT/DS472/AB/R, 13 December 2018, para. 6.6.
[72] WTO, Reports of the Panel, Brazil – Certain Measures Concerning Taxation and Charges, WTDS472/R, 30 August 2017, para. 7.225.
[73] WTO, Reports of the Appellate Body, Brazil – Certain Measures Concerning Taxation and Charges, WT/DS472/AB/R, 13 December 2018, para. 6.7.
[74] WTO, Appellate Body Report and Panel Report, EC – Asbestos, WT/DS135/12, 11 April 2001, para. 88.
[75] Legal text available at https://www.wto.org/english/tratop_e/dispu_e/dsu_e.htm (last access 08 December 2023).
[76] A strong example is the US Inflation Reduction Act where the European Union is questioning its compliance with GATT but has currently refrained from bringing the case to the Dispute Settlement Body.
[77] WTO, Appellate Body and Panel Report, EC – Asbestos, WT/DS135/12, 11 April 2001, paras. 99 and 101-102.
[78] WTO Appellate Body and Panel Report, EC – Asbestos, WT/DS135/12, 11 April 2001, para. 103.
[79] WTO Panel Report, EU — Energy Package, WT/DS476/R, ITL 174, 10 August 2018, para. 7.576 also for further references.

second, whether green hydrogen and its derivatives are like products according to these principles.

For the latter question, the answer seems simpler as for in the – pending - case EU — Energy Package, the EU has successfully argued that LNG and Russian natural gas are not like products.[80] The Panel ruled that LNG is distinct from natural gas, mainly arguing that LNG has different end use options than natural gas and that they are differently classified by the Harmonised System Codes (HS).[81] Notably, legal provisions treating products equally are no evidence for likeness.[82] This line of arguments also applies to hydrogen and its derivatives. Each derivative, for instance ammonia or methanol, has different end uses and they are differently classified by the HS. This might also be true for gaseous hydrogen and liquefied hydrogen.[83]

Not as simple, however, is the question of the likeness of green hydrogen and fossil-based hydrogen. Both are indistinguishable in physical characteristics and share identical chemical compositions. International tariff classifications do not differentiate. The end use of both is identical. Hence, there is a strong case, they should be considered like products according to WTO law. Since all relevant evidence must be considered, consumers perception may be the only argument against and must thus make a strong case. However, from a market point of view, green and fossil-based hydrogen are in a direct competitive relationship and are – if not regulated – substitutable. Most convincing and distinguishable in this regard is only the effect on climate change and the role of green hydrogen in the urgent energy transition.

In general, WTO law aims for trade liberalisation. On a first glance, this collides with effective climate protection measures. However, WTO members may adopt environmental policies, including those related to climate change, at the level they choose, even if these significantly restrict trade, as long as they do not introduce unjustifiable or arbitrary discrimination or disguised protectionism.[84]

Discrimination of a fossil-based product in relation to its green counterpart may be an exemption according to GATT provisions and has been disputed in WTO law for decades.[85] Art. XX GATT lays down general exceptions to the GATT provisions. Particularly, GATT provisions should not hinder measures,

- necessary to protect human, animal or plant life or health,
- relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption,
- undertaken in pursuance of obligations under any intergovernmental commodity agreements which conform to criteria submitted to, and not disapproved by the contracting parties, or which are themselves so submitted and not so disapproved.

According to the WTO, these three circumstances cited above include matters of environmental protection.[86] For a GATT-inconsistent environmental measure to be justified under Art. XX GATT, two cumulative requirements must be met:

- The measure falls under at least one of the exceptions.
- The measure is not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail

[80] WTO Panel Report, EU — Energy Package, WT/DS476/R, ITL 174, 10th August 2018, para. 7.835. This case is currently under appeal.
[81] WTO Panel Report, EU — Energy Package, WT/DS476/R, ITL 174, 10th August 2018, paras. 7.843 and 7.855.
[82] WTO Panel Report, EU — Energy Package, WT/DS476/R, ITL 174, 10th August 2018, para. 7.844 and 7.845.
[83] See also IPHE, International Trade Rules for Hydrogen and its Carriers: Information and Issues for Consideration, 2022, 37, available at: https://www.iphe.net/_files/ugd/45185a_29c90ec0ea15463eadf5d585cfd7b20a.pdf (last access 15 December 2023).
[84] WTO, World Trade Report 2022, p. 93, available at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf (last access 26 January 2024).
[85] For a general discussion of environmental aspects of production see *B. Cooreman*, in: International & Comparative Law Quaterly, Addressing Environmental Concerns through Trade: A Case for Extraterritoriality?, 229; 2019, also *C. Conrad*, Processes and production methods (PPMs) in WTO law: Interfacing trade and social goals, 2011.
[86] Cf. e.g. World Trade Organization, Trade and Environment at the WTO, 2004, available at: https://www.wto.org/english/tratop_e/envir_e/envir_wto2004_e.pdf. (last access 08 December 2023), For an overview of environment-related disputes under WTO see: World Trade Organization, Environmental disputes in GATT/WTO, available at: https://www.wto.org/english/tratop_e/envir_e/edis00_e.htm (last access 08 December 2023).

and is not a disguised restriction on international trade.[87]

Global trade in green hydrogen is a key element for countries to reach their climate goals and thus a big part in the global climate protection plan. Important to note in this context is, that in general, climate protection agreements such as the Paris Agreement have equal legal status for the contracting parties as the WTO Agreement.[88] Consequently, climate protection could, in theory, be construed as necessary to protect human, animal or plant life or health or relating to the conservation of exhaustible natural resources. Also, the third option of pursuing obligations under intergovernmental commodity agreements might be of relevance in conjunction with green global hydrogen partnerships. However, in a WTO Dispute Resolution, the Paris Agreement would merely have an interpretative effect, only GATT remains directly applicable in this case.

On 12 December 2021 the WTO issued a ministerial statement[89] on trade and environmental sustainability, including ministers of the European Union, the United States, China and Uruguay - as one of the partner countries of the PtX Hub. Among other, they especially agreed to

- launch dedicated discussions on how trade-related climate measures and policies can best contribute to climate an environmental goals and commitments while being consistent with WTO rules and principles,
- Explore opportunities for promoting and facilitating trade in environmental goods and services to meet environmental and climate goals also through addressing regulatory elements,
- Identify best practices and explore opportunities for voluntary actions and partnerships to ensure that trade and trade policies contribute to the global uptake of new and emerging low-emissions and other climate-friendly technologies.

The statement shows that awareness of potential conflicts on this matter is rising among WTO members but also that efforts are still at the very beginning and only at discussion state. The statement has no binding effect and merely indicates a direction some of the WTO members want to take. As of yet, there is no significant WTO ruling on climate protection measures. Therefore, the dispute settlement mechanism has yet to interpret the WTO law's scope of climate protection. However, a few WTO Case Law rulings point into the right direction showing the dynamics of WTO Case Law and its adaptability.

In the Brazil –Retreated tyres case: the Appellate Body elaborates on the term *necessary to protect human, animal or plant life or health* and acknowledges that *complex environmental problems may only be tackled with a comprehensive policy comprising a multiplicity of interacting measures* that also may only be evaluated with the benefit of time.[90] This shows that the Appellate Body is willing to refrain from a strict dogmatic approach to the definition of the exemptions but rather look at the individual case in the context of the present situation.

In the United States – Shrimp case: the Appellate Body upheld the Panel's ruling stating that import restrictions for shrimps aiming at protecting sea turtles are justified under Article XX GATT. It most notably stated that the term **natural resources** are *not static in its content or reference but is rather, by definition, evolutionary*.[91] The regulation in question imposed an

[87] World Trade Organization, WTO rules and environmental policies: GATT exceptions, 2023, available at: https://www.wto.org/english/tratop_e/envir_e/envt_rules_exceptions_e.htm (last access 08 December 2023).
[88] Wissenschaftlicher Dienst des Bundestages, Kurzinformation, Das Spannungsfeld zwischen Klimaschutz und Freihandel, WD 2 – 3000 – 057/19, 2019, 1, available at https://www.bundestag.de/resource/blob/650664/adf293a6dad182aea8ca5ff0c298c931/WD-2-057-19-pdf-data.pdf (last access 15 December 2023).
[89] Trade and Environmental Sustainability Structured Discussions (TESSD), Ministerial Statement on Trade and Environmental Sustainability, WT/MIN (21)/6/Rev.2, available at https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/WT/MIN21/6R2.pdf&Open=True (last access 15 December 2023).
[90] Brazil – Measures affecting imports of retreaded tyres, AB-2007-4, Report of the Appellate Body, para. 151, available at https://www.wto.org/english/tratop_e/dispu_e/332abr_e.pdf (last access 15 December 2023).
[91] United States – Import Prohibition of Certain Shrimp and Shrimp Products, Recourse to Article 21.5 of the DSU by Malaysia, Report of the Appellate Body, AB-2001-4, WT/DS58/AB/RW, 2001, para. 130, available at https://www.wto.org/english/tratop_e/dispu_e/58abrw_e.pdf (last access 08 December 2023).

import ban on shrimp that have been harvested with commercial fishing technology which may adversely affect sea turtles. This provision was designed to influence countries to adopt national regulatory programs requiring the use of turtle excluder devices by their shrimp fishermen. The Appellate Body found that the regulation is not disproportionately wide in its scope and reach in relation to the policy objective of protection and conservation of sea turtle species. The *means are, in principle, reasonably related to the ends,* the Appellate Body found and thus deemed it a measure relating to the conservation of an exhaustible natural resource within the meaning of Art. XX (g) GATT by further establishing a concrete criterion for the definition: *appropriateness of the measure*. In more generic words, one could derive from the ruling that regulation designed to privilege a product depending on the production method could be justified under Art. XX GATT.

These examples highlight that Art. XX GATT sets the requirements for the justification of trade-related climate measures. Future rulings of the WTO dispute settlement system will have to show where the exact legal demarcations of WTO consistent climate measures are.

3.4.1.2 Agreement on Subsidies and Countervailing Measures (ASCM)

Subsidies granted by a WTO Member State shall in general have no adverse effect on other Member States of the WTO.

Subsidies contingent upon the use of domestic over imported goods are prohibited under the ASCM.

Local content requirements may be challenged under the ASCM.

The Agreement on Subsidies and Countervailing Measures[92] (ASCM) regulates subsidies with an impact on import or export by defining the term subsidies (Art. 1 ASCM), prohibiting certain subsidies (Art. 3 ASCM) as well as providing rules on countervailing measures to harmful subsidies (Art. 4 ASCM).

