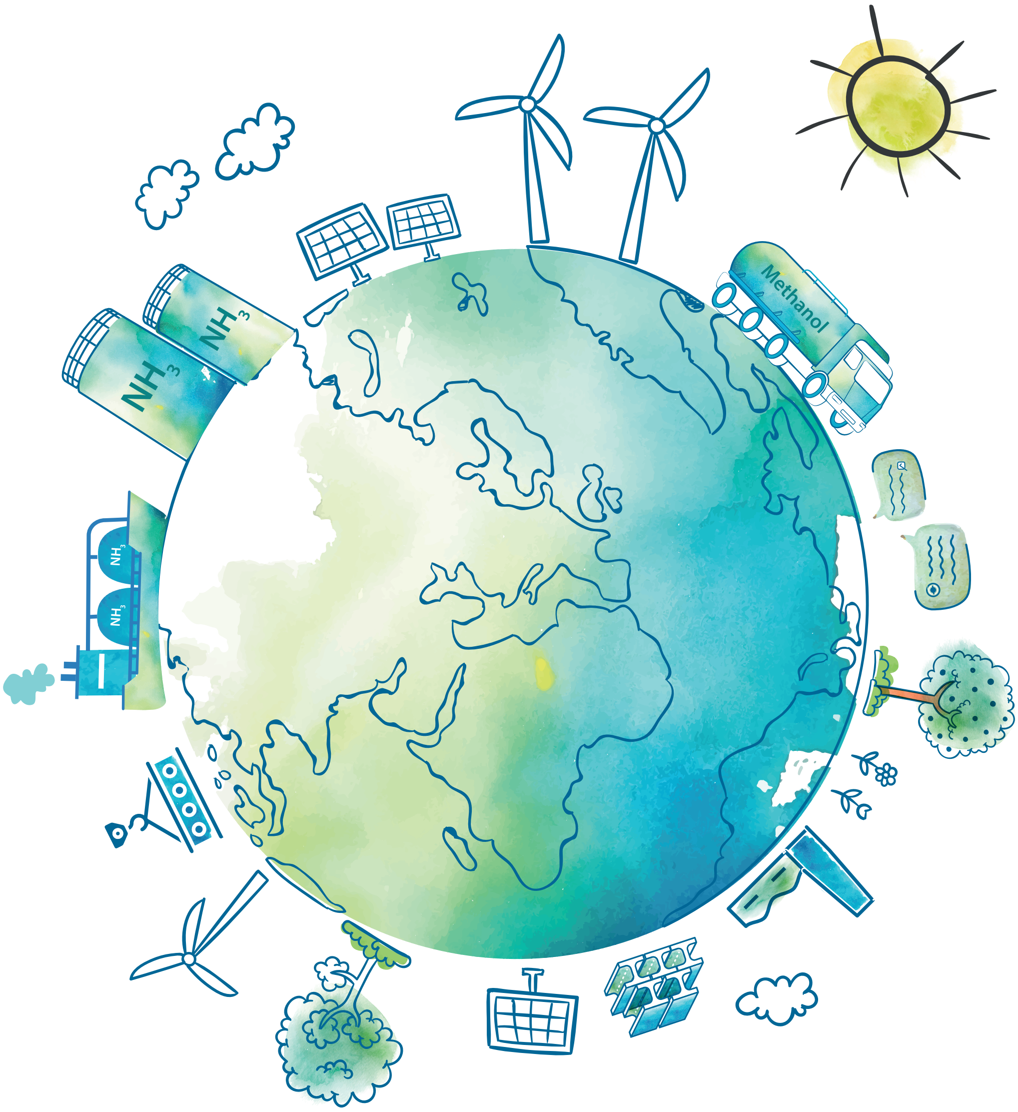
IRENA
International Renewable Energy Agency

Global trade in green hydrogen derivatives

Trends in regulation, standardisation and certification



Co-funded by the European Union

Supporting the BREAKTHROUGH AGENDA

ISBN: 978-92-9260-619-0

Citation: IRENA (2024), *Global trade in green hydrogen derivatives: Trends in regulation, standardisation and certification*, International Renewable Energy Agency, Abu Dhabi.

Acknowledgements

This report was authored by Karan Kochhar, Deepti Siddhanti, Jaidev Dhavle, Arno van den Bos and James Walker under the guidance of Francisco Boshell and Roland Roesch (Director, IRENA Innovation and Technology Centre). The report also benefited from contributions from Jeffrey Tchouambe and Steven Go (ex-IRENA).

IRENA also would like to express sincere appreciation to the following technical experts who reviewed the report and provided insightful feedback, specific comments and constructive suggestions: Florian Ausfelder (Dechema), Ruta Baltause (European Commission), Trevor Brown (Ammonia Energy Association), Harriet Culver (UK government), Katherine Davis (UK government), Greg Dolan (Methanol Association), Smeeta Fokeer (United Nations Industrial Development Organization), Will Hall (International Energy Agency), Marc Melaina (US government), Gareth Mottram (UK government), Marc Moutinho (Mission Possible Partnership), Dorothea Nold (HIF Global), Fabio Passaro (Climate Bonds Initiative), Andrew Purvis (World Steel Association), Maria Sandqvist (International Organization for Standardization), Sunita Satyapal (US government), Fiona Skinner (United Nations Industrial Development Organization), Jan Stelter (NOW), Andrei Tchouvelev (International Organization for Standardization) and Lachlan Wright (Rocky Mountain Institute). Additional insights were provided in discussions with Tudor Florea (French government), Alexandra Ullmann (Ludwig-Bölkow-Systemtechnik) and Oscar Pearce (Ammonia Energy Association).

The report benefited from reviews by several IRENA staff: Emanuele Bianco, Ann-Kathrin Lipponer, Luis Janeiro and Paul Komor.

Publications and editorial support were provided by Francis Field and Stephanie Clarke. The report was edited by Emily Youers with design by Strategic Agenda.

This project has received funding from the European Union's Horizon Europe programme under grant agreement 101075095 and a voluntary contribution from the Government of Norway. This report also serves as an input under the Breakthrough Agenda's Hydrogen Breakthrough priority action on certification and standards.

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

Disclaimer

Contents

Figures

Tables

Boxes

Abbreviations

AEA	Ammonia Energy Association	**IRS**	(United States) Internal Revenue Service
AISI	American Iron and Steel Institute	**ISCC**	International Sustainability and Carbon Certification
ANAB	American National Accreditation Board	**ISO**	International Standards Organization
CBAM	Carbon Border Adjustment Mechanism	**kg**	Kilogramme
CCEE	(Brazil) Electric Energy Trading Chamber	**$kgCO_2eq$**	Kilogramme of carbon dioxide equivalent
CH_3OH	Methanol	**kgH_2**	Kilogramme of hydrogen
CO_2	Carbon dioxide	**KZR INiG**	Certification system of the (Polish) Instytut Nafty i Gazu
COP	Conference of the Parties	**MJ**	Megajoule
DEKRA	Deutscher Kraftfahrzeug-Überwachungs-Verein	**Mt**	Megatonne
DNV	Det Norske Veritas	**NH_3**	Ammonia
DRI	Direct reduced iron	**RED**	Renewable Energy Directive
elNa	Elektronischer Nachhaltigkeitsnachweis	**RFNBO**	Renewable fuel of non-biological origin
ETS	Emissions trading scheme	**RMI**	Rocky Mountain Institute
EU	European Union	**RSB**	Roundtable on Sustainable Biomaterials
EUR	Euro (currency)	**RTFO**	(United Kingdom) Renewable Transport Fuel Obligation
G7	Group of Seven	**SAF**	Sustainable aviation fuels
GHG	Greenhouse gas	**SBTi**	Science Based Targets Initiative
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model	**TfS PCF**	Together for Sustainability Product Carbon Footprints
GSCC	Global Steel Climate Council	**UK**	United Kingdom
IAS	International Accreditation Service	**UKAS**	United Kingdom Accreditation Service
IEA	International Energy Agency	**US**	United States of America
IMPCA	International Methanol Producers and Consumers Association	**USD**	United States dollar
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy	**WEF**	World Economic Forum
IRENA	International Renewable Energy Agency	**WTO**	World Trade Organization

Executive summary

Trade in hydrogen is an emerging energy transition priority – and a potential economic opportunity – for countries around the world. Working jointly with the Rocky Mountain Institute, IRENA previously published a stocktake report that analysed the role of certification schemes and regulatory frameworks in driving the anticipated global markets for green hydrogen (IRENA, 2023a). These global markets are expected to emerge as a result of the competitive advantage in renewable resources as well as in land and water availability that may permit green hydrogen to be produced at lower cost in some regions than in others. Certification schemes can be used to provide the confidence required by consumers and regulators that any hydrogen being traded internationally satisfies sustainability requirements. Such confidence is essential in de-risking international markets.

Analysis is increasingly showing that derivative commodities produced using green hydrogen, such as low-emission ammonia, low-emission methanol, and iron and steel, will play a significant role in the global trade flows associated with hydrogen. Moving gaseous green hydrogen itself over long distances may be technically challenging due to its low volumetric energy density; its derivatives may therefore be easier to ship intercontinentally. As a result, certification schemes may be increasingly required to guarantee the attributes of the derivatives. Regulatory frameworks may evolve to set requirements for acceptable levels of greenhouse gas emission intensity associated with the production of "green" or low-emission ammonia or methanol. This report is intended to extend IRENA's prior stocktake of global green hydrogen certifications and regulations to derivative commodities and to provide insight into the interactions and links between the schemes and frameworks developed for green hydrogen and those developed for its derivatives.

This report summarises the status of regulatory framework development in many of the first-mover markets. Regulators in these markets are establishing rules and expectations for what can be considered low-emission hydrogen, ammonia, methanol or steel. Some of these frameworks are designed to set rules and market conditions primarily for domestic production, while others set rules for what types of commodities can be imported. Several countries and regions have developed regulations for hydrogen with similar emission accounting methodologies. However, the allowable emission thresholds differ among these regulations, meaning that producers may need to adhere to multiple and differing requirements when considering export. While the development of regulations is quickly progressing for hydrogen, IRENA analysis suggests that progress in developing regulations for its derivatives lags substantially. Given the significant role foreseen for these derivatives in international trade, this comparative lack of regulations could be a barrier to international market development, and policy makers should consider the treatment of derivatives when developing their policy frameworks.

The European Union (EU) has been among the jurisdictions quickest to develop detailed sustainability requirements for green hydrogen and its derivatives. EU rules require demonstration that the volumes of such commodities produced or imported reflect at least a 70% emission saving relative to fossil-derived benchmarks, and producers must demonstrate that the renewable power used for hydrogen production is new (not diverted from other uses) and can be correlated in time and location to the production plant, to confirm that the power was generated specifically for hydrogen production. These requirements apply to producers within the EU and to producers in other countries seeking to export to the EU. These rules also extend to the derivatives of green hydrogen, if they are being used as fuels.

Certification scheme owners are also incorporating the data collection, analysis and accounting methodologies that will need to be followed to provide the evidence required for certification. This report includes tabulated summaries of the schemes in development across the hydrogen, ammonia, methanol, and iron and steel sectors. In summarising and comparing these schemes, IRENA has found significant heterogeneities in the emission measurement boundaries and expected emission thresholds specified for certification. Fundamentally different approaches are also being taken in the sectors considered. While there are good reasons for these differences, not least that the shape of the markets for the various commodities is very different, this heterogeneity is likely to be challenging for producers, introducing administrative complexity – especially if they are seeking to supply multiple markets concurrently.

This report proposes recommendations for how regulatory frameworks and certification schemes for green hydrogen and its derivatives can be made interoperable. International collaboration and transparency are of course key in this. Another key recommendation is for policy makers from different jurisdictions to align the methodologies accepted for calculating the emission intensity of green hydrogen and its derivatives. The report also acknowledges the utility of pre-certification activities and other capacity-building initiatives to support producers in understanding the regulatory requirements against which they must report.

Summary of recommendations

1. **Regulators should consider the impact of the frameworks they are developing on the derivative commodity markets and should aim to ensure that the framework's requirements are robust to the characteristics and unique needs of those markets. This should include consideration of carbon-sourcing requirements for low-emission methanol.**

2. **Interoperability should be the goal of international efforts to align regulatory requirements or achieve mutual recognition of certification schemes. This interoperability should ideally extend to hydrogen and its derivatives.**

3. **To minimise the challenges for potential exporters in navigating regulatory and certification schemes, scheme owners and developers are encouraged to work directly with producers, for example through pre-certification activities, to increase producer understanding of what is required of them.**

4. **Transparency and specificity of requirements are essential in driving good outcomes via certification. Scheme owners and developers are encouraged to provide clear and detailed guidance on accepted methodologies (and underpinning requirements).**

5. **Where alignment of requirements is not possible, the focus on engagement via international fora should be on working towards interoperability of schemes.**

6. **There may be a role for agreements to develop common standards in the hydrogen, ammonia and methanol sectors, as was achieved in the iron and steel sector by the Steel Standards Principles.**

1. Introduction and scope

Demand for green hydrogen and its derivatives is set to grow exponentially, driven by climate policies and associated industry strategies. Policy makers and end-use sector operators want reasonable levels of assurance that the hydrogen and/or derivatives they support and use are low emission. The purpose of this report is to evaluate the status of emerging regulatory frameworks, international standards and certification schemes for hydrogen and hydrogen-derived commodities. This report builds on prior work undertaken jointly by IRENA and the Rocky Mountain Institute, which gave an overview of emerging frameworks for the development of global green hydrogen markets (IRENA, 2023a). This report updates that overview and widens the scope to also consider the hydrogen-derived commodity sectors. Regulation, standardisation and certification are key pillars in building confidence in the markets for green hydrogen and low-emission derivatives. This report also includes recommendations for how these frameworks and schemes can be aligned or made interoperable to support the growth of global markets.

Arriving at common definitions and a shared understanding of terminology is fundamental when aligning international frameworks in such markets. However, the terms “green hydrogen” and “low-emission derivative” themselves require definition due to the technical specificity with which they are intended. Box 1 sets out the terminology adopted in this report.

Box 1 Terminology

The plethora of colours used to describe hydrogen produced under various circumstances has been well discussed. While this “hydrogen rainbow” provides engineers and commentators with the technical shorthand to enable discussion, it can also cause confusion. Addressing this confusion is one of the main priorities for standardisation, and many regulatory frameworks for hydrogen have been based on national or regional definitions of “low-emission” hydrogen. This report concerns the full hydrogen value chain, as well as the role for hydrogen as an input and feedstock in derivative commodity value chains. “Green hydrogen” refers to hydrogen produced via renewably powered electrolysis, an electrochemical process in which water molecules are split to generate hydrogen. Green hydrogen is referred to throughout this report due to its focus on the renewable energy sectors. Some sections of the report refer more generally to “hydrogen”, meaning all types of hydrogen, when setting out relevant context or when encompassing the broader hydrogen sector. The term “low-emission hydrogen” is used when describing regulatory frameworks or standards that include hydrogen produced from fossil sources alongside the use of abatement technologies, such as carbon capture and storage. When discussing green hydrogen as a feedstock and input in the ammonia, methanol, and iron and steel value chains, the term “low emission” is used for the product commodities. Carbon plays a role in these value chains, especially in methanol production, so this terminology is preferred in place of discussing the “decarbonisation” of these commodities. Further terminology and technical concepts relevant to specific regulatory frameworks, standardisation measures and certification schemes are discussed and defined in the relevant sections throughout the report.

This introductory chapter of the report provides an overview of the markets and typical supply chains of the commodities discussed, providing context on the size of the current and potential global markets and the most relevant sustainability challenges faced by actors along these supply chains. **Chapter 2** focuses on the regulatory frameworks being developed, including in regions that are leading in terms of ambitious demand-side targets for the use of the commodities considered, and presents the associated minimum sustainability requirements regulators are setting. **Chapter 3** discusses fundamental concepts in the context of standardisation and certification, describing the mechanisms that can or must be used by market participants to demonstrate the sustainability characteristics of their products (*e.g.* emission accounting standards and certification schemes). **Chapter 4** describes the main existing emission accounting standards and certification schemes (both voluntary and obligatory) for each commodity, as well as for the chemicals manufactured from the feedstocks discussed. The chapter concludes with an overview of the main challenges and opportunities for industry players in adopting the schemes and for the certification ecosystem in adapting to emerging sustainability requirements. **Chapter 5** provides recommendations on how standards and certification schemes for hydrogen and its derivates can be harmonised and consolidated as markets continue to develop.

Hydrogen as a flexible energy vector and feedstock for emission reductions in end-use sectors

To be compliant with the 2015 Paris Agreement, IRENA's *World Energy Transitions Outlook 2023: 1.5°C Pathway* clearly identifies that two-thirds of the required carbon dioxide (CO_2) emission reductions in a net-zero scenario can be achieved through an increased supply of renewable energy, the electrification of various energy services currently reliant on fossil fuels and the improvement of energy efficiency. In pursuit of this ambition, IRENA World Energy Transitions Outlook analysis suggests that green hydrogen – hydrogen produced using electrolysis, powered from renewable sources – will be a key enabler for the decarbonisation of end uses and flexibility of the power system. IRENA's 1.5°C scenario projects that the global final energy consumption would decrease by 6% between 2020 and 2050 due to the avenues associated with the net-zero CO_2 reductions (IRENA, 2023b).

IRENA analysis shows that most end uses of energy can be electrified. However, in "hard-to-abate" sectors, other tools will be required to reduce emissions. Some processes and end uses require the input of a chemical fuel or feedstock. This is true of hydrogen as a chemical building block for ammonia and methanol production or of hydrogen as a chemical agent, like its role in primary steel production (as described later in this chapter). Hence, tangible solutions are needed that can close the decarbonisation gap in applications where direct use of renewable electricity is not technically viable or cost-effective. In this context, green hydrogen can facilitate the use of renewable energy in hard-to-abate sectors (WTO and IRENA, 2023). IRENA's 1.5°C scenario estimates that green hydrogen, along with hydrogen-derived commodities (ammonia, methanol, and iron and steel), have the potential to address a reasonable fraction (14%) of the global final energy demand in 2050 (IRENA, 2023b).

The current hydrogen production landscape is still fossil fuel based, with capacities reaching approximately 0.1 gigatonnes (Gt) of hydrogen per year. This fossil-derived hydrogen is largely used as feedstock material for industries such as oil refining, fertiliser production as well as in downstream chemical processes. Hydrogen production is currently responsible for the emission of 1 100-1 300 megatonnes (Mt) of CO_2 globally per year, meaning that hydrogen production is currently a major net contributor to climate change (IEA *et al.,* 2023).

