International Hydrogen Ramp-up Programme – H2Uppp

Overview of GHG calculation standards & methodologies for PtX products

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List of abbreviations

A6.4	Article 6.4 of the Paris Agreement	DAC	Direct air capture
A6.4-PMM001	Proposed methodology 001 under Article 6.4	DCS	Data Collection System
A6.4-PNM006	Proposed new methodology 006 under Article 6.4	DLUC	Direct land-use change
ACV	Accredited Carbon Verification	DNSH	Do no significant harm
AM0124	CDM methodology AM0124	EC	European Commission
ANRE	Agency for Natural Resources and Energy	ESG	Environmental, social and governance
AR5	Fifth Assessment Report of the IPCC	ETS	Emissions Trading System
AR6	Sixth Assessment Report IPCC	EU	European Union
ASTM	ASTM International	FLL	Fuel Lifecycle Label
ATR	Autothermal reforming	FT	Fischer-Tropsch
BAT	Best available technology	FT-SPK	Fischer-Tropsch synthetic paraffinic kerosene
BEE	Bureau of Energy Efficiency	G-DAM	Green Day-Ahead Market
CAEP	Committee on Aviation Environmental Protection	GCC	Global Carbon Council
CAPEX	Capital expenditure	GFI	GHG Fuel Intensity
CBAM	Carbon Border Adjustment Mechanism	GFS	Global Fuel Standard
CCEE	Electric Energy Trading Chamber	GH2-Organisation	Green Hydrogen Organisation (Green Hydrogen Standard™)
CCS	Carbon capture and storage	GHCI	Green Hydrogen Certification Scheme of India
CCTS	Carbon Credit Trading Scheme	GHG	Greenhouse gas
CCU	Carbon capture and utilisation	GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
CDM	Clean Development Mechanism	GO	Guarantee of Origin
CEF	CORSIA Eligible Fuel	GWP	Global Warming Potential
CFMS	CORSIA Fuel Monitoring System	GWP100	100-year Global Warming Potential
CFP	Carbon footprint of a product	H_2	Hydrogen
CFR	Clean Fuel Regulation	H2Uppp	International Hydrogen Ramp-up Program
CH4	Methane	HEFA	Hydroprocessed esters and fatty acids
CHCS	Clean Hydrogen Certification Scheme	IA	Implementing Agency
CHPS	Clean Hydrogen Production Standard	ICAO	International Civil Aviation Organisation
CI	Carbon intensity	IMO	International Maritime Organisation / Organisation
CO_2	Carbon dioxide	IPCC	Intergovernmental Panel on Climate Change
CO_2-eq / CO_2-eq	Carbon dioxide equivalent	IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
CoC	Chain of Custody	IRA	Inflation Reduction Act
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation	ISCC	International Sustainability and Carbon Certification
CPM	Carbon pricing mechanism	ISWG-GHG	Intersessional Working Group on Reduction of GHG Emissions from Ships
CSRD	Corporate Sustainability Reporting Directive	ITMO	Internationally Transferred Mitigation Outcome

JOGMEC	Japan Organisation for Metals and Energy Security	PtX	Power-to-X
KEEI	Korea Energy Economics Institute	PV	Photovoltaic
KPX	Korea Power Exchange	REC	Renewable energy certificate
LCA	Life cycle assessment	RED II / RED III	Renewable Energy Directive II / III
LCAF	Lower Carbon Aviation Fuel	RFNBO	Renewable Fuel of Non-Biological Origin
LCEF	Life-cycle emissions value	RSB	Roundtable on Sustainable Biomaterials
LCF	Low-carbon fuels	RTFO	Renewable Transport Fuel Obligation
LCI	Life-cycle intensity	RU	Remedial unit
LCV	Lower calorific value	SAF	Sustainable aviation fuel
LHV	Lower heating value	SBTi	Science Based Targets initiative
LNG	Liquefied natural gas	SCS	Sustainability Certification Scheme
LOHC	Liquid organic hydrogen carrier	SFCS	Sustainable Fuel Certification Scheme
MEPC	Marine Environment Protection Committee	SMR	Steam methane reforming
METI	Ministry of Economy, Trade and Industry	T&D	Transmission and distribution (of electricity)
MJ	Megajoule	TSO	Transmission system operator
MTJ	Methanol-to-Jet	UDB	Union Database
MNRE	Ministry of New and Renewable Energy	UK	United Kingdom
MOTIE / MOTIR	Ministry of Trade, Industry and Energy / Resources	UN	United Nations
MRV	Monitoring, reporting and verification	UNFCCC	United Nations Framework Convention on Climate Change
N_2O	Nitrous oxide	UNIDO	United Nations Industrial Development Organisation
NCA	National Competent Authority	USA	United States of America
NDC	Nationally Determined Contribution	VCS	Verified Carbon Standard / Voluntary Carbon Standard
NGHM	National Green Hydrogen Mission	VER	Voluntary Emission Reduction
NH_3	Ammonia	WTG	Well-to-gate
NMC	New methodology concept	WTT	Well-to-tank
NZF	Net-Zero Framework	WTW	Well-to-wake / well-to-wheel
PPA	Power purchase agreement		

1 Executive Summary

The global acceleration of green hydrogen (H_2) and Power-to-X (PtX) production is a cornerstone of international climate policy. Driven by energy transition and decarbonisation targets in many countries as well as sectoral objectives in global aviation and maritime shipping, renewable H_2 and its derivatives – including e-ammonia (NH_3), e-methanol, e-kerosene, and other synthetic fuels and products – are transitioning from niche applications to traded commodities at scale.

As of March 2026, over 35 distinct frameworks for assessing the greenhouse gas (GHG) intensity of PtX products have emerged, each developed by different regulatory, sectoral, or commercial bodies. As a result, they differ in purpose, scope, system boundaries, thresholds, and economic implications for PtX producers.

This report provides a structured, comparative analysis of the GHG emission calculation standards for H_2 and PtX products. Based on a stocktake of currently operational, recently introduced, and emerging standards, the report evaluates the frameworks most relevant to producers targeting international markets. The selection of coverage was informed by an industry stakeholder consultation conducted in February 2026, comprising an online survey and a webinar that brought together 45 participants from producers, project developers, regulators, and development cooperation agencies across 15 countries and four continents, with over 60% of attendees representing active green hydrogen and PtX producers and developers spanning Asia, Africa, Latin America, and Europe.

The report is designed as a practical decision-support tool for two primary audiences: for **H_2/PtX producers**, structured guidance on which methodologies are relevant to their specific product and target market, what compliance entails operationally, and how standard choice shapes project design, electricity sourcing strategy, and monitoring, reporting and verification (MRV) architecture. In addition, it draws conclusions for **national authorities**, what can be done to facilitate domestic PtX industry – such as data provision, certification support infrastructure, and alignment of requirements for accessing regulated export markets.

The report identifies and evaluates eleven major standards in detail, organised into four functional categories:

- First, **compliance with national and supranational legislation**: the EU RFNBO framework, EU CBAM, the Indian Green Hydrogen Certification Scheme, South Korea's Clean Hydrogen Certification Scheme, and Japan's guideline for hydrogen and ammonia carbon intensity calculation[1]. These frameworks condition market access, subsidies, and carbon levies, making compliance non-negotiable for producers targeting these markets.
- Second, **compliance with sectoral frameworks**: ICAO CORSIA (aviation) and IMO Net Zero Framework (maritime shipping).
- Third, **corporate commitments and voluntary net zero strategies**: ISO/TS 19870 and ISO/WD 14067, which support product carbon footprint calculations, and the Green Hydrogen Standard (GH2), which provides globally applicable, high-quality certification for green PtX.
- Fourth, **carbon credit methodologies**: UNFCCC Article 6.4, Verra VCS, Gold Standard, and the Global Carbon Council (GCC), which quantify emission reductions from PtX use to generate tradeable carbon credits.

This list is not complete, and other frameworks can be highly relevant depending on a PtX producer's situation. The selection reflects consulted stakeholders' interest at this point in time.

As part of this work, **PtX carbon intensity calculation tools** have been developed to make life easier for PtX project producers by giving them a first estimate of whether their intended project meets the GHG requirements and quantitative benchmarks of a given standard. Three tools have been developed covering hydrogen, ammonia and methanol / sustainable aviation fuel. Six standards are covered: the EU Carbon Border Adjustment Mechanism (CBAM), the EU rules for renewable fuels of non-biological origin (RFNBO), the Indian Green Hydrogen certification scheme, the Korean certification standard, ICAO CORSIA, and the IMO guidelines. It is available for download at https://ptx-hub.org/ publication /GHG_intensity_calculators_PtX_products.

[1] "Recommended Guideline for Greenhouse Gas and Carbon Intensity Accounting frameworks for LNG/Hydrogen/Ammonia Projects (JOGMEC CI Guideline)"

To test the tool and assess its applicability for PtX project developers, it has been **applied to real projects** covering different PtX types and geographies: ammonia production in India, methanol production in Brazil, and methanol production in South Africa. This was done in close interaction with industry developing the respective PtX projects. This made it possible to examine the practical challenges of meeting the standards' requirements, gathering the necessary data, and completing the tool first-hand. This engagement ran throughout the project, and the feedback received from industry has been incorporated into both the tool and this report.

The **EU RFNBO framework** – operationalised through Delegated Regulations 2023/1184 and 2023/1185 under RED II/III – defines the benchmark for certain PtX products aiming to be considered "renewable" in the EU markets and thus qualify for price premiums. It requires PtX fuels to achieve a minimum of 70% GHG savings relative to a fossil comparator of 94 g CO_2-eq/MJ – resulting in a maximum lifecycle intensity of 28.2 g CO_2-eq/MJ, or ca 3.4 kg CO_2-eq/kg H_2 - and governs electricity sourcing through additionality, temporal correlation (hourly matching from 2030), and geographical correlation requirements. These highly ambitious rules directly influence site selection, electrolyser dispatch, and PPA contract structure, and must be considered from the earliest stages of project development.

The **EU CBAM** (Regulation (EU) 2023/956), fully operational since the begin of the definitive period in January 2026, applies a carbon price – which is linked to the current prices in the EU emissions trading scheme (EU ETS) – to a selection of carbon intensive imported goods proportional to their embedded emissions. H_2 is directly in scope with direct emissions; NH_3-based fertilisers are additionally subject to indirect emissions accounting. Default values – escalating by e.g. 10%, 20%, and 30% annually (exact numbers depending on product type) in 2026-2028 – incentivise producers to move to verified actual data. Importantly, CBAM and RFNBO employ fundamentally different accounting logics: RFNBO as a lifecycle-emissions 'eligibility gate', CBAM as an embedded-emissions price mechanism. A single producer exporting to the EU wants to run both calculations, using different system boundaries and emission factor rules.

Beyond the EU, Japan, Korea and India are attracting a lot of interest from PtX producers. The **Indian Green Hydrogen Certification Scheme** sets a threshold of ≤2 kg CO_2-eq/kg H_2 and links national subsidies to a positive certification. **South Korea's Clean Hydrogen Certification Scheme** defines a maximum threshold of 4.0 kg CO_2-eq/kg H_2 and differentiates four tiers (sometimes called "grades"). It is mandatory for government-supported hydrogen power generation. **Japan's Hydrogen Strategy** provides a lifecycle GHG intensity benchmark of ≤3.4 kg CO_2-eq/kg H_2 tied to its carbon pricing and subsidy systems. Producers targeting multiple export markets must satisfy each framework's distinct rules – compounding the multi-standard compliance challenge.

For producers targeting international aviation and maritime markets, ICAO's **CORSIA** and the **IMO Net Zero Framework** define the eligibility conditions for PtX e-fuels. CORSIA requires sustainable aviation fuels (SAF) to achieve a minimum 10% lifecycle GHG reduction versus an 89 g CO_2-eq/MJ fossil benchmark, verified through ICAO-approved sustainability certification schemes. Once operational, the IMO's Carbon Intensity Indicator will reward low-emission fuels on the basis of its own GHG calculation methodology. The **ReFuelEU Aviation** and **FuelEU Maritime** regulations also apply incentives for supplies of sustainable aviation fuels (SAF) and marine e-fuels by defining minimum SAF-blending rates that increase over time (ReFuelEU Aviation), or by mandatory limits for the greenhouse gas intensity of energy used on board of ships (FuelEU Maritime). However, they do not establish own GHG calculation methodologies but rely on the existing EU RED/RFNBO frameworks and/or refer to the ISO methodology. They are therefore not addressed in detail in this report.

ISO/TS 19870:2023 and ISO/WD 14067 provide important frameworks for corporate Scope 1-3 accounting and product carbon footprinting. ISO/TS 19870 specifically addresses GHG intensity quantification for H_2 production across multiple pathways; ISO/WD 14067 is the underlying general LCA-based framework. The Green Hydrogen Standard of the **Green Hydrogen Organisation (GH2)** offers globally applicable voluntary certification with an ambitious ≤1 kg CO_2-eq kg H_2 threshold and additional ESG criteria. The Green Hydrogen Standard™ is based on the "Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen"[2] developed by the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) but adjusted to reflect GH2's objectives.