At the current market situation, green hydrogen comes at a significantly higher cost than fossil fuels.[93] Closing this cost gap is essential for a global hydrogen market. Next to the generally decreasing costs of renewable electricity[94], two instruments are generally discussed. First, elevated carbon pricing, which would raise the cost of fossil fuels, and second, the redirection of some of the thus allocated funds to the hydrogen economy.[95] Many of the instruments of reallocation may be classified as subsidies according to the ASCM. Therefore, when setting up funding instruments, Member States must be aware of the Provisions of the ASCM.

In the light of Art. 1.1 ASCM, a subsidy in general is a financial contribution by a government or any public body or any form of income or price support in the sense of Art. XVI GATT. Art. XVI GATT states that the

[92] Legal text available at https://www.wto.org/english/docs_e/legal_e/24-scm.pdf (last access 23 January 2024).
[93] IEA, Global Hydrogen Review 2023, p. 47; IRENA/WTO, International trade and green hydrogen. Supporting the global transition to a low-carbon economy, 2023, p. 10 f.
[94] IRENA/WTO, International trade and green hydrogen. Supporting the global transition to a low-carbon economy, 2023, p. 10.
[95] See also for the potential of freeing funds for fossil fuels, IRENA/WTO, International trade and green hydrogen. Supporting the global transition to a low-carbon economy, 2023, p. 34.

income or price support must operate directly or indirectly to increase exports of any product form or reduce imports of any product. Additionally, a benefit must be conferred by the support (Art. 1.1 lit. b ASCM). Examples are direct transfer of funds (Art. 1.1 lit. a (1) (i) ASCM), tax credits (Art. 1.1 lit. a (1) (ii) ASCM) or the government providing goods or services other than general infrastructure (Art. 1.1 lit. a (1) (iii) ASCM).

The ASCM divides subsidies in three categories:

- Prohibited subsidies (Art. 3 ASCM)
- Actionable subsides (Art. 5 f. ASCM)
- Non-actionable subsides (Art. 8 ASCM)

Every subsidy is subject to the provisions of part II of the ASCM on prohibited subsidies in. According to Art. 3.1 ASCM, subsidies contingent in law or in fact upon export performance (lit. a) or subsidies contingent upon the use of domestic over imported goods (lit. b) are prohibited. WTO Member States shall grant or maintain neither (Art. 3.2 ASCM).

Against this backdrop, local content requirements can also be challenged under the ASCM as done in the aforementioned Dispute Settlement *Brazil - Certain Measures Concerning Taxation and Charges*. The Appellate Body upheld the Panel's findings[96] that PPBs requiring the use of domestic components as a prerequisite for accreditation for tax exemptions and reductions is also inconsistent with Art. 3.1 lit. b ASCM.[97]

Furthermore, subsidies that are specific in the light of Art. 2 ASCM are subject to the provisions on actionable subsidies of part III and on countervailing measures of part V of the ASCM. Art. 2.1 ASCM lays down three principles to determine the specificity of a subsidy. First, a subsidy is specific when the access is limited to certain enterprises (lit. a). Second, specificity is ruled out when objective criteria or conditions meaning neutral criteria not favouring certain enterprises over others and which are economic in nature and horizontal in application govern the eligibility for the subsidy being clearly determined in law or any official document (lit. b). Third, other factors may also be considered, especially when there is reason to believe that the subsidy is in fact only available to a limited number of enterprises (lit.c).

Actionable subsidies according to Art. 5 ASCM are subsidies with adverse effects to the interests of other Member States. This could be by injuring the domestic industry of another Member State (lit. a), nullification or impairment of benefits under GATT (lit. b) or serious prejudice to the interests of another Member State (lit. c). Serious prejudice is further defined in detail in Art. 6 ASCM especially shedding light on the effect of discrimination of *like* products from other Member States. When a Member State is in doubt about a subsidy being granted by another Member State, it can refer the matter to the Dispute Settlement Body after a consultation period of 60 days (Art. 7 ASCM).

Non-actionable subsidies are either subsidies which are not specific (Art. 8.1 lit. a ASCM) or specific subsidies which meet the provisions of Art. 8.2 ASCM. Art. 8.2 ASCM contains exemptions for research activities (lit. a), development of disadvantaged regions (lit.b) and assistance to the adaption of facilities in operation for more than two years to new environmental requirements (lit. c). They shall be notified to the Committee in advance of their implementation (Art. 8.4 ASCM).

The ASCM thus sets the global legal framework for funding instruments in alignment with the European state aid legislation.

[96] WTO, Reports of the Panel, Brazil – Certain Measures Concerning Taxation and Charges, WTDS472/R, 30 August 2017, para. 7.319.
[97] WTO, Reports of the Appellate Body, Brazil – Certain Measures Concerning Taxation and Charges, WT/DS472/AB/R, 13 December 2018, para. 6.25.

3.4.1.3 Agreement on Technical Barriers to Trade (TBT)

Where appropriate, WTO Members should base their national regulations and standards on international standards.

Like products must be treated equally in respect of technical regulations.

Technical regulations should not be more trade-restrictive than necessary to protect the environment or human health.

The Agreement on Technical Barriers to Trade[98] (TBT), tackles non-tariff barriers to international trade (taxes on imports and exports). It applies to all products, including industrial and agricultural products (Art. 1.3 TBT). The TBT Agreement aims to ensure that technical regulations, standards, and conformity assessment procedures do not create unnecessary barriers to global trade.[99] To achieve this, it encourages WTO members to base their national regulations and standards, where appropriate, on international standards (Art. 1.1 TBT). For this purpose, the WTO TBT Committee has developed six principles for the Development of International Standards, Guides and Recommendations, including transparency, effectiveness, and coherence.[100]

Art. 2.1 TBT also requires equal treatment of *like* products in respect of technical regulations, as defined by the TBT (Annex 1 para. 1) as a *document which lays down product characteristics or their related processes and production methods, including the applicable administrative provisions, with which compliance is mandatory. It may also include or deal exclusively with terminology, symbols, packaging, marking or labelling requirements as they apply to a product, process, or production method.* According to Art. 2.2 TBT, technical regulations should not create unnecessary obstacles to international trade, and they shall not be more trade-restrictive than necessary to fulfil a legitimate objective. A legitimate objective is the *protection of human health [...] or the environment.* If climate protection would also be a legitimate objective is subject to WTO case law and has yet to be fully determined.

As it is particularly concerned with the international harmonisation of the regulation and standardisation of production processes, the TBT Agreement plays an important role in promoting international trade in green hydrogen by advocating the adoption of international standards, reducing technical barriers to trade. For green hydrogen and its derivatives, this means establishing and using internationally recognised standards for the production, storage, transport, and use of green hydrogen and PtX products. This harmonisation can streamline regulations worldwide, making it easier to trade and deploy green hydrogen and PtX products on a global scale. The TBT Agreement addresses conformity assessment procedures, which are mechanisms used to verify that products, including green hydrogen technologies, meet regulatory requirements. Harmonisation of these procedures can reduce barriers to international trade and facilitate the global acceptance of green hydrogen technologies. Cases where nations impose technical regulations or standards that differ significantly from international norms can create technical barriers to trade.

The TBT Agreement promotes transparency in the development of such regulations and standards (Arts. 10, 11 TBT). This openness allows stakeholders to

[98] Agreement on Technical Barriers to Trade, available at: https://www.wto.org/english/docs_e/legal_e/tokyo_tbt_e.pdf (last access 08 December 2023).
[99] World Trade Organization, Technical barriers to trade, available at: https://www.wto.org/english/tratop_e/tbt_e/tbt_e.htm (last access 08 December 2023).
[100] Available at https://www.wto.org/english/tratop_e/tbt_e/principles_standards_tbt_e.htm (last access 26 January 2024).

participate in the process and provide input on measures related to green hydrogen. The TBT Agreement is in line with global efforts to promote clean and sustainable technologies. It does so by facilitating the acceptance and incorporation of such technologies into international trade, thereby promoting the transition to cleaner and more sustainable energy sources. This alignment supports the global shift towards cleaner and more sustainable energy sources, with green hydrogen playing a key role in this transition.

3.4.2 CBAM[101]

- **Hydrogen and ammonia fall within the scope of CBAM and thus shall be imported into the customs territory of the Union only by an authorised CBAM declarant**
- **For the import of hydrogen and ammonia, the importer or its indirect customs representative should apply for authorisation via the CBAM registry**
- **The importer has a reporting obligation including quantity and emissions of each type of goods as well as the carbon price in the country of origin**
- **CBAM opens up an opportunity for supplying countries to establish similar systems that are acknowledged by the European Commission so there is no money drain towards the EU but it can rather foster local economies**

The Carbon Border Adjustment Mechanism[102] (CBAM) is a policy instrument introduced by the European Union as part of its comprehensive climate policy and the European Green Deal. The CBAM started with a transitional phase from 1 October 2023 and comes to full effect from January 2026.[103] Until then, the obligations of the importers are limited to reporting obligations (Art. 32 CBAM Regulation). The primary aim of CBAM is to address carbon emissions associated with imported goods, particularly those that could lead to carbon leakage. Carbon leakage occurs when companies relocate production outside the EU to avoid carbon costs, while importing their products back into the EU market.[104]

CBAM aims to level the playing field by adding a carbon price on imported goods, so they are subject to similar carbon costs to those produced within the EU.[105] Under EU Emissions Trading System (EU ETS) [106], companies in the EU are already required to buy carbon allowances to cover their carbon emissions. CBAM extends this carbon pricing mechanism to certain imported goods. Importers of these goods will be responsible for purchasing carbon allowances equivalent to the carbon emissions associated with the production of the imported products. The calculation of the carbon

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[101] International PtX Hub, Öko Institute, adelphi & ecologic, 2023, available at https://ptx-hub.org/publication/explaining-the-new-eu-carbon-border-adjustment-mechanism-cbam-implications-for-ptx-imports-to-the-eu/
[102] Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism.
[103] European Commission, Press release, 2023, available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4685 (last access 15 December 2023).
[104] Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism, recital 9.
[105] Umweltbundesamt, Introduction of a Carbon Border Adjustment Mechanism (CBAM) in the EU, 2023, 1, available at https://www.umweltbundesamt.de/publikationen/introduction-of-a-carbon-border-adjustment (last access 15 December 2023).
[106] Cf. European Commission, EU Emissions Trading System (EU ETS), 2023, available at: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en (last access 15 December 2023).

content considers factors such as the production process and the carbon intensity of the industry in the exporting country. Initially, it will be applicable to specific goods and selected precursor imports characterised by carbon-intensive production and a high risk of carbon leakage. With this broader scope, when fully implemented, CBAM will encompass over 50 % of the emissions from activities that, if located in the EU, would fall under the scope of the EU ETS.[107] According to Art. 2 para. 1 in conjunction with Annex I CBAM Regulation, the mechanism directly applies to hydrogen and ammonia. The CBAM Regulation neither makes a direct exception for green hydrogen nor for green ammonia. Hence, also for the import of green hydrogen, the importer has at least reported obligations according to CBAM. However, a more detailed Delegated Act like the Delegated Acts under the RED II may be issued. This way, green hydrogen and its derivatives could be exempted from the obligations.