To reduce the emissions from current hydrogen production, a massive expansion in renewable power integration is required, in tandem with an unprecedented scale-up and deployment of electrolyser capacity. IRENA analysis suggests that the global green hydrogen sector will need to grow from a negligible installed base today to more than

5700 gigawatts of electrolytic production capacity by 2050 (IRENA, 2023b). A major hurdle that has prevented the rapid deployment of green hydrogen has been higher production costs than its dominant fossil fuel counterparts. This narrative can be altered through two crucial vectors: the cost of renewable electricity and the cost of electrolysers. In relation to the first of these vectors, IRENA's latest analysis reveals that the cost of renewable power generation is falling very quickly. Most notably, from 2010 to 2022, the cost of solar photovoltaic and of onshore and offshore wind power has dropped by almost 90%, 69% and 59%, respectively. Today, solar and wind are the cheapest forms of new power generation in many regions of the world, and costs have the potential to continue to decline as these technologies mature (IRENA, 2023c). In relation to the second of the vectors, IRENA's analysis suggests that, if electrolyser technology deployment volumes were to reach those in the 1.5°C scenario, the spillover effects from "learning by doing" and economies of scale would trigger substantial cost reductions for electrolysers (IRENA, 2022a).

The technical potential offered by green hydrogen is sufficient to meet expected (and rising) global energy demand. However, there are economies and/or regions where the local production potential for green hydrogen might not be sufficient to meet national requirements for the gas and/or its derivatives. In this case, it might be more economical for these markets to import this energy carrier from locations where the production avenues are more cost-effective. IRENA estimates that of the hydrogen expected to be internationally traded by 2050 in the 1.5°C scenario, approximately 55% would be transported as hydrogen, via pipelines. The remaining 45% of traded volumes would be shipped, predominantly as ammonia, which would mostly be used without being reconverted to hydrogen, as an input for the fertiliser industry or as synthetic fuel for international shipping (IRENA, 2022a).

When looking at global trade markets, the hydrogen-as-a-commodity market is currently very small when compared to the market for its derivatives (*e.g.* ammonia, methanol). According to the World Trade Organization, the total value of global hydrogen imports reached approximately USD 300 million in 2022. The envisioned growth of green hydrogen is likely to boost hydrogen as a traded commodity in future years (WTO and IRENA, 2023) due to the comparative advantage of some producing regions. This growing trade ecosystem will require standardisation and certification to provide confidence in the sustainability attributes of the traded commodities, and this standardisation will need to be reflected in emerging regulatory frameworks.

Ammonia as an existing industrial commodity, important in fertiliser production

The Haber-Bosch process that converts hydrogen and nitrogen to ammonia is one of the most important industrial chemical reactions ever developed. This process made ammonia fertiliser widely available, helping to support a world population boom by enabling yields from agriculture to increase rapidly in a short time. Globally, ammonia production reached 182 Mt in 2022 (IFA, 2022), and demand in existing markets is expected to reach 333 Mt by 2050 in a 1.5°C scenario (IRENA, 2022b). Between 75% and 90% of this ammonia is used to make fertiliser, and about 50% of the world's food production relies on ammonia fertiliser. The rest of the ammonia makes pharmaceuticals, plastics, textiles, explosives and other chemicals. Almost every synthetic product we use containing nitrogen atoms comes to us through the Haber-Bosch process (Boerner, 2019). Ammonia production accounts for around 2% of global final energy consumption and 1.3% of CO_2 emissions from the global energy system (IEA, 2021). Ammonia's annual direct and indirect emissions have plateaued at approximately 0.42 Gt of CO_2, and current production processes like steam methane reforming and autothermal reforming rely heavily on natural gas and therefore have a high emission intensity (WEF, 2023).

The production of ammonia involves two main steps: first, the isolation of hydrogen and, second, the Haber-Bosch process. Less than 0.02 Mt of ammonia produced annually (0.01% of global production) is low emission (The Royal Society, 2020). Approximately 98% of ammonia value chain emissions stem from the hydrogen production stage, which is heavily reliant on fossil fuels, particularly natural gas, for both feedstock and energy needs (WEF, 2023).

From a global trade perspective, the landscape for ammonia is more inclusive and less regionalised than for hydrogen, reflecting ammonia's importance as a globally traded commodity. The top three importing countries for ammonia in 2021, in order, were India, the United States and Morocco; the top five suppliers of ammonia, in order, were Trinidad and Tobago, the Russian Federation, Indonesia, Saudi Arabia and Algeria (IRENA *et al.*, 2023). As ammonia is an important feedstock in fertiliser production, many of these markets are also active in the import and export of fertiliser.

Methanol as an essential chemical building block

The majority of the world's methanol is currently produced from natural gas; only in China is methanol produced from coal. Global consumption of methanol reached 98.3 Mt in 2019, with this figure expected to reach 120 Mt and 500 Mt by 2025 and 2050, respectively (IRENA, 2022c). China remains the world's largest producer and consumer of methanol, largely as a fuel, with consumption there reaching 55 Mt in 2018. Methanol is also a key product in the chemical industry, mainly used for producing other chemicals such as formaldehyde, acetic acid and plastics. Since the mid-2000s, the use of methanol as a fuel, either by itself, in a blend with gasoline, for the production of biodiesel, or in the form of methyl tert-butyl ether (MTBE) or dimethyl ether (DME), has also proliferated. Together, these fuel uses now represent about 31% of methanol consumption (IRENA, 2022c).

The production of methanol from fossil fuels is carbon intensive, with emissions reaching approximately 0.5 kilogrammes of CO_2 equivalent ($kgCO_2eq$) per kilogramme of methanol produced by natural gas and between 2.6 $kgCO_2eq$ and 3.8 $kgCO_2eq$ per kilogramme of methanol produced by coal. Hence, there is a growing drive to produce methanol from renewable sources, which currently only account for 0.2% of global methanol production. Low-emission methanol produced from biomass sources such as forestry, agricultural waste or biogas is referred to as "bio-methanol". When CO_2 and green hydrogen produced with renewable electricity are used to produce methanol, the resulting commodity is called "e-methanol" (Methanol Institute, 2022).

From a trade perspective, China is the largest methanol market, accounting for a quarter of global methanol imports. The next largest markets are, in order, India, the Netherlands, the United States, the Republic of Korea and Japan, accounting for 5-7% of global methanol imports in 2021. The main suppliers of methanol are also producers of natural gas, with – in order – Trinidad and Tobago, Saudi Arabia, Oman, the United Arab Emirates, the United States and the Russian Federation dominating methanol export markets (IRENA *et al.*, 2023).

Iron and steel as essential modern materials and priority sectors for emission reductions

Steel is a key enabler of human development. Around 2 000 Mt of steel is consumed annually and has widespread applications, mainly in buildings and infrastructure (52%), automotive applications (12%), equipment (16%) and metal products (10%) (IEA, 2020). China, the European Union (EU), India and the United States dominate global steel production, accounting for over 70% of the steel produced globally. These countries and regions are also significant steel consumers, accounting for over 80% of the steel consumed (IRENA, 2023d). Steel demand is expected to grow mostly from emerging economies, with both primary and secondary steel production playing a key role.

However, the iron and steel sector emits roughly 10% of global CO_2 emissions due to the sector's reliance on fossil fuels for energy sources and feedstocks (IEA, 2023a). Coal provides roughly three-quarters of the energy demand of the steel sector (IEA, 2020). However, this may change in the future as the falling costs of renewable energy are making low-emission steel production, particularly using green hydrogen, a more viable option.

The role of hydrogen in derivative production

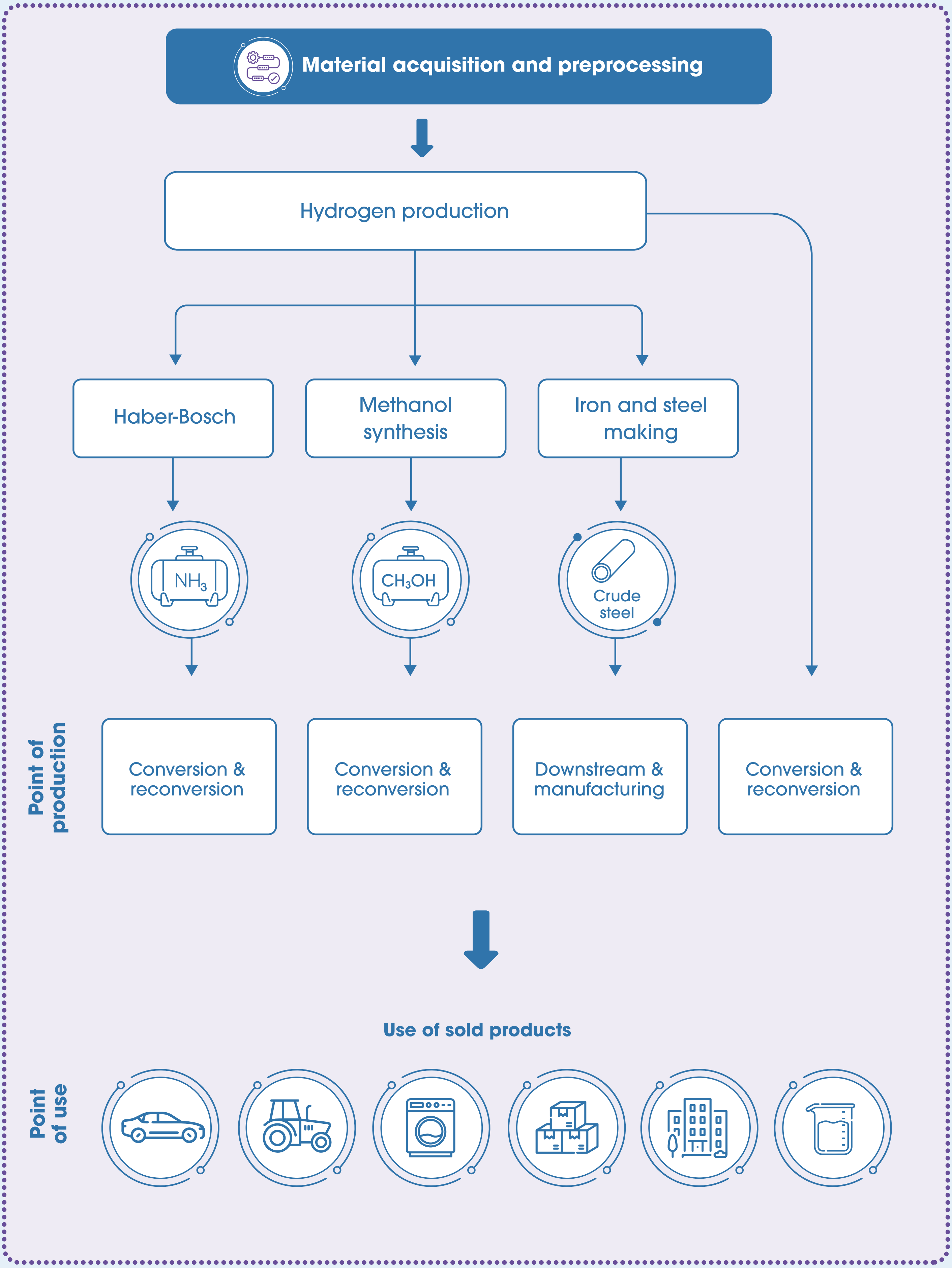
Hydrogen is primarily used as a feedstock for the production of the derivative commodities featured in this report (ammonia, methanol and iron and steel) (Figure 1).

Ammonia has several production routes from different fossil-based hydrogen sources, such as natural gas, coal and naphtha. The Haber-Bosch process, which is the most common method for ammonia synthesis, involves the reaction of hydrogen with nitrogen to produce ammonia. The hydrogen used in this process is usually derived from natural gas through steam methane reforming, but there is growing interest in green hydrogen production from renewable sources as a more environmentally friendly option. The efficient production and supply of hydrogen are vital for the synthesis of ammonia, which in turn is crucial for fertiliser production and, hence, global agriculture.

Methanol is usually produced from concentrated carbon sources, such as natural gas, coal, biomass, by-product streams, or CO_2 from sources including industrial flue gases or direct air capture. Hydrogen is again an indispensable component, especially in the processes such as steam methane reforming or gasification, where syngas is produced. Green hydrogen plays a crucial role in reducing the emissions associated with methanol production, particularly when integrated with Power-to-X technologies to use excess heat and renewable energy sources effectively. This integration not only makes the methanol production process more sustainable but also helps in meeting the increasing demand for methanol as a cleaner fuel alternative and chemical feedstock.

Iron and steel are primarily produced using the blast furnace–basic oxygen furnace production method. In this process, iron ore is reduced in a blast furnace to produce iron. The iron is then transferred to a basic oxygen furnace for steel making. Alternatively, it can be produced using the direct reduced iron (DRI)–electric arc furnace process, where iron ore is reduced in a furnace before being fed to an electric arc furnace for steel making. Traditionally, both these processes use natural gas and coal to reduce iron ore. However, hydrogen can also be directly used for the reduction process. With the decreasing cost of renewable energy, green hydrogen has become a viable option for DRI. A DRI plant can consume between 50 kg and 100 kg of hydrogen to produce 1 tonne of iron (Ampofo, 2023). By 2050, the demand for steel is projected to increase, which could result in a significantly increased demand for green hydrogen if a considerable amount of this steel is to be produced with green hydrogen via the DRI route.

Figure 1 Overview of the hydrogen and derivatives value chains



2. Regulation landscape for hydrogen and its derivatives

Low-emission hydrogen is rapidly emerging as a critical enabler of the energy transition. As of February 2024, around 50 countries have national hydrogen strategies, in total targeting the production of 27-35 Mt of low-emission hydrogen by 2030. On the demand side, the strategies aim for 4-6% of the global energy demand to be met by low-emission hydrogen in the industrial sector (IEA, 2023b).

In translating these strategies into implementable policy frameworks, policy makers are increasingly developing regulations that aim to set the rules for future low-emission hydrogen markets. Regulations are intended to ensure compliance on aspects such as safety, reliability, performance and quality. Regulations that set expectations regarding sustainability are also shaping hydrogen strategies in many emerging markets. These regulations are being used to establish definitions of low-emission hydrogen, linked with internationally recognised technical codes and standards, to guarantee that the hydrogen procured is actually low emission. Such regulations highlight the role regulators play in managing the energy transition by creating market arrangements that require or incentivise sustainable practices, following frameworks that stem from national targets.

Regulatory frameworks designed to ensure the sustainability of the hydrogen volumes procured or subsidised are essential pillars of many import-oriented hydrogen strategies, as outlined in this chapter. These regulatory frameworks are also a key tool for governments looking to make provisions for the future importation of green hydrogen and derived commodities. Despite the ample global potential to produce enough green hydrogen to meet demand, certain regions may face challenges in producing enough for their needs. Moreover, importing hydrogen from regions with lower production costs might be a more cost-effective option for certain economies in specific cases. International trade can serve as a bridge between supply and demand.

In regulations intended for the management of both domestic and import-export markets, regulators are balancing many competing priorities. Policy makers are developing regulatory frameworks appropriate to their local circumstances and priorities; however, some fundamental principles are emerging internationally. Although their terminologies are not necessarily aligned, these common principles require the demonstration of technological **additionality**, of **deliverability** and of the **time and space correlation** of renewable electricity inputs. Additionality is the principle of ensuring that the renewable electricity used for hydrogen production comes from new or repowered capacity so that renewable generation is not diverted away from the wider electricity system in the producing geography. Additionality can be achieved in three ways:

- constructing and using new clean energy production facilities
- increasing an existing renewable energy project’s capacity (referred to as an “uprate”)
- using clean electricity that would have otherwise been curtailed.

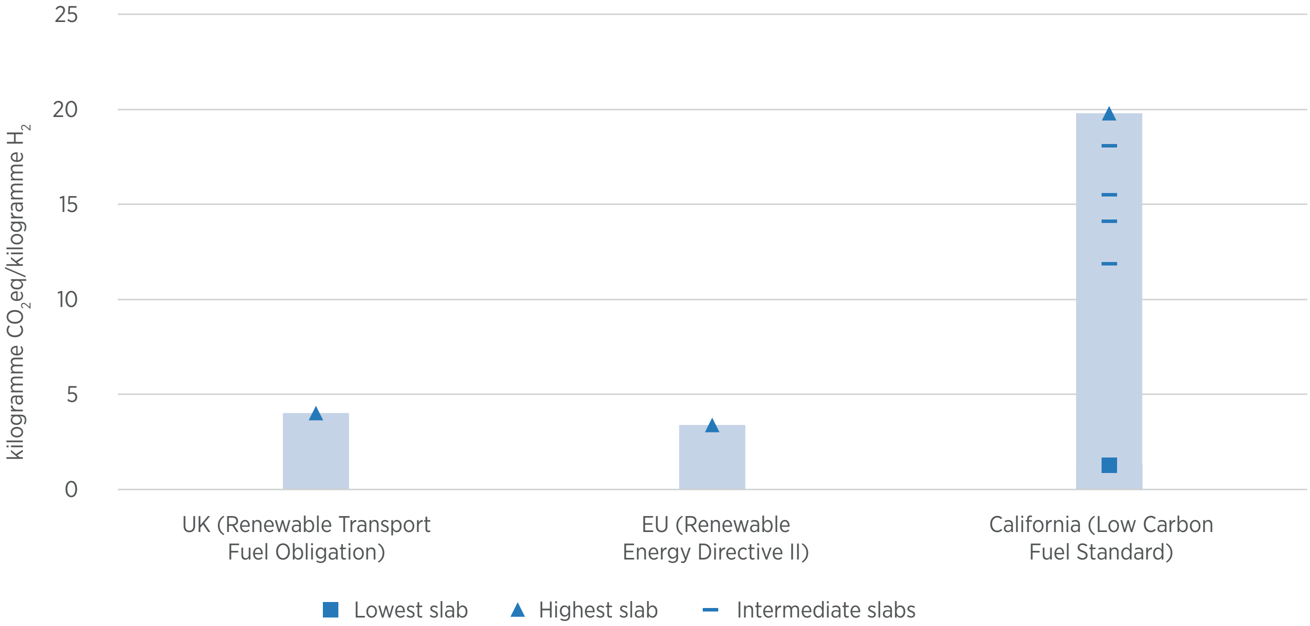
A claim of deliverability requires evidence that renewable power inputs are physically located in the geographical vicinity of the hydrogen production plant, for example in the same power network zone. A claim of time and space correlation requires producers to demonstrate that their electrolysers were operated alongside time-matched renewable power generation, to confirm the origin of the power used, this would also help demonstrate additionality.