[2] https://www.iphe.net/iphe-working-paper-methodology-doc-oct-2021

Carbon credit methodologies represent a fourth, economically distinct category. Rather than quantifying GHG intensity, these frameworks quantify emission reductions from substituting fossil fuels with PtX fuels – enabling the issuance of tradeable credits. As of fall 2026, several PtX-specific methodologies have been submitted for approval under key standards, and some already have been approved: three proposals are in the approval process of the **UNFCCC Article 6.4** Supervisory Body (one for ammonia production via electrolysis, one for renewable-based ammonia in fertiliser production, one for hydrogen production from electrolysis). **Gold Standard** has approved a green ammonia methodology in July 2026, and a separate green hydrogen methodology is still under review. **Verra's Voluntary Carbon Standard** (VCS) still accepts a 2023 methodology that was approved under the Clean Development Mechanism (CDM) and has released a methodology for low-carbon fuels in the shipping sector that is relevant for PtX in June 2026. The **Global Carbon Council** (GCC) is still in the process of developing a methodology for green/low-carbon H_2. That means that PtX projects can now apply for registration under those standards with approved methodologies. Carbon credit revenues can meaningfully improve projects' economics – particularly for production for domestic use. Article 6 is the only mechanism under UN-rules, creating additional demand from governmental buyers (e.g. EU).

Multi-standard compliance can be highly relevant to enhance commercial viability and offtaker flexibility of PtX products. A producer selling green ammonia to the EU while supplying local fertiliser producers must simultaneously satisfy RFNBO or CBAM requirements (if using actual emissions), and those of a carbon credit methodology for the domestic share. A producer of e-methanol targeting EU markets, the international aviation sector (CORSIA), and the maritime sector (IMO/FuelEU Maritime) must demonstrate eligibility under three distinct frameworks. This multiplicity creates significant transaction costs in data collection, auditing, and certification, and can result in conflicting requirements around system boundaries, electricity accounting, and MRV documentation.

Section 5 of this report presents a comparative matrix enabling direct comparison of the analysed standards. While all address GHG emissions of hydrogen and PtX products, they differ fundamentally across eight dimensions relevant to project developers and national authorities. Key findings are:

Purpose and operational status

The standards can be divided into mandatory and voluntary ones. EU RFNBO and CBAM are mandatory for producers targeting the EU market: RFNBO determines whether a fuel qualifies as renewable and can access EU quotas and price premiums; CBAM determines the carbon cost applied to imported goods. South Korea's Clean Hydrogen Certification Scheme is mandatory for access to subsidised power-bidding markets, and Japan's framework is mandatory for subsidy access and carbon pricing relief. India's GHCI is quasi-mandatory for domestic incentives, though purely export-oriented projects may be exempt. CORSIA becomes mandatory for airlines from 2027. The Green Hydrogen Organisation's Standard and ISO/TS 19870 are fully voluntary, serving respectively as a premium or product label and as a reference methodology for schemes and policymakers.

GHG thresholds and functional units

Only some frameworks set a pass/fail GHG threshold. EU RFNBO requires at least 70% GHG savings relative to a fossil comparator of 94 g CO_2-eq/MJ, setting a maximum lifecycle intensity of 28.2 g CO_2-eq/MJ. India sets a threshold of $\leqslant$2.0 kg CO_2eq/kg H_2. Japan benchmarks at $\leqslant$3.4 kg CO_2-eq/kg H_2. South Korea uses a tiered grading framework with four tiers (sometimes called "grades") spanning 0.0 – 4.0 kg CO_2-eq/kg H_2. The Green Hydrogen Organisation's standard sets the tightest ceiling at $\leqslant$1.0 kg CO_2-eq/kg H_2 and $\leqslant$0.3 kg CO_2-eq/kg NH_3. CORSIA requires a minimum 10% lifecycle GHG reduction versus an 89 g CO_2-eq/MJ fossil benchmark. EU CBAM sets no threshold: the lower the embedded emissions, the lower the CBAM financial adjustment, with default values escalating annually in 2026–2028 to incentivise producers to move to verified actual data. For most products, markups of 10% (2026), 20% (2027), and 30% (2028 onwards) apply. Fertilisers are a notable exception and subject to a 1% markup on default values. ISO/TS 19870 sets no threshold at all, providing only a calculation methodology.

System boundaries

India GHCI, South Korea CHCS, Japan, Green Hydrogen Organisation, and ISO/TS 19870 all apply well-to-gate lifecycle accounting, covering feedstock extraction through to the production gate. EU RFNBO, CORSIA and the

IMO LCA Guidelines extend the boundary to well-to-wake[3] (but with separate reporting), including combustion emissions, reflecting the sectoral focus on end-use in aviation and shipping. EU CBAM is the outlier: it applies an installation-based, process-oriented boundary aligned with EU ETS monitoring logic, not a full lifecycle assessment. This means a producer exporting to the EU may need to run two separate accounting exercises on the same product batch – one well-to-gate calculation for RFNBO compliance and one installation-based calculation for CBAM reporting – using different boundary definitions and emission factor rules.

Electricity accounting

Electricity sourcing rules represent the single dimension with the greatest practical divergence across frameworks, and the greatest cost implication for producers. EU RFNBO imposes the most stringent requirements: electricity must meet additionality, temporal correlation (hourly matching from 2030), and geographical correlation criteria to be credited at zero emissions; otherwise, national or bidding-zone grid emission factors apply. South Korea requires monthly matching. Japan and ISO/TS 19870 require tracking of electricity source without prescribing matching frequency. EU CBAM rules for indirect emissions use national grid or actual emission factors with a direct physical connection or physical PPA with hourly matching with no additionality requirement. The GH2 Green Hydrogen Standard de-facto requires closely 100% renewable electricity, with limited non-renewable backup permitted. These differences create divergent operational constraints for electrolyser dispatch, PPA contract design, and MRV infrastructure.

Additional sustainability requirements

Only three of the nine frameworks extend beyond GHG accounting. The latest CORSIA sustainability requirements for CORSIA eligible fuels cover several non GHG-related pillars, including impacts on water, soil, air, land use and land use rights, human rights, local and social development, and food security. The IMO LCA Guidelines address water, air quality, soil, waste and chemicals, nature conservation, carbon source, and direct and indirect land use change but these requirements are still elaborated. The GH2 Green Hydrogen Standard sets the broadest scope, covering ESG reporting, stakeholder engagement, social impact, health and safety, transparency, water management, and environmental management. All remaining frameworks are GHG-only.

Recommendations

The application of the developed carbon intensity calculation tools for hydrogen, ammonia and e-fuels (available for download at https://ptx-hub.org/ publication /GHG intensity calculators PtX products) to real PtX projects show that a single PtX project performs differently under the standards. This is mainly due to differences in system boundaries and electricity accounting. That means the same physical PtX product can count as near-zero-carbon in one standard, marginally compliant in a second, and non-compliant in a third, without any change to the installation. For electrolytic hydrogen, for instance, EU CBAM excludes indirect electricity emissions, but the same project may fail under EU RFNBO and again a different valuation under a national scheme, driven by the applicable grid emission factor. The choice of standards is therefore a strategic variable, as it impacts both market access and requirements on the PtX production design.

Recommendations for PtX project developers

- **Start from the target market:** Identify which standards gate access to each intended offtake market and the premium or carbon price relief that these markets can offer. This should be done before fixing the technical configuration of the PtX plant.
- **Integrate the binding methodology from the outset:** Electricity sourcing is the dimension with the greatest cost- and market access implication. The additionality and hourly temporal matching (from 2030) rules defined for EU RFNBOs are the most demanding ones. Site selection, dispatch, and PPA structure must be designed so that they meet the requirements from day one. That applies both to those that are valid for transitional periods and those already defined for the longer term.

[3] Well-to-gate covers emissions from feedstock production (e.g. electricity and water supply) up to the exit gate or shipping point of the production plant, excluding transport, distribution and end use. Well-to-wake covers the full fuel lifecycle, from feedstock production through processing, transport and bunkering to combustion on board a ship or aircraft; it is the maritime and aviation equivalent of "well-to-wheel" in road transport.

- **Design for the strictest plausible standard, and weigh premium against effort:** Where the offtake market is uncertain or may change, it may make sense to build the installation and MRV such that it meets the most stringent methodology amongst the offtake market candidates. However, one should carefully assess each scheme's premium against the likelihood and effort of meeting its threshold rather than principally chasing the highest headline premium.
- **Account for product-specific sensitivities:** The carbon intensity calculator tools developed as part of this project – available for download at https://ptx-hub.org/publication/GHG_intensity_calculators_PtX_products - can support PtX producers in getting an early, high-level understanding on how the intended technical set-up performs under the covered standards. Default values offered in the tools should be replaced with product-specific data to make the estimates as accurate as possible. Users of the tools shall note that it can only support initial screening but is not an audit-grade tool or a substitute for verified certification.
- **Explore monetisation of domestic carbon emission reductions from PtX use under international carbon markets:** Instead of exporting PtX products and shipping them around the globe to harness green premiums in markets abroad, the Paris Agreement Crediting Mechanism (PACM) and its Article 6.4 – as well as several voluntary carbon market standard - offer PtX producers a way to harness green premiums for domestic use of PtX. For example, if green ammonia is used in domestic fertiliser production, one can create tradeable carbon credits that can be sold on top of the commodity and thus generates additional revenue. Both PACM and voluntary markets are about ready to credit emission reductions from PtX use: the initial methodologies for hydrogen and ammonia are currently being approved (some already are, see Table 2), meaning that PtX projects will soon be able to apply for registration.

Recommendations for policy makers and national authorities

National authorities can support PtX project developers to plan correctly and proceed towards project implementation by making essential data and MRV infrastructure available. From the analysis, we derive the following recommendations.

- **Providing the public sector data compliance depends on:** National and bidding zone grid emission factors (including transmission and distribution losses) and data on renewable generation and consumption are decisive inputs across almost every framework and are most credibly supplied by public institutions.
- **Establish registries and certification infrastructure:** Proof-of-origin and proof-of-production registries – interoperable with those of key export markets – together with accredited verification bodies allow producers to substantiate claims, prevent double-counting, and obtain the certification export markets require.
- **Align with existing standards rather than adding new ones:** In a landscape of over 35 frameworks, align national requirements with – or seek mutual recognition against – the frameworks of priority export markets, basing any domestic scheme on established reference methodologies (e.g. ISO/TS 19870).
- **Pursue harmonisation and balance rigour with practicability:** Advocate for international convergence and mutual recognition to reduce the multi-standard compliance burden and weigh methodological accuracy against administrative feasibility so requirements stay workable for producers without losing credibility in export markets.
- **Signal readiness to use Article 6 and encourage PtX project developers to engage in international carbon markets:** Instead of exporting PtX products and shipping them around the globe to harness green premiums in markets abroad, the Paris Agreement Crediting Mechanism (PACM) and its Article 6 offers PtX producers a way to harness green premiums for domestic use of PtX. For example, if green ammonia is used in domestic fertiliser production, one can create tradeable credits that can be sold on top of the commodity and thus generates additional revenue. Both PACM and voluntary markets are about ready to credit emission reductions from PtX use – the initial methodologies for hydrogen and ammonia have been approved and more are underway, meaning that projects are now able to apply for registration. Therefore, policy makers should clearly communicate their willingness to make use of Article 6 and encourage project developers to get involved in the mechanisms.

2 PtX greenhouse gas accounting in brief - the principles behind every methodology

Before turning to the details of the greenhouse gas (GHG) calculation frameworks analysed in this report, it helps to understand the basic principles behind every product GHG calculation. While the specific methodologies differ in their scope, default values and verification rules, they all rest on the same logic.

The core principles

A product GHG calculation adds up all greenhouse gases linked to producing, using, and transport of a product, then converts them into one common unit – **CO_2-equivalents (CO_2-eq)**. Different gases warm the planet by different amounts: one tonne of methane (CH_4) traps roughly 28 times more heat over 100 years than one tonne of CO_2, and nitrous oxide (N_2O) about 265 times more. To make them comparable, all gases are converted into CO_2-eq using **Global Warming Potential (GWP) values** – typically GWP100 from IPCC AR5 or AR6, depending on the methodology.

Every emission calculation comes down to the following approach:

Emissions = Activity data × Emission factor

(kg CO_2-eq) (kWh, kg, km, …) (kg CO_2-eq per unit)

Activity data is how much of something is used or produced – kWh of electricity, kg of feedstock, m³ of water, km of transport, or tonnes of hydrogen, ammonia or other PtX products. **Emission factors** tell how much CO_2-eq is associated with one unit of that activity – for example, 0.4 kg CO_2-eq per kWh of grid electricity. Multiplying the two results in the total emissions from that activity.

When determining the GHG emissions embodied a PtX product, the emission contributions of each step in the production, processing and eventually transport chain are considered and summed up.

What drives GHG emissions of hydrogen and PtX?

For fossil fuel-based hydrogen – e.g. steam methane reforming, autothermal reforming, coal gasification -, most emissions (ca. 75%) result from the reforming or gasification process, but also upstream from exploration, natural gas methane leakage and coal-mining emissions are substantial (ca. 25% of total emissions).