CBAM has the potential to incentivise the import of green hydrogen into the EU, as it will become the more attractive alternative to fossil-based hydrogen, for which the purchase of carbon allowances will be necessary when entering the EU market. However, it also imposes administrative expenses on the importer.

For countries wanting to export to the EU, Art. 2 para. 4 CBAM Regulation becomes relevant as the regulation shall not apply to goods originating in third countries and territories listed in point 1 of its Annex III. Third countries and territories are listed in point 1 of its Annex III when they fulfil all the following conditions (Art. 2 para. 6 CBAM Regulation):

- The EU ETS applies, or an agreement has been concluded between the country and the EU linking the EU ETS and the emission trading system of that country.
- The carbon price paid in the country in which the goods originate is effectively charged on the greenhouse gas emissions in those goods without any rebates beyond those also applied in accordance with the EU ETS.

The inclusion of a country in the list in Annex III CBAM Regulation would make the export of goods to the territory under the scope of the CBAM Regulation easier in terms of administrative expenses but would also allow the country to keep the income arising from the additional charges on greenhouse gas emission within the local economy.

3.4.3 Trade-related support policies

As the previous chapters depicted, the early hydrogen economy will rely on state aid and financial instruments to foster trade. Most trade projects are based on bilateral trade arrangements, often between companies, but in some cases also involving government institutions. Within these contracts, clear pricing mechanisms or fixed prices provide investment security to develop capital-intensive hydrogen projects such as production facilities or trade infrastructure.[108]

To achieve fixed prices and investment security at the current nascent stage of the green hydrogen economy, governmental funding instruments are essential. However, they need to avoid lock-in effects and ineffective operational structures and thus be well-targeted at the cost-gap without too much hampering trade and competition. The European Union and Germany have opted for an auction-based model to achieve this goal.

[107] Cf. European Commission, Taxation and Customs Union, Carbon Border Adjustment Mechanism, Key elements, available at: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en (last access 15 December 2023).
[108] IEA, Global Hydrogen Review, 2023, p. 108, available at: https://iea.blob.core.windows.net/assets/ecdfc3bb-d212-4a4c-9ff7-6ce5b1e19cef/GlobalHydrogenReview2023.pdf (last access 23 January 2024).

3.4.4 H2Global Funding Programme

Minimizing investment risks especially for first movers in the global trade of green hydrogen and PtX is essential for the market ramp-up

H2 Global aims at providing a stable market platform to connect supply and demand by means of an intermediate funding as well as long term supply contracts. It is therefore an important tool for suppliers of green hydrogen and PtX aiming to enter the European market

Within the first funding period, production standards are based on RED II and its DAs

H2Global is a funding scheme aimed at promoting the rapid and effective growth of green hydrogen technologies and markets. For an initial funding period, the Federal Ministry for Economic Affairs and Climate Action (BMWK) has allocated EUR 900 million for the procurement of green hydrogen derivatives from partner countries outside of the European Union and the European Free Trade Association (EFTA) for the European market over a ten-year period.[109] The H2Global Foundation implements and develops the scheme providing the funds. A subsidiary, the Hydrogen Intermediary Company GmbH (HINT.CO), uses the provided funds to bridge the gap between supply and demand prices. The goal of H2Global is to support the market ramp-up of PtX products using a market-based approach.[110] Ultimately, once a successful market has developed, HINT.CO should be redundant.[111]

The instrument is based on a competitive double auction model following the Contracts for difference (CfD) approach. Via a public auction, HINT.CO purchases PtX products to the best market price and concludes long-term purchase contracts on the purchase side minimising the price, market, regulatory, and contractual risks for the suppliers and producers.[112] HINT.CO then concludes short-term sales contracts to feasible market prices on the demand side via a second auction that enable a demand-oriented placement on the market.[113] Expected price differences between purchase price and demand prices due to the current high production and infrastructure costs are covered by the funding of the H2GlobalStiftung.

HINT.CO operates at the intersection of supply and demand as a reliable and solvent contracting partner for both sides.[114] This is intended to provide producers and suppliers with the necessary investment security to establish initial supply and value chains. H2Global enables investors to align their business and financing models with long-term supply contracts at cost-reflective prices with a solvent contractual partner. This is intended to expedite the implementation of concrete and scalable projects. On the demand side, H2Global allows for the integration of hydrogen derivatives into the economy at market prices.

H2Global only focuses on green hydrogen derivatives, and the first tender process concentrates on green ammonia, methanol and electricity based aviation fuel (SAF) as the technology readiness level (TRF) is most

[109] *T. Bollerhey* et al., H2Global – Idea, Instrument and Intentions, Policy Brief H2 Global Stiftung, 2023, 9 f., available at: https://files.h2-global.de/H2Global-Stiftung-Policy-Brief-01_2022-EN.pdf (last access 23 October 2023).
[110] For further information see Bollerhey et al., H2Global – Idea, Instrument and Intentions, Policy Brief H2 Global Stiftung, 2023.
[111] *T. Bollerhey* et al., H2Global – Idea, Instrument and Intentions, Policy Brief H2 Global Stiftung, 2023, 6.
[112] *T. Bollerhey* et al., H2Global – Idea, Instrument and Intentions, Policy Brief H2 Global Stiftung, 2023, 6.
[113] H2Global Stiftung, How does the H2Global instrument work?, available at: https://www.h2global-stiftung.com/project/h2g-mechanism (last access 26 October 2023).
[114] *T. Bollerhey* et al., H2Global – Idea, Instrument and Intentions, Policy Brief H2 Global Stiftung, 2023, 7.

advanced for these products.[115] The grant decision for the first funding period entails product specifications and additional sustainability requirements which will be the basis of the tender documents and contracts and are based on RED II and its DAs.[116] Hence, those regulatory requirements on production standards for green hydrogen become binding on a different level and will be essential for suppliers aiming to use H2Global as a facilitating tool to enter the European market. For the industry, the H2Global instrument thus significantly reduces regulatory risks, as product requirements are fixed for the contract duration.[117]

3.4.5 European Hydrogen Bank

The European Hydrogen Bank was implemented as a measure proposed by the European Commission within its "hydrogen accelerator"[118] concept. The aim is to push the ramp-up of renewable hydrogen, ammonia and other derivatives by creating investment security and business opportunities for renewable hydrogen production at European and global level. In March 2023 the European Commission published a Communication on the European Hydrogen Bank[119]. The goal is that through the European Hydrogen Bank private investments are unlocked and flow into the hydrogen value chain in the EU as well as in third countries. Thereafter Renewable energy supply and EU demand are connected through the European Hydrogen Bank.

the ramp-up of the hydrogen economy shall be achieved through a competitive bidding model (auctions)[120] under the Innovation Fund creating competition between producers.[121] This mechanism is anchored in the revised Directive on the EU ETS[122] The first competitive bidding mechanism under this Funding approach is being developed as a pilot auction that started on the 23th November. The auctioned good is renewable hydrogen as defined in the RED II.[123] Bidders are the project developers. A budget of 800 million Euro was made available for the first auction. For each verified and certified kg of renewable hydrogen the selected project developers will be awarded a fix premium. This fix premium is guaranteed for up to ten years of operation and additional to the market revenues. The European Climate, Infrastructure and Environment Executive Agency (CINEA) is the implementing authority for the scheme. Hence, the selected projects will have to enter into a grant agreement with this Agency.[124]

The proposals must relate to projects located in the European Economic Area (EEA) but there is no geographical limitation on the origin of members of the consortium.[125] To be eligible, beneficiaries will have to

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[115] *T. Bollerhey* et al., H2Global – Idea, Instrument and Intentions, Policy Brief H2 Global Stiftung, 2023, 10.
[116] *T. Bollerhey* et al., H2Global – Idea, Instrument and Intentions, Policy Brief H2 Global Stiftung, 2023, 10.
[117] *T. Bollerhey* et al., H2Global – Idea, Instrument and Intentions, Policy Brief H2 Global Stiftung, 2023, 8.
[118] European Commission, Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, REPowerEU Plan – COM/2022/ 230 final, 2022, available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0230 (last access 15 December 2023).
[119] European Commission, Communication from The Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the European Hydrogen Bank - COM/2023/156 final, 2023, available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023DC0156 (last access 15 December 2023).
[120] The reason why this is the chosen mechanism can be found in European Commission, Competitive bidding, available at: https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund/competitive-bidding_en#stakeholder-consultation-on-pilot-auction (last access 15 December 2023).
[121] European Commission, Hydrogen, available at: https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en (last access 15 December 2023).
[122] Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading system.
[123] European Commission, COM (2023) 156 final, Anex I.
[124] European Commission, Competitive bidding, 2023, available at https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund/competitive-bidding_en (last access 15 December 2023).
[125] European Commission , Innovation Fund Auction, Terms and Conditions, 2023, 6, available at: https://climate.ec.europa.eu/system/files/2023-08/innovationfund_pilotauction_termsandconditions_en.pdf (last access 15 December 2023).

provide proof that the total volume of RFNBO hydrogen produced complies with the requirements on the greenhouse gas emission thresholds established in the RED II and DA.[126]

3.5 Standardisation: Physical product characteristics

ISO Standards are internationally recognised and voluntary guidelines or specifications that establish best practices and requirements for a wide range of products, services, and systems.

By static or dynamic reference in national or international law, they become mandatory.

Importers thus should adhere to the standards, depending on the purpose of import.

ISO 14687:2019 establishes basic criteria and specifies the minimum quality characteristics for the physical properties of hydrogen as a product when supplied for use in both vehicles and stationary applications.

Since hydrogen and its derivatives can have different admixtures and aggregate states due to their physical properties, production methods and other factors, the determination of some of the physical characteristics of the product has been internationally harmonised through standards. The level of purity of the hydrogen is especially important for different end-uses. Standardisation on this matter is thus especially useful.

The report highlights – when appropriate – some of the most relevant ISO standards for the hydrogen economy.[127] Especially when it comes to safety and transport, ISO standards are crucial to ensure a harmonised level of safety.[128] Given the scale up of the hydrogen economy, it also can be expected that more ISO Standards will follow.

ISO Standards, developed by the International Organization for Standardization[129] (ISO), are internationally recognised and voluntary guidelines or specifications that establish best practices and requirements for a wide range of products, services, and systems. ISO standards are designed to ensure quality, safety, efficiency, interoperability and consistency across different industries and sectors. Albeit these standards are not mandatory, they may be incorporated in regulation and national laws by dynamic or static reference. Before realising a project, all potentially relevant (mandatory) ISO Standards should be examined and ideally (even when not mandatory) be adhered to.