The following sections look at the regulatory frameworks emerging in many potential importing markets for hydrogen, as well as the frameworks setting rules for the publicly funded support provided to producers in those geographies. This analysis has identified commonalities as well as differences in approach.

Regulations for domestic production

The landscape of regulations for hydrogen and its derivatives for domestic production and use is quite diverse across the globe. Many countries and regions are developing or have developed regulations for hydrogen. These regulations align (partially) with the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) methodology for emissions accounting (IEA, 2023b). This methodology was adopted and converted into the ISO/TS 19870 standard, presented at COP28. However, there are differences in the emission thresholds enforced (or to be enforced) in these regulations (Figure 2). For regulations with a well-to-gate scope,[1] the highest emission thresholds vary from 2 $kgCO_2eq$ to 4 $kgCO_2eq$/kilogramme of hydrogen (kgH_2). Similarly, the emission limits for regulations with a well-to-point of use scope[2] vary substantially and depend on the production pathway. For instance, the emission intensity levels foreseen in the California Low Carbon Fuel Standard vary between 1.3 $kgCO_2eq/kgH_2$ from dedicated solar or wind power to 19.8 $kgCO_2eq/kgH_2$ for electrolysis from the grid, though these are not mandatory thresholds and lower emission intensities are possible (IEA, 2023b).

Figure 2 Emission intensity levels under well-to-point of use (A) and well-to-gate[3,4] (B) hydrogen regulations in selected regions and countries



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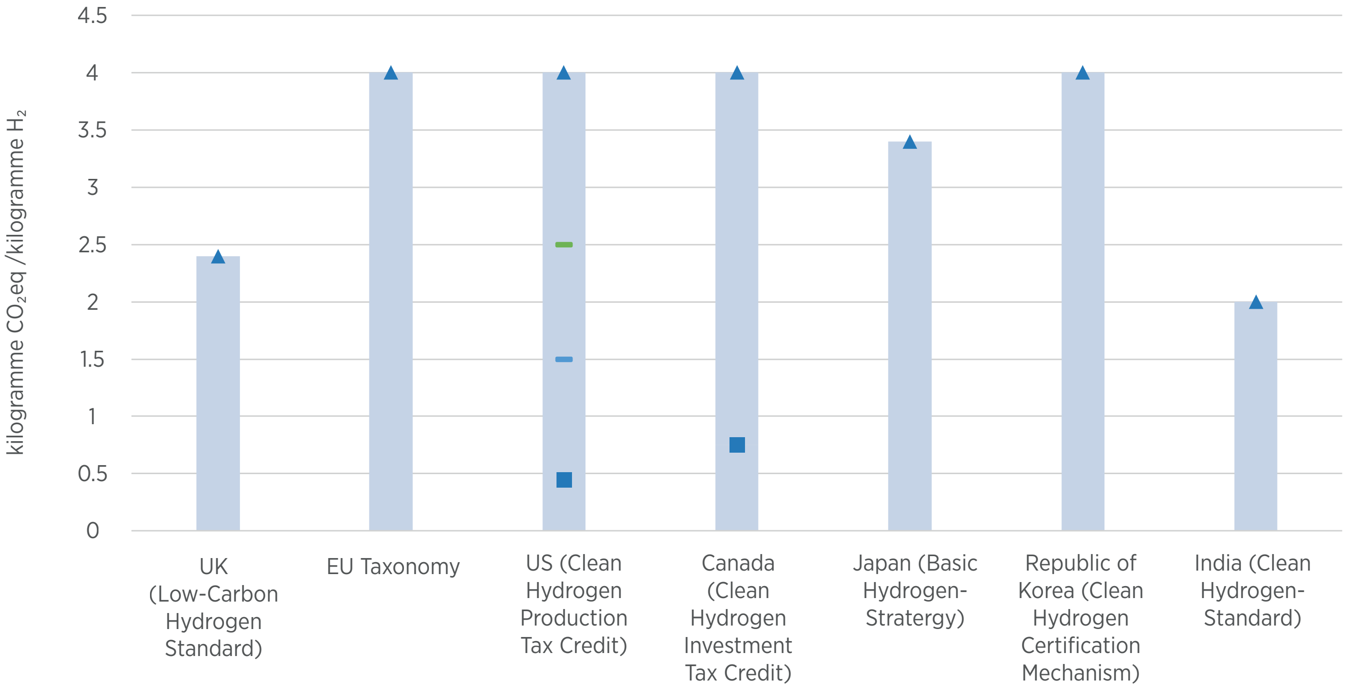
[1] Defined in the "System boundaries (scope) of the supply chain covered" section in Chapter 3.

[2] Also defined in the "System boundaries (scope) of the supply chain covered" section in Chapter 3.

[3] The UK Renewable Transport Fuel Obligation excludes hydrogen use from emission accounting in cases of electrolytic production.

[4] The UK Renewable Transport Fuel Obligation and the EU Renewable Energy Directive II/III are also applied to imports.

Figure 2 Emission intensity levels (B) hydrogen regulations in selected regions and countries



Source: (IEA, 2023b).

Notes: EU = European Union; UK = United Kingdom; US = United States

The EU regulatory framework for renewable hydrogen targets, thresholds, emission calculation methodology and certification was finalised in 2023, with the European Commission adopting two Commission's delegated regulations, more commonly referred to as "delegated acts". The delegated acts established detailed implementing rules on non-biological, renewable, low-emission fuels. These regulations specify criteria and a methodology for assessing emissions from the production through to the consumption of such fuels. The concept of renewable fuels of non-biological origin (RFNBOs) was first introduced in EU Renewable Energy Directive (RED) II to define renewable energy targets for EU member states in the transport sector. However, with the adoption of RED III,[5] the use of RFNBOs is also extended to the industry sector.

The delegated acts define the production of RFNBOs under several rules that aim to minimise the greenhouse gas (GHG) emissions caused by the additional electricity demand arising from the production of RFNBOs. To achieve this, the delegated acts refer to three principles: additionality, temporal correlation and geographical correlation. Table 1 provides an overview of the rules under these three principles.

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[5] *RED III sets a minimum target of 1% of RFNBOs in the share of energy consumed in the transport sector and a binding target to replace 42% of fuel use with RFNBOs by 2030, and 60% by 2035, for the industry sector.*

Table 1 Overview of the three principles of the delegated acts on RFNBOs

Principle	Conditions	Timeline	Exemptions[6]
Additionality	For grid electricity to be considered fully renewable, fuel producers must sign power purchase agreements with renewable energy providers. The renewable energy asset must operate no earlier than **36 months** before the electrolyser commissioning date and should not have received any public financial **support** in the form of operating or investment aid.	For RFNBO installations commissioned before the **end of 2027**: rule applies from **1 January 2038**. For RFNBO installations commissioned after **2028**: rule applies **immediately**.	If the electrolyser is in a region with a renewable electricity share of more than 90% or in regions where the electricity's emission intensity is below **18 gCO_2eq/MJ**. (No power purchase agreement is required for direct electricity connection [off grid]).
Temporal correlation	For grid electricity to be considered fully renewable, there should be a **temporal correlation** between the producer's bilateral renewable power purchase agreement and the fuel production unit.	Until **31 December 2029**, RFNBO production electricity must match renewable power generation **within the same month**. From **1 January 2030**, it must match renewable power generation **within the same hour**.	If electrolyser operates during hours when the day-ahead electricity price in the bidding zone is ≤ EUR 20/MWh or when it is ≤ 0.36 times the price of the Emissions Trading System allowance (EUR/tCO_2) during the relevant period.
Geographical correlation	The renewable energy asset and the electrolyser must **share the same bidding zone or be in an interconnected bidding zone**.[7]		Not required for offshore bidding zones.

Source: (European Commission, 2023a, 2023b).

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[6] *Electricity sourced from a renewable generator which would otherwise be curtailed is exempted from the three conditions.*

[7] *The day-ahead market prices in the renewable energy bidding zone should be equal to or higher than those in the zone where the RFNBO plant is located.*

Box 2 Carbon sourcing requirements in the European Union

The delegated acts also provide guidance on permitted sources of carbon, and on the methodology that should be used to determine the emissions associated with their sourcing, when producing low-emission methanol. Biogenic carbon and carbon captured from the air are allowed sources, while carbon sourced from industrial emission streams can only be used on a phased basis, until 2035 or 2040, depending on the industrial application, and only if the emissions have been paid for under an "effective carbon pricing system". These stipulations give clarity on how carbon should be sourced for low-emission methanol produced in the EU or intended for export to the EU market.

Source: (European Commission, 2024).

In the United States, the federal Inflation Reduction Act includes a proposed incentive structure for low-emission hydrogen. The US Department of the Treasury and the Internal Revenue Service (IRS) have released proposed regulations that offer initial guidance on the low-emission hydrogen tax credit. The proposed regulations are comparable to the EU delegated acts and address key aspects such as determining how life-cycle GHG emissions affect credit value and link electricity generation to hydrogen production. The Inflation Reduction Act requires that low-emission hydrogen be produced with emission intensities under 4 $kgCO_2eq/kgH_2$, and projects must additionally comply with criteria related to working conditions and job creation. Rules on how emissions should be accounted for are established by the Department of the Treasury and the IRS. The IRS proposed a draft version[8] of these rules (Federal Register, 2023), which, if enacted, would require hydrogen producers to meet the criteria on incrementality (also known as additionality), time matching and deliverability, as follows:

Incrementality: Projects making hydrogen via electrolysis must use a clean power source that came online no more than three years prior to project commissioning.

Time matching: Hydrogen producers must use only as much electricity as their correlated power source produced, and they must demonstrate that the renewable generator operated concurrently with the electrolyser. This time matching will be calculated on an annual basis until the end of 2027, and hourly from 2028.

Deliverability: Hydrogen producers and their correlated renewable energy source must fall within the same power region (as classified in the 2023 National Transmission Needs Study).

The prescribed methodology for calculating life-cycle GHG emissions is set by the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model. A specific GREET module has been developed for hydrogen value chains (Department of Energy, 2023a). For now, the Department of the Treasury leaves open the question of whether it will allow a crediting system whereby producers would buy conventional natural gas and claim a credit for using renewable natural gas from a renewable natural gas producer in another part of the country.

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[8] *Proposed rules under the Section 45V Credit for Production of Clean Hydrogen; Section 48(a)(15) Election To Treat Clean Hydrogen Production Facilities as Energy Property are available here.*

These proposed regulations are underpinned by guidance similar to the EU delegated acts' principles of additionality and temporal and geographical correlation, but they use slightly different terminology. The broader guidance on the three principles is also quite similar, except that the US regulations focus on annual temporal matching until the end of 2029 and will then switch to hourly matching. However, there is much left to be decided.

At the state level, California has a comprehensive legal framework for hydrogen production from renewable sources. The California Air Resources Board set a target to produce 33% of total hydrogen volumes from renewable sources. The Low Carbon Fuel Standard aims to reduce GHG emissions, and renewable hydrogen is defined as hydrogen from electrolysis based on renewable energy, catalytic cracking or steam methane reforming based on biomethane, or thermochemical conversion of biomass. Direct air capture projects are also eligible to receive Low Carbon Fuel Standard credits (California Air Resources Board, 2020).

Regimes in the EU and the United States are the most developed so far; however, this report also summarises a number of frameworks under development in other countries[9] (refer to Table 2; although the table does not summarise the scope of the frameworks, which may vary in different jurisdictions). While the development of regulations is quickly progressing for hydrogen, progress on regulations for its derivatives lags substantially. For ammonia, only the EU has regulatory instruments in place that include targets and regulations setting emission thresholds for production and establishing a methodology for their calculation and certification. Although Canada, India and Japan are currently developing regulations on ammonia, further development will likely be required in these countries and elsewhere. There is also a potential need globally for the development of regulations for methanol, specifically on the carbon source, and for iron and steel to define ambitious emission thresholds for production.

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[9] *The EU framework has a full life-cycle scope, whereas those in Canada, India, Japan, the United Kingdom and the United States have a well-to-gate approach.*

Table 2 Overview of definitions of green and low-emission hydrogen and its derivatives in selected markets

<table>
<tr><th></th><th>Hydrogen</th><th>Ammonia</th><th>Methanol</th><th>Iron and steel</th></tr>
<tr><td>Canada</td><td>Investment Tax Credit: Emission intensities <0.75, 0.75-2, 2-4 $kgCO_2eq/kgH_2$</td><td>Investment Tax Credit: Emission intensities <4 $kgCO_2eq/kgH_2$</td><td></td><td></td></tr>
<tr><td>European Union</td><td colspan="3">RED: <3.4 $kgCO_2eq/kgH_2$. Includes criteria on temporal correlation, geographical correlation and additionality; additional criteria apply to the sourcing of carbon for methanol.
EU Taxonomy (for hydrogen): <3 $kgCO_2eq/kgH_2$</td><td>EU Taxonomy:
<1 331 $kgCO_2eq$/kg of hot metal[10]</td></tr>
<tr><td>India</td><td colspan="3">Clean Hydrogen Standard: From renewable energy with emission intensity <2 $kgCO_2eq/kgH_2$</td><td></td></tr>
<tr><td>Japan</td><td colspan="2">Basic Hydrogen Strategy: Production with emission intensity <3.4 $kgCO_2eq/kgH_2$</td><td></td><td></td></tr>
<tr><td>Republic of Korea</td><td>Clean Hydrogen Certification Mechanism: Production with emission intensity <4 $kgCO_2eq/kgH_2$</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">United Kingdom</td><td>UK Low Carbon Hydrogen Standard: Production with emission intensity <2.4 $kgCO_2eq/kgH_2$</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Renewable Transport Fuel Obligation:[11] Production with emission intensity <4 $kgCO_2eq/kgH_2$</td><td></td><td></td></tr>
<tr><td>United States</td><td>Production Tax Credit: Emission intensities <0.45, 0.45-1.5, 1.5-2.5, 2.5-4 $kgCO_2eq/kgH_2$</td><td></td><td></td><td></td></tr>
<tr><td>California (United States)</td><td>Low Carbon Fuel Standard: Default values of emission limits ranging from 1.3 to 18.1 $kgCO_2eq/kgH_2$</td><td></td><td></td><td></td></tr>
</table>

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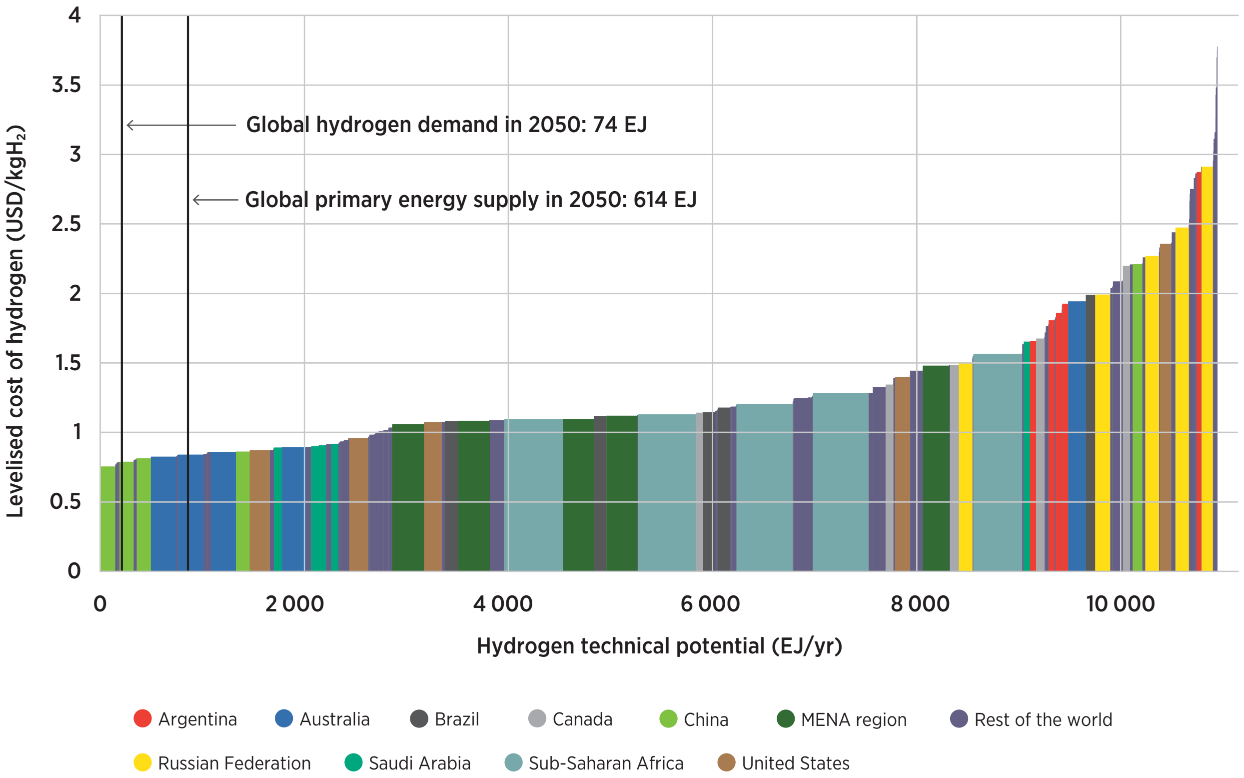
[10] *Not specifically tied to hydrogen-based production routes.*

[11] *The UK Renewable Transport Fuel Obligation is applicable to ammonia and methanol for maritime and aviation fuels.*

Regulations for import from other regions or countries

Under IRENA's 1.5°C scenario, the global demand for low-carbon hydrogen may reach as much as 74 exajoules (EJ) per year by 2050 (IRENA, 2023b). The technical potential for green hydrogen production is much higher than the projected global demand (IRENA, 2022d). However, the cost of producing hydrogen will vary significantly in different regions. Hydrogen can be produced at a lower cost in areas with the best renewable energy resources and low project development costs. Additionally, constraints in land and water availability will influence which geographies have a competitive advantage in the production of low-cost green hydrogen.

Figure 3 Global supply-cost curve of green hydrogen for the year 2050 under optimistic assumptions



Source: (IRENA, 2022d).

Note: MENA = Middle East and North Africa; EJ = exajoules. Optimistic assumptions for 2050 capital expenditures are as follows: solar photovoltaic, USD 225/kilowatt (kW) to USD 455/kW; onshore wind, USD 700/kW to USD 1 070/kW; offshore wind, USD 1 275/kW to USD 1 745/kW. Weighted average cost of capital per 2020 values without technology risks across regions. Electrolyser capital expenditure and efficiency set to USD134/kWe (kilowatt-electric) and 87.5% (higher heating value). Technical potential has been calculated based on land availability, with several exclusion zones (protected areas, forests, permanent wetlands, croplands, urban areas, slope of 5% [solar photovoltaic] and 20% [onshore wind], population density, and water stress).