For green hydrogen produced by water electrolysis, emissions from electricity consumption dominate the footprint – typically 80–95 % of cradle-to-gate emissions. Three variables have key impact on GHG intensity:

1. **Electricity consumption per kg of H_2 – the electrolyser efficiency**

   State-of-the-art systems use ~50–55 kWh per kg H_2; future targets are ca. 45 kWh per kg H_2. A 10 % efficiency improvement cuts the footprint by 10 %.

2. **Emission intensity of the electricity consumed**

   This is by far the single biggest lever: the same electrolyser at 50 kWh per kg H_2 produces around 20 kg CO_2-eq/kg H_2 on a 0.4 kg/kWh grid and well under 1 kg CO_2-eq/kg H_2 on dedicated renewables.

3. **System boundaries**

   The definition of system boundaries is highly important – for example, the inclusion (or exclusion) of life-cycle emissions of wind, PV and electrolyser manufacture, or the inclusion/exclusion of transport emissions from place of production to end consumer.

For downstream PtX products (e-ammonia, e-methanol, e-kerosene, e-methane, Fischer-Tropsch fuels), the same three drivers apply to the hydrogen input – plus additional electricity for synthesis, the CO_2 source for synthesis

(DAC, biogenic, or fossil capture), and the nitrogen source for ammonia. Figure 1 summarises the basic principles of GHG accounting and provides an example.

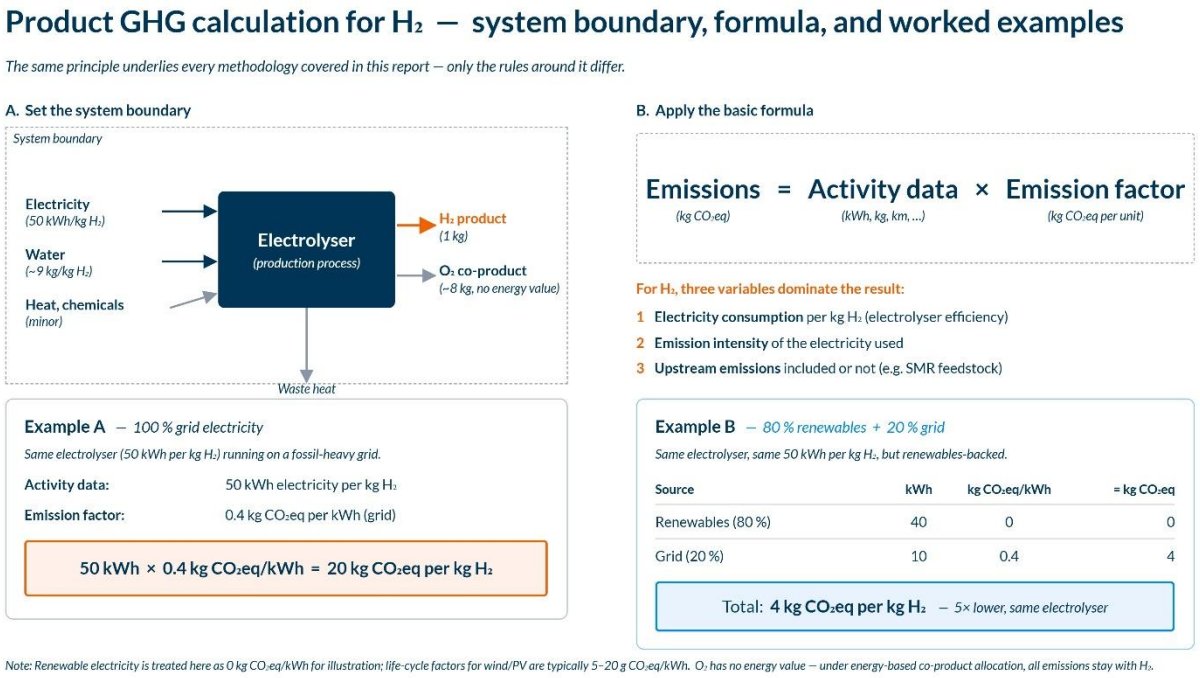


Figure 1: Basic principles of GHG emission calculations of PtX

Source: authors' own illustration

Dealing with the oxygen by-product

Water electrolysis produces oxygen (O_2) alongside hydrogen, in a fixed stoichiometric ratio of about **8 kg O_2 per kg H_2**. Oxygen can be sold (industrial gas markets, medical, steel, water treatment), but it has no energetic value. This matters because several frameworks – EU RFNBO Annex C, IMO LCA, India GHCI and South Korea CHCS, all building on ISO/TS 19870 – allocate emissions between co-products on the basis of their **lower heating value (LHV)**. Under energy-based allocation, O_2 receives a zero share and 100 % of the production emissions stay with hydrogen. Methodologies that use mass-based, economic, or substitution approaches can assign some emissions to O_2, lowering the H_2 figure. The same physical facility can therefore have different reported footprints under different frameworks, even when nothing about the process changes.

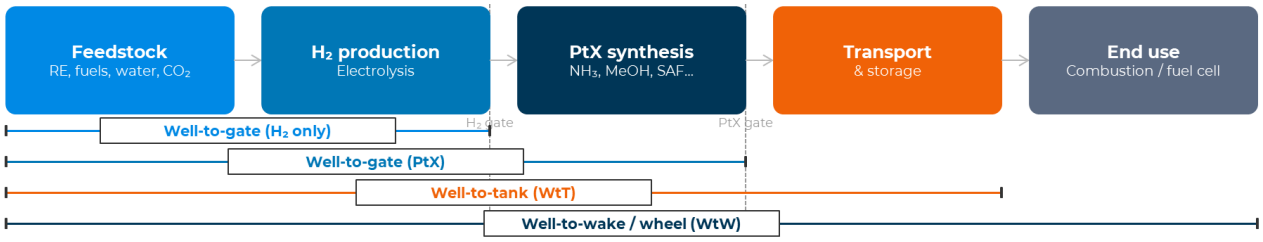
Differences in the GHG calculation methodologies

The GHG calculation methodologies examined in this report all use the logic above. But they differ in:

- **System boundaries**
  Which steps of the complete production, processing, transport and consumption chain are included. Figure 2 below visualises the typical concepts of well-to-gate, well-to-tank and well-to-wake/wheel.
- **Which default emission factors must be used** when site-specific data are unavailable, and how strict the rules are on substituting measured values.
- **How upstream emissions are treated** (electrolyser life cycle, electricity life cycle, methane leakage for SMR/ATR routes).
- **Which GWP apply** (IPCC AR5 vs AR6; in almost all cases GWP100).

- **How co-products – especially O_2 – are handled** (energy-based, mass-based, economic allocation, or substitution).
- **Verification and reporting requirements** (self-declaration, third-party audit, accredited verifier, recognised certification scheme).

Once the basic formula is clear, each methodology can be read as a structured ruleset on *which* activity data and *which* emission factors are acceptable for which product, on which date, and for which market. Chapter 3 takes each framework in turn and works through these specifics.



Framework	Scope / product	System boundary
EU RFNBO (RED III) *	H_2 NH_3	Well-to-wake
EU CBAM	Imported H_2; NH_3 in fertilizers	Well-to-gate
India GHCI	H_2	Well-to-gate
South Korea CHCS	H_2	Well-to-gate
Japan JOGMEC	H_2, NH_3, LNG	Well-to-gate
IMO LCA (MEPC.391)	Marine fuels	Well-to-wake
CORSIA (ICAO)	Aviation SAF / CEF	Well-to-wake
ISO TS 19870	H_2, NH_3	Well-to-tank
Green Hydrogen Organisation Standard	H_2, NH_3	Well-to-gate

Figure 2: System boundary concepts in GHG emission calculation of PtX[4]

Source: author's own illustration

[4] Note that in parallel to the "well-to-X" terminology, ISO applies a similar but slightly differentiated "Cradle-to-X" LCA terminology. The two families mean roughly the same things, but with one important nuance: 1. Cradle-to-gate ≈ well-to-gate. Covers raw material extraction through production to the facility exit. The "cradle" is the point where materials are first extracted from nature. 2. Cradle-to-grave ≈ well-to-wake/wheel. The full lifecycle including end-of-life disposal or decommissioning of the product. 3. Cradle-to-cradle goes one step further – it assumes materials are fully recycled back into a new product cycle, with no waste. Not used in PtX regulation.
The key nuance for PtX: "cradle" language in strict LCA practice can include the embodied emissions from manufacturing capital goods – electrolysers, wind turbines, PV panels, compressors. The "well" language in energy regulation typically does not. Most PtX frameworks explicitly exclude capital goods emissions from scope.

Excursus: Chain of Custody (CoC) approaches

In the context of PtX GHG accounting, Chain of Custody (CoC) refers to the system that ensures **uninterrupted tracking of GHG-relevant information along the entire supply chain** – from feedstock to end product. It relates to the integrity of the GHG emissions data attached to the product. The following models dominate in the PtX context:

- ***Physical segregation*** keeps the certified product physically separate from non-certified material at every step. The GHG attributes stay welded to the actual molecules. This is the most rigorous model but rarely practical for fungible energy carriers – pipelines, shared storage, and bulk shipping make true segregation prohibitively expensive.
- ***Mass balance*** allows certified and non-certified material to be physically mixed within a defined system (a facility, a storage tank, sometimes a transport network) provided that the quantities are tracked in the bookkeeping. A producer who inputs 100 t of certified hydrogen and 50 t of grey hydrogen can sell up to 100 t as certified – the rest must be sold as conventional. This is the operational backbone of EU RFNBO certification.
- ***Book and claim*** decouples the sustainability attribute entirely from the physical product. The certificate (e.g. a Guarantee of Origin) is traded independently of the molecule, similar to how renewable electricity certificates work in many markets. This maximises commercial flexibility but is contested for fuels because the buyer's claim has no physical link to a low-carbon product.

3 Overview of GHG calculations standards & methodologies for PtX products

3.1 Stocktake of existing GHG calculations standards & methodologies

The following GHG certification standards relevant for PtX products have been identified at the project start:

Table 1: Overview of PtX GHG certification standards

#	Scheme name	Country	Status
1	Guarantee of Origin scheme	Australia	Operational
2	Electric Energy Trading Chamber (CCEE) certification scheme(s)	Brazil	Not yet implemented
3	Low carbon hydrogen scheme	Brazil	Under development
4	Clean Hydrogen – Investment Tax Credit	Canada	Operational
5	Fuel Regulation (CFR)	Canada	Operational
6	Low Carbon Fuel Standard	Canada (British Columbia)	Operational
7	China Hydrogen Alliance's Standard	China	Operational
8	CertifHy EU RFNBO Voluntary Scheme	European Union	Operational
9	EU Maritime regulation (FuelEU Maritime)	European Union	Operational
10	EU RED II / III and EU RFNBO	European Union	Operational
11	EU CBAM	European Union	Operational
12	EU taxonomy	European Union	Operational
13	EU FuelEU Aviation	European Union	Operational
14	Guarantees of origin	France	Not yet implemented
15	Guarantees of traceability	France	Not yet implemented
16	Indian Green Hydrogen Certification Scheme	India	Operational
17	Japanese Hydrogen Society Promotion Act	Japan	Under development
18	Low-carbon hydrogen certification	Japan (Chubu Region)	Operational
19	CertHiLAC: Certifying green and low-carbon hydrogen in Latin America and the Caribbean	Latin America and the Caribbean	Not yet implemented
20	ICAO: Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)	Sectoral scheme (Aviation)	Operational
21	International Maritime Organisation (IMO) : Framework on life cycle GHG intensity of marine fuels (2023)	Sectoral scheme (International Maritime Shipping)	Operational
22	UK Low-Carbon Hydrogen Certification	United Kingdom	Under development
23	UK Renewable Transport Fuel Obligation (RTFO)	United Kingdom	Operational
24	United States: 45V IRA	USA	Operational
25	United States: Clean Hydrogen Production Standard (CHPS)	USA	Operational
26	Bureau Veritas renewable hydrogen certification scheme	Other	Operational

#	Scheme name	Country	Status
27	Green Hydrogen Organisation	Other	Operational
28	GHG Protocol	Other	Operational
29	International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)	Other	
30	ISO/TS 19870	other	Operational
31	ISO/WD 14067	other	Operational
32	REDCert EU Voluntary Scheme	Other	Operational
33	TÜV AUSTRIA green hydrogen and low-carbon hydrogen certification schemes	Other	Operational
34	TÜV Rheinland green hydrogen certification scheme	Other	Operational
35	TÜV Süd CMS 70	Other	Operational

Sources: https://www.iphe.net/h2-certification-schemes-inventory, own research

Note that not all of these standards entail specific methodologies – i.e., calculation rulesets for quantifying GHG emissions of hydrogen and PtX or are still in the process of developing one.