ISO 14687:2019[130] for example establishes basic criteria and specifies the minimum quality characteristics for the physical properties of hydrogen as a product when supplied for use in both vehicles and stationary

[126] European Commission, Innovation Fund Auction, Terms and Conditions, 2023, 11.
[127] For a comprehensive overview of all relevant standards see IRENA/WTO, International trade and green hydrogen. Supporting the global transition to a low-carbon economy, 2023, Annex, p. 51.
[128] The German federal project *TransHyDE* currently analyses all relevant Standardisation for the transport of hydrogen and its derivatives. Publication of the results can be expected in 2025. For further information see: https://www.wasserstoff-leitprojekte.de/leitprojekte/transhyde (last access 15 December 2023).
[129] *M. Heires*, in: New Political Economy (2008), The International Organization for Standardization (ISO).
[130] ISO 14687:2019(en) Hydrogen Fuel quality – Product specification.

applications.[131] The standard applies to both gaseous and liquid forms of hydrogen as fuel. By establishing standardised quality requirements, ISO 14687:2019 enables manufacturers and distributors to produce and supply hydrogen to be used as fuel that consistently meets reliable specifications.

These specifications cover various physical properties and quality parameters of hydrogen as fuel to ensure that it meets the necessary criteria for safe and efficient use. It covers parameters such as hydrogen purity, impurity limits such as moisture content, oxygen content and various hydrocarbons as well as other relevant physical properties. The purity requirements are critical for fuel cell operation, as impurities can adversely affect fuel cell performance and durability. In addition to purity standards, ISO 14687:2019 also provides standardised measurement methods to consistently assess the quality of hydrogen as fuel. This helps to ensure consistent test procedures across different production and distribution facilities, contributing to the reliability and accuracy of fuel quality assessment. In addition, ISO 14687:2019 covers aspects of safe storage, transport, and handling of hydrogen as fuel. Proper storage and handling practices are essential not only to maintain fuel quality, but also to minimise contamination and ensure safety throughout the supply chain.

ISO/DIS 24078[132] is a draft standard intended to serve as a guidance document. Its primary purpose is to provide basic terms and definitions that clarify the role of hydrogen in energy systems.[133] In addition, it directs to a variety of standards, technical reports, glossaries, guides and similar resources that delve into specific areas and provide a more comprehensive vocabulary. In developing this document, a careful process has been undertaken to identify, evaluate and propose terms and definitions relating to the technical facets of hydrogen in energy systems. This effort has drawn on a variety of sources, including ISO/IEC standards, European standards from organisations such as CEN and CENELEC, national standards, and pre-existing definitions found in dictionaries relevant to specific industries. The ultimate purpose of this document is to present the basic principles underlying the concepts that are subject to standardisation within the domains associated with hydrogen in energy systems. The terms and definitions in ISO/DIS 24078 are systematically grouped into several key areas, including energy carriers, energy systems, energy infrastructure, smart grids, energy systems integration, electricity networks, electrical energy storage, hydrogen production methods (including electricity-based and alternative production methods), hydrogen production equipment, transmission, distribution and storage within dedicated hydrogen infrastructures and gas networks, and hydrogen blending with natural gas and separation processes.[134] In addition, topics such as the role of hydrogen in heat and power generation, ISO/DIS 24078[135] is a draft standard intended to serve as a guidance document. Its primary purpose is to provide basic terms and definitions that clarify the role of hydrogen in energy systems.[136] In addition, it directs to a variety of standards, technical reports, glossaries, guides and similar resources that delve into specific areas and provide a more comprehensive vocabulary. In developing this document, a careful process has been undertaken to identify, evaluate and propose terms and definitions relating to the technical facets of hydrogen in energy systems. This effort has drawn on a variety of sources, including ISO/IEC standards, European standards from organisations such as CEN and CENELEC, national standards, and pre-existing definitions found in dictionaries relevant to specific industries. The ultimate purpose of this document is to present the basic principles underlying the concepts that are subject to standardisation within the domains associated with hydrogen in energy systems. The terms and definitions in ISO/DIS 24078 are systematically grouped into several key areas, including energy carriers, energy systems, energy infrastructure, smart grids, energy systems integration, electricity networks, electrical energy storage, hydrogen production

[131] ISO 14687:2019(en), Scope, available at: https://www.iso.org/obp/ui/en/#iso:std:iso:14687:ed-1:v1:en (last access 15 December 2023).
[132] ISO/DIS 24078 Hydrogen in energy systems, Vocabulary.
[133] ISO/DIS 24078, Foreword, available at: https://www.iso.org/obp/ui/en/#iso:std:iso:24078:dis:ed-1:v2:en (last access 15 December 2023).
[134] ISO/DIS 24078, Introduction, available at: https://www.iso.org/obp/ui/en/#iso:std:iso:24078:dis:ed-1:v2:en (last access 15 December 2023).
[135] ISO/DIS 24078 Hydrogen in energy systems, Vocabulary.
[136] ISO/DIS 24078, Foreword, available at: https://www.iso.org/obp/ui/en/#iso:std:iso:24078:dis:ed-1:v2:en (last access 15 December 2023).

methods (including electricity-based and alternative production methods), hydrogen production equipment, transmission, distribution and storage within dedicated hydrogen infrastructures and gas networks, and hydrogen blending with natural gas and separation processes.[137] In addition, topics such as the role of hydrogen in heat and power generation, electricity to hydrogen conversion, hydrogen to X processes and energy storage are addressed. Cross-cutting issues such as hydrogen safety, metrology, fuel quality, certification and material compatibility are also included in this comprehensive framework.

3.6 Production standards and certification

Whereas the standards on physical product characteristics refer to the chemical quality, production standards refer to the method of production, predominantly whether its fossil-based or based on renewable energy.

Proving adherence to established production standards and definitions is crucial to market a product as well as to be able to take it into account when assessing the compliance with, for example, renewable energy quotas. Furthermore, certification has a value-adding effect.[138] Certification stands as a fundamental and essential element in the realisation and facilitation of global trade in green hydrogen and its derivatives. Thus, certification is the tool to demonstrate compliance with these standards or regulations. The development of standards and the consequent certification process can be either driven by legal obligations or by consumers' demand.[139] Definitions and standardisation thus can be anchored in public or private law; they can be mandatory or voluntary. Failure to comply with the criteria may have certain legal or economic consequences, which may consist of direct government sanctions or indirect market sanctions.

[137] ISO/DIS 24078, Introduction, available at: https://www.iso.org/obp/ui/en/#iso:std:iso:24078:dis:ed-1:v2:en (last access 15 December 2023).
[138] PtX Hub provides a comprehensive briefing on certification for Green Hydrogen and Power-to-X: https://ptx-hub.org/wp-content/uploads/2023/05/International-PtX-Hub_202305_Certification-for-green-hydrogen-and-PtX.pdf (19 October 2023).
[139] IPHE (2023), Hydrogen Certification 101, available at: https://www.iphe.net/_files/ugd/45185a_fe8631bbe2ad496c9da93711935f7520.pdf (last access 15 December 2023).

Voluntary or policy driven certification schemes

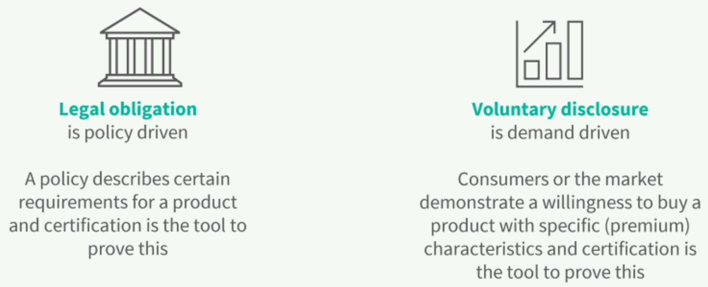

Figure 6: Own illustration

The following figure shows how standards and certification schemes are interconnected.

System for the implementation of certification schemes based on the provisions of legal acts

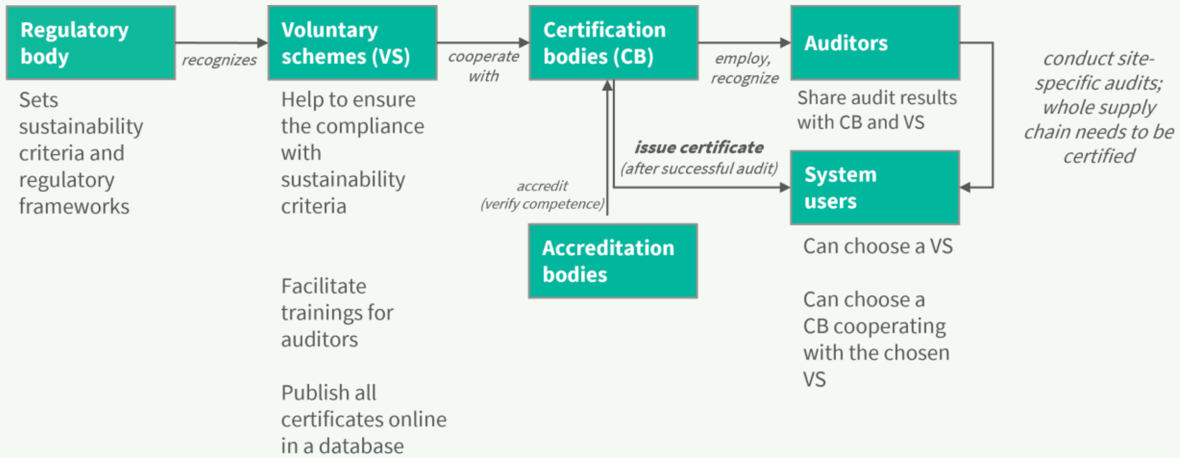

Figure 7: Own illustration

Regarding hydrogen, standardisation mostly reflects the greenhouse gas emissions and other environmental impacts of production and their qualification as *green*. For a global trade of hydrogen, the definition of green hydrogen is the most crucial and highly debated question on almost all levels and should be answered as uniformly as possible to avoid a patchwork rule system. Especially strongly debated aspects are how to define renewable energy and whether to include additional criteria such as sustainability aspects or as the EU did, criteria to ensure additional resources of renewables. Views on these matters differ vastly depending on regional interests.

Therefore, as of yet, most definitions and standards for green hydrogen have a geographically limited scope and are not applicable to cross-border situations without further adaptation or transposition into national law.[140] It is therefore important that producers either decide on one off-take market and certify their products according to the corresponding standards and schemes[141] or decide on the most narrow and elaborate standard that is likely to comply with all other standards and requirements.

However, standards and certification schemes with a cross-border scope do exist or are under development.[142] The aim of the following chapters is to examine the standards set forth in international and supranational public and private law, and to describe the certification systems that follow from them.[143]

3.6.1 Mandatory standardisation and corresponding certification systems: European Union

Currently, several mandatory green hydrogen standards have been established around the world.[144] The following chapters focus on the legal framework of the European Union as an example and only provide some examples of other similar legal frameworks.