Cost-competitive hydrogen production in certain regions can create trade opportunities with regions that have a high demand for hydrogen or hydrogen-derived commodities. So far 31 Mt of low-emission hydrogen projects have been announced; 16 Mt of this hydrogen is intended for export (IEA, 2023b). Under IRENA's 1.5°C scenario, a quarter of global hydrogen volumes will likely be traded (IRENA, 2023b). The EU, Japan and the Republic of Korea have announced intentions to import significant quantities of hydrogen and its derivatives due to the cost-competitiveness of hydrogen in nearby regions and the countries' anticipated high demand (IRENA, 2022d).

The growing expectations of hydrogen trade are driving the development of regulations intended to ensure that imported hydrogen conforms to domestic rules, especially with regard to sustainability criteria, such as emission intensity. These rules and regulations are particularly well developed in the EU. Other potential importing markets are actively developing policy and regulatory frameworks in this area, and further analysis will be required to understand the implications of the various approaches taken, once more is known.

The EU delegated acts apply to imports from outside the bloc as well as to domestic production. This ensures that hydrogen and its primary derivatives imported to the EU possess identical characteristics to those produced domestically. The delegated acts require EU member states to accept evidence from voluntary schemes recognised by the European Commission or competent national authorities. As of April 2024, the Commission had received applications for recognition from CertifHy, International Sustainability and Carbon Certification (ISCC), RedCert, KZR INiG System, and CCEE Hydrogen and Derivatives Certification System.

The delegated acts specify concepts that might differ from definitions in regions outside the EU. For instance, the domestic production rules on geographical correlation specify the concept of a bidding zone. Regarding curtailment rules, the delegated acts state that the electricity sourced from the grid can be considered renewable if the adjustments made to the production of renewable electricity are in line with EU regulations on redispatch. The European Commission has also published a Q&A document on implementation of the delegated acts, including on their application in third countries. Due to the EU-specific nature of the concepts used, feedback from certifiers and fuel producers on their implementation experiences can help refine and tailor these concepts for non-EU regions. Moreover, the impact of these regulations on the development of renewable energy in importing regions must be evaluated (PtX-Hub, 2023).

The Carbon Border Adjustment Mechanism (CBAM) is another crucial regulation that governs the import of hydrogen and other commodities into the EU. CBAM applies the same carbon price for goods produced in the EU to imports into the region. CBAM currently applies to the cement, iron, steel, aluminium, fertiliser, hydrogen and electricity sectors. The discussion on CBAM in this report focuses only on hydrogen and its derivatives, namely ammonia (as a precursor to fertilisers) and iron and steel.

From October 2023, CBAM entered the transitional phase, focusing on monitoring and reporting the emissions associated with producing goods. The quantity of imported goods and the production region's carbon price (if any) must also be reported. During the transitional phase, no financial obligations are associated with monitoring and reporting. Table 3 provides an overview of the requirements for importers during the transitional phase. After the transitional phase (in 2026), importers will have to purchase and forfeit CBAM certification.

Table 3 Obligations for importers of hydrogen and its derivates under CBAM in the transitional period

Commodity	Direct emissions	Indirect emissions	Precursor emissions
Hydrogen	Monitoring & reporting	Monitoring & reporting	-
Ammonia	Monitoring & reporting	Monitoring & reporting	Monitoring & reporting
Iron and steel	Monitoring & reporting	Monitoring & reporting	Monitoring & reporting

Source: (GIZ, 2023).

The implementation of the delegated acts alongside CBAM can be quite complex. The delegated acts only apply to renewable liquid and gaseous fuels, but CBAM applies to various sectors, including hydrogen and some of its derivatives. As a result, both hydrogen and ammonia are covered by the delegated acts and by CBAM. In contrast, iron and steel are covered only by CBAM, and methanol is covered only by the delegated acts (Figure 4).

The differences in the accounting methodologies and values for emissions generated used for CBAM and ETS may be challenging for non-EU producers of commodities for which both regimes will apply. CBAM specifies two approaches for estimating direct emissions: a calculation-based approach and a measurement-based approach (European Commission, 2023c). For indirect emissions, relevant emissions factors must be used to calculate the emissions, and data from the International Energy Agency or other publicly available sources can be used.

However, for a commodity to be eligible to count towards the EU's renewable energy targets and zero emission allocation under the ETS and CBAM, the delegated acts estimate the amount of emissions saved compared to the fossil fuel comparator.[12] The total emissions are the sum of the emissions from the inputs, processing, transport, distribution and use minus the emissions saved from carbon capture. For indirect emissions from non-renewable electricity, emissions factors can come from either the national or the bidding region's grid mix or from the emission intensity of the marginal unit generation of the bidding zone, if publicly available.

Furthermore, there are differences in the scope and the emission accounting methodology for renewable hydrogen and non-renewable hydrogen. For renewable hydrogen that is compliant with RED and the delegated acts, zero emissions are allocated under CBAM and the ETS.

CBAM, for now, only covers direct emissions for all other kinds of hydrogen (indirect and precursor emissions are to be reported separately), but emissions from the entire value chain must be included under the provisions of the delegated acts for the commodity to be considered "zero emissions" under CBAM and the ETS.

Link between regulations, standards and certifications

For the production of hydrogen and derivatives to count towards targets, and for producers and/or distributors to get access to State support, governments require producers to demonstrate the sustainability and quality of their products. These characteristics are typically demonstrated through voluntary certification schemes and sometimes by systems developed and operated by States themselves. These systems build on robust standards to ensure compliance, provide minimum levels of assurance and facilitate smooth trade, particularly between regions with different climate ambitions. Standards help align the scope and GHG accounting methodologies prescribed in regulations, while certifications (ideally verified by third parties) ensure compliance. In the EU's hydrogen and derivatives regulation landscape, for example, regulations are driving the development and adoption of standards and certifications (Figure 4).

The iron and steel industry has taken a different approach, prioritising the establishment and alignment of standards and certification schemes ahead of regulatory mandates. There has also been alignment between a few major accounting methodologies and definitions of low-emission steel. Such alignment could be replicated for commodities like hydrogen, where significant heterogeneities in emission thresholds currently exist (IEA *et al.*, 2023; IRENA, 2023a). Moreover, several stakeholders launched the Steel Standards Principles at COP28 in 2023, and these include principles to enable common measurement methodologies (WTO, 2023).

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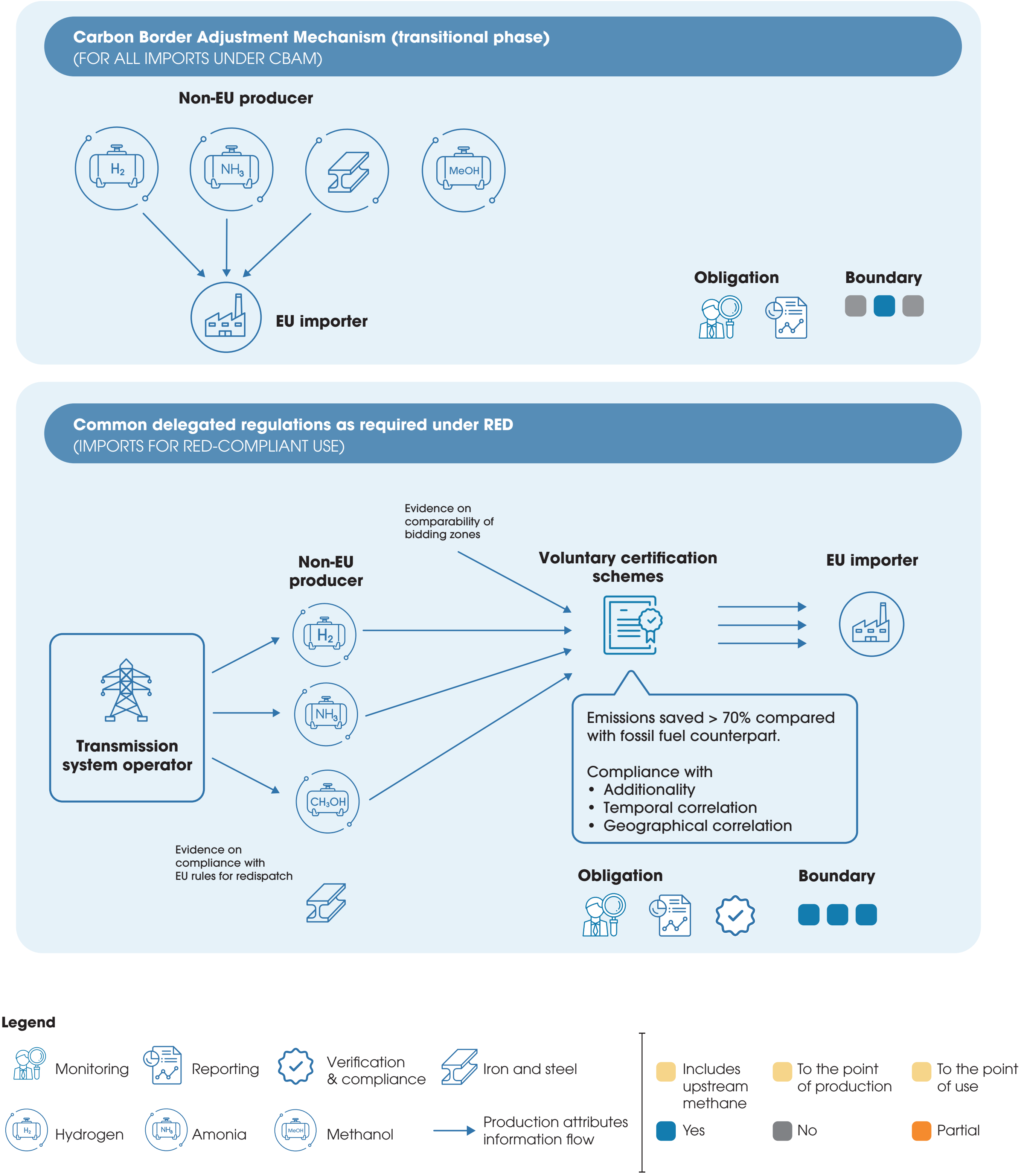
[12] The emission intensity of the fossil fuel counterpart is taken to be 94 g of CO_2 equivalent per megajoule.

Figure 4 Flow of information to comply with regulations for importing hydrogen and its derivates into the European Union



Source: (European Commission, 2023c, 2023b, 2023a).

Notes: The figure shows the flow of information needed to comply with the import regulations; it does not show the flow of actual commodities. For renewable hydrogen that is compliant with the EU RED and its delegated acts, zero emissions are allocated under CBAM and the ETS. The common delegated regulations only cover renewable gaseous and liquid fuels; they do not cover iron and steel products. The CBAM transitional phase only includes hydrogen, ammonia (through fertilisers), and iron and steel products; it does not include methanol. As of 17 January 2024, CertifHy, ISCC and RedCert had submitted applications for recognition by the European Commission. In addition to CO_2 and methane emissions, the delegated acts also consider nitrous oxide.

3. Accounting, standards and certifications: the fundamentals

As discussed in Chapter 2, governments and industry support markets for hydrogen and its derivatives through various mechanisms. To be eligible for economic incentives or recognition towards national, regional or industry targets, the regulators and, sometimes, industry players require the producers, traders and suppliers of these commodities to comply with certain sustainability criteria. To demonstrate compliance with these sustainability requirements, these actors can – and often must – make use of certification schemes. Standards and schemes developed to assure compliance with regulations are referred to as "mandatory" schemes or initiatives. Industry-led initiatives intended to enhance consumer confidence or drive change within a given sector are referred to as "voluntary" schemes or initiatives. This terminology is used hereafter in the report.

The following sections present the main actors and components involved in certifying, the main existing certification schemes for hydrogen-based commodities, the standards they apply, and their compatibility with the main regulated markets described in Chapter 2. This chapter is intended to provide an overview of the fundamental components of standardisation systems and methodologies and of certification schemes. Figure 5 provides some initial definitions.

Figure 5 Definitions and key elements for standards and certification schemes

	Standard	**Certifications**
Explanation	A formal method or formal guidance that stipulates how to determine the characteristics of a system and may also define the characteristics of a system	Certification is the formal process which an accredited third-party body ensures a system adheres to a specified standard
Key elements	Procedures for evaluating characteristics and conformity, terms and definitions, Criteria for compliance	Assessment Process, third-party involvement, conformity to standards, validity period

Source: (IRENA, 2015).

Certification schemes

A certification scheme is a system that provides end users and regulators with varying levels of assurance that established sustainability requirements of the target markets have been met for a given product. It does this by setting conformity assessment rules and procedures, by defining the verification, accounting and calculation methodologies to be used; stipulating the way that (sustainability) information must follow the supply chain (chain of custody); and establishing rules that certifiers need to follow to issue sustainability certifications. All these components and mechanisms aim to provide minimum levels of assurance that the sustainability requirements have been met, increasing trust in the supply chain.

The main actors involved in developing and operating a certification scheme are the regulator, the scheme owner, certification bodies, accreditation bodies and standard-setting organisations. The sustainability criteria set by regulators or voluntary industry initiatives, (*e.g.* minimum or maximum permitted values for GHG emissions) are vital elements of any such certification scheme. Compliance is to be assessed and certified by accredited certification schemes. Standard-setting organisations can develop standards for calculation methodologies and for what sources can be used for the data (primary or secondary sources).

Certification scheme owner

The scheme owner (sometimes called the "scheme holder") is typically a non-profit organisation, though it can also be a private company or public organisation. It is responsible for designing and operating the certification scheme, for setting and operating the governance structure, for establishing the sustainability criteria, and for defining how compliance with the certification criteria should be demonstrated.

The governance structure of the certification scheme owner determines who participates in the decision making and what decision-making process is used. The types of actor that can participate in establishing the sustainability criteria might include:

- private companies or industry organisations
- national and/or supranational government representatives
- civil society (*e.g.* social and environmental non-governmental organisations)
- standard-setting organisations.

Where the interests of all stakeholders are better represented, the more legitimacy the certification scheme is likely to have. In the case of national certification schemes or private schemes recognised by governments, governments can play a supervisory role.

The governance of the scheme should also establish rules for how decisions are made by participating actors, for example whether consensus is required or whether a majority vote is sufficient.

The scheme owner also establishes rules for how compliance with the sustainability criteria should be demonstrated, including what calculation methodologies should be used (see also the Accounting methodologies and standards section), which certification bodies are allowed to certify the actors in the supply chain, what processes should be followed in cases of non-conformity (*i.e.* what happens if an actor does not comply with the requirements), and what mechanisms exist – if any – to denounce non-compliance. The scheme owner can also require that certification bodies are validated by accreditation bodies (which is akin to certifying the certifier).

Certification bodies

Certification bodies are independent third parties whose certifiers (or auditors) perform audits to verify and validate that the different actors along the supply chain comply with the requirements of the certification scheme. They can do this by physically inspecting production and processing facilities, by evaluating documents submitted by these parties and/or, in some cases, by testing the skills and competence of the personnel.

Certification bodies are responsible for ensuring that their auditors are sufficiently knowledgeable about the supply chains they are auditing and the methodologies to be used. Some certification bodies also offer "pre-certification" or capacity-building services, through which they support producers in navigating the potentially complex regulatory landscape in which the certification operates.

To work on behalf of a certification scheme, a certification body and its auditors must be recognised by the scheme owner and approved to certify on behalf of the certification scheme (based on the specifications and requirements defined by the scheme).

Certification schemes often require certification bodies to themselves be accredited by accreditation bodies (see the next section), which is a mechanism for increasing trust in the certification bodies and the certificates they emit.

Examples of certification bodies include TÜV SÜD, DEKRA, Bureau Veritas, DNV, Control Union and GSCS.

Accreditation bodies

Accreditation bodies assess and monitor the technical competence, reliability, independence and integrity of certification bodies.

National accreditation bodies act as a regulatory authority on behalf of a State. As the worldwide system of accreditation is based on common international standards, accredited certification bodies are understood to operate within a common set of parameters. This standardisation can enhance trust in, and therefore recognition of, certification schemes.

Certification schemes often require certification bodies to be accredited according to certain standards, such as ISO 17065 (Conformity assessment – Requirements for bodies certifying products, processes and services).

Examples of accreditation bodies include ANAB (the ANSI National Accreditation Board in the United States), IAS (the International Accreditation Service) and UKAS (the United Kingdom Accreditation Service).

These national accreditation bodies are often members of the International Accreditation Forum, which provides guidance and best practices in conformity assessment, thereby improving coherence and co-ordination among accreditation bodies and reducing risk for businesses and their customers.

Issuing bodies and registries

The issuance of certificates that certify conformity with a particular certification scheme can be done by the certification body (in which case, the certification body is also the issuing body), or it can be done by a separate entity. Registries are used for traceability and to prevent double accounting. Some countries have national registries that trace certain commodities and their proof of sustainability. For example, in Germany, the national registry for biofuels is Nabisy and in Austria it is elNa. (In Germany, the responsible authority for this registry is the German Federal Agency for Agriculture and Food). However, not every country has such a centralised registry in place, and non-government issuing bodies also exist, such as the SAFc Registry for sustainable aviation fuels.

The EU's Union Database for Biofuels is another example of a registry, in this case established under RED (art. 31a) to ensure, at the EU level, the traceability of renewable fuels along the entire supply chain and to prevent double or multiple accounting. This database centrally traces renewable fuels that fulfil the EU sustainability and GHG reduction criteria and are therefore eligible to be counted towards EU renewable energy targets. In 2023, RED III extended the scope of the database to gaseous renewable fuels, including renewable hydrogen, and to certificates for fuels that are not allowed to be counted towards the EU renewable energy targets (guarantees of origin).[13] The database also stores data on the transactions made, on the sustainability and GHG emission characteristics of fuels, on certificates, and on public support received for each consignment.

The Union Database covers economic operators that inject hydrogen or biomethane into gas grids. Economic operators are certified by voluntary schemes (via certification bodies) from the point of production of sustainable gaseous fuels to their point of use. The voluntary scheme and certification body must keep the certification data up to date. Economic operators and gas transmission and distribution system operators must notify the database of their transactions directly or through voluntary schemes or national registries. EU member states' authorities can access the database for the purposes of monitoring and verifying data.