Besides frameworks for quantifying GHG emissions of PtX products, there are also standards for quantifying GHG reductions that can be achieved by producing or using renewable-based PtX instead of fossil fuels. They are used for issuance of carbon credits – Internationally Tradeable Mitigation Outcomes (ITMOs) or Voluntary Emission Reductions (VERs) – and include:

I. Global Carbon Council (GCC)
II. Gold Standard
III. UNFCCC Art. 6.4
IV. Verra's VCS

The rules for quantifying carbon credit volumes from a specific project type are defined by so-called "methodologies". They always compare a "baseline scenario" – i.e. the emissions that would occur in absence of a project (i.e. continued use of fossil fuels) with the "project emissions" (i.e. the production/use of fossil fuels). As of fall 2026, three new methodologies for PtX have been proposed by project developers to the Art. 6.4 Supervisory Body: one to produce ammonia through electrolysis[5], one for the use of renewable-based ammonia in fertiliser production[6], and one to produce electrolytic hydrogen[7]. They are currently being reviewed and may be ready for use early 2027. The Gold Standard as recently approved a methodology for green ammonia[8] and is in the process of approving one for green hydrogen production. The Global Carbon Council (GCC) is developing a specialised framework and methodology (GCCNM002) to certify emission reductions from green and low-carbon hydrogen projects. Verra accepts a methodology for hydrogen production from electrolysis from water[9] that was formerly developed for the Clean Development Mechanism (CDM). In addition, a methodology for use of low-carbon fuels in the shipping sector was approved in June 2026. It is also relevant for green ammonia and green methanol.

[5] https://unfccc.int/process-and-meetings/the-paris-agreement/paris-agreement-crediting-mechanism/a64-methodologies/A6.4-PNM001

[6] https://unfccc.int/process-and-meetings/the-paris-agreement/article-6/article-64-pacm/mechanism-process/methodologies/proposed-new-methodology-fertilizer-production-with-renewables-based-ammonia

[7] https://unfccc.int/process-and-meetings/the-paris-agreement/article-6/article-64-pacm/mechanism-process/methodologies/A6.4-PMM011

[8] https://globalgoals.goldstandard.org/in-development/green-hydrogen-production/

[9] https://verra.org/methodologies/hydrogen-production-from-electrolysis-of-water/

3.2 Applicability framework: which standard for which purpose?

For PtX producers, the first and most fundamental step is to understand which GHG accounting methodologies are relevant for their specific product(s) and offtake market(s). The major standards listed in section 3.1 above ultimately address the calculation of GHG emissions of PtX products, but they differ significantly in purpose, scope, and MRV requirements. Particularly in early-stage projects without a secured offtaker(s), this can create significant uncertainty for PtX project developers. The "label" they achieve will impact access to different markets and, consequently, price premiums. A structured applicability framework is therefore essential.

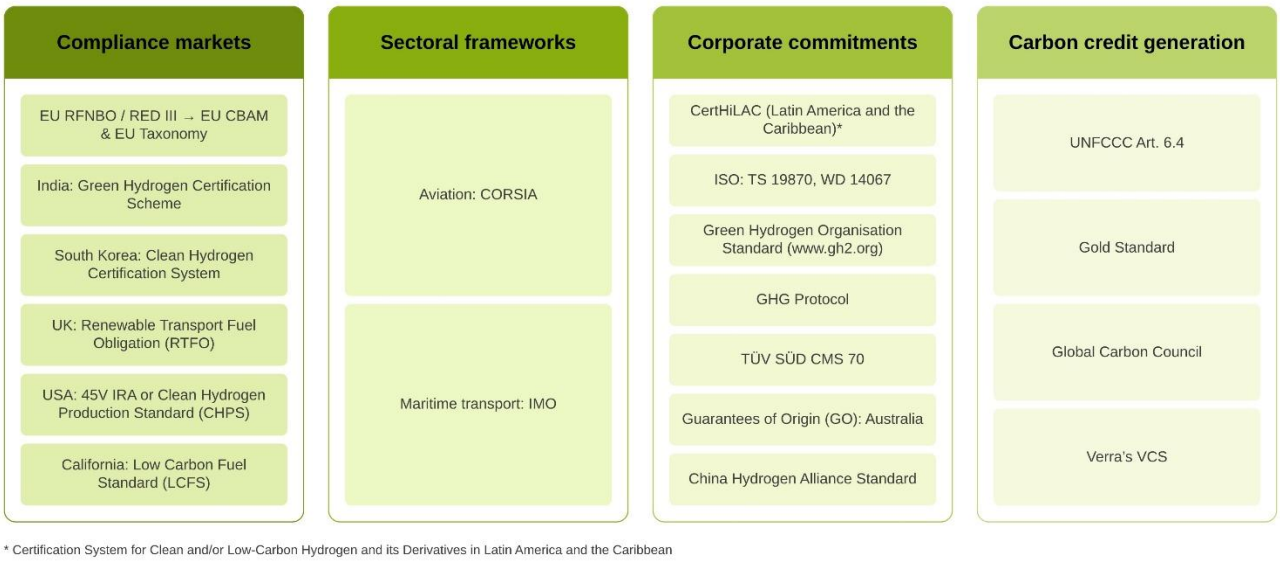


Figure 3: Applicability framework for GHG emission standards – which standard for what purpose?

Source: author's own illustration

We categorise the landscape into four main groups and as a practical orientation for project developers (Figure 3).

1. **Compliance with national or supranational legislation**
   These standards are primarily relevant when PtX producers aim to access regulated markets, public support schemes, or tax benefits. Examples include the EU framework for renewable fuels of non-biological origin under RED III (RFNBO), the U.S. 45V tax credit under the Inflation Reduction Act (IRA), national schemes in Japan and South Korea, and carbon pricing mechanisms such as the EU Carbon Border Adjustment Mechanism (CBAM). In these cases, compliance directly determines economic benefits: GHG intensity thresholds, methodological rules (e.g., additionality, temporal matching, system boundaries), and certification requirements define whether a fuel can access a given market, qualifies for subsidies or reduced carbon levies. For producers targeting these markets, alignment with the relevant legislative methodology is non-negotiable and should be integrated into project design from the outset.
2. **Compliance with sectoral frameworks**
   A second category includes international sector-specific schemes such as CORSIA for aviation and the IMO framework for maritime shipping. These frameworks define how emissions are calculated and accounted for within their respective sectors and are linked to decarbonisation targets. PtX fuels that meet the methodological requirements of these frameworks can command strategic value, as they enable sector participants to meet reduction targets or avoid penalties. For PtX producers targeting e-fuels for aviation or maritime markets, methodological compatibility with these sectoral rules is therefore a critical commercial consideration.
3. **Corporate commitments and voluntary Net Zero strategies**
   Beyond regulation, an increasing share of demand is driven by corporate climate commitments. Industrial players from various sectors have been adopting Science Based Targets and Net Zero strategies. These

actors require robust and transparent product carbon footprints to account for Scope 1–3 emissions reductions. In this context, the relevant standards focus on credible, traceable GHG accounting at product level. For PtX producers, alignment with widely accepted accounting methodologies enhances bankability and marketability, especially when supplying voluntary premium markets.

4. **Carbon credit methodologies (quantification of emission reductions)**
   A distinct fourth category goes beyond product carbon intensity and instead quantifies the **emission reductions** achieved by substituting fossil fuels with PtX. This is the domain of carbon market standards such as UNFCCC Article 6.4, Verra (VCS), Gold Standard, and the Global Carbon Council. Here, the methodological focus lies on baseline setting, additionality, monitoring, reporting, and verification to generate tradable carbon credits. Participation in these schemes can create an additional revenue stream for PtX products used domestically or not exported to compliance markets. The economic logic differs from compliance fuel markets: instead of qualifying a product for regulated demand, the project generates certified emission reductions as a standalone asset.

In practice, PtX producers must evaluate each standard in these four categories against their target markets, offtake strategy, and financing structure.

Example 1: Green ammonia production with partial export to EU, partial domestic use

Let's assume a PtX producer located in the MENA region, who wants to sell 50% of its green ammonia production to the EU, and 50% to local fertiliser producers. The ammonia exported to the EU must comply with EU CBAM rules. Hence, the GHG emissions of the exported ammonia must be calculated according to CBAM regulation when the importer reports them to the EU CBAM registry. The lower the carbon intensity of the ammonia, the lower the CBAM financial adjustments. Ammonia produced exclusively with renewable energy thus gains a competitive advantage to "grey" or "low carbon" ammonia. The share of the ammonia production for local use, however, does not get a competitive advantage under CBAM. Instead, it could benefit from carbon credit revenues. The PtX producer then needs to apply one of the carbon credit standards in addition to meeting CBAM reporting standards – see Figure 4.

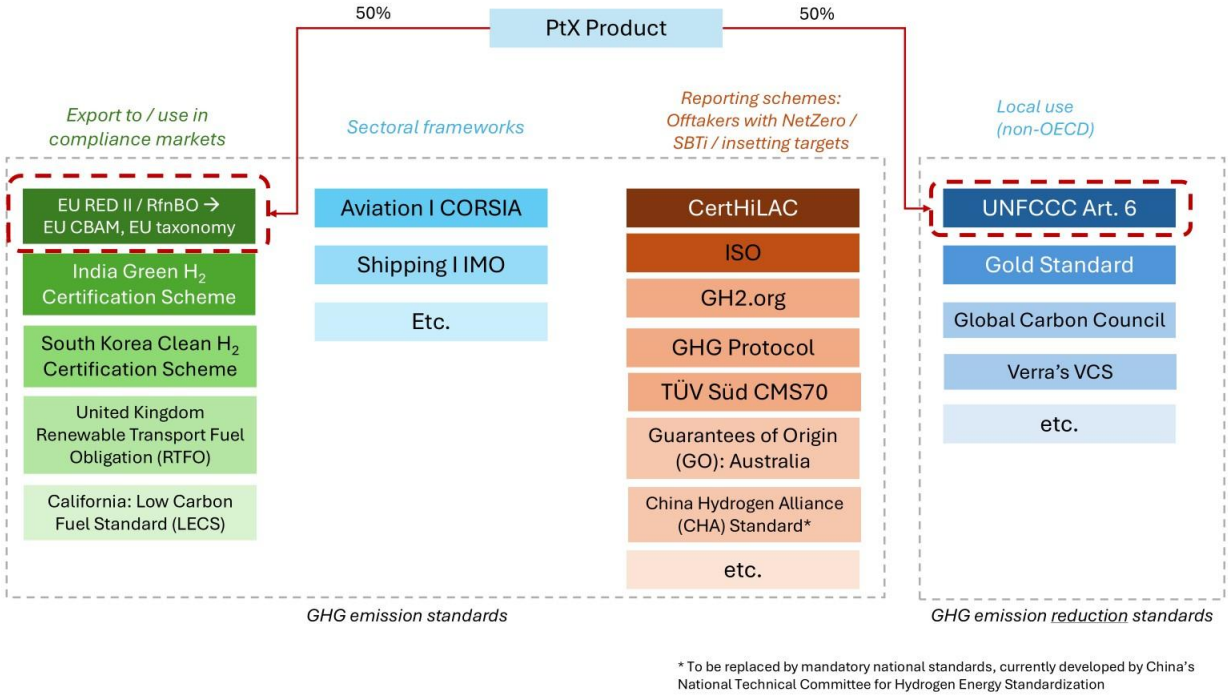


Figure 4: Targeting different markets – the need for multi-standard compliance

Source: author's own illustration

Similarly, if a PtX producer targets two different export markets, e.g. EU plus South Korea or Japan, they need to meet the requirements of all targeted export markets. Thus, multi-standard compliance will be highly relevant in practice. From a PtX producers' point of view, this is cumbersome and creates additional transaction costs.

Example 2: E-methanol production with partial export to EU, partial domestic use and export to third countries

Let's now assume a producer of e-methanol located in South Africa. The e-methanol could be i. consumed domestically, ii. exported to a country without stringent decarbonisation policies, ii. exported to the EU or other countries with stringent decarbonisation policies, iv. sold to the international maritime transport sector (shipping), or v. sold to airlines (directly as methanol or indirectly after conversion to eSAF).