3.6.1.1 Standardisation

The regulations until now establishing the strictest sustainability production standards were adopted by the European Union. These are the European Delegated Acts[145] supplementing the European Directive on the promotion of the use of energy from renewable sources (Renewable Energy Directive, RED II)[146], now RED III[147].

Renewable Energy Directive (RED III)

The more ambitious targets regarding RFNBOs, which include renewable hydrogen and the broader scope of the definition of RFNBO now applying to all sectors have the potential to increase the demand for hydrogen compliant with the requirements of RED III and the DAs in the EU. The European regulatory framework thus sets corner stones for an European offtake market.

The requirements of the previous RED II were tightened up by a revision (RED III). This Directive now has a broader scope and greater detail. Among other, the revision brings three major amendments with regard to the scaling of global trade in green hydrogen.

First, the share of energy from renewable sources in the total energy mix (gross energy consumption) must be at least 42,5 %, ideally 45 % by 2030 (Art. 3 para. 1 RED III) and thus considerably higher than stated in the current version (32 % by 2030, Art. 3 para. 1 RED II).

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[140] German Energy Agency, Global Harmonisation of Hydrogen Certification, 2022, 10, available at https://www.dena.de/newsroom/publikationsdetailansicht/pub/report-global-harmonisation-of-hydrogen-certification/ (last access 15 December 2023).
[141] German Energy Agency, Global Harmonisation of Hydrogen Certification, 2022, 11.
[142] German Energy Agency, Global Harmonisation of Hydrogen Certification, 2022, 9.
[143] For further reference and information see German Energy Agency (2022), Global Harmonisation of Hydrogen Certification.
[144] For a comprehensive overview see IEA, Global Hydrogen Review, 2023, p. 165.
[145] Commission Delegated Act (EU) 2023/1184 of 10 February 2023; Commission Delegated Act (EU) 2023/1185 of 10 February 2023.
[146] Directive (EU) 2018/2001 of the European Parliament and of the Council, of 11 December 2018 (RED II) on the promotion of the use of energy from renewable sources.
[147] Directive 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2028/2001, Regulation (EU) 2019/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources and repealing Council Directive (EU) 2015/652.

Second, RED III sets (new) **targets for the transport, building and industry sectors.** In the transport sector, Art. 25 para. 1 lit. a RED III opens up two options for the Member States. Either the amount of renewable fuels and electricity leads to a share of 29 % by 2030 within the final energy consumption - which is more than double than the current quota - or a greenhouse gas intensity reduction of at least 14.5 % by 2030. Additionally, there is a binding sub-target of 5.5 % by 2030 (1 % by 2025) of advanced biofuels and RFNBOs, whereby the share of the latter must be at least 1 % point by 2030 (Art. 25 para. 1 lit. b RED III). RED III also encourages EU Member States to comply with a quota for RFNBOs for the maritime sector (1.2 % of the total amount of energy supplied by 2030 for Member States with maritime ports, Art. 25 para. 1 UA 3). According to a new Art.22a para. 1 UA 5 RED III, Member States shall ensure that the contribution of RFNBO used shall be at least 42 % by 2030 and 60 % by 2023 of the hydrogen used in industry. Lastly, an equally new Art. 15a para. 1 RED III sets a target of at least 49 % share of energy from renewable sources in the building sector.

Third, a new definition in Art. 2 para. 2 no. 36 RED III no longer limits the scope of RFNBOs to the transport sector, but generally includes *liquid and gaseous fuels the energy content of which is derived from renewable sources other than biomass*. The recitals explicitly refer to renewable hydrogen as RFNBOs but the directive does not define renewable hydrogen itself. Thus, the European Commission will have to adapt DA 27 and DA 28 as they only refer to RFNBOs used in the transport sector. Furthermore, a new definition in Art. 2 para. 2 no. 22a RED III defines renewable fuels as – inter alia – RFNBOs and thus broadens the scope of application.

Furthermore, Art. 19 para. 2 RED III now extends the scope of guarantee of origin from renewable energy sources to RFNBOs, notably hydrogen. Thus, apart from a few exceptions related to funded projects, EU Member States shall ensure that a guarantee of origin is issued in response to a request of a producer of hydrogen.

European Delegated Acts according to RED II

Avoiding an increase in fossil fuel-generated electricity in other sectors due to an increasing demand of green hydrogen is the core of the two European Delegated Acts (DA) based on Art. 27 para. 3 and Art. 25 para. 2 in conjunction with Art. 28 para. 5 of RED II, notably the first DA (DA 27) which defines the criteria for a definition of green hydrogen. The second Delegated Act (DA 28) specifies the RED II requirement for a minimum 70 % emission reduction from the use of electricity-based fuels and establishes a methodology for calculating emission reductions for these fuels and for recycled carbon fuels.

It is crucial to note that both Delegated Acts apply not only to hydrogen production within EU Member States but also to imports. As a result, compliance with these standards is vital for countries interested in exporting hydrogen to the EU. However, from a pure legal perspective, the DAs only contain requirements for hydrogen in the transport sector: only if fuels meet the requirements of the Delegated Acts, can its use in the transport sector be counted towards the quota. Nevertheless, many argue that DA 27 essentially will shape the future European legal framework for defining green hydrogen and its derivatives, especially in light of the now adopted RED III broadening the scope of the definition of RFNBOs.

DA 27 defines RFNBO and outlines the necessary specifications for the electricity used for their production. According to Art. 2 para. 36 of the RED II RFNBO means liquid or gaseous fuels which are used in the **transport sector** other than biofuels or biogas, the energy content of which is derived from renewable sources **other than biomass**. Energy from renewable sources or renewable energy means energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas (Art. 2 para. 1 RED II).

The DA 27 outlines four distinct methods of procuring renewable energy: [148]

- Direct connection to an installation generating renewable electricity.

[148] For further details see the PtX Hub Briefing on EU Requirements for renewable hydrogen and its derivatives, 2023, available at https://ptx-hub.org/wp-content/uploads/2023/04/International-PtX-Hub_EU-Requirements-for-green-hydrogen-and-PtX.pdf (last access 19 October 2023)

- Purchase of grid electricity in a bidding zone with a share of more than 90% renewable energy in the electricity mix.
- Purchase of electricity from renewable energy sources via a power purchase agreement with renewable energy producers (PPA)
- Electricity consumption that avoids a shutdown of a renewable energy plant in the course of a redispatch measure.

3.6.1.2 Examples of certification schemes adhering to the production requirements set forth in RED II and DA

Regarding certification schemes according to the requirements set in the RED II and the DAs, the RED II establishes in Art. 30 para. 4 that the European Commission may decide that specific national or international voluntary schemes might be eligible for counting towards the renewable energy targets set in the RED II.

Additionally, the RED II determines in Art. 30 para. 6 that Member States may develop and establish national schemes that guarantee that RFNBO comply with the sustainability criteria and the greenhouse gas saving thresholds of the RED II. The European Commission then decides if the scheme complies with the requirements of the RED II. The recognition of the European Commission of a certification scheme ensures that Member States do not ask economic operators (producers) going through a certification process according to one of the recognised schemes for further evidence of compliance (Art. 30 para 9 RED II). Hence the recognised national certification schemes have to be accepted by all other Member States.

To enter the European market the use of such certification schemes is beneficial. Until now, 15 voluntary schemes have been recognised by the European Commission to guarantee compliance with the sustainability and greenhouse gas emissions thresholds of RED II (mostly in relation to biofuels) and another 9 are going through the process. Of those 9 voluntary schemes, 3 of them are meant for the certification of RFNBO[149]. The decision of the European Commission on those is still pending. The European Commission has not received any request for the recognition of national certification scheme for RFNBO as of yet. Even though private voluntary schemes and national schemes can apply for recognition by the European Commission, the recognition is not strictly necessary for certification. Certification schemes and national schemes established by EU Member States are also acceptable "if the competent authorities in those countries are confident about the quality of the certification services provided by these schemes"[150]. However, national certification schemes do not fall under the scope of this study due to their limited geographical applicability.

CertifHy

CertifHy has been co-founded by the European Commission with the mission to promote and facilitate hydrogen production, procurement, and utilisation, encompassing non-renewable, renewable, or low-carbon sources while adhering to stringent environmental criteria to support decarbonisation goals. CertifHy actively contributes to sustainable hydrogen production across various applications by developing certification schemes that cover consumer disclosure from production sources to distribution and compliance with the RED II from sources to end-use. It places a strong emphasis on maintaining high quality standards and a robust framework for transparent disclosure of hydrogen's origin and environmental attributes. Furthermore, CertifHy fosters collaboration through a stakeholder platform, uniting producers, consumers, traders, issuing bodies, regulators, and hydrogen-focused institutions. CertifHy has been conceived to work internationally so it can also be used as an international voluntary standard.[151]

Once approved by the European Commission, CertifHy has the potential to become one of the central certification schemes for the certification of hydrogen as RFNBO compliant with RED II and its DAs.

[149] European Commission, Voluntary Schemes, available at https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/voluntary-schemes_en (last access 15 December 2023).
[150] European Commission, Voluntary Schemes, available at https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/voluntary-schemes_en (last access 15 December 2023).
[151] International Renewable Energy Agency and Rocky Mountain Institute, Creating a global hydrogen market: Certification to enable trade, 2023, 25, https://www.irena.org/Publications/2023/Jan/Creating-a-global-hydrogen-market-Certification-to-enable-trade (last access 15 December 2023).

International Sustainability & Carbon Certification: ISCC PLUS

The International Sustainability and Carbon Certification (ISCC) is a globally recognised certification scheme known for assessing and certifying the sustainability and environmental performance of various industries and products. It covers a wide range of sectors, including agriculture, forestry, bioenergy, food and feed production, and the chemical industry.

The ISCC PLUS is an extension of the ISCC EU certification scheme (already recognised by the European Commission), tailored to assess and certify the sustainability and environmental performance of green hydrogen and RFNBO production processes. ISCC PLUS covers several essential aspects of green hydrogen and RFNBOs production such as providing a sustainability assessment, greenhouse gas emissions, land use and biodiversity, water use, social and ethical standards, transparency and certification and market confidence. As mentioned, ISCC PLUS evaluates the sustainability of the feedstock used in green hydrogen production, including the origin and management of renewable energy sources.

This certification serves as an important assurance mechanism for various stakeholders, including governments, investors and consumers, to demonstrate that the green hydrogen they use or invest in has been produced in an environmentally responsible and sustainable manner. ISCC's involvement helps to build trust and transparency within the green hydrogen supply chain, thereby furthering the global transition to clean and renewable energy sources.