Accounting methodologies and standards

Assessing the environmental impact of a commodity over its life cycle can be done in different ways. Such assessments are particularly relevant for GHG footprints but can also be applied to water footprints and even to social impacts. To evaluate compliance with sustainability criteria, it is important to agree on the methodology to be used to measure this compliance. The main methodological elements relevant for sustainability criteria are which emissions are to be included and which tracking model is to be used to track the sustainability characteristics through the supply chain (often referred to as the "chain of custody").

System boundaries (scope) of the supply chain

Bringing a commodity to its end users involves many steps, including energy-consuming processes and transportation. Emission accounting methodologies need to specify which of these emissions should be accounted for and whether specific or generic data should be used (provided by primary and secondary sources). From a life-cycle perspective, it makes sense to include specific data for as many emission sources as possible, as deep into the supply chain as possible. However, from a practical perspective, to limit verification and administration costs, it can be more convenient to focus on the main sources of direct and indirect emissions (from electricity and heat generation and from fuel production and transport) and to use generic data for the indirect emissions associated with the manufacturing of technologies and their embedded materials. The majority of the regulations and certification systems require accounting for emissions within well-to-gate system boundaries (Figure 6), considering the emissions generated during production and conversion.

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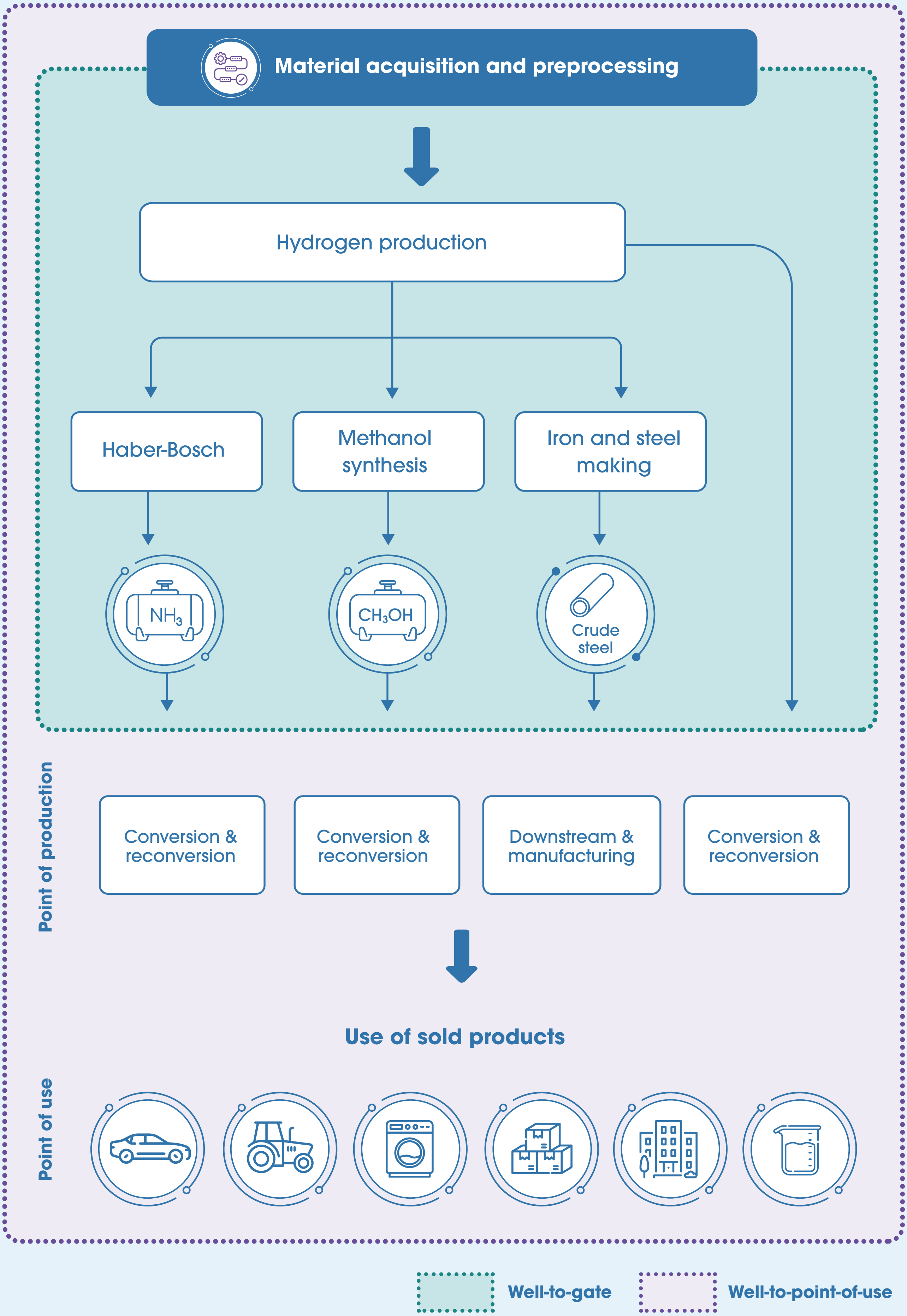
[13] *Article 31a of Directive (EU) 2023/2413*

Figure 6 Typical system boundaries for hydrogen and derivative supply chains



The "well" refers to the original source of energy – a literal fossil well in the case of fossil fuels (for blue hydrogen) and the (renewable) power generation for green hydrogen. The "gate" refers to the boundary of the outgoing gate of the hydrogen or derivative production plant. In the case of transport fuels, the term "well to tank" is also used, which includes emissions from distributing and transporting the fuel to where it is sold to the end user (the filling station). The "tank" refers to the fuel tank of the vehicle. The term "well to wheel" includes the efficiency with which a vehicle uses a fuel, which is outside the control of fuel suppliers and is therefore not relevant for hydrogen supply chains.

Tracking model (supply chain)

The tracking model determines how commodity flows and associated certificates are handled. A number of primary models are used:

- **Identity preserved:** Certified hydrogen from a specific production plant is kept separate from all other hydrogen, even if it comes from other plants that meet the certification requirements. This model may be challenging to implement in practice due to the physical mixing of gases in transportation and storage infrastructure.
- **Segregation:** Certified hydrogen from different production plants can be mixed in a single supply chain, so long as it all complies with the certification requirements, but it must be physically segregated from non-certified hydrogen. This model offers a balance between traceability and logistical feasibility.
- **Mass balance:** Certified and non-certified hydrogen are allowed to be mixed along the supply chain. However, the certificate is passed along the supply chain until the point that a consumer requiring certified hydrogen consumes a given volume. This balancing can be done in different ways in terms of claim method (using a declared percentage or a certified source content value) and in terms of scale (per batch produced or on the basis of site or company). These variances can result in different outcomes from a conformity perspective.
- **Book and claim:** No physical link is maintained between the production and consumption of hydrogen. A certified producer "books" the sustainability attributes embedded in its hydrogen and, at the other end of the value chain, buyers "claim" a contribution to the production of an equivalent volume of compliant products.

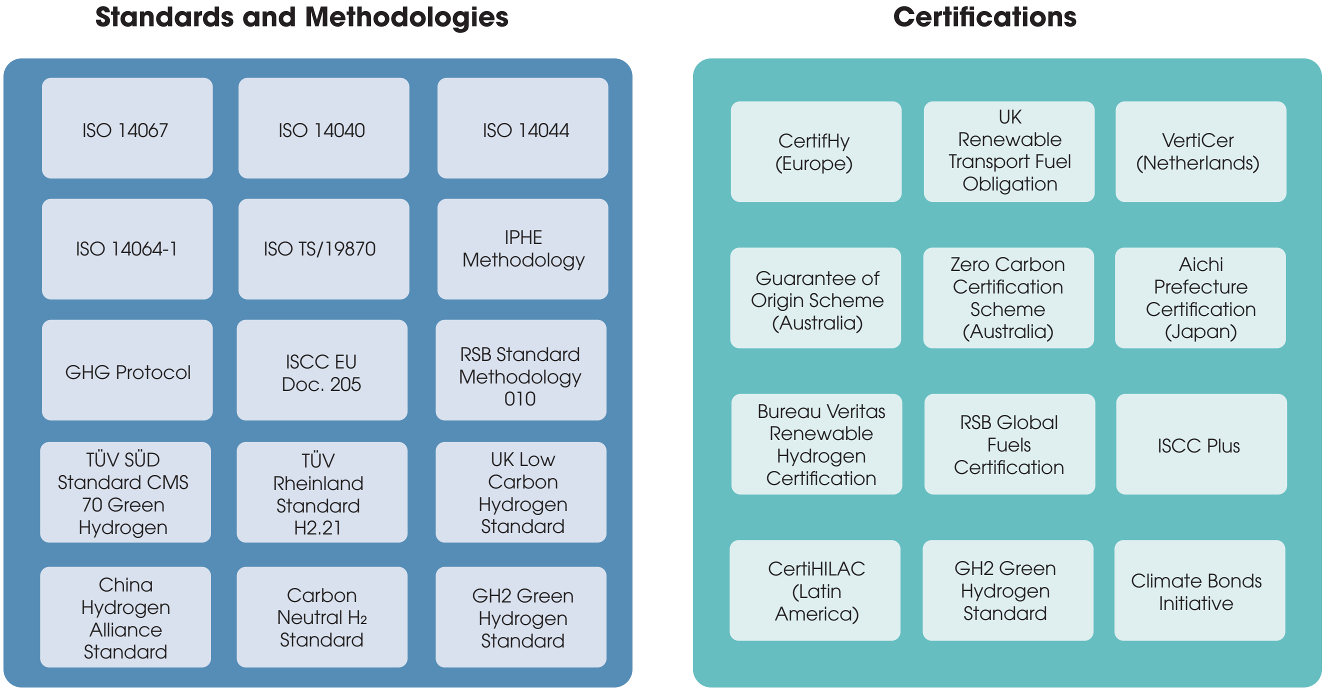
4. Surveying the landscape of accounting standards and methodologies and of certification schemes

This chapter provides an overview of emerging standards, methodologies and certification schemes either in use or in development for hydrogen, ammonia, methanol, and iron and steel. It is important to draw a distinction between the standards and certification schemes that have emerged to address mandatory regulatory requirements (for the EU market, for example) and those that are being developed through voluntary, industry-led initiatives. The market scope (mandatory or voluntary, but also geographical) of the initiatives is specified where relevant.

Hydrogen

Several initiatives exist to provide international standards and collaboratively developed methodologies for the emerging low-emission hydrogen value chain. More than 30 countries came together at COP28 in 2023 to sign a declaration of intent to work together towards mutual recognition of their certification schemes for this sector (COP28, 2023), and there are other efforts focused on ensuring that schemes developed will at least be interoperable. However, there is currently no globally agreed or mandated framework or standard that provides guidance on the definition of low-emission hydrogen. IRENA's literature review has identified the landscape of existing standards and certifications for hydrogen, as illustrated in Figure 7.

Figure 7 Landscape of standards and certification initiatives for hydrogen



Notes: ISO = International Organization for Standardization; IPHE = International Partnership for Hydrogen and Fuel Cells in the Economy; ISCC = International Sustainability & Certification; RSB = Roundtable on Sustainable Biomaterials; TÜV = the Technischer Überwachungsverein (Technical Inspection Association); UK = United Kingdom; GH2 = the Green Hydrogen Organization. The International Organization for Standardization standard and committee numbers are detailed in Box 3.

Accounting methodologies

Most of the GHG emission accounting methodologies used for hydrogen production are based on the following standards: ISO 14040, ISO 14044, ISO 14064-1 and ISO 14067. The IPHE methodology and the GHG Protocol are examples of parent accounting methodologies that have been developed based on these ISO standards. Box 3 gives an overview of a new ISO technical specification (ISO/TS 19870), covering an emission accounting methodology for hydrogen technologies.

Box 3 ISO/TS 19870:2023 – Hydrogen technologies — Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate

A new technical specification, **ISO/TS 19870:2023**, has been developed by the International Organization for Standardization (ISO), aiming to add new value to existing GHG emission accounting methodologies (ISO, 2023). This ISO document was published in November 2023 and officially launched at COP28 in Dubai.

The normative standards on which ISO/TS 19870:2023 builds include:

- ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework
- ISO 14044, Environmental management – Life cycle assessment – Requirements and guidelines
- ISO 14067: 2018, Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification
- ISO 14083:2023, Greenhouse gases – Quantification and reporting of greenhouse gas emissions arising from transport chain operations
- ISO/TS 14071, Environmental management – Life cycle assessment – Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006

ISO 14040 and ISO 14044 contain guidance on how to undertake a general and comprehensive life-cycle analysis. The latter also encompasses requirements for the quantification of complete or partial carbon footprints. ISO 14027 provides guidance for developing and updating product category rules, which provide instructions on how life-cycle assessment for a product should be implemented. ISO 14027 has strong synergies with the general life-cycle assessment guidance provided in ISO 14040 and ISO 14044. ISO 14067 builds on ISO 14044 and ISO 14027 by providing specificity parameters to determine the carbon footprint of products across their complete life cycle. ISO 14083 gives guidelines for GHG quantification and emission reporting arising from transport chain operations.

GHG accounting for hydrogen can be challenging because hydrogen with identical properties can be produced and combined from different production sources that have different GHG intensities. In the absence of a robust emission accounting system, the indistinguishable character of hydrogen (and its derivatives) can lead to the hydrogen being claimed as low emission even if carbon-intensive production methods are used. To address this challenge, ISO/TS 19870:2023 provides guidance on several emission accounting methodologies for the production block of the hydrogen value chain (up to the production gate) and considers the various production pathways for hydrogen: electrolysis of water; steam reforming of natural gas with carbon capture and storage; autothermal reforming of natural gas with carbon capture and storage; generation as a co-product in industrial applications; coal gasification with carbon capture and storage; and production from biomass.

A key objective of this technical specification is to contribute to global efforts in developing a recognised international framework for accurate emission accounting that avoids practices such as miscounting or double counting. Such a framework will provide a standardised approach to guaranties or certificates of origin and will cover GHG inputs used for hydrogen production, conditioning, conversion and transport.

The accounting approaches considered part of this standard are:

- Attributional approach: assigns elementary flows and potential environmental impacts to a specific product system, typically as an account of the history of the product.
- Consequential approach: studies the environmental consequences of possible (future) changes between alternative product systems.

The scope of this technical specification is the "well-to-consumption gate" system boundary and includes all direct and indirect emissions. Indirect emissions encompass emissions arising from raw material acquisition and transport, among other activities. Focusing specifically on hydrogen production pathways, a future ISO standard, ISO 19870-1, builds on ISO/TS 19870:2023 and will focus on the "well-to-production gate" system boundary.

Within the system boundary of this standard, the GHG emissions arising from commissioning and decommissioning of production facilities are only included when considering emissions related to capital goods. The emissions associated with the setup and disassembly of installations and/or of the application consuming the hydrogen are not included.

The GHGs considered by the standard are CO_2, methane and nitrous oxide, and their global warming potential (expressed in $kgCO_2eq$) must be reported. The GHG footprint arising from the electricity used for hydrogen production only focuses on direct and partial indirect emissions – under which the GHG impact from renewables is set to zero.

Upstream emissions arising from inputs into the system (*e.g.* coal, oxygen, natural gas) are also included in this standard. Upstream emissions from sources such as salts used for electrolysis and chemicals used for water treatment are also included. The calculation for the upstream emissions as per this standard is:

$$E_{upstream\ emissions} = \sum_i E_{upstream\ emissions,i}$$

where $E_{upstream\ emissions}$ is the emissions of CO_2, methane and nitrous oxide (as applicable) associated with input *i* within the system module and measured in tonnes of CO_2 equivalent.

Some of the key data points that should be considered for quantification of GHG emissions include the hydrogen production process, the emission accounting method, the emissions inventory, the energy supply and the emission allocation. Time-related and geographical coverage, a technology overview, and data precision and sources are some of the key reporting characteristics that need to be considered when collecting information for emission calculation.

The emissions inventory that is required to determine the overall GHG impact in tonnes of CO_2 equivalent for hydrogen production must include the following categories:

- Combustion emissions: The emissions arising from the combustion of relevant solid, liquid and/or gaseous fuels; these emissions can be measured using a variety of approaches, such as direct measurements and emission factors.
- Fugitive emissions: The emissions that arise from structural and operational losses occurring due to incidents such as leakages, accidents and incorrect facility management.
- Industrial process emissions: The emissions from specific GHGs (*e.g.* hydrofluorocarbons, sulphur hexachloride) used in industrial refrigeration, cooling systems and electrical switchgear. These values can be estimated through assumed leakage rates and/or changes in stock levels of gases.
- Supply emissions: The emissions of GHGs associated with the supply of energy required for hydrogen production, as well as transmission and distribution losses.
- Upstream emissions: The emissions associated with any input into the hydrogen production system.

The emission allocation approach proposed in this standard has three steps:

- "**Step 1:** Wherever possible, allocation should be avoided by a) dividing the unit process to be allocated into two or more sub-processes separately and collecting the input and output data related to these sub-processes, OR b) expanding the product system to include the additional functions related to the co-products.
- **Step 2:** Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them.
- **Step 3:** Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and the functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products." - (ISO, 2023)

A life-cycle assessment report, as recommended by ISO 14044, can be prepared once the life-cycle impact assessment has been completed according to ISO 19870.

(ISO, 2023)

GHG emission thresholds

The imposed emission intensity levels for well-to-gate system boundaries vary widely among regulations and certification systems, reflecting different regional circumstances. For systems with a well-to-gate boundary, the range goes from 0.45 $kgCO_2eq/kgH_2$ in the US Clean Hydrogen Production Tax Credit to 14.5 $kgCO_2eq/kgH_2$ in China's Hydrogen Alliance standard.

Methodologies

- The scope for most of the surveyed certifications and standards is well to gate (*i.e.* up to the output gate of the point of production).
- The validity for most certifications is one year, and monitoring of compliance is achieved through surveillance audits.
- Tracking methods (chain of custody) are not harmonised, but common options are mass balance and book and claim.
- There are important differences in eligible hydrogen production pathways; for example, blue hydrogen and nuclear-based electrolytic hydrogen is admissible in the United States, but not currently in the EU under RED.

This variability in criteria, scope and methodologies increases the regulatory and certification barriers faced by project developers, who need to undertake an ad hoc certification process for each country and/or industry customer if they want to access the domestic subsidies or green premium for sustainability from the market, increasing transaction costs. This complexity is likely to limit international deals for renewable and low-emission hydrogen, thereby hampering the development of an international market.