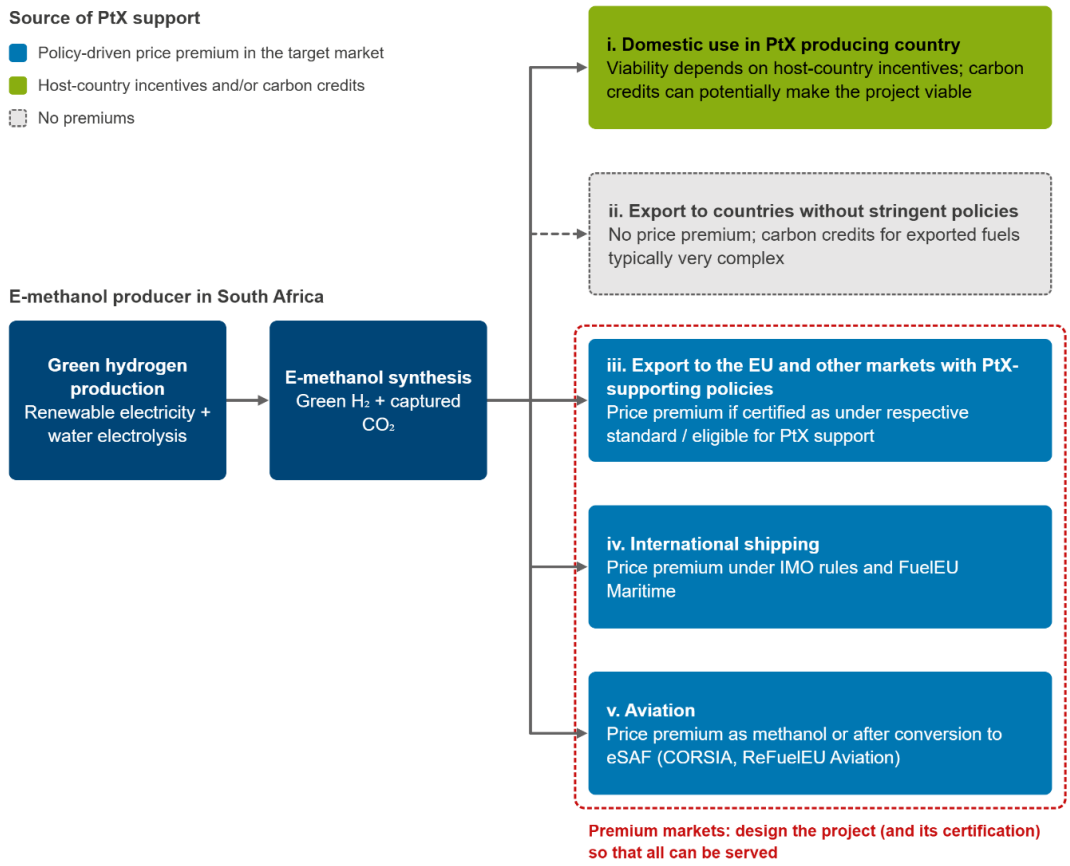


Figure 5: Types of PtX support depending on offtake route

Source: author's own illustration

As the cost of production of e-methanol currently is significantly higher than the cost of fossil methanol, it needs to achieve higher prices – which can either come as price premiums resulting from climate policies in certain markets, or from carbon credits. In our example, option ii. would likely not be interesting as there are no incentives for offtakers to pay price premiums and the generation of carbon credits for exported fuels is often and typically very complex. Economic attractiveness of option i., domestic consumption, depends on the incentives offered in the specific host country. But even if no policy incentives exist, carbon credits may be claimed and thus make the project viable. Export to the EU can result in significant price premiums if the e-methanol is certified as a RFNBO. Likewise, selling to airlines (CORSIA or EU ReFuel Aviation) or the international shipping sector (IMO and/or FuelEU Maritime for vessels calling into the EU) will lead to price premiums. The e-methanol producer will need to assess the opportunities and certification requirements of each of these markets/schemes. In many cases, it can make sense to design the project in a way that all premium markets can be served.

4 Understanding the key aspects of major PtX standards and methodologies

Based on a stocktake of currently operational, recently introduced, and emerging standards, the report evaluates the frameworks most relevant to producers targeting international markets. An industry stakeholder consultation – an online survey and a webinar conducted in February 2026 – shaped the selection of coverage. The webinar brought together 45 participants from across the green hydrogen and PtX value chain, spanning 15 countries and four continents. Over 60% of attendees represented active producers and project developers, including companies developing green hydrogen, ammonia, methanol, and e-fuels projects in India, the Middle East and North Africa, Brazil, Namibia, South Africa, Morocco, Chile, and Europe. Regulatory and standards-setting bodies were also represented. The following frameworks and markets were seen as most relevant:

- EU Renewable Energy Directives (RED II & III) and EU RFNBO regulations
- EU Carbon Boarder Adjustment Mechanism (EU CBAM)
- Indian Green Hydrogen Certification Scheme
- South Korea's Clean Hydrogen Certification Scheme
- Japanese Hydrogen Strategy & Framework
- Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)
- International Maritime Organisation (IMO)
- International Organisation for Standardisation (ISO)
- Carbon credit frameworks for PtX

Each of these key standards will be presented concisely below, as they define a detailed GHG calculation methodology for hydrogen or PtX. Selected other standards will also be introduced, but in less detail. We acknowledge that not all currently existing standards can be covered in this report due to limitations in scope of work.

4.1 Overview: the regulative framework for PtX in the EU

In the EU context different regulatory frameworks refer to and interact with each other. This subchapter explains these interactions before going into the details of the specific methodologies.

The European Union has established a comprehensive regulatory framework to support the decarbonisation of industry, transport, and energy systems. For hydrogen and PtX producers – especially those exporting to or operating within the EU – the following key regulatory pillars define market access requirements, sustainability criteria, and financing conditions:

1. The Renewable Energy Directives and the Delegated Acts on Renewable Fuels of Non-Biological Origin – RFNBOs)
2. The Carbon Border Adjustment Mechanism (CBAM)
3. The EU Taxonomy for Sustainable Activities
4. FuelEU Maritime
5. ReFuelEU Aviation

Although interrelated, each regulation pursues distinct objectives and uses different methodological approaches for determining GHG emissions of PtX products.

4.1.1.1 EU Renewable Energy Directive and RFNBO Delegated Acts

The Renewable Energy Directive (EU) 2018/2001 (RED II) sets binding targets for renewable energy uptake across the EU energy system. In 2023, the Commission adopted two Delegated Acts defining the rules for Renewable Fuels of Non-Biological Origin (RFNBOs) – primarily renewable hydrogen and hydrogen-derived PtX fuels such as e-ammonia, e-methanol, and e-kerosene (European Commission 2023a; 2023b).

The objective of the RFNBO framework is to ensure that hydrogen labelled as "renewable" delivers genuine GHG savings by adhering to strict electricity sourcing and lifecycle emissions rules. If emissions of a PtX product are at least 70% lower as the fossil fuel comparator (i.e., a maximum lifecycle intensity of the PtX of 28.2 g CO_2-eq/MJ) as per RFNBO methodology, they are eligible to count toward EU renewable energy targets in industry and transport.

4.1.1.2 EU Low-Carbon Fuels Delegated Act

Commission Delegated Regulation (EU) 2025/2359 supplements the recast Gas Directive (EU) 2024/1788 by specifying the methodology for assessing GHG emissions savings from low-carbon fuels. It is the legal counterpart to the RFNBO methodology for fuels that are not of renewable origin – most prominently low-carbon hydrogen produced via steam methane reforming or autothermal reforming combined with carbon capture and storage, electrolytic hydrogen using low-carbon (non-renewable) electricity, and synthetic gaseous and liquid fuels derived from low-carbon hydrogen. Recycled carbon fuels remain under Delegated Regulation (EU) 2023/1185 and are explicitly excluded from this scope.

The methodology closely mirrors the RFNBO calculation framework: the same fossil fuel comparator of 94 g CO_2-eq/MJ applies and the same minimum savings threshold of 70% must be met. Also, the same rules govern CO_2 source eligibility, co-product allocation, and process emissions. The lifecycle formula is structurally identical, with the addition of one new element: recognising emission credits for CO_2 that is permanently chemically bound in long-lasting products as listed under Delegated Regulation (EU) 2024/2620.

The main difference concerns the treatment of electricity inputs. Whereas the RFNBO framework requires renewable electricity to satisfy additionality, temporal correlation, and geographical correlation criteria as gatekeeping conditions, the low-carbon fuels Delegated Act (DA) offer producers a choice of four methods for valuing the carbon intensity of electricity that does not qualify as fully renewable[10].

The Low-Carbon Fuels (LCF) Delegated Act itself is a methodology, not a subsidy – its financial value lies in unlocking other EU instruments that reward compliant fuels. The largest benefit for low-carbon ("blue") hydrogen producers is avoided EU ETS costs: emissions that are captured and either permanently stored or chemically bound in qualifying products do not require EU ETS allowance surrender, which is worth roughly €60–90 per tonne of CO_2 at recent prices. LCF-Compliance is also the entry ticket to the EU regulated hydrogen and gas market and to several national support schemes and the EU Innovation Fund. · · · · · ·

4.1.1.3 The EU Carbon Border Adjustment Mechanism (CBAM)

The CBAM (Regulation (EU) 2023/956) is the EU's carbon equalisation mechanism designed to prevent "carbon leakage" – the relocation of emissions-intensive production outside the EU. It introduces a carbon price on imported goods equivalent to the EU Emissions Trading System (ETS) price.

Its purpose differs fundamentally from RED II: CBAM defines a financial adjustment (price for CBAM certificates) on embedded carbon of covered carbon intensive goods that are imported into the EU. It does not regulate renewable energy production. In contrast to RED, CBAM doesn't define a benchmark of GHG emissions intensity that PtX products need to meet. The logic is simple: the higher embedded emissions, the higher the CBAM-related carbon price.

4.1.1.4 EU Taxonomy for Sustainable Activities

The EU Taxonomy (Regulation (EU) 2020/852) is a sustainable finance classification system. It defines when an economic activity can be described as "environmentally sustainable" for investment and reporting purposes

[10] Options are: 1. Annual country or bidding-zone averages (with default values published in the Annex), 2. Day-ahead hourly forecasts provided by the transmission system operator, 3. A full-load-hours approach referenced to marginal pricing by renewables or nuclear, or 4. Hourly marginal-technology values.

(European Commission 2025). The Taxonomy is not a product regulation; instead, it guides capital allocation and corporate disclosures under the EU's Corporate Sustainability Reporting Directive (CSRD).

Hydrogen is addressed under the Climate Delegated Act (EU 2021/2139 of 4 June 2021), which sets a lifecycle GHG threshold of ≤ 3 t CO_2-eq per t H_2, corresponding to a 73.4% reduction compared to the fossil benchmark (Wikborg Rein 2021). Activities meeting this criterion – and Do-No-Substantial-Harm (DNSH) and social safeguards – are considered "taxonomy-aligned".

Unlike RED II, the Taxonomy:

- Does **not** define electricity sourcing rules;
- Does **not** differentiate between renewable and low-carbon hydrogen;
- Does **not** regulate PtX fuels directly.

The EU Taxonomy does *not* specify a calculation methodology for CO_2 emissions of hydrogen or PtX products. Instead, it refers to external methodologies - mainly those under the RED II and ISO 14067:2018(123) or ISO 14064-1:2018(124)[11].

For PtX producers, the Taxonomy still matters when:

- Companies seek sustainable finance (green bonds, ESG investment);
- Parent companies must report Taxonomy KPIs;
- Investors evaluate project alignment.

For producers, alignment with the Taxonomy's thresholds improves access to capital but does not affect access to premium prices for PtX products in the EU. Given that the EU Taxonomy does not have its own GHG calculation methodology for hydrogen or PtX, it will not be assessed in detail below.

4.1.1.5 FuelEU Maritime

FuelEU Maritime entered into full application on 1 January 2025 as part of the EU's Fit for 55 package. It applies to commercial vessels exceeding 5,000 gross tonnes calling at EU/EEA ports, regardless of flag, and sets mandatory GHG intensity reduction targets measured against a 2020 baseline of 91.16 g CO_2-eq/MJ, with progressive reductions of 2% (2025), 6% (2030), 14.5% (2035), 31% (2040), 62% (2045), and 80% (2050).

Compliance is assessed on a well-to-wake (WtW) basis, covering CO_2, CH_4, and N_2O across the full fuel lifecycle. The regulation is fuel-neutral, indirectly creating demand for renewable and low-carbon fuels including green hydrogen, ammonia, methanol, and other PtX products. RFNBOs receive a 2× multiplier on their energy content in GHG intensity calculations until the end of2033, rewarding early movers (Carboneer, 2025). Annex II provides default WtW values for e-fuels that meet RED sustainability criteria; for RFNBOs, actual certified values may be used. Importantly, FuelEU Maritime does not establish an independent GHG calculation methodology for PtX fuels – it defers to the RFNBO Delegated Act under RED (EU) 2018/2001.

4.1.1.6 ReFuelEU Aviation

ReFuelEU Aviation (Regulation (EU) 2023/2405), adopted in October 2023 and applicable from January 2025, mandates aviation fuel suppliers to progressively blend sustainable aviation fuels (SAF) into conventional jet fuel at EU airports. Overall SAF blending targets rise from 2% in 2025 to 70% by 2050, with a dedicated sub-mandate for synthetic e-fuels (PtX/RFNBOs) starting at 1.2% in 2030 and reaching 35% by 2050 (Carbon Gap Policy Tracker, 2026).

Synthetic aviation fuels – produced from renewable hydrogen and captured CO_2 – qualify as SAF provided they meet the sustainability and GHG criteria of RED II/III. Specifically, PtX-derived SAF must be produced using renewable hydrogen as defined under the RFNBO rules and must achieve lifecycle GHG savings of at least 70% compared to the fossil fuel comparator. All SAF must comply with lifecycle emissions savings criteria in RED II as amended by RED III, while first-generation biofuels from food and feed crops are excluded (Hundt, 2024).

[11] https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/275/view

Like FuelEU Maritime, ReFuelEU Aviation is not a self-standing GHG calculation methodology – it fully defers to the RED framework for sustainability certification and GHG accounting of PtX fuels. Compliance and traceability are managed via the EU Union Database (UDB), with annual reporting obligations for fuel suppliers.

In the next chapters, the report provides a more detailed overview of the most relevant PtX calculation methodologies.

4.2 EU Renewable Energy Directives (RED II/ RED III) and EU RFNBO

EU Renewable Energy Directive (RED II / RED III) and EU RFNBO

Geographical or sectoral focus

European Union — mandatory for fuels counting towards EU renewable targets used in the EU; applies independently of the region where the fuels are produced.

MRV guidelines / procedures

- Based on the RED II Article 30 verification framework
- Independent third-party verification by certification bodies cooperating with recognised voluntary schemes
- Annual auditing required
- Mass-balance chain of custody, with the Union Database (UDB) as central digital infrastructure

Application: In which context relevant for PtX developer?