REDcert

REDcert was founded by several German associations and organisations in the agricultural and biofuel sector. The REDcert-EU is a certification scheme, guaranteeing the compliance of biofuels, bioliquids and biomass fuels with the sustainability criteria set forth in the RED I but the current scheme certifies according to the criteria of the RED II[152], mainly protection of land with high biodiversity value, protection of land with high carbon stocks, protection of peatland and sustainable management[153]. The REDcert certification scheme also provides guarantee that biofuels, bioliquids and biomass fuels comply with the requirements established in the RED II regarding the greenhouse gas emissions saving along the supply chain.[154]

REDcert has also been recognised by competent authorities at national level also for the certification of biofuels, bioliquids and biomass (e.g. REDcert-DE).[155] The scope of REDcert-EU was initially the European market it can now be used in all countries with a REDcert specific country scheme.[156] Even though not specifically mentioned, RFNBO can be certified with the REDcert scheme regarding the production process and its compliance with the “chain of custody” requirements, as long as biofuels, bioliquids and biomass fuels are in play.[157]

Other national mandatory standards and corresponding certification schemes

As of yet, most countries have neither adopted differentiated standards on green hydrogen nor developed corresponding certification schemes. However, next to the EU, for example the United Kingdom has developed the Low Carbon Hydrogen Standard (by the Department of Business, Energy, and Industrial Strategy) and plans to implement the subsequent Low Carbon Certification Scheme form 2025.[158] Also, in 2008 , the Government of the United Kingdom established a so-called distribution quota for renewable fuels meaning that fuel suppliers have to guarantee that a percentage of the supplied fuels comes from renewable and sustainable sources. For the fuels to be recognised as renewable and sustainable fuels, they have to comply with the requirements set in

[152] REDcert-EU, Scope and basic scheme requirements, 2021, 19, available at https://www.redcert.org/images/SP_EU_Basic_Vers.06.pdf (last access 15 December 2023).
[153] REDcert-EU, Scope and basic scheme requirements, 13.
[154] REDcert-EU, Scope and basic scheme requirements, 15.
[155] REDcert-EU, Scope and basic scheme requirements, 5.
[156] REDcert-EU, Scope and basic scheme requirements, 7.
[157] REDcert-EU, Scope and basic scheme requirements, 9.
[158] Department for Energy Security & Net Zero (United Kingdom), Low Carbon Hydrogen Certification Scheme. Government Response, 2023, 4, available at https://assets.publishing.service.gov.uk/media/653b74e880884d000df71bf3/low-carbon-hydrogen-certification-scheme-consultation-response.pdf, (last access 15 December 2023).

the Renewable Fuel Transport Obligation Order[159] (by the Ministry of Transportation). To provide evidence of compliance with the carbon and sustainability criteria the suppliers can engage recognised voluntary sustainability schemes.[160]

Another example is the Clean Hydrogen Production Standard (CHPS) Guidance[161] developed and released by the United States (U.S.) Department of Energy's in June 2023. The standard establishes a threshold for greenhouse gas emissions of 4 kg CO_{2eq} /kgH2 (well-to-gate lifecycle approach) to qualify as low-carbon hydrogen. The aim is to encourage low-carbon hydrogen production from different feedstock. The CHPS is not per se a mandatory standard but can be used as reference when selecting projects for State subsidies. This shows that development is in progress and will speed up with the hydrogen economy upscaling. Developments thus should be closely monitored.

3.6.2 Examples of voluntary standards and corresponding certification schemes

The subsequent chapters examine some relevant standards with an international scope and their corresponding certification schemes. The requirements are set forth by the same organisations that aim to certify the hydrogen od PtX product or they lean on legally established requirements in some region. The most advanced voluntary schemes to the date are following.

3.6.2.1 The Green Hydrogen Organisations (GH2): Green Hydrogen Standard

A first attempt to develop a global standard for green hydrogen was made by the Green Hydrogen Organisation[162] (GH2). GH2 is a non-profit and its mission is to promote the production and utilisation of green hydrogen and related products like green ammonia, with the goal of facilitating the incorporation of green hydrogen into different sectors and driving extensive decarbonisation across industries.[163]

The GH2 Green Hydrogen Standard[164] defines green hydrogen as produced through water electrolysis using 100 % or nearly 100 % renewable energy sources, resulting in minimal greenhouse gas emissions.[165] The standard sets a global minimum threshold for greenhouse gas emissions at 1 kg CO_{2eq}/kg of hydrogen and aligns with international best practices while providing clear definitions of carbon accounting boundaries and green hydrogen criteria, consistent with the IPHE methodology[166] following a well-to-gate approach.[167]

Next to the definition of green hydrogen, the GH2 standard sets out seven additional requirements among which are the social and environmental impact (Req. 4 and 5), health and safety (Req. 6) as well as government, transparency, and accountability (Req. 7). The seven requirements must be met in order for

[159] Renewable Transport Fuel Obligations Order 2007 No. 3072, amended by The Renewable Transport Fuel Obligations (Amendment) Order 2021 No. 1420, available at https://www.legislation.gov.uk/ukdsi/2021/9780348228854 (last access 15 December 2023).
[160] Department of Transport, RTFO list of recognised voluntary schemes, 2021, available at https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-voluntary-schemes/rtfo-list-of-recognised-voluntary-schemes (last access 15 December 2023).
[161] United States Department of Energy, Clean Hydrogen Production Standard (CHPS) Guidance, 2023, available at https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/clean-hydrogen-production-standard-guidance.pdf (last access 15 December 2023).
[162] Green Hydrogen Organisation, Foundation Statute, available at: 22.04.26_Acte constitutif.pdf (gh2.org), (last access 15 December 2023).
[163] Green Hydrogen Organisation, Foundation Statute, Preamble, available at: 22.04.26_Acte constitutif.pdf (gh2.org) (last access 15 December 2023).
[164] Green Hydrogen Standard: The Global Standard for Green Hydrogen and Green Hydrogen Derivatives including Green Ammonia, 2023, available at: https://gh2.org/sites/default/files/2023-01/GH2_Standard_A5_JAN%202023_1.pdf (last access 15 December 2023).
[165] Green Hydrogen Standard: The Global Standard for Green Hydrogen and Green Hydrogen Derivatives including Green Ammonia, 2023, 1.
[166] IPHE, Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen, 2021, available at https://www.iphe.net/iphe-working-paper- methodology-doc-oct-2021 (last access 14 December 2023).
[167] Green Hydrogen Standard: The Global Standard for Green Hydrogen and Green Hydrogen Derivatives including Green Ammonia, 2023, 23.

projects to be accredited and certified by GH2.[168] Hence, the GH2 standards makes an attempt to include the aforementioned principles in a global standard for green hydrogen next to the mere definition.

The GH2 Standard therefore evaluates the overall social, environmental, and governance performance of green hydrogen production, focusing on renewable energy technologies that lead in green hydrogen production. The broader social and environmental impacts of additional renewable capacity are thereby considered. It includes aspects such as stakeholder engagement, human rights compliance, environmental impact assessments, water resource management, and safety standards.

Responsible and sustainable development and operation of green hydrogen facilities are integral. Therefore, the GH2 Green Hydrogen Standard acknowledges the potential of green hydrogen technology and fuel to contribute significantly to the achievement of various Sustainable Development Goals (SDGs), including SDGs 7 (affordable and clean energy), 8 (decent work and economic growth), and 13 (climate action), as well as SDGs 6 (clean water and sanitation), 9 (industry, innovation, and infrastructure), 12 (responsible consumption and production), 14 (life below water), and 15 (life on land). It mandates green hydrogen project operators to assess their projects' development impact and contribution to the SDGs, with a focus on maximising development potential and supporting energy sector growth and energy security.

The GH2 standard also mandates an assessment of electricity use and its impact on the energy market to promote energy efficiency and decarboniation. Green hydrogen projects are expected to contribute to the expansion of renewable energy capacity while avoiding an increase in fossil fuel-generated electricity elsewhere.

3.6.2.2 Zero Carbon Certification Scheme

The Zero Carbon Certification Scheme is an industry-led initiative with the main objective to encourage the global upscaling of a market for renewable hydrogen products and their derivatives.[169] The Scheme has already pre-certified three large-scale ammonia and hydrogen projects in Australia. It is part of the Australian National Hydrogen Strategy and thus has a more regional scope so far. However, it the scheme will in future be based on the CertifHy scheme in Europe (with regard to the green aspects of this scheme)[170] and this already shows an ongoing integration process.

The Zero Carbon Certification Scheme is a voluntary scheme and applies to renewable hydrogen and green ammonia with a Guarantee of Origin (GO), certifying the products have been made from renewable energy sources such as wind, solar, biomass and hydro energy with an additional carbon rating following the Australian Federal Government Renewable Energy Target.[171] Guarantee of Origin is a certificate instrument certifying the origin of a product and providing information on the source of their products.[172] The scheme provides flexibility by allowing the sourcing of electricity from renewable generation facilities directly, through third-party power purchase agreements, or via the grid, provided zero emissions can be demonstrated, often through methods like surrendering large-scale certificates, procuring green power, and purchasing additional carbon offsets in accordance with international carbon accounting standards. Carbon Capture Storage (CCS) technologies are not within the scope. Additionally, the Smart Energy Council is working together with the Green Hydrogen

[168] Green Hydrogen Standard: The Global Standard for Green Hydrogen and Green Hydrogen Derivatives including Green Ammonia, 2023, 10.
[169] Smart Energy Council, Zero Carbon Certification Scheme, 2023, available at https://smartenergy.org.au/zero-carbon-certification-scheme/ (last access 25 October 2023).
[170] Hydrogen Australia, Overview of Zero Carbon Certification Scheme, 2023, 1, available at https://www.hopgoodganim.com.au/content/Document/overview_of_the_zero_carbon_certification_scheme(23383308_1).pdf, (last access 15 December 2023).
[171] Smart Energy Council, Launch of the Zero Carbon Certification Scheme, 2023, https://smartenergy.org.au/articles/breaking-news-smart-energy-council-launches-zero-carbon-certification-scheme/ (last access 25 October 2023).
[172] Hydrogen Australia, Overview of Zero Carbon Certification Scheme, 2023, 1, available at https://www.hopgoodganim.com.au/content/Document/overview_of_the_zero_carbon_certification_scheme(23383308_1).pdf (last access 15 December 2023).

Organisation to develop a global standard for green hydrogen.[173]

3.6.2.3 TÜV SÜD Standard CMS 70

TÜV SÜD is a certification body in Germany that has developed a standard[174] in 2020 for the certification of green hydrogen while also providing the according certification. The standard defines requirements for the production of green hydrogen using renewable energies and can be applied worldwide. For the certification the production pathways and the greenhouse gas emission thresholds lean on the requirements of the RED II. However, being issued in 2020, the standard currently does not adhere to the applicable law of the DAs and RED III. This is where the differentiation between dynamic or static reference becomes relevant in the reversed order: Certification bodies or schemes referring to mandatory standards and to regulatory requirements in their current version avoid the constant need for updating and the risk of being outdated.