Table 4 Summary of standards and methodologies for low-emission hydrogen

Organisation/initiative and version names	Type	Market	Boundary	Emission thresholds	Validity	Chain of custody model	Status
UK Low Carbon Hydrogen Standard (Associated certification scheme to be launched in 2025)	Standard/ regulation	Voluntary	🟦 🟦 🟧	Threshold (2.4 kgCO$_2$eq/kgH$_2$)	1 year (this is an assumption as not specified)	Mass balance	Standard is operational Certification scheme to be launched from 2025
Clean Hydrogen Production Standard (United States)	Standard	Mandatory	🟦 🟦 🟧	<4.0 kgCO$_2$eq/kgH$_2$ (in addition to the statutorily required ≤2 kgCO$_2$eq/kgH$_2$ “clean hydrogen” target for emissions at the site of production)	Not specified	Not specified	Operational
Low Carbon Fuel Standard (California, United States)	Standard	Mandatory	🟦 🟦 🟦	10.51 gCO$_2$eq/MJH$_2$ (compressed hydrogen produced in California from electrolysis using renewable electricity) 164.46 gCO$_2$eq/MJH$_2$ (compressed hydrogen produced in California from electrolysis using California average grid electricity)	1 year	Book and claim	Operational
China Hydrogen Alliance Standard	Standard	Voluntary	🟦 🟦 🟧	14.51 kgCO$_2$eq/kgH$_2$ (low-carbon hydrogen) 4.9 kgCO$_2$eq/kgH$_2$ (green hydrogen)	Not specified	Not specified	
ISO/TS 19870	Standard	Voluntary, Global	🟦 🟦 🟧	Not applicable	Not applicable	Not applicable	Operational

🟨 Includes upstream methane 🟨 To the point of production 🟨 To the point of use

🟦 Yes ⬛ No 🟧 Partial

Table 5 Summary of certification schemes for low-emission hydrogen

Organisation/initiative and version names	Type	Market	Boundary	Emission thresholds	Validity	Chain of custody model	Status
International Sustainability and Carbon Certification (ISCC) Plus (ISCC EU, on which ISCC Plus is built)	Certification	Voluntary	🟦🟦🟦	<3 $kgCO_2eq/kgH_2$	1 year	Mass balance and controlled blending	Operational for hydrogen Awaiting approval by /European Commission for RFNBO use
CertifHy	Certification	Voluntary	🟦🟦🟧	36.4 gCO_2eq/ MJH_2, which is equivalent to 4.37 $kgCO_2eq/kgH_2$	1 year	Book and claim (for renewable energy used to produce hydrogen)	Operational for hydrogen Awaiting approval by European Commission for RFNBO use
Green Hydrogen Standard	Standard and certification	Voluntary, Global Africa India China	🟦🟦🟧	1 $kgCO_2eq/kgH_2$	1 year	Book and claim (for renewable energy used to produce hydrogen)	Also covers derivatives (ammonia)
RSB Global Fuels Certification	Certification	Voluntary, Global and EU specific	🟦🟦🟧	Depends on chain of custody model used	5 years	Identity preserved Segregation Controlled blending Mass balance Book and claim (Operator decides which model to use)	Operational
Bureau Veritas Renewable Hydrogen Certification	Certification	Voluntary	🟦🟦🟧	<2 $kgCO_2eq/kgH_2$	1 year	Not specified	Operational
TÜV SÜD Standard CMS 70 Green Hydrogen	Standard and certification	Voluntary	🟦🟦🟧	Hydrogen plant must have emission intensity <28.2 gCO_2eq/MJ	1 year	Book and claim	Operational

TÜV Rheinland Standard H2.21 Renewable and Low-Carbon Hydrogen Fuels	Standard and certification	Voluntary	🟦 🟦 🟧 (depends on user of standard)	3.384 kgCO$_2$eq/kgH$_2$	1 year	Not specified	Operational
UK Renewable Transport Fuel Obligation (RTFO)	Certification	Mandatory (if fuel supplied is >450 000 litres)	🟦 🟦 🟦	Maximum 32.9 gCO$_2$eq/MJ of fuel)	1 year	Mass balance	Operational
VertiCer (The Netherlands) (Guarantee of Origin Regulation)	Certification	Voluntary	🟦 🟦 🟧	Not specified	1 year	Not specified	Operational
Aichi Prefecture low carbon certification (Japan) (Certification website in Japanese)	Certification	Voluntary	🟦 🟦 🟦	No threshold (3.4 kgCO$_2$eq/kg is being proposed by Japan Hydrogen Association)	Not specified (assume 1 year)	Book and claim	Operational
Guarantee of Origin scheme (Government of Australia)	Certification	Voluntary	🟦 🟦 🟧	Not specified	1 year	Not specified	Operational
Zero Carbon Certification Scheme (Smart Energy Council, Australia)	Certification	Voluntary	🟦 🟦 🟧	Not specified	Not specified	Not specified	Operational
CertHILAC	Certification	Undefined, Latin America	Undefined	Undefined	Undefined	Undefined	Under development by the Inter-American Development Bank and Organización Latinoamericana de Energía

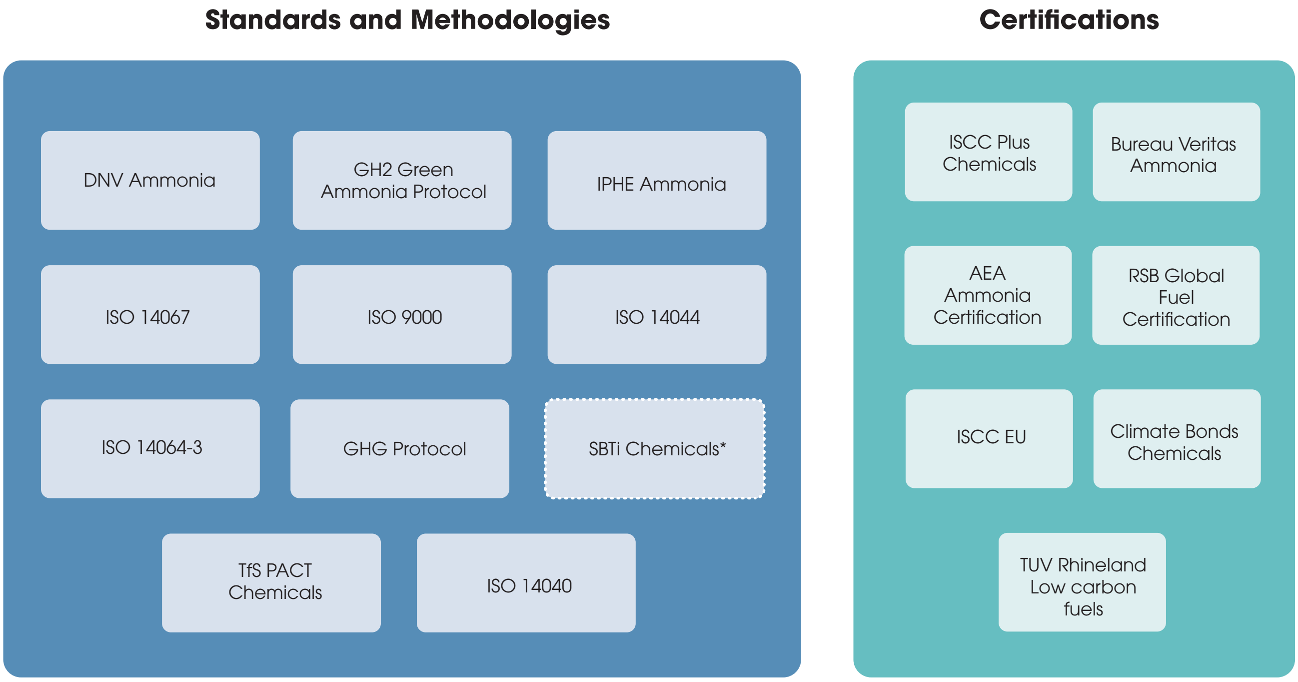
🟨 Includes upstream methane
🟨 To the point of production
🟨 To the point of use

🟦 Yes
◼ No
🟧 Partial

Ammonia

Ammonia is a prominent global commodity, with approximately 20 Mt traded internationally out of the current annual supply of 180 Mt (IRENA, 2023). The expansion of cross-border trade is anticipated as markets transition towards decarbonisation, with regions abundant in renewables transforming into hubs of cost-effective production, exporting low-emission ammonia to consumption centres. In addition to this shift in existing markets, there may be new opportunities to use ammonia in decarbonising other hard-to-abate sectors. While the potential for such trade to contribute to global decarbonisation objectives is evident, a complex regulatory landscape is evolving. Figure 8 shows an overview of the standards and certificates currently in use.

Figure 8 Landscape of standards and certification initiatives for ammonia



*SBTi chemicals standard is not yet launched.

Notes: DNV = Det Norske Veritas; GH2 = Green Hydrogen Organization; IPHE = the International Partnership for Hydrogen and Fuel Cells in the Economy; ISO = International Organization for Standardization; GHG = greenhouse gas emissions; SBTi = the Science Based Targets Initiative; TfS PACT = Together for Sustainability Partnership for Carbon Transparency; ISCC = International Sustainability & Certification; AEA = the Ammonia Energy Association; RSB = the Roundtable on Sustainable Biomaterials; TÜV = the Technischer Überwachungsverein or Technical Inspection Association.

Lack of clarity in guidelines and disparities in emission accounting

The alignment and interoperability of certification schemes is crucial, given the inherent uncertainty faced by ammonia producers at the initial certification stage regarding the end use of the product. To realise the potential of ammonia as a low-emission commodity on a global scale, an internationally recognised certification system is imperative. The development of such a certification scheme is particularly complex given the various uses for ammonia. The certification scheme must reflect the end uses of ammonia. For example, when ammonia is used as a chemical feedstock, the focus might be more on reducing emissions from the production process and managing end-of-life impacts. As a fuel or energy storage vector, the emphasis shifts towards reducing life-cycle emissions. In addition, the certification scheme should prevent double counting and maintain transparency through public access and disclosure. Different initiatives must align with international standards to facilitate the collection and presentation of data in formats compatible across diverse certification schemes and different stakeholders and ensure strict oversight of all participants and the certification scheme itself, thereby maintaining trust and compliance. Table 6 presents a sample of the standards in use for ammonia. Some of these guidelines lack precision in or do not specify credit allocations and their calculation methodologies. These uncertainties or areas of limited precision could lead to calculation disparities across different ammonia production sites and products.

A robust certification mechanism across all stages of the ammonia supply chain, building on existing ammonia production schemes, has the potential to catalyse advancements in certifying ammonia derivatives and environmentally sustainable products. Establishing a global low-emission ammonia market hinges on the development and widespread acceptance of certification schemes that furnish comprehensive information regarding the emission footprint within the ammonia production value chain. Table 7 provides an overview of the certifications used for ammonia. The need for new national and regional policies is driven by an objective to increase the use of low-emission ammonia. This is made more challenging by the need for public bodies to first develop a comprehensive understanding of the characteristics inherent in ammonia production processes. Policies encompassing industrial and transportation quotas, carbon border adjustment mechanisms, sustainable public procurement, product quotas, carbon contracts for difference, and bilateral auctions will all necessitate a coherent and universally accepted ammonia certification scheme. However, current schemes present divergent technical criteria in terms of scope, emission thresholds and accounting methodologies. Consequently, a common label, such as "green ammonia", may not necessarily denote identical products or thresholds. Compounding this complexity, various schemes may incorporate additional environmental, social and governance criteria. These requirements may serve legitimate aims, but they can also introduce further challenges in terms of comparability with other schemes.

Table 6 Summary of standards and methodologies for ammonia

Organisation/ initiative and version names	Market	Boundary	Pollutants covered	Emission thresholds	Credits allotted for export of by-products	Credits allotted for exported energy	Credits allotted for offsets
DNV ammonia service specification May 2023	Voluntary, Global	🟦 🟦 🟦	GHGs	Unspecified	Unclear	Unclear	Unclear
GH2 Green Ammonia Protocol Version 2.0 December 2023	Voluntary, Global	🟦 🟦 🟦	CO_2	0.3 $kgCO_2/kgNH_3$	No	Yes	No
IPHE Ammonia Version 3 July 2023	Voluntary, Global	🟦 🟦 🟧	CO_2	Unspecified	Yes	Yes	Yes
TfS PCF Guideline for Chemical Industry Version 2.1 February 2024	Voluntary, Global	🟦 🟦 🟦	GHGs	Unspecified	Yes	Yes	Yes
SBTi Chemicals	Voluntary, Global	To be launched soon					

🟨 Includes upstream methane	🟨 To the point of production	🟨 To the point of use
🟦 Yes	⬛ No	🟧 Partial

Table 7 Summary of certification schemes for ammonia

Organisation/ initiative and version names	Market	Boundary	Certification validity (years)	Emission thresholds	Chain of custody model
Bureau Veritas Renewable Ammonia scheme[14] September 2023	Voluntary, Global	⬛ 🟦 🟧	Unspecified	0.5 $kgCO_2eq/kgNH_3$	Unclear
AEA Ammonia Certification Version 1.0 November 2023	Voluntary, Global	🟦 🟦 ⬛	Unspecified	Unspecified	Book and claim *and* mass balance
Climate Bonds Basic Chemicals Criteria April 2023	Voluntary, Global	🟦 🟦 🟦	3	Undefined	Unclear
RSB Standard for Advanced Fuels Version 2.6 December 2023	Voluntary, Global	🟦 🟦 🟧	5	Unspecified	Book and claim *and* mass balance
TÜV Rheinland Renewable and Low-Carbon Hydrogen Fuels Version 2.1 March 2023	Voluntary, Global	🟦 🟦 🟦	1	0.094 $kgCO_2eq/MJ$	Unclear
ISCC Plus	Voluntary, Global	⬛ 🟦 🟧	1	Unspecified	Mass balance
ISCC EU	Voluntary, Global	⬛ 🟦 🟧	1	Unspecified	Mass balance

🟨 Includes upstream methane 🟨 To the point of production 🟨 To the point of use

🟦 Yes ⬛ No 🟧 Partial

Methanol

As a pivotal raw material for both the petrochemical and energy sectors, methanol holds the potential for widespread applications across diverse industries. From its use in chemicals as a solvent or as an intermediary to produce olefins, formaldehyde, acetic acid and esters, to its role in the energy sector as a standalone fuel (blended with gasoline or used in direct or reformed methanol fuel cells), methanol's influence is poised to escalate. Compared with fossil fuels, low-emission methanol used as a fuel can reduce carbon emissions by 65-90% depending on the feedstock and conversion process used. Low-emission methanol can also be used as a substitute for low, medium and high conventional methanol blends. It can also be converted into a fuel for gasoline, diesel and marine engines, with system modifications.

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[14] *Documentation of the certification guideline is not available publicly.*

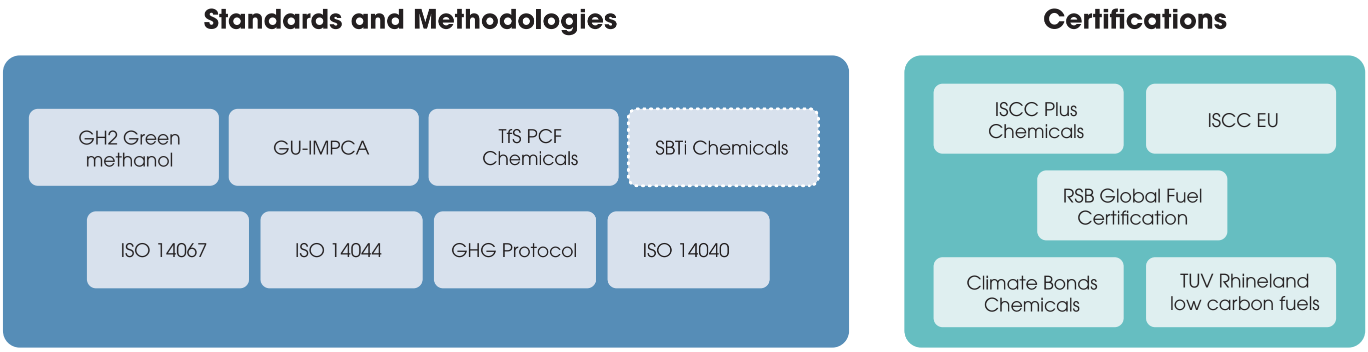
Leveraging existing certification schemes for low-emission methanol

The certification process for low-emission methanol, similar to that for ammonia, is intricate due to low-emission methanol's diverse present and future applications in the energy sector. Figure 9 shows an overview of the standards and certifications currently in use for methanol.

As with ammonia, methanol's wide-ranging applications underscore the necessity for a harmonised, modular and interoperable emission accounting system. Standardisation is necessary to ensure consistent measurement and reporting of methanol's environmental impact across its diverse uses. By leveraging existing certification systems for methanol, industries could avoid inefficiencies associated with multiple conflicting standards. Harmonised guidelines would facilitate comparability and transparency among industries and countries, enabling more effective regulatory oversight and sustainability initiatives. Modular and interoperable frameworks allow for flexibility and adaptability in integrating methanol's emission data into broader environmental management and corporate sustainability strategies, ensuring that the standards remain relevant and can evolve with technological advancements and regulatory changes.

One unresolved challenge in the future certification of low-emission methanol is in the treatment of carbon sourcing. Carbon is an essential component of methanol, and carbon is, at present, usually sourced from fossil fuels. In future low-emission methanol value chains, it will be important to provide consumers and regulators with some assurance as to the source of the carbon used in the production of the methanol. Acceptable carbon, for these purposes, could be sourced from biogenic value chains or via direct air capture, for example. Accounting for the emissions associated with the carbon source used is an additional dimension unique to the methanol sector, and this issue requires further consideration. At present, certifying the carbon source in low-emission methanol typically involves assessing and verifying the sustainability and carbon intensity of the source, whether it be fossil based or from alternative sources like biomass or captured CO_2. The ISCC's recent updates offer a detailed methodology for incorporating biogenic carbon, with the aim of enhancing clarity, transparency and enforceability in the sourcing and documentation of materials, particularly focusing on waste, residues and forest sources.

Figure 9 Landscape of standards and certification initiatives for methanol



*SBTi chemicals standard is not yet launched.

Notes: GH2 = the Green Hydrogen Organization; GU-IMPCA = Guidance from the International Methanol Producers & Consumers Association; TfS PCF = the Together for Sustainability Product Carbon Footprint; SBTi = the Science Based Targets Initiative; ISO is International Organization for Standardization; GHG = greenhouse gas emissions; ISCC = International Sustainability & Certification; RSB = the Roundtable on Sustainable Biomaterials; TÜV = the Technischer Überwachungsverein or Technical Inspection Association.