- Offtakers of PtX products / exports to the EU. Companies selling fuels in EU (*Inverkehrbringer*) must meet RED quotas. This may result in premiums for RFNBO-certified PtX
- Supplying maritime fuels to vessels calling at the EU (FuelEU Maritime)
- Supplying aviation fuels for airlines serving the EU (ReFuelEU Aviation)
- Accessing subsidies (e.g. H2Global, European Hydrogen Bank auctions, etc.)
- Corporate Scope 3 emission targets (if aligned with RED criteria)

Authorised certification bodies

Certification via EU-recognised voluntary schemes:

- ISCC EU
- REDcert EU
- CertifHy
- Further Commission-approved schemes pending

Origin and legal base

- RED II — Directive (EU) 2018/2001
- RED III — Directive (EU) 2023/2413
- EU RFNBO rules — Delegated Regulations (EU) 2023/1184 & 2023/1185

Timelines & modalities of certification

- Initial certification: ~3–6 months (depending on producer data availability)
- Annual audits required
- Certificates valid for one year

Implementation status quo

- Legally adopted in 2023; fully applicable under RED III
- Transitional rules until 2028 (additionality flexibility)
- Binding for EU Member States
- Increasingly embedded in offtake contracts and state-aid schemes

Benefits

- Legally recognised renewable-electricity qualification
- Well-established framework with broad EU market acceptance
- Unlocks EU hydrogen quotas, SAF mandates and FuelEU compliance
- Supports contract structuring with high legal precision
- Builds on the already-established biofuel certification system

Key components of methodology

- **Scope / system boundary:** well-to-wheel (incl. upstream, processing, transport, end-use)
- **Core GHG equation:** $E = e_i + e_p + e_{td} + e_u - e_{ccs}$ with e_i = emissions from inputs, e_p = processing emissions, e_{td} = transport / distribution, e_u = utilisation / combustion, e_{ccs} = eligible CCS savings.
- **GHG savings threshold:** ≥ 70% vs. fossil comparator (94 gCO_2eq/MJ)
- **GHG emissions covered:** CO_2, CH_4, N_2O — in t CO_2-equivalents
- **Chain of custody:** mass balance, via the Union Database (UDB)

Challenges

- Complex electricity-qualification rules: additionality, temporal matching, geographic correlation
- Significant data and auditing complexity
- Grid-based projects may face quality-of-supply constraints
- Divergence from CBAM and ETS accounting (parallel reporting required)

4.2.1 Application & Purpose

The **Renewable Energy Directive II** (RED II - Directive (EU) 2018/2001) introduced in 2018 aims to increase the EU's renewable energy share to at least 32% by 2030, driving decarbonisation, energy security, and industrial sustainability.

The **Renewable Energy Directive III (**RED III - Directive (EU) 2023/2413) of 2023 raises the 2030 renewable energy target to 42.5% and to 60% in 2035. EU Member States must take measures to ensure these targets are met. In 2030, 42% of hydrogen used in industry must be from RFNBOs by 2030, rising to 60% by 2035.

The **EU "Renewable Fuels of Non-Biological Origin" (RFNBO)** rules[12] define when fuels can be recognised as renewable and climate-beneficial for EU compliance purposes. For PtX project developers, the methodology is most relevant when a project targets EU demand, wants eligibility for regulatory counting/quotas, or needs verification-grade proof of "renewable hydrogen / e-fuels". In that context, the RFNBO framework is an eligibility gate that may even influence site selection (grid conditions by bidding zone), electricity sourcing strategy (direct connection to dedicated renewable energies versus grid connection and/or Power Purchase Agreements (PPAs)), electrolyser dispatch (matching requirements), and MRV architecture (GIZ 2023; European Union, 2018; European Commission, 2023a). The methodology has two linked aims:

(1) Ensure electrolysis is backed by renewable electricity in a way that avoids simple re-labelling of fossil-marginal grid power (additionality, time and geographic correlation); and
(2) Deliver well-to-wake/wheel results so projects can be benchmarked and audited consistently across supply chains.

4.2.2 Legal base and implementation status quo

RFNBOs were introduced in RED II (Directive (EU) 2018/2001), which mandated delegated acts for (a) renewable electricity qualification for RFNBO production and (b) lifecycle GHG accounting. These mandates are implemented through:

- **Delegated Regulation (EU) 2023/1184:** conditions under which electricity used for RFNBO production may be counted as "fully renewable".
- **Delegated Regulation (EU) 2023/1185:** methodology to calculate lifecycle GHG emissions and savings for RFNBOs (and recycled carbon fuels (RCF)), using a fossil comparator of **94 g CO_2-eq/MJ**.

The interplay of RED II and the delegated acts is summarised in Figure 6.

[12] Note that at the time of writing this report, the planned revision process by the EU COM has not been concluded

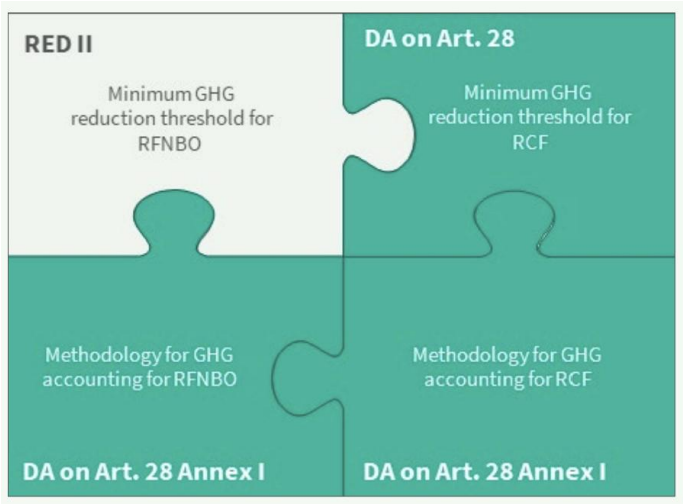


Figure 6: Interplay of RED II and the delegated acts.

Source: PtX Hub (2023): https://ptx-hub.org/wp-content/uploads/2023/04/International-PtX-Hub_EU-Requirements-for-green-hydrogen-and-PtX.pdf

The RED III directive of 2023 raises EU renewables/RFNBO ambition and requires the Commission to assess impacts of the electricity methodology and report by **1 July 2028**, with the option to amend the rules thereafter. In practice, compliance is implemented through sustainability certification systems and independent auditing.

4.2.3 Key components

Underlying logic: The EU's RFNBO framework requires that a "renewable" fuel produces at least 70% fewer lifecycle GHG emissions than the fossil fuel it replaces – measured across the entire chain from electricity generation through to processing and transport, using the formula on Figure 6 above. The fossil benchmark is set at 94 g CO_2-equivalent per megajoule, meaning renewable hydrogen must come in below **roughly 3.4 kg CO_2-eq/kg H_2** across its full lifecycle.

1) Product scope and threshold

RFNBOs are PtX fuels that must both (i) meet electricity sourcing conditions and (ii) achieve minimum lifecycle GHG savings. RED applies a **70% savings** threshold for RFNBOs relative to a fossil comparator of **94 g CO_2-eq/MJ** (i.e., a maximum lifecycle intensity of **28.2 g CO_2-eq/MJ**).

2) System boundary and emissions included

Lifecycle emissions are accounted is g CO_2-eq/MJ on a well-to-wake/wheel basis. Total emissions **E** are calculated according to the following master formula:

$$E = e_i + e_p + e_td + e_u - e_ccs$$

considering total emissions from inputs (e_i), processing (e_p), transport/distribution (e_{td}), onsite utilisation/combustion ($e_{u,}$), minus eligible CCS savings (e_{ccs}) – see Figure 7. Embedded emissions from manufacturing machinery/equipment are not included in this framework.

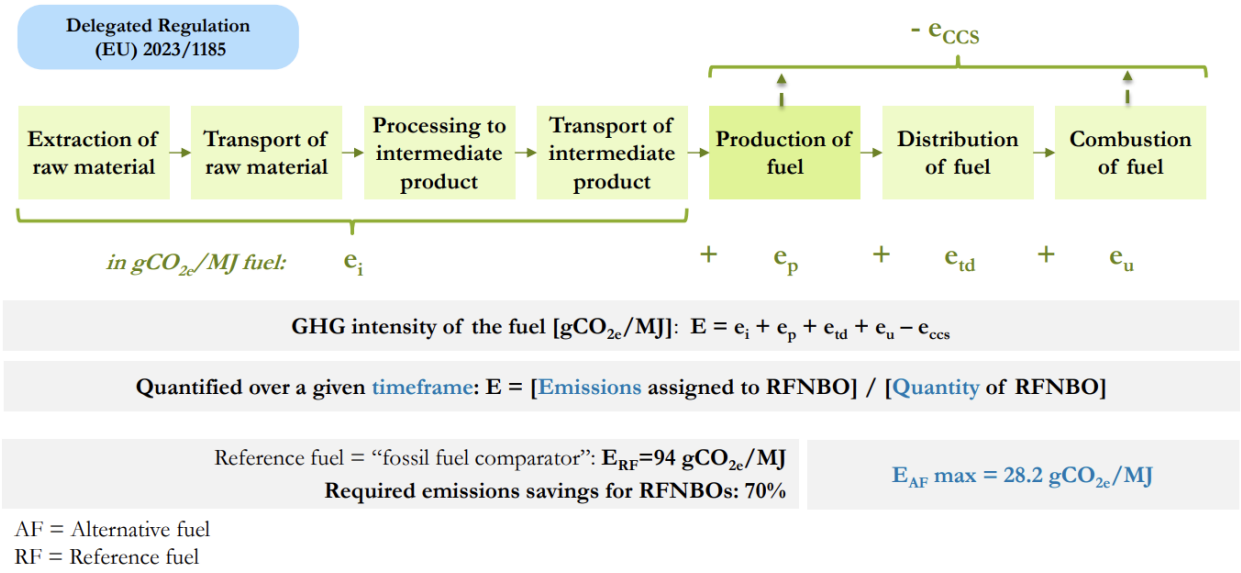


Figure 7: GHG calculation as per RED II framework

Source: https://ptx-hub.org/wp-content/uploads/2026/03/H2Uppp_EU-RFNBO-Compendium_2026.pdf, page 21

3) Electricity qualification: "fully renewable" electricity

The two delegated acts are coupled: electricity qualifying under 2023/1184 can be assigned zero emissions under **2023/1185**; otherwise, non-zero grid emission factors apply. The electricity rules apply inside and outside the EU, but several proof concepts are EU-specific (bidding zones, imbalance settlement periods, ETS-linked price criteria), so third-country compliance often relies on "equivalent concepts" and evolving certification practice.

The grid route is commonly described in four options:

- **IIa) High renewable-share grid:** in bidding zones with >90% average renewable electricity share, grid electricity can be treated as fully renewable, with operation constrained in proportion to renewable share.
- **IIb) Low-emission grid:** in bidding zones with electricity intensity <18 g CO_2-eq/MJ, electricity can be treated as fully renewable if PPAs cover the claimed renewable volume and temporal and geographical correlation are demonstrated. Contracted plants do not need be "new" or unsubsidised.
- **IIc) Curtailment/imbalance periods:** consumption during defined imbalance settlement periods can qualify if it corresponds to curtailed renewables and reduces redispatch; evidence is required from the transmission system operator.
- **IId) Default grid route:** electricity can qualify if all three integrity tests are met:
    - **Additionality:** PPAs or own renewables cover the claimed electricity; renewable plants are "new" (≤36 months older than the RFNBO plant), with defined exceptions; transitional relief applies for RFNBO plants starting before 1 Jan 2028 (deferred elements until 1 Jan 2038).
    - **Temporal correlation:** monthly matching until 31 Dec 2029; hourly matching from 1 Jan 2030; eligible "new" storage can support matching; a price-based route exists for very low day-ahead prices (≤€20/MWh or <0.36× EU ETS allowance price).
    - **Geographical correlation:** same bidding zone (or qualifying interconnected/offshore zones); for interconnected zones, an additional price condition applies; Member States may add criteria for grid planning.