3.6.3 Taxonomy regulations for the categorisation of financial products as sustainable

The demand for green financial products has led the sector to develop guidelines establishing what constitutes a green or sustainable investment that contributes to the achievement of the envisioned environmental or climate goals via taxonomies: *"A sustainability and/or green taxonomy is a classification system identifying activities, assets and revenue segments that deliver on key sustainability goals based on the eligibility conditions set out by the taxonomy."*[175]

For example, ASEAN, China, Colombia, the EU, Indonesia, Japan, Malaysia, Mongolia, Russia, South Africa, South Corea, Sri Lanka and Vietnam have already released taxonomy regulations or guidance. Bangladesh has adopted a taxonomy guidance.[176] The taxonomy regulations are different in each of the countries. This means that the harmonisation of taxonomy regulations is also a goal to pursue. China and the EU are, for example, currently negotiating the Common Ground Taxonomy (CGT).[177] Taxonomies can enhance trade in products classified as sustainable as they enjoy benefits especially in the marketing sector. Since this report focuses on the European legal framework, it only sheds light on the European Taxonomy as a reference and example.

[173] International Renewable Energy Agency and Rocky Mountain Institute, Creating a global hydrogen market: Certification to enable trade, 2023, 30, available at https://www.irena.org/Publications/2023/Jan/Creating-a-global-hydrogen-market-Certification-to-enable-trade (last access 15 December 2023).
[174] TÜV SÜD, TÜV SÜD Standard CMS 70, Version 11/2021, available at: https://www.tuvsud.com/de-de/-/media/de/industry-service/pdf/broschueren-und-flyer/is/energie/tv-sd-standard-cms-70_grund--und-zusatzanforderungen-deutsch-englisch.pdf (last access 15 December 2023).
[175] Climate Bonds Initiative, Global green taxonomy development, alignment, and implementation, 2023, 3, available at: https://www.climatebonds.net/files/reports/cbi_taxonomy_ukpact_2022_01f.pdf (last access 15 December 2023).
[176] Future of Sustainable Data Alliance, Taxomania! International Overview Update 2022, available at: https://futureofsustainabledata.com/taxomania-international-overview-update-2022/ (last access 15 December 2023).
[177] Future of Sustainable Data Alliance, Taxomania! International Overview Update 2022.

3.6.3.1 EU Taxonomy

As the financial sector tries to shift towards a more sustainable investment policy, the EU Taxonomy Regulation provides terminology for certification and classification of financial investments as environmentally sustainable. It also implements some of the principles, such as transparency and sustainability.

In a Delegated Act, the European Commission sets the criteria for when the production of hydrogen may be classified as environmentally sustainable that refer to the GHG emissions reduction potential instead of production criteria.

For market and trade participants, external investments may be essential for upscaling production and trade. Complying with the EU Taxonomy may help the marketing of corresponding financial products.

The EU Taxonomy Regulation[178] establishes the criteria for determining whether an economic activity qualifies as environmentally sustainable for the purposes of establishing to what degree an investment is environmentally sustainable (Art. 1 para. 1 Taxonomy Regulation). The framework is defined by a set of criteria that encompass six environmental objectives: (1) mitigating climate change, (2) adapting to its impacts, (3) fostering sustainable use and protection of water and marine resources, (4) promoting the transition to a circular economy, (5) preventing and controlling pollution, and (6) preserving and restoring biodiversity and ecosystems.

Furthermore, the EU Taxonomy Regulation places a strong emphasis on transparency and disclosure. It mandates that financial market participants and associated activities disclose the extent to which their operations align with the taxonomy criteria, including climate-related goals. This disclosure mechanism ensures that investors and the general public have access to comprehensive information regarding the environmental impact of investments.

According to Art. 3 lit. c Taxonomy Regulation, an economic activity shall qualify as environmentally sustainable where that economic activity complies with technical screening criteria that have been established by the European Commission. In a Delegated Act[179] (DA Taxonomy), the European Commission sets out technical screening criteria for determining the conditions under which an economic activity qualifies as substantially to climate change mitigation (Art. 1 in conjunction with Annex I DA Taxonomy). Annex I No. 3.10 DA Taxonomy also includes criteria on the manufacture of hydrogen, which must comply with a life-cycle greenhouse gas emissions savings requirement of 73,4 % for hydrogen (70 % for hydrogen-based synthetic fuels). The EU Taxonomy thus does not refer to the source of energy used for the hydrogen production.

[178] Regulation (EU) of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment and amending Regulation (EU) 2019/2088.
[179] Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives.

3.7 Safety requirements

Safety requirements for hydrogen and its derivatives can vary by country and region, but there are some international guidelines and standards that are widely recognised and followed.[180] Implementing an efficient infrastructure also requires compliance with as thoroughly harmonised safety requirements as possible as different safety standards in different supplying and purchasing countries can complicate and hinder efficient trade processes.[181]

3.7.1 UN Globally Harmonised System of Classification and Labelling of Chemicals

The United Nations' Globally Harmonised System of Classification and Labelling of Chemicals[182] (GHS) is an internationally recognised system developed by the UN to standardise the classification and labelling of chemicals.[183] Its primary purpose is to enhance chemical safety, protect human health and safeguard the environment by providing a consistent and universally understood approach to communicating the hazards associated with chemicals.[184] The GHS provides a standardised framework for classifying the physical, health, and environmental hazards of chemicals.[185]In addition, the GHS establishes specific labelling requirements for chemical products. When chemicals are stored, transported or used in containers, GHS-compliant labels must be applied to communicate their hazards. GHS also requires the preparation of Safety Data Sheets (SDS) for chemicals.[186] SDSs provide comprehensive information on a chemical's properties, hazards, safe handling procedures, emergency response measures and more.

Hydrogen, ammonia and methanol are not explicitly regulated under the GHS framework, but are to be classified under various categories according to the GHS criteria.[187] SDSs for hydrogen, ammonia, and methanol must follow the standardised GHS format and content to ensure that essential safety information is readily available.

3.7.2 ISO Safety Standards

In the area of hydrogen safety and regulation, the Technical Committee of Hydrogen Technologies (ISO/TC 197) of the International Organization for Standardization[188] has published several standards relevant to the safe handling and use of hydrogen.[189] These standards play a crucial role in shaping hydrogen safety regulations and practices worldwide.

ISO/TR 15916 is a technical report on "Basic considerations for the safety of hydrogen systems".[190] It provides essential safety requirements for the handling of hydrogen in its gaseous and liquid forms and for the

[180] For an overview of safety related hydrogen energy law and regulations across several countries, cf. OECD, Risk-based Regulatory Design for the Safe Use of Hydrogen, 2023, 211 ff.; a database for safety standards and information on hydrogen is provided by Hydrogen Safety, available at: https://www.h2safety.info/ (last access 15 December 2023).
[181] International Energy Agency, The Future of Hydrogen, Seizing today's opportunities, 2019, 14 https://www.oecd.org/fr/publications/the-future-of-hydrogen-1e0514c4-en.htm (last access 15 December 2023).
[182] United Nations, Globally Harmonized System of Classification and Labelling of Chemicals (GHS Rev. 10, 2023), available at: https://unece.org/transport/dangerous-goods/ghs-rev10-2023 (last access 15 December 2023).
[183] United Nations Economic Commissions for Europe, About the GHS, 2023, available at: https://unece.org/about-ghs (last access 15 December 2023).
[184] United Nations, Globally Harmonized System of Classification and Labelling of Chemicals (GHS Rev. 10, 2023), para. 1.1.1.4, available at: https://unece.org/transport/dangerous-goods/ghs-rev10-2023 (last access 15 December 2023).
[185] United Nations, Globally Harmonized System of Classification and Labelling of Chemicals (GHS Rev. 10, 2023), Part 2., 3., and 4., available at: https://unece.org/transport/dangerous-goods/ghs-rev10-2023 (last access 15 December 2023).
[186] United Nations, Globally Harmonized System of Classification and Labelling of Chemicals (GHS Rev. 10, 2023), para. 1.5, available at: https://unece.org/transport/dangerous-goods/ghs-rev10-2023 (last access 15 December 2023).
[187] Cf. Safety Data Sheets for hydrogen, ammonia, and methanol, available at: https://www.airgas.com/msds/001026.pdf; https://www.airgas.com/msds/001003.pdf; https://www.airgas.com/msds/001065.pdf (last access 15 December 2023).
[188] *M. Heires*, in: New Political Economy (2008), The International Organization for Standardization (ISO).
[189] *Y. Yang, H. Xu, L. Lin* et al., in: E3S Web of Conferences (2020), Development of Standards for Hydrogen Safety, para. 3.1.
[190] International Organization for Standardization, ISO/TR 15916, scope, 2023, availabe at: https://www.iso.org/obp/ui/en/#iso:std:iso:tr:15916:ed-2:v1:en (last access 15 December 2023).

storage of hydrogen in its various forms, including hydrides.[191] It describes the basic safety concerns, hazards and risks associated with the use of hydrogen and explains its safety-related characteristics. Detailed safety criteria for specific hydrogen applications are provided in separate international standards.[192]

The technical report also serves as an informative reference to different standards with more detailed safety requirements, providing a single and consistent source of hydrogen safety information. Its purpose is also to minimise redundancy and potential inconsistencies between these separate standards.