Table 8 Summary of standards and methodologies for methanol

Organisation/ initiative and version names	Market	Boundary	Pollutants covered	Emission thresholds	Requirements on source of carbon used defined[15]	Credits allotted for export of by-products	Credits allotted for exported energy	Credits allotted for offsets
IMPCA – Methanol Guideline May 2022	Voluntary, Global	🟦 🟦 🟦	GHGs	Unspecified	Yes	Yes	Yes	Yes
GH2 Protocol for Green Methanol Version 2.0 December 2023	Voluntary, Global	🟦 🟦 🟦	CO_2	0.3 $kgCO_2$/ $kgCH_3OH$	Yes	Yes	Unclear	Unclear
TfS PCF Guideline for Chemical Industry Version 2.1 February 2024	Voluntary, Global	🟦 🟦 🟦	GHGs	Unspecified	Yes	Yes	Yes	Yes
SBTi Chemicals	Voluntary, Global	To be launched in 2025.						

Table 9 Summary of certification schemes for methanol

Organisation/ initiative and version names	Market	Boundary	Certification validity	Emission thresholds	Requirements on source of carbon used defined[16]	Chain of custody model
ISCC Plus	Voluntary, Global	⬛ 🟦 🟧	1 year	Unspecified	Yes	Mass balance
ISCC EU	Voluntary, Global	⬛ 🟦 🟧	1 year	Unspecified	Yes	Mass balance
Climate Bonds Basic Chemicals Criteria April 2023	Voluntary, Global	🟦 🟦 🟦	3 years	Unspecified		Unclear
RSB Standard for Advanced Fuels Version 2.6 December 2023	Voluntary, Global	🟦 🟦 🟧	5 years	Unspecified	Yes	Book and claim *and* mass balance
TÜV Rheinland Renewable and Low-Carbon Hydrogen Fuels Version 2.1 March 2023	Voluntary, Global	🟦 🟦 🟦	1 year	94 gCO_2eq/MJ	Yes	Unclear

🟨 Includes upstream methane 🟨 To the point of production 🟨 To the point of use

🟦 Yes ⬛ No 🟧 Partial

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15 *Eligible sources of CO_2 to produce methanol include CO_2 from biomass, direct air capture, unavoidable industrial emissions, or emissions that have paid compensations through a credible carbon price mechanism. All the standards have an explicitly defined methodology to account for the carbon source and its emissions; however, for some, the data collection and documentation system is still evolving and may require further improvement in clarity and transparency.*

16 *Eligible sources of CO_2 to produce methanol include CO_2 from biomass, direct air capture, unavoidable industrial emissions, or emissions that have paid compensations through a credible carbon price mechanism. All the standards have an explicitly defined methodology to account for the carbon source and its emissions; however, for some, the data collection and documentation system is still evolving and may require further improvement in clarity and transparency.*

Box 4 Regulation and certification of emissions in the chemical sector

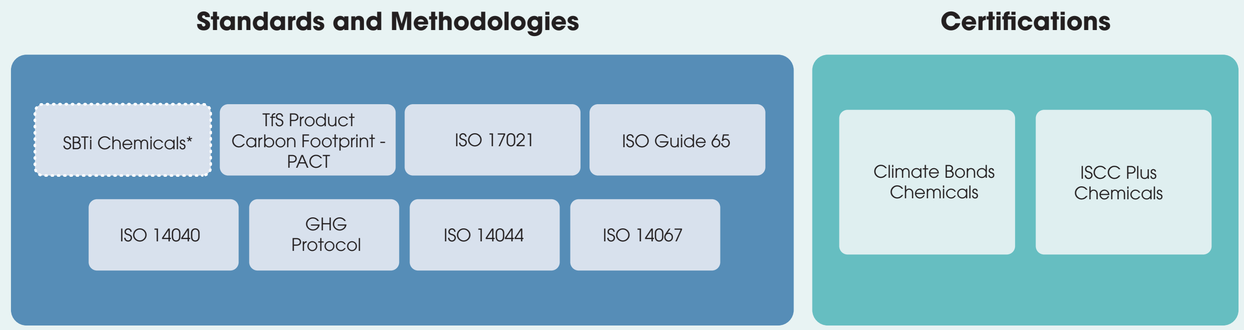
Ammonia and methanol are not the only hydrogen-containing chemicals whose value chains will likely require certification as emission reduction efforts proceed across industries. The development of accounting standards and certificates within the wider chemical sector is both urgent and critical because of the sector's significant emission footprint and its integral role in producing feedstocks for sustainability efforts in other sectors.

The existing standards and guidelines designed to measure product carbon footprints fall short in addressing the unique requirements of chemical suppliers. Notably, limitations in accounting for downstream emissions arise from a predominant reliance on a "cradle-to-gate" system, where the carbon impact is assessed only up to the point of product departure from the factory. This approach overlooks the complete life cycle of a product by excluding considerations relating to its use and disposal. Comparing product carbon footprints for chemical products is challenging due to variations in methodological decisions, data uncertainties, diverse levels of data quality, and technological differences.

Together for Sustainability has partnered with the Partnership for Carbon Transparency under the World Business Council for Sustainable Development to enhance the chemical sector's capacity to exchange comprehensive Scope 3 emissions data. The partnership is expected to facilitate better analysis and understanding of the environmental impact of the industry's supply chains. This standard includes the entire value chain, across all scopes of emissions, with specific guidelines for calculating and reporting Scope 3 emissions of purchased goods, which historically have been challenging to measure due to the complexity of chemical production. Scope 3 includes emissions from upstream and downstream operations within a corporate framework. The evaluation of emissions, the identification of opportunities for influencing reductions, the fulfilment of stakeholder information requirements, and the effective management of emissions must be harmonised during the measurement, reporting and management of Scope 3 emissions. In the initial stages, organisations must make informed decisions regarding the specific Scope 3 emission categories they intend to disclose. For instance, entities engaged in the production of intermediate products may opt against publicly reporting downstream emission information due to inherent challenges in estimating these emissions accurately. Furthermore, not all emission categories may be pertinent to every company, and stakeholders such as municipalities, non-governmental organisations or the broader society may perceive some categories as more relevant than others, thereby influencing the reporting decisions of companies.

Currently, two certification schemes are used in the chemical industry. ISCC Plus is a voluntary sustainability certificate scheme not just for chemicals but also for the plastics, food and feed markets. This scheme is more of a supply-side initiative. The Climate Bonds certification scheme, focusing more on the finance side, serves as a user-friendly tool for investors and issuers, aiding them in prioritising investments that effectively address climate change, encompassing both resilience and mitigation aspects. This certification scheme requires issuers to obtain independent verification pre- and post-issuance to ensure the bond meets the guidelines of the certificate.

The following schematic shows the landscape of standards and certification initiative for the chemical sector.



*SBTi chemicals standard is not yet launched.

Notes: Where SBTi is the Science Based Targets Initiative, TfS is Together for Sustainability, ISO is the International Organization for Standardization, GHG is Greenhouse Gas, and ISCC is International Sustainability & Carbon Certification.

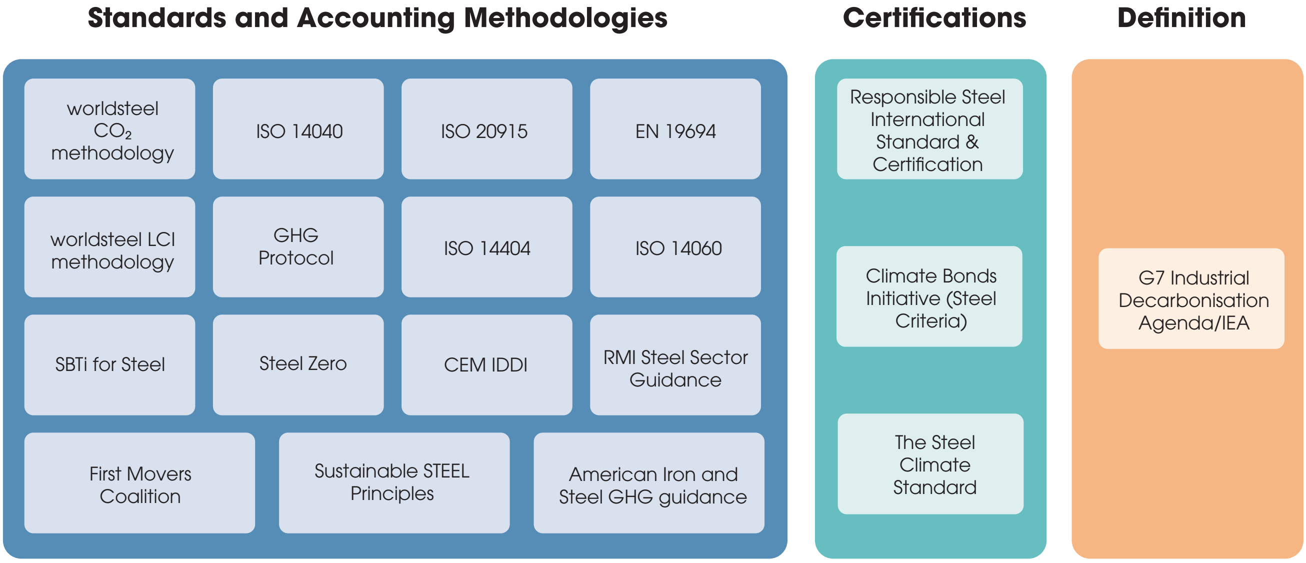
Iron and steel

The processes and inputs used to produce steel vary considerably across regions, making it challenging to qualifying the “green-ness” of steel. Accounting standards are aimed at having a harmonised measurement system to achieve an “apples-to-apples” comparison of the emissions of different production processes and sites across different regions.

The iron and steel sector is witnessing a surge in initiatives from various stakeholders, such as those in financial institutions, industry associations and international organisations, each proposing a similar yet distinct approach to account for emissions and to set criteria for labelling steel products or facilities. This landscape of initiatives is notably intricate, showcasing comprehensive decarbonisation efforts encompassing not only the production side but also finance and demand aspects. These initiatives have been useful in broadening the reach of low-emission products across diverse sectors, regions and stakeholders and could serve as a template for other commodities (Figure 10). However, an alignment in different approaches should be prioritised as well.

While it would be advantageous to have a unified set of guidelines addressing the global iron and steel sector, the implementation of such guidelines may encounter challenges stemming from political considerations and logistical complexities. However, it is encouraging that several stakeholders launched the Steel Standards Principles at COP28 in 2023, which have principles to enable common measurement methodologies (WTO, 2023).

Figure 10 Landscape of standards and certification initiatives for iron and steel[17, 18]



The standards boxes may include criteria for compliance for emissions, in addition to the methodologies for calculating emissions

Notes: ISO = the International Organization for Standardization; EN = European Standard; GHG = Greenhouse Gas; SBTi = Science Based Targets Initiative; CEM IDDI = the Clean Energy Ministerial Deep Decarbonisation Initiative; RMI = the Rocky Mountain Institute; G7 = the Group of Seven.

Most accounting standards for iron and steel are closely linked with one another. However, there are several key differences in the boundaries and how these standards allot credits for the export of by-products and energy, as well as in the use of offsets. Even when guidelines share common boundary terminology, such as “well to gate” or “well to point of use”, variations exist in the sources of emissions considered. For instance, some initiatives with a well-to-point of use boundary may include all finishing processes within the boundary, whereas other initiatives include only a select few processes.

In several instances, the available guidance lacks clarity regarding the allocation of credits for by-products. Furthermore, even when credits are assigned, diverse methodologies (physical allocation/economic allocation, system expansion and others) may be employed for the calculation of the credits, and those methodologies may not be specified. The effects of varying boundaries on emissions are recognised and can be significant, whereas the consequences of variations in credit allocation remain uncertain, potentially resulting in emission disparities across sites and products. The Clean Energy Ministerial’s Industrial Deep Decarbonisation Initiative released a white paper in 2023 highlighting the impact of different allocation methods (IDDI, 2023). The comparison tables (Table 10, Table 11) could facilitate alignment by highlighting the heterogeneities and enabling their consideration in future harmonisation initiatives.

Several accounting standards on the supply side also contain one or more than one normative emission threshold limit. Additionally, there has been convergence of these emission thresholds between major demand- and supply-side initiatives, such as ResponsibleSteel and the First Movers Coalition (IEA *et al.*, 2023). This convergence indicates an alignment between supply- and demand-side definitions of low-carbon steel, which is essential for the development of a market for the commodity. However, such demand-side initiatives may also lack comprehensive details on emission accounting methodology, scope and default values, among other things, potentially affecting prospective markets due

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[17] *The landscape is a mix of site-level, product-level and company-level initiatives.*

[18] *The three certification schemes also have their own respective standards.*

to the adoption of uncertified low-emission steel. The Industrial Deep Decarbonisation Initiative's forthcoming product category rules and methodology may be a useful reference for demand-side initiatives to procure steel with robust environmental attributes.

For this report, three certification schemes – the ResponsibleSteel International Production Standard and certification, the Global Steel Climate Council's Steel Climate Standard and the Climate Bonds Initiative Steel Criteria – have been examined. Table 10 highlights the characteristics of these initiatives. The ResponsibleSteel standard and certification scheme aims to promote responsible sourcing and production of steel, focusing on environmental, social and governance aspects, with 13 principles. Principle 10 focuses on emission mitigation. The ResponsibleSteel membership now covers 272 Mt of annual steel production, representing 15% of global steel production (IEA *et al.*, 2023). ResponsibleSteel has a scrap-based emission threshold approach, where steel is labelled based not only on its carbon footprint but also on the level of scrap used to produce it. However, the emission threshold limits imposed under the Steel Climate Standard are independent of scrap charge. The Climate Bonds Initiative Steel Criteria assess and certify financial instruments related to steel production and can cover retrofits, assets, activities and entities. For instance, using the Climate Bonds Initiative Steel Criteria, Hybar raised USD 330 million in 2023 to finance the development of a production and manufacturing site in the United States (Climate Bonds Initiative, 2023).

Table 10 Summary of standards and methodologies for iron and steel[19]

Organisation/ initiative and version names	Market	Boundary	Pollutants covered	Emission threshold (CO_2/steel)	Credits allotted for export of by-products	Credits allotted for exported energy	Credits allotted for offsets
ResponsibleSteel Principle 10 Version 2.1 May 2024	Voluntary, Global	🟦 🟦 ◼	GHGs	I: 0.5-2.8 II: 0.35-2.0 III: 0.2-1.2 IV: 0.05-0.4	No	Yes	No
RMI Steel GHG Emissions Reporting Guidance Version 1 August 2022	Voluntary, Global[20]	🟦 🟦 🟧	CO_2	-	No[21]	Yes	No
AISI GHG emissions calculation guidelines[22] Version 1 November 2022	Voluntary, Global	🟦 🟦 🟦	GHGs	-	Yes	Unclear	No
Sustainable STEEL Principles Version 1 September 2022	Voluntary, Global	◼ 🟦 🟦	CO_2	-	No[23]	No	No

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[19] The 'dash' in the table signifies the information is not applicable or available for the particular field.

[20] Point-of-use emissions are considered partial, as emissions for semi-finishing or finishing processes are only included for certain products.

[21] Emission credits are outside the scope of the fixed boundary system.

[22] Under revision.

[23] Credits only allotted for the export of intermediate products that are also usable in steel production, such as coke, lime, pellets and sinter.

World Steel Association CO2 data collection guide Version 11 January 2023	Voluntary, Global	⬛ 🟦 ⬛	CO_2	-	Yes	Yes	No
World Steel Association life-cycle inventory methodology 2017	Voluntary, Global	🟦 🟦 🟦	GHGs	-	Yes	Yes	Unclear
ISO 14404	Voluntary, Global[24]	⬛ 🟧 ⬛	CO_2	-	Yes	Yes	Unclear
ISO 20915	Voluntary, Global	🟦 🟦 🟦	GHGs	-	Yes	Yes	Unclear
GSCC Steel Climate Standard Version 1 2023	Voluntary, Global[25]	🟦 🟦 ⬛	GHGs	1.31 (for flats) and 1.11 (for long products) by 2030 0.12 by 2050 (for all)	No	Yes	No
First Movers Coalition Version 1 November 2022	Voluntary, Global	⬛ 🟦 ⬛	CO_2	0.1-0.4	Unclear	Unclear	Unclear
SteelZero	Voluntary, Global	Aligned with ResponsibleSteel V2.0					

🟨 Includes upstream methane	🟨 To the point of production	🟨 To the point of use
🟦 Yes	⬛ No	🟧 Partial

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[24] Indirect fossil fuels are not included in emissions reporting.

[25] The Steel Climate Standard scope includes reheat processes beyond the casting of steel. The preparation of scrap material is also taken into account for measurement of emissions.

Table 11 Summary of certification schemes for iron and steel

Organisation/ initiative and version names	Market	Boundary	Approach	Certification validity (years)	Emission threshold (CO_2/steel)	Monitoring and evaluation	Chain of custody model
ResponsibleSteel Principle 10 Version 2.1 May 2024	Voluntary, Global	🟦 🟦 ◼	Scrap dependent	3	I: 0.5-2.8 II: 0.35-2.0 III: 0.2-1.2 IV: 0.05-0.4[26]	Surveillance audits	Mass balance
GSCC Steel Climate Standard Version 1 2023	Voluntary, Global	🟦 🟦 ◼	Scrap independent	3	1.31 (for flats) and 1.11 (for long products) by 2030 0.12 by 2050 (for all)[27]	Surveillance audits	Unclear[28]
Climate Bonds Steel Criteria Version 3 December 2022	Voluntary, Global	◼ 🟦 ◼	Threshold	5	Different criteria depending on the technology pathway, year of operation and current emissions intensity	Surveillance audits	Unclear

🟨 Includes upstream methane
🟨 To the point of production
🟨 To the point of use
🟦 Yes
◼ No
🟧 Partial

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[26] For crude steel.

[27] For hot-rolled steel.