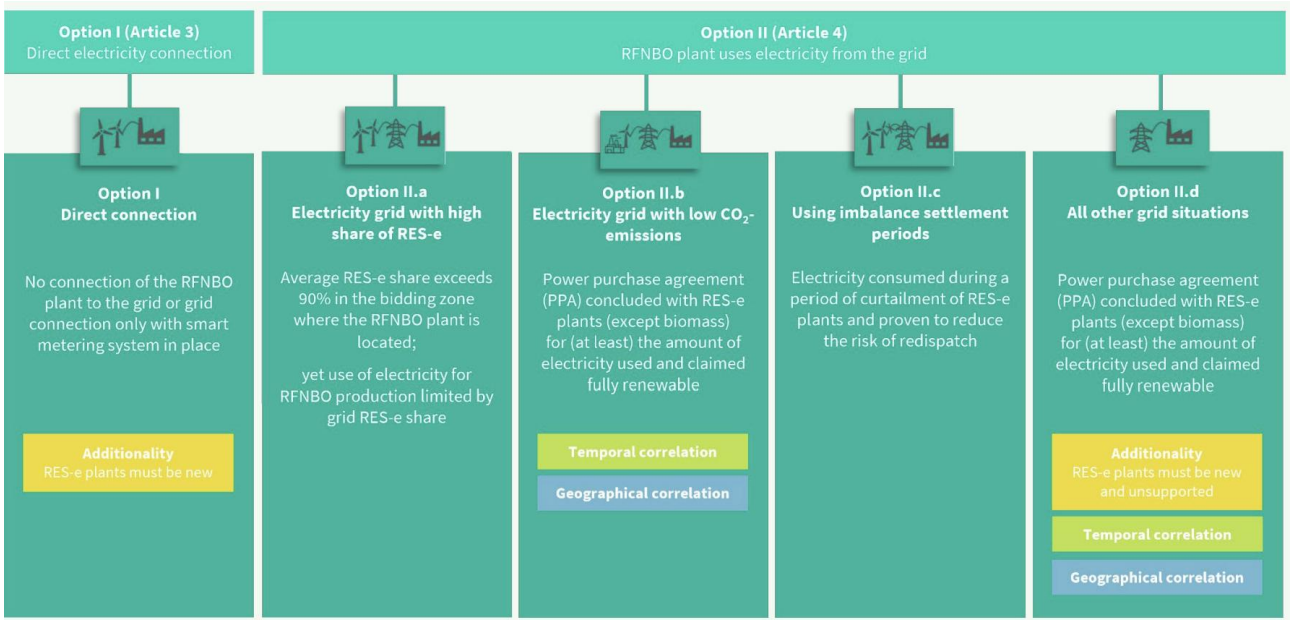


Figure 8: RED conditions for counting electricity as fully renewable

Source: https://ptx-hub.org/wp-content/uploads/2023/04/International-PtX-Hub_EU-Requirements-for-green-hydrogen-and-PtX.pdf, page 10.

4) GHG accounting defaults and data needs (2023/1185)

Electricity: qualifying dedicated renewable electricity is counted at zero. Otherwise, country-level (or bidding-zone) grid emissions including upstream- and generation-related emissions are applied. The directive's Annex provides standard values for common elastic inputs and fuels.

Developers must provide auditable activity data and emission factors for conversion steps, relevant inputs (including CO_2 supply for e-fuels), transport, distribution, and any eligible CCS deductions. For PtX e-fuels, CO_2 origin is compliance-critical: the methodology restricts when "avoided" emissions from captured CO_2 incorporation may be subtracted and specifies eligible carbon source categories for this subtraction[13].

5) Allocation, co-production and co-processing

Where multiple products are produced, the methodology applies energy-content related allocation. Co-products without energy content are allocated based on economic value. When RFNBO production draws on both renewable and non-renewable electricity, the carbon intensity of the output is calculated as a weighted average of all energy inputs.

A detailed discussion of emission allocation for different input- and co-processing cases can be found in the EU RFNBO Certification Compendium (GIZ, 2026, https://ptx-hub.org/wp-content/uploads/2026/03/H2Uppp_EU-RFNBO-Compendium_2026.pdf)

6) Monitoring, Reporting and Verification (MRV)

The European Commission describes RFNBO compliance as certification-based: voluntary schemes and national schemes verify renewable electricity origin and sufficient GHG savings, with an external auditor verifying the production chain. The schemes require traceability, documentation and regular audits.

Voluntary schemes may be recognised by the Commission (typically for 5 years), but Member States can accept other schemes they consider reliable. Recognised voluntary schemes for RFNBO certification include currently CertifyHy, the International Sustainability and Carbon Certification (ISCC EU), and REDcert. The full list of all

[13] More information can be found here: https://ptx-hub.org/publication/identification-carbon-feedstock-ptx-europe/

recognised schemes can be found at https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/voluntary-schemes_en. Further applications are assessed on an ongoing basis.

Operationally, MRV needs robust metering, time-stamped datasets for matching, PPA documentation (volumes, plant commissioning date/support status, bidding zone), and evidence for special routes (Transmission System Operators (TSO) confirmations; market price data).

4.2.4 Roles, responsibilities, and consequences of non-compliance

- **European Commission:** Sets the RFNBO methodologies through delegated legislation, recognises voluntary schemes; it also publishes practical guidance and recognition materials
- **EU Member States' competent authorities:** Enforce the framework nationally.
- **Certification/voluntary schemes (CertifHy, ISCC EU, REDcert-EU):** Operationalise the EU rules into certification procedures, audit protocols, chain-of-custody and documentation requirements, and certificate-management processes; they do not create the substantive EU RFNBO rules themselves.
- **Auditors / certification bodies:** External auditors perform the actual audit and verification of the production chain and evidence; the certification body issues, suspends, or withdraws the certificate. The certification bodies who work under one of the listed certification schemes are usually listed on the certification schemes' website.
- **Producers and counterparties:** Provide the metering, contractual, operational and pathway-specific evidence needed to demonstrate compliance, including power-sourcing and matching data, and in some cases TSO confirmations.

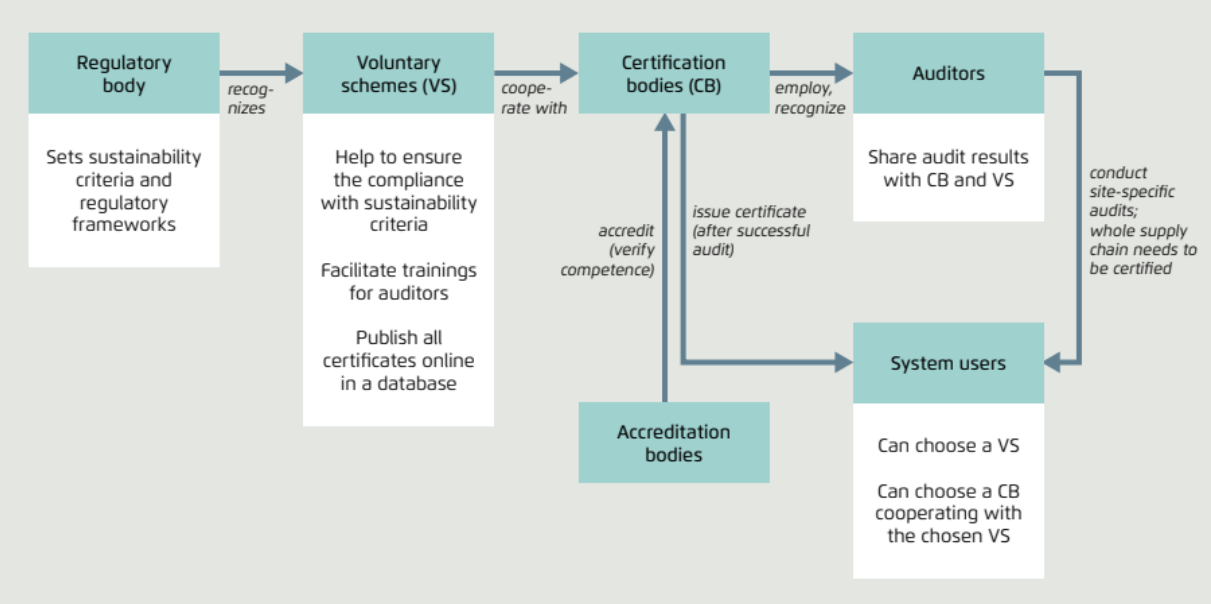


Figure 9: Certification requirements under EU RFNBO

Source: PtX Hub and Agora Verkehrswende (2024), p. 30

If compliance with RFNBO requirements cannot be demonstrated, the product cannot be claimed as RFNBO for EU target counting. As a consequence, it is likely to lose market access or contract eligibility tied to RFNBO status.

4.2.5 Current status

The delegated acts are in place and operational, with staged tightening: temporal correlation shifts from monthly to hourly intervals from 1 January 2030. Additionality has transitional relief for plants starting before 1 January 2028 (deferred elements until 1 Jan 2038). RED III mandates a formal Commission assessment and review by 1 July 2028, meaning that rules may be adjusted as a result.

The certification process around the certification schemes and certification bodies is operational since first RFNBO certificates have already been issued.

4.2.6 Available support instances, resources and authorities

European Commission DG Energy – the primary institutional contact for RFNBO regulatory implementation. Its Renewable Hydrogen page provides an overview of the policy framework, and the dedicated Voluntary Schemes page hosts the current list of Commission-recognised schemes.

Direct downloads of legislation:

- **RED II** – Directive (EU) 2018/2001 of the European Parliament and of the Council (11 December 2018) on the promotion of the use of energy from renewable sources: https://eur-lex.europa.eu/eli/dir/2018/2001/oj/eng
- **RED III** – Directive (EU) 2023/2413 amending RED II (18 October 2023): https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023L2413
- **Delegated Regulation (EU) 2023/1184** – electricity sourcing conditions (additionality, temporal and geographic correlation): https://eur-lex.europa.eu/eli/reg_del/2023/1184/oj/eng
- **Delegated Regulation (EU) 2023/1185** – GHG calculation methodology and 70% savings threshold: https://eur-lex.europa.eu/eli/reg_del/2023/1185/oj/eng

Commission-recognised RFNBO certification schemes – the schemes formally approved by the Commission to issue legally valid sustainability certificates under the RED framework. Currently recognised schemes with RFNBO scope include CertifHy EU RFNBO Scheme, ISCC EU, and REDcert EU. Each scheme publishes its own system documents, audit procedures, and accredited certification body lists. Producers should consult these directly early in project development, as scheme selection has implications for auditor availability and chain-of-custody requirements downstream.

GIZ (International PtX Hub and H2Uppp) technical synthesis documents – GIZ-implemented projects have produced comprehensive technical guidance of the two Delegated Acts from a third-country producer perspective. Key documents are: the main policy brief – a systematic article-by-article analysis of CDR 2023/1184 and 2023/1185 - and the "RFNBO Compendium – summarising key insights from expert workshops and case studies in Non-EU countries" (https://ptx-hub.org/publication/the-rfnbo-compendium-key-insights-from-expert-workshops-and-case-studies-in-non-eu-countries/).

4.3 EU Carbon Border Adjustment Mechanism (EU CBAM)

EU Carbon Border Adjustment Mechanism (EU CBAM)

Geographical and sectoral focus

- Applies to imports of CBAM goods into the customs territory of the European Union (mandatory scheme)
- Initial CBAM goods: hydrogen, fertilisers, cement, iron & steel, aluminium and electricity
- For PtX, the most direct relevance is hydrogen and ammonia (mainly via fertiliser value chains)
- Importers of CBAM goods are the legal entities having the duty to report and comply with CBAM-regulations. This may be the PtX producer, but often is the offtaker of a PtX product.

MRV guidelines / procedures

- Definitive phase from 1 January 2026: first annual CBAM declaration via the CBAM Registry; certificate surrender from 2027
- If actual values are used, embedded emissions must be verified by an accredited verifier
- Installation-level monitoring plan required; operator's emissions report, summary report and declarant-specific information
- Actual values, default values and (for complex goods) mixed actual/default approaches possible under defined conditions

Application: In which context relevant for PtX developer?

- Importing hydrogen into the EU
- Importing ammonia or other hydrogen-derived products under CBAM-covered product chains, especially fertilisers
- Supplying hydrogen as a precursor into other CBAM-covered EU value chains (e.g. iron & steel)
- Providing emissions data requested by EU importers, offtakers and verifiers for pricing and compliance

Authorised certification bodies

- No voluntary certification scheme comparable to the RFNBO voluntary schemes
- Formal compliance actor is the authorised CBAM declarant (typically the EU importer or indirect customs representative)
- Verification carried out by accredited verifiers
- Oversight by Member State competent authorities, customs authorities and the European Commission via the CBAM Registry

Origin and legal base

- Regulation (EU) 2023/956 — establishing the CBAM
- Implementing Reg. (EU) 2023/1773 — transitional-period reporting
- Implementing Reg. (EU) 2025/2547 — methods for calculating embedded emissions
- Implementing Reg. (EU) 2025/2621 — establishing default values
- Verification / accreditation — Implementing Reg. (EU) 2025/2546 & Delegated Reg. (EU) 2025/2551

Timelines and modalities of certification

- Definitive regime started 1 January 2026
- Authorised declarants can purchase CBAM certificates from February 2027 to cover 2026 imports
- Annual CBAM declaration due 31 May each year; first definitive declaration due 30 September 2027 (for 2026 imports)

Implementation status quo

- Legally established; full implementation phase started January 2026, replacing the interim phase
- CBAM financial adjustment phased in progressively from 2026 to 2034
- Detailed calculation methodology and default values adopted December 2025
- Methodological architecture closely aligned with EU ETS monitoring & reporting logic
- Default values to be reviewed by the Commission by December 2027 at the latest

Benefits

- Creates a transparent carbon-cost signal for lower-emission goods, incl. hydrogen and ammonia / PtX exports to the EU
- Lets exporters with robust plant data demonstrate lower actual embedded emissions than conservative default values
- Can strengthen offtake negotiations by making carbon-cost exposure visible and quantifiable
- Encourages alignment of plant data systems with EU-style MRV and verification practice

Key components of methodology

- **Overall logic:** CBAM is not a green-hydrogen certification with a pass/fail threshold — it is a carbon-pricing mechanism where higher embedded emissions mean higher certificate cost
- **Scope / system boundary:** embedded emissions of imported goods — direct emissions and, where applicable, indirect and precursor emissions
- **GHG emissions covered:** product-specific gases under Annex I, expressed as CO_2-equivalent. Hydrogen: only CO_2 and only direct emissions for now. Ammonia (fertilisers): indirect electricity emissions also included
- **Electricity:** ETS-style emission-factor approach ($Em_{el} = E_{el} \times EF_{el}$); no automatic zero-emission treatment just because electricity is renewable

  with Em_{el} = electricity-related emissions, E_{el} = electricity produced / consumed, EF_{el} = applied electricity emission factor. EF_{el} may be the country-of-origin grid average, a lower official grid factor (with reliable evidence), or an actual factor (under strict evidence requirements).
- **Allocation of co-products:** not the RED / RFNBO energy-allocation logic — emissions attributed according to a relevant physical relationship

Challenges

- High installation-level data requirements — especially with multiple precursors, electricity sources or production routes
- Importers as legally responsible entities rely on data from producers and/or exporters of CBAM goods - requires comprehensive data gathering and good collaboration along the whole product chain.
- Parallel reporting may still diverge from RFNBO, ISO or corporate product-carbon-footprint methodologies

4.3.1 Application and purpose

EU CBAM is relevant for PtX producers aiming to place CBAM-covered goods on the EU market – either by exporting from outside the EU to an EU customer, or by importing CBAM goods into the EU (e.g. via an indirect customs representative). The most direct touchpoint is **hydrogen** itself, which is explicitly listed among the initial CBAM sectors - alongside cement, iron and steel, aluminium, fertilisers and electricity (European Commission, 2025a; Umweltbundesamt, 2024). Indirect coverage is given for **ammonia** e.g. in fertiliser production, which can be produced based on renewable hydrogen instead of fossil-fuel (natural gas, coal) derived hydrogen. Hydrogen can also be used for production of green steel, which also leads to an indirect coverage.