3.7.3 International Association for Hydrogen Safety

The International Association for Hydrogen Safety (HySafe) is an organisation dedicated to promoting and advancing the safe use of hydrogen as an energy carrier and industrial feedstock.[193] HySafe focuses on hydrogen safety research, the development of safety guidelines and best practices, and the dissemination of knowledge related to the safe handling, storage, transport and use of hydrogen.[194] While it doesn't create regulations itself, it contributes to the development of safety regulations by creating and maintaining a forum for communication between stakeholders and providing support to governments, industry, and organisations in the field of hydrogen safety.[195]

3.8 Legal metrology

Metrology issues are crucial for ensuring efficient and fair global trade,[196] however, uniform units of measurement are also not always used with regard to the trading of hydrogen and its derivatives. The most common system for quantifying the energy contained in molecules is the watt-hour. However, specifications in joules or weight-related specifications in tonnes are also common. As the hydrogen industry expands globally, harmonisation of measurement standards could foster an efficient trade.[197]

The International Organization of Legal Metrology[198] (OIML) is an intergovernmental organisation that focuses on the establishment and maintenance of international standards and guidelines related to legal metrology. [199] Legal metrology involves measurements

[191] *M. Aziz,* in: Energies (2021), Liquid Hydrogen: A review on Liquefaction, Storage, Transportation, and Safety, para. 5.3.
[192] A search query in the Online Browsing Platform of the International Organization for Standardisation for the search term "Hydrogen safety" returns 23 related standards published by ISO/TC 197, 2023, available at: https://www.iso.org/obp/ui/en/#search (last access 15 December 2023).
[193] International Association for Hydrogen Safety, Statutes of the International Association for Hydrogen Safety, Final Version 11.12.2008, Article 3 – Objectives, available at https://hysafe.info/download/hysafe-statutes/ (last access 15 December 2023).
[194] International Association for Hydrogen Safety, About us, Objectives, 2023, available at: https://hysafe.info/about/ (last access 15 December 2023).
[195] International Association for Hydrogen Safety, Statutes of the International Association for Hydrogen Safety, Final Version 11.12.2008, Article 3 – Objectives.
[196] *M. Kellermann*, World Bank Group / PTB, Ensuring Quality to Gain Access to Global Markets, 2019, 77., available at https://thedocs.worldbank.org/en/doc/249621553265195570-0090022019/original/FullQIToolkitReport.pdf (last access 15 December 2015).
[197] *A. Murugan, M. de Huu, T. Bacquart* et al., in: International Journal of Hydrogen Energy, Measurement challenges for hydrogen vehicles, 19332, 2019, available at https://www.researchgate.net/publication/332545891_Measurement_challenges_for_hydrogen_vehicles/fulltext/5e65568692851c7ce0534260/Measurement-challenges-for-hydrogen-vehicles.pdf (last access 15 December 2015).
[198] International Organisation of Legal Metrology, Convention, 2023, available at: https://www.oiml.org/en/files/pdf_b/b001-e68.pdf (last access 15 December 2015).
[199] International Organization of Legal Metrology, What is the OIML?, 2023, available at: https://www.oiml.org/en/about/about-oiml (last access 15 December 2015).

and measuring instruments that are subject to legal and regulatory requirements.[200] The primary goal of OIML is to promote uniformity in metrology practices across the globe to facilitate fair trade and protect consumers.[201] OIML develops and publishes international standards, known as OIML Recommendations, which cover various aspects of metrology, including measurement devices, testing procedures, and conformity assessment.[202] These recommendations are intended to be adopted by member countries and used as a basis for national metrology regulations and standards. OIML collaborates with various international organisations and standards bodies. In the context of hydrogen, this collaboration can extend to organisations working on hydrogen-related standards, fostering alignment and consistency in measurement practices.

OIML R 81is an international recommendation issued by the OIML referring to the use of hydrogen.[203] This recommendation pertains to dynamic measuring systems used for the measurement of hydrogen. OIML R 81 addresses the metrological and technical requirements for dynamic measuring systems.[204] These systems are critical for accurately measuring the quantity of hydrogen supplied to vehicles or storage containers.

3.9 Transportation

The transportation of hydrogen and its derivatives via international shipping, road, rail or inland shipping is mostly covered by a widely harmonised legal framework.

To avoid discrepancies and barriers to export in certain circumstances all security and construction requirements should be adhered to.

Transportation of hydrogen and its derivatives represent the physical link between production and consumption. Hydrogen presents unique challenges due to its low volumetric energy density and high reactivity. The challenges also include safety, efficiency, cost, and infrastructure development.

In general, the cheapest transport option for long distances is pipeline-bound transport. Compressed gaseous hydrogen can be transported through dedicated pipelines. Particularly, the already existing gas pipeline infrastructure can be reused for a hydrogen net infrastructure. However, a big part of the global trade will be across the Atlantic and Pacific, distances that can only be covered by international shipping. For this large-scale international transport, hydrogen will be transported mostly via one of its derivatives, due to its high energy density and the high cryogenic temperatures (-253°C) of LH2. For short to medium-distance transport (the last mile) high

[200] International Organization of Legal Metrology (2020), OIML D 1:2020 (E), National metrology systems – Developing the institutional and legislative framework, para 2.6.
[201] International Organization of Legal Metrology (2020), OIML D 1:2020 (E), National metrology systems – Developing the institutional and legislative framework, para 6.5.
[202] International Organization of Legal Metrology (2020), OIML D 1:2020 (E), National metrology systems – Developing the institutional and legislative framework, Foreword, 4.
[203] International Organization of Legal Metrology (1998), OIML R 81; 1998 (E), International Recommendation, Dynamic measuring devices and systems for cryogenic liquids.
[204] International Organization of Legal Metrology (1998), OIML R 81; 1998 (E), International Recommendation, Dynamic measuring devices and systems for cryogenic liquids, paras 1 and 2.

pressure tanks and cylinders can enable a transport of hydrogen and its derivatives via rail and road.

A number of international regulations and standards already cover transport and storage of hydrogen and its derivatives for the various transportation modes, especially within the International Maritime Law.

3.9.1 International classification

Hydrogen in specific forms (compressed or liquefied) or in specific receptacles (in reversible metal hydride storage systems) and most PtX products (for instance ammonia and methanol) are classified as dangerous goods. The applicable regulatory framework for transport heavily depends on the nature of the transported goods. Goods with hazardous characteristics and which are frequently being transported are classified as dangerous goods and thus fall within the scope of the regulation on the transport of dangerous goods which is internationally regulated. The UN have issued Recommendations on the Transport of Dangerous Goods – Model Regulations[205] (Orange Book), which lays the groundwork for regulation on all levels for the transport of dangerous goods. It provides for general recommendations on safety and construction measures as well as definitions. The Annex to the Orange Book lists all dangerous goods that are subject to classification. The classification is the basis for the applicable technical rules for transport via ship in packaged form (IMDG Code[206]), or via road, rail, and inland shipping (ADR/RID/ADN). The following chapters outline the applicable regulatory framework for the respective transport modes starting with International Maritime Transport in bulk.

3.9.2 International maritime transport

Particularly for the maritime transport, diverging security requirements could lead to compatibility deficits for imports and exports when the respective infrastructures in the ports of import and export apply different technical or security requirements, hindering the implementation of a global hydrogen import and export infrastructure. Following international guidelines and regulation therefore is crucial.

The International Convention for the Safety of Life at Sea[207] (SOLAS Convention) is an international UN Convention regarding ship safety. It has been ratified by 167 States, for all of which the SOLAS Convention is thus legally binding. It generally applies to ships with more than 500 gross tonnages, entitled to fly the flag of States of Contracting Governments (Art. II SOLAS), which are engaged on international voyages (Reg. I/1, 3 SOLAS). Within its scope, the SOLAS-Convention overrides all other treaties, conventions and arrangements relating to safety of life at sea, or matters appertaining thereto (Art. VI SOLAS).

The SOLAS Convention is central when it comes to safety rules in international shipping. It specifies minimum standards for the construction, equipment, and operation of ships.[208] The SOLAS Convention refers for further specific regulation to various publication of the International Maritime Organization (IMO). As being incorporated in SOLAS, the Codes are also binding law for all states that have ratified SOLAS. The International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk[209] (IBC Code) covers chemical tankers for the carriage in bulk of liquids listed in Chapter 17 of the code (as is for instance methanol). The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk[210] (IGC Code) applies to gases like hydrogen and ammonia.

Most notably, any vessel within the scope of SOLAS and IMO Codes must be certified to be fit for transport of the respective substance ensuring compliance of the vessel with all applicable provisions of SOLAS and the IMO Codes. Certification is issued after detailed survey of

[205] United Nations, New York and Geneva, 2019.
[206] International Maritime Dangerous Goods Code adopted by the Maritime Safety Committee of the Organization by resolution MSC.122(75).
[207] International Convention for the Safety of Life at Sea, 1974, as amended.
[208] IMO, available at https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx (last access 15 December 2023).
[209] International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk adopted by the Maritime Safety Committee by resolution MSC.4(48) as amended.
[210] International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk adopted by the Maritime Safety Committee by resolution MSC.5(48).

the vessel according to the provisions of SOLAS and the Codes.

The IMO has issued Interim Guidelines for Carriage of Liquefied Hydrogen[211] and thus started a process of developing safety requirements for vessels carrying liquefied hydrogen. The IMO issues interim guidelines to circulate within the Member States and over the course of a couple of years uses feedback and expertise gained to implement the interim guidelines into the binding codes. International Maritime Law is thus comprehensive of the constant technical development and innovation in the shipping sector and IMO Regulations rather provide support and increase safety standards instead of resulting in legal barriers for shipment of dangerous goods. They have a dynamic approach and IMO committees constantly monitor technical innovations. IMO Regulations thus tend to be open to new technology and aim to provide support and increase safety standards.

The transport of liquid hydrogen, ammonia, and methanol in packaged form (via receptables) falls within the scope of the International Maritime Dangerous Goods Code[212] (IMDG Code) and is thus subject to detailed technical provisions as well as requirements for labelling, classification, and documentation. A Dangerous Goods Manifest is necessary for all three transport options in packaged form. The IMDG Code aims to increase the safety of transporting dangerous goods at sea while simultaneously enabling an unimpeded transport and preventing environmental pollution (Preamble No 1 IMDG Code). It covers the classification, packaging, labelling, and handling of hazardous materials and substances to prevent accidents, protect human health, and minimise environmental risks in maritime transportation. The IMDG Code also includes provisions for safety measures during transport, emergency response procedures, and training requirements for personnel involved in handling and transporting dangerous goods like hydrogen.

3.9.3 Transport via road, rail and inland shipping

The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) regulates the transportation of dangerous goods by road within Europe and between European countries that are parties to the agreement. The Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) is an agreement that focuses on the international rail transportation of dangerous goods. RID sets out rules and requirements for the classification, packaging, labelling, and transportation of dangerous goods by rail. The European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN) governs the international transportation of dangerous goods on inland waterways within Europe. They establish the regulatory framework for the classification, packaging, labelling, and transportation of dangerous goods by water.

When hydrogen is classified as a dangerous good, it must thus adhere to the regulations and guidelines outlined in these agreements. ADR/RID/ADN stipulate specific packaging and labelling requirements. These requirements ensure that containers, such as cylinders or tanks, are designed and marked in a way that minimises risks during transport. Proper labelling communicates the hazards associated with the cargo. ADR/RID/ADN include provisions for safety measures during the transport of dangerous goods. This encompasses aspects like vehicle or vessel equipment requirements, personnel training, and emergency response procedures to manage potential incidents involving dangerous substances like hydrogen. While each agreement primarily applies to a specific mode of transport, they align with international regulations governing the transportation of dangerous goods. This alignment ensures that the transport of hazardous materials, including hydrogen, conforms to globally recognised safety standards.

[211] Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk, adopted by the Maritime Safety Committee of the Organization by resolution MSC.420(97) on 25 November 2016.
[212] International Maritime Dangerous Goods Code adopted by the Maritime Safety Committee of the Organization by resolution MSC.122(75).

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