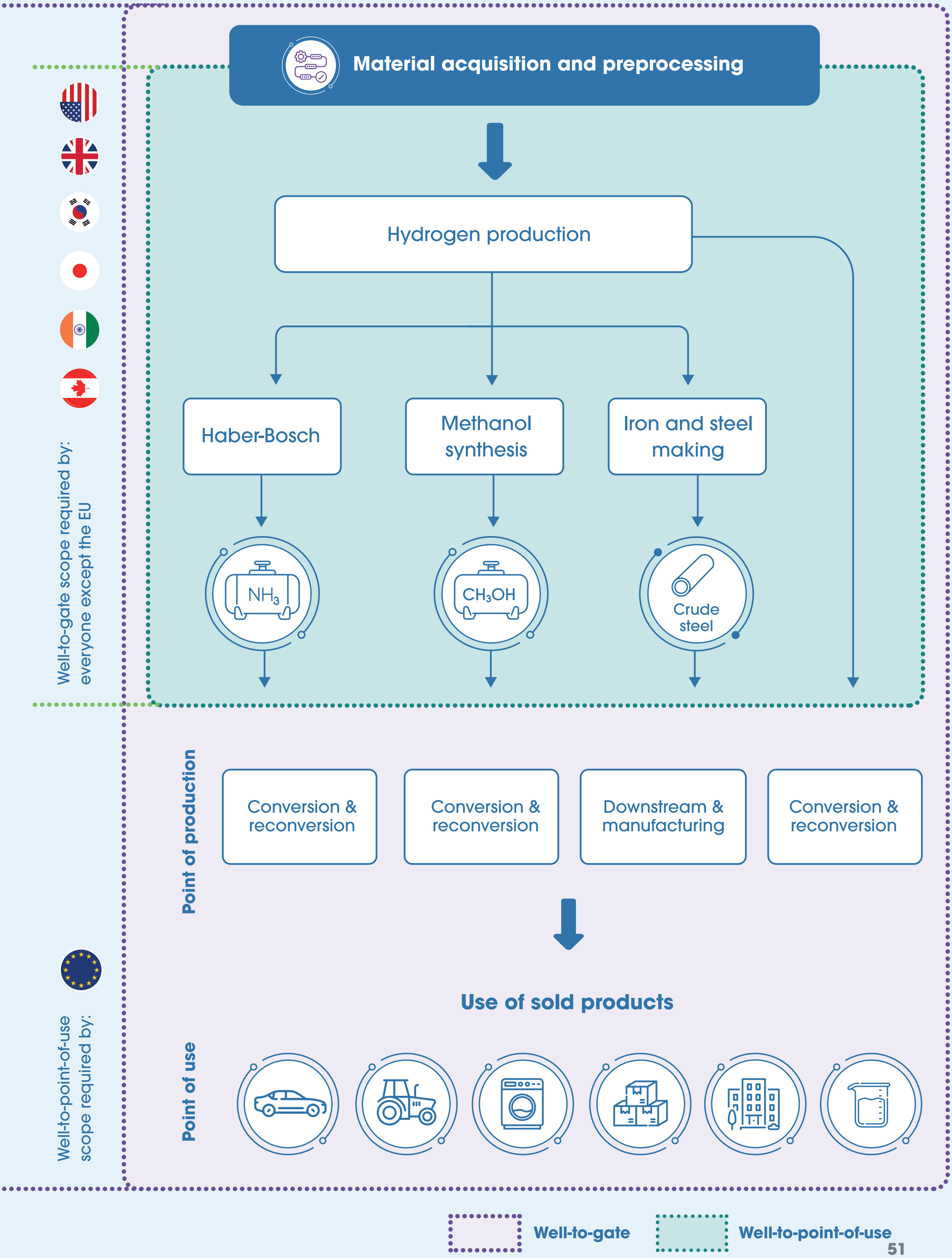
[28] The Steel Climate Standard recommends different options to producers for gathering primary data.

5. Summary, conclusions and recommendations for enhancing market development and trade of commodities

This report summarises the status of regulatory frameworks, standards and certification scheme design and implementation across key markets for green hydrogen and its derivatives. Figure 11 collates regulatory framework requirements for the monitoring of emissions across the hydrogen and derivative value chains, noting in particular the scope of emission intensity measurements that regulators require in key markets. Regulators in these markets are working to nominate accredited certification schemes that will provide the evidence required to satisfy regulatory requirements (refer to Chapter 4).

Standards and certification schemes for hydrogen could play a vital role in supporting the development of initiatives related to commodities such as methanol, ammonia, and iron and steel. The production of these commodities on a large scale with low emissions will require a reliable and substantial source of hydrogen. This hydrogen could either be produced on site or imported from elsewhere. Existing hydrogen standards and certification schemes can be employed to ensure the traceability of the hydrogen used, mainly when imported from elsewhere. In essence, standards for hydrogen can complement those for related commodities such as methanol, ammonia, and iron and steel. Regulatory frameworks for hydrogen are more developed than those in the derivative commodity sectors. Table 12 summarises the requirements that regulatory frameworks in the first-mover hydrogen markets are placing on the certification schemes discussed in Chapter 4. It is ultimately a matter for the governments and regulators responsible in each jurisdiction to determine which certification schemes they will accredit and accept. However, this summary should provide insights for would-be producers on the requirements in place and can be cross-referenced against the details provided for the schemes in Chapter 4.

Figure 11 Summary of emission monitoring required under the regulatory frameworks in the hydrogen and derivative value chains



Box 5 Provisions for the derivative sectors in regulation

Table 12 provides a summary of the emerging regulatory frameworks and sustainability requirements for hydrogen, as well as the emission calculation methodologies and scopes that regulators require from the certification schemes in development for those markets. A similar comparison is not yet possible for low-emission methanol, ammonia, or iron and steel, as regulatory requirements for the sustainability attributes of these commodities have not yet been articulated in most markets. Rather, as described in the preceding chapters, most initiatives to track and demonstrate compliance with sustainability criteria in these markets have been voluntary, industry-led initiatives. The impact of this can be seen in the comparatively loosely defined criteria for the sourcing of carbon for low-emission methanol production in most markets, for example.

The summaries provided in Table 12 and in Table 1 to Table 11 demonstrate significant heterogeneity both in the rules that regulators are putting forward for their markets and in the design fundamentals of the certification schemes emerging across the focus sectors. One of the primary aims for this report was the elucidation of these heterogeneities to inform further work that may be undertaken to address them. IRENA's analysis indicates that the main areas of difference between the regulatory frameworks are in the types of sustainability attributes under regulation and in the emission measurement methodologies that regulators are requiring from approved certification schemes. These differences are then observed in the schemes being developed to address regulators' requirements, as summarised in Table 4 to Table 11.

There can be good reasons for these heterogeneities; for example, heterogeneity may be required to address nationally determined and locally appropriate objectives. The sectors discussed in this report are at different stages of development and maturity, and the role that governments play in the management and development of the associated markets varies as a result. Some of the regulatory frameworks discussed are also intended to govern acceptable standards for domestic production, rather than to set rules on allowable imports. Until import-focused frameworks are developed, as international markets evolve, these differences in approach are likely to reflect the degree of import orientation of the markets discussed. Nonetheless, such fundamental differences in approach are likely to increase the administrative costs for producers aiming to address regulatory requirements. Interoperability of certification between jurisdictions and, to some extent, between the commodity sectors will be essential in realising a global market. Even countries and regions that are not currently focusing on importing hydrogen or derivatives may find it worthwhile to dedicate efforts to achieving interoperability now to insure against the risks of regulatory divergence and market fragmentation in the future. The recommendations that follow focus on the means through which this interoperability could be achieved.

Table 12 Main sustainability requirements for leading hydrogen-consuming jurisdictions

Country/region	Emission limit	Life-cycle scope	Minimum tracking model (chain of custody)	Renewable energy additionality (for green H_2)	Renewable energy temporal correlation (green H_2)	Renewable energy geographic correlation (green H_2)
Canada	**Investment Tax Credit:** <0.75, 0.75-2, 2-4 kgCO$_2$eq/kgH$_2$	Well to gate	Mass balance	No known requirements	No known requirements	No known requirements
European Union	**RED**: <3.38 kgCO$_2$eq/kgH$_2$ **EU Taxonomy (for hydrogen)**: <3 kgCO$_2$eq/kgH$_2$	Well to point of use	Mass balance	Renewable energy asset maximum 36 months in operation before electrolyser commissioning and not in receipt of public financial support. **Exemptions:** Grid electricity emission intensity <18 gCO$_2$eq/MJ, or electrolyser is in a region with over 90% renewable electricity, or electricity is used that would otherwise be curtailed.	Monthly (until **31 December 2029**) Hourly (from **1 January 2030**)	Same or interconnected (if importing) bidding zone or nationally determined requirements (exceptions for low-carbon grids)
India	**Clean Hydrogen Standard:** <2 kgCO$_2$eq/kgH$_2$	Well to gate	Not defined	No known requirements	No known requirements	No known requirements
Japan	**Basic Hydrogen Strategy:** <3.4 kgCO$_2$eq/kg H$_2$	Well to gate	Book and claim	No known requirements	No known requirements	No known requirements
Republic of Korea	**Clean Hydrogen Certification Mechanism and Clean Hydrogen Portfolio Standard** < 4 kgCO$_2$eq/kgH$_2$	Well to gate (Temporarily excludes emissions from shipping raw materials)	Unclear	No known requirements	No known requirements	No known requirements
United Kingdom	**UK Low Carbon Hydrogen Standard:** <2.4 kgCO$_2$eq/kgH$_2$ **Renewable Transport Fuel Obligation (RTFO):** < 4 kgCO$_2$eq/kgH$_2$	Well to gate	Mass balance	For RFNBOs in RTFO: many options, including direct connection or through grid; renewable energy asset in operation at same time or after hydrogen facility starts operating	In RTFO: Must demonstrate that hydrogen facility does not consume more than renewable energy generated during settlement period (up to 30 mins)	Not specified
United States	**Production Tax Credit:** <0.45, 0.45-1.5, 1.5-2.5, 2.5-4 kgCO$_2$eq/kgH$_2$ ranges for different PTC support levels	Well to gate	Mass balance	Renewable energy source must come online no longer than 3 years prior to electrolysis facility	Annual basis until 2028; hourly after that	Renewable energy source must be in same region (as defined by 2023 National Transmission Study) as electrolyser
California, USA	**Low Carbon Fuel Standard:** No thresholds but default pathways ranging from 1.3 to 18.1 kgCO$_2$eq/kgH$_2$ depending on the production route	Well to gate	Mass balance	No known requirements	No known requirements	No known requirements

The following recommendations stem from the analysis of the status of regulatory frameworks, voluntary initiatives, standards and certification schemes in green hydrogen and the derivative commodities discussed in this report. These recommendations are targeted at various value chain participants and are also intended to guide further work in international collaborative fora, including through the IRENA Collaborative Framework on Green Hydrogen. The core recommendations are divided into three pillars:

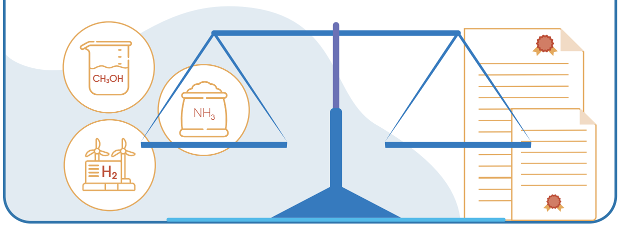
- regulatory framework design
- logistics of certification scheme development and management
- value of and priorities for international collaboration.

Figure 12 Summary depicting the hydrogen and derivative value chains, overlayed with the emissions monitoring scopes required under the regulatory frameworks discussed in this report

Regulatory framework design

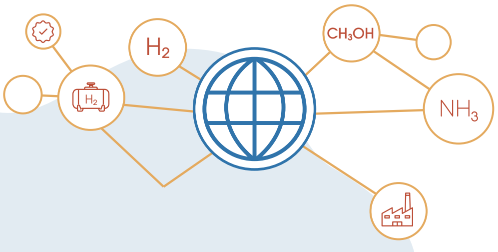
1

Regulators should consider the impact of the frameworks they are developing on the derivative commodity markets and should aim to ensure that the framework's requirements are robust to the characteristics and unique needs of those markets. This should include consideration of carbon-sourcing requirements for low-emission methanol.



2

Interoperability should be the goal of international efforts to align regulatory requirements or achieve mutual recognition of certification schemes. This interoperability should ideally extend to hydrogen and its derivatives.



Logistics of certification scheme development and management

3

To minimise the challenges for potential exporters in navigating regulatory and certification schemes, scheme owners and developers are encouraged to work directly with producers, for example through pre-certification activities, to increase producer understanding of what is required of them.

4

Transparency and specificity of requirements are essential in driving good outcomes via certification. Scheme owners and developers are encouraged to provide clear and detailed guidance on accepted methodologies (and underpinning requirements).

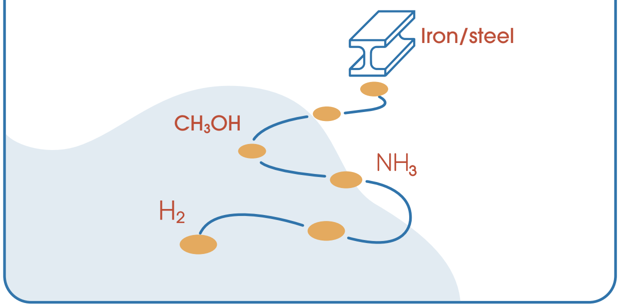
Value of and priorities for international collaboration

5

Where alignment of requirements is not possible, the focus on engagement via international fora should be on working towards interoperability of schemes.

6

There may be a role for agreements to develop common standards in the hydrogen, ammonia and methanol sectors, as was achieved in the iron and steel sector by the Steel Standards Principles.



Regulatory framework design

1. **Regulators should consider the impact of the frameworks they are developing on the derivative commodity markets and should aim to ensure that the framework's requirements are robust to the characteristics and unique needs of those markets. This should include consideration of carbon-sourcing requirements for low-emission methanol.**

2. **Interoperability should be the goal of international efforts to align regulatory requirements or achieve mutual recognition of certification schemes. This interoperability should ideally extend to hydrogen and its derivatives.**

Further efforts are required globally to develop regulations for hydrogen derivatives, particularly in defining expectations regarding carbon sourcing for low-emission methanol and in defining ambitious emission thresholds for iron and steel products. The requirements of the derivative markets can be quite different than those for green hydrogen markets, where government support is intended to drive uptake. As an example, ammonia is already a commodity with a well-developed international market. Different interventions are required to drive low-emission ammonia market development and to potentially regulate that market.

In many of the sectors considered in this report, non-EU producers may be subject to several regulations arising from RED and CBAM, with different associated requirements. This could be challenging for producers to navigate, due to the differences in accounting methodologies and sources specified for acceptable values for input electricity emission factors. Increasing the clarity of the options offered to producers would be beneficial going forward as it would reduce administrative barriers. With other regions also considering carbon border adjustment mechanisms to manage carbon, regulators in the prospective importing markets should consider the complementarity of these regimes.

Governments should work together to align their regulatory frameworks as far as possible, while also addressing local and regional circumstances and priorities. Policy makers can help grow international markets for green hydrogen and its derivatives by ensuring the interoperability of regulatory frameworks and associated certification schemes. Interoperability is important in reducing administrative burdens on would-be producers and exporters and would reduce overall trade costs in all commodities. In the context of hydrogen and its derivatives, interoperability is very complex and arguably very important. While it may be unrealistic to expect regulatory frameworks, standards and certification schemes for hydrogen and those for hydrogen-derived commodities to align, these frameworks, standards and schemes should be designed to be complementary, given how interdependent the respective value chains will be in the future.

Where alignment is not possible, then mutual recognition and bilateral or multilateral co-operation are likely to be useful routes towards harmonisation.

Logistics of certification scheme development and management

3. **To minimise the challenges for potential exporters in navigating regulatory and certification schemes, scheme owners and developers are encouraged to work directly with producers, for example through pre-certification activities, to increase producer understanding of what is required of them.**

4. **Transparency and specificity of requirements are essential in driving good outcomes via certification. Scheme owners and developers are encouraged to provide clear and detailed guidance on accepted methodologies (and underpinning requirements).**

Clarity and specificity of requirements across standards and certification schemes is vitally important in delivering useable criteria and, in turn, the confidence required for purchasing markets. This is especially true for schemes focused on hydrogen-derived commodities, for which schemes are comparatively underdeveloped. Value chain participants, including industry associations, are actively working to develop the schemes required, and further activity in this area is vital.

Compliance with certification schemes requires significant efforts from actors along the supply chain of hydrogen-based commodities. Compliance often requires adaptations to management processes, and sometimes requires adaptations to physical infrastructure and capacity building of personnel. It can be helpful to perform **pre-certification** exercises during an early stage of project development. These exercises can provide valuable learning experiences and bring to the surface many barriers or limitations in producer capacity, which can be adjusted before certification becomes obligatory. Would-be suppliers are encouraged to engage with pre-certification schemes, and certifiers should offer such schemes where possible. Equally, regulators could look to refine their frameworks as the markets grow. Producers in prospective exporting regions will be well placed to offer their perspectives on potential challenges associated with the framework designs implemented.

The requirements of regulators (*e.g.* the EU's RED and its delegated acts) are often complex, particularly for would-be suppliers in countries outside of these demand markets, who may not be used to navigating similar frameworks (*e.g.* many countries do not operate national certificates for the production and use of renewable electricity). It may also be the case that the required data on energy system characteristics (*e.g.* the carbon intensity of national grids) is not available or not detailed enough. As such, investment in capacity building will likely also be necessary for regulatory authorities in the would-be importing markets.

Transparency is also a key requirement for further development of schemes and frameworks in the value chains discussed. In general, certifiers are encouraged to be as transparent as possible with would-be suppliers to build confidence and encourage engagement. Digitalisation and automation may be helpful tools to facilitate open information flow, while also reducing the associated administrative burden. As there are gaps in the schemes summarised for the various commodities, it would also be helpful for entities developing schemes in each subsector to be openly engaged with their counterparts working in other sectors and subsectors.

Value of and priorities for international collaboration

5. **Where alignment of requirements is not possible, the focus on engagement via international fora should be on working towards interoperability of schemes.**

6. **There may be a role for agreements to develop common standards in the hydrogen, ammonia and methanol sectors, as was achieved in the iron and steel sector by the Steel Standards Principles.**

These recommendations were conceived in the spirit of an agreement reached by over 30 countries and unveiled at COP28 (Department of Energy, 2023b), indicating significant international willingness to collaborate in this area. The Steel Standards Principles model (WTO, 2023), discussed in Chapter 4, could offer a framework for using international engagement to drive the development of shared standards and accounting methodologies for the other sectors considered in this report.

IRENA's Collaborative Framework on Green Hydrogen can serve as a potential conduit to co-ordinate activities and share information between member countries to help facilitate this harmonisation in future. Mutual recognition or interoperability of frameworks and schemes are also priorities being taken forward in other international fora for collaboration, such as the IPHE, the International Hydrogen Trade Forum and the International Energy Agency's Technology Collaboration Programme tasks on hydrogen and its derivatives.

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Global trade in green hydrogen derivatives

Trends in regulation, standardisation and certification