CBAM's methodological core is to quantify **"embedded emissions"** in imported goods and apply a carbon price that mirrors the EU Emissions Trading Scheme (EU ETS) carbon cost for comparable domestic production. The aim is to reduce carbon leakage risk, i.e. the relocation of production outside EU boundaries, while encouraging cleaner production in non-EU countries.

CBAM obligations fall on the "authorised CBAM declarant" – an EU-established entity granted that status by the competent authority of its Member State – who must submit the annual CBAM declaration and surrender the corresponding CBAM certificates. Producers of CBAM goods in third countries are not themselves subject to CBAM, but they need to follow the reporting rules if their EU-offtakers want to use actual emissions data instead of default values.

PtX producers are therefore affected in one of two ways: directly, where they (or their corporate group) act as the authorised CBAM declarant; or indirectly, where their EU off-takers act as the declarant and ask the producer to provide verified emissions data – a monitoring plan and an operator's emissions report under Implementing Regulation (EU) 2025/2547 – to substantiate the figures in the CBAM declaration.

4.3.2 Implementation status quo, origin and legal base

CBAM has been established by Regulation (EU) 2023/956. It had a transitional phase running from 1 October 2023 until 31 December 2025, focussing on reporting and learning. The definitive regime started on 1 January 2026. Since then, authorised reporting declarants importing CBAM goods must surrender CBAM certificates corresponding to embedded emissions (European Commission, 2025a; Commission Implementing Regulation (EU) 2023/1773, 2023).

CBAM rules and methods for the calculation of embedded emissions in the definitive period are set out in Commission Implementing Regulation (EU) 2025/2547. It sets out, in its Annexes:

- Annex I: the functional units and system boundaries per aggregated goods category
- Annex II: installation-level monitoring rules including calculation-based and measurement-based methodologies; and the sector-specific provisions for cement clinker, nitric acid, etc.
- Annex III: attribution rules from production processes to goods, and the calculation of specific embedded emissions for complex goods
- Annex IV: template for the operator's emissions report
- Annex V: rules for applying alternative, region-specific default values

In May 2026, the EU published a draft Implementing Regulation setting out the approach for claim a reduction in CBAM certificates to reflect a carbon price already paid abroad, to avoid double payment on the same emissions. According to the draft, the following pillars can be considered:

a) Carbon price paid in third countries. The deduction applies only to a binding tax, levy, fee or ETS, requires actual-value emissions reporting (or the Commission's country-specific default carbon price), and must be netted of rebates and certified independently.
b) Carbon credits used in domestic carbon pricing mechanisms (CPM). Domestic credits count with no extra criteria, while international credits must be issued as Internationally Tradeable Mitigation Outcomes (ITMOs) under Article 6.2 or 6.4 of the Paris Agreement and evidenced via the UNFCCC registries. Such international credits are capped at 10% of reported CPM emissions.

4.3.3 Key components of the methodology

1) Product scope

CBAM applies to imports of a selection of carbon-intensive goods and certain precursors in these sectors: **cement, iron and steel, aluminium, fertilisers, electricity and hydrogen** (European Commission, 2025a; Umweltbundesamt, 2024). As discussed above, for PtX producers not only hydrogen (directly, or indirectly in iron / steel) but also ammonia (fertilisers) is relevant.

2) GHG accounting: embedded emissions of PtX products

CBAM focuses on **embedded emissions associated with the production** of the imported good. It is not a full lifecycle-assessment (LCA) scheme; instead, it is oriented around production processes and installation-level emissions attribution for alignment with the EU ETS MRV logic. The implementing regulation explicitly states that rules for calculating embedded emissions "should be based on the methodology applicable under the EU ETS" (Commission Implementing Regulation (EU) 2023/1773, 2023).

Under CBAM, hydrogen is a direct-emissions-only good, so indirect emissions from electricity used for electrolysis are excluded. For ammonia, which is not treated as a direct-only Annex II good, the ammonia installation's own direct emissions and own electricity-related indirect emissions are included. Where hydrogen is used as a precursor to ammonia, the direct embedded emissions of hydrogen are included, but the indirect electricity emissions of hydrogen are excluded because hydrogen is an Annex II precursor. This applies to electrolytic hydrogen, for which the electrolyser electricity is excluded, while electricity used by the ammonia plant itself remains included. Infrastructure and equipment purchase/maintenance emissions are outside the CBAM system boundary.

The specific embedded emissions of a CBAM good are calculated from the attributed emissions of the production process and the embedded emissions of any precursors, divided by the activity level.

For hydrogen, the master formula based on Annex III §A.3 (equations 55, 57, 58) and Annex III §B (equation 59) are:

$$\mathbf{Attr_{Em_Dir} = Dir_{Em*} + Em_{_H,imp} - Em_{_H,exp} + WG_{_corr,imp} - WG_{_corr,exp} - Em_{_el,prod}}$$

$$\mathbf{Attr_{Em_indir} = Em_{_el,cons}}$$

$$\mathbf{SEE_g = (Attr_{Em_g} + EE_{_InpMat}) / AL_{_g} \quad with \quad EE_InpMat = \Sigma\,(M_i \times SEE_{_i})}$$

With:

SEE_g	Specific embedded emissions of good g, in t CO_2-eq per functional unit (Annex III §B). For hydrogen the functional unit is tonnes of H_2 under CN 2804 10 00 (Annex I §3.6; Article 4(2)).
AttrEm_Dir	Attributed direct emissions of the production process over the reporting period, in t CO_2-eq (Annex III §A.3, eq. 55).
AttrEm_indir	Attributed indirect emissions of the production process over the reporting period, in t CO_2-eq (Annex III §A.3, eq. 56). Applies only to CBAM goods not listed in Annex II to Regulation 2023/956 (Article 3(2)).
DirEm*	Directly attributable emissions of the production process, determined under Annex II point B (combustion and process emissions; calculation-based or measurement-based methodology). For hydrogen, system boundaries are set in Annex I §3.6: SMR / partial oxidation cover all processes linked to H_2 production, separation of H_2 / CO, flue gas cleaning, and all fuels regardless of energetic or non-energetic use; steam cracking covers all processes directly linked to H_2 production and from flue gas cleaning.

Em_H,imp	Emissions equivalent to measurable heat imported into the production process, per Annex III §A.2.2 (eq. 44–52). Heat from exothermic non-combustion processes is assigned zero emissions.
Em_H,exp	Emissions equivalent to measurable heat exported from the production process (Annex III §A.2.2).
WG_corr,imp	Correction term for waste gases imported from other production processes and consumed in this process (Annex III §A.2.3, eq. 53), using the standard natural-gas emission factor.
WG_corr,exp	Correction term for waste gases exported from this production process for consumption elsewhere (Annex III §A.2.3, eq. 54), using the standard natural-gas emission factor and an efficiency correction Corr_η (default 0.667).
Em_el,prod	Emissions equivalent to electricity produced within the production process boundary, per Annex II §D.
Em_el,cons	Emissions equivalent to electricity consumed within the production process boundary, calculated as Em_el = E_el × EF_el (Annex II §D.1, eq. 35). For hydrogen, see Annex II §D.4 – default: country-of-origin grid emission factor (five-year moving average per §D.4.4); actual values only where Annex IV point 6 criteria of Regulation 2023/956 are met (direct technical link or PPA, with hourly smart-meter evidence per §D.4.3).
EE_InpMat	Embedded direct or indirect emissions of all precursors consumed during the reporting period, in t CO_2-eq (Annex III §B, eq. 60). For hydrogen as a standalone good there are no CBAM precursors.
M_i	Mass of precursor i used in the production process, in functional units of precursor i (Annex III §B).
SEE_i	Specific embedded emissions of precursor i, in t CO_2-eq per functional unit of precursor i (Annex III §B).
AL_g	Activity level: total mass of goods leaving the production process during the reporting period, in functional units and in tonnes (Annex II §F).
EF_el	Emission factor for electricity, in t CO_2 / MWh, determined per Annex II §D.2 (imported electricity) or §D.4 (electricity used in producing other goods).
E_el	Electricity produced or consumed, in MWh (Annex II §D.1). Only active power is metered; reactive power disregarded (§D.3).

Notes: all definitions and references below are from Implementing Regulation (EU) 2025/2547. Functional unit for hydrogen: tonnes of H_2 under CN 2804 10 00 (Article 4(2); Annex I §3.6).

Indirect emissions from electricity consumption are to be determined as per equation 35 of Annex II Section D of Implementing Regulation (EU) 2025/2547:

$$\mathbf{Em_{el} = E_{el} \times EF_{el}}$$

Where:

- $\mathbf{E_{el}}$ = electricity consumed (MWh)
- $\mathbf{EF_{el}}$ = emission factor for electricity (t CO_2/MWh)
- $\mathbf{Em_{el}}$ = emissions related to electricity consumption (t CO_2)

Emission factors EF_{el} are determined based on:

- **The average emission factor of the country-of-origin electricity grid**, made available under Annex II of the CBAM Implementing Regulation (EU) 2025/2621 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32025R2621); **or**
- An **alternative default value** where reliable official data shows a lower grid factor; **or**

- **Actual** emission factors. These may only be used if the operator demonstrates a direct technical link to the electricity source or an equivalent PPA. For the direct technical link route, the following preconditions apply: a physical electrical connection between the generator and the CBAM installation, a single-line electrical diagram proving the connection, smart-meter data for generation and delivery, hourly matching, and contractual evidence covering the electricity volume claimed. For the PPA-route, the following preconditions apply: direct PPA with the generator, smart-meter data for generation and delivery, hourly matching, physical connection evidence. Evidence for such must be provided and confirmed by a verifier. Otherwise, the conservative default values must be used.

If an installation producing goods receives electricity from multiple sources, embedded indirect emissions are calculated using a weighted average of the emission factors of each electricity source, weighted by each source's share of total electricity consumed in the installation.

Use of default values for embedded emissions:

In CBAM, the use of default factors/values are a fallback way to quantify embedded emissions when a PtX producer cannot (yet) provide verified actual data. These default factors are deliberately chosen conservatively to avoid underestimating emissions and to preserve environmental integrity.

Annex I of CBAM Implementing Regulation (EU) 2025/2621 provides default values for hydrogen, differentiated by country of origin. For creating an incentive to hydrogen producers to use actual data, the default factors increase over time, with a 10% "mark-up" in 2026, 20% in 2027 and 30% from 2028 onwards. The same Annex I also contains default values for ammonia (specified to CN8 codes) in fertilisers; the annual mark-up is only 1% (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32025R2621).

3) Reporting requirements

CBAM reporting is driven by what the EU importer (or their customs representative) must report. Practically, EU-importers are expected to provide the following information:

- Identification of **installation** and location details (often including coordinates / UN/LOCODE)
- **Production route** classification (technology route)
- **Activity data** for production and energy use relevant to the route
- **Emission factors** used and/or calculation steps per the CBAM Annex approach
- Evidence of any **carbon price paid** in country of origin (where applicable), since the definitive regime allows deductions when importers can prove a carbon price was effectively paid. The European Commission is in the process of adopting the rules under which a carbon price effectively paid can be actually deduced (Commission Implementing Regulation (EU) 2023/1773, 2023; European Commission, 2025a).

Where actual emissions are used, this information must be based on a formal installation-level MRV system in the third country: the operator must prepare a monitoring plan and an operator's emissions report (with summary), both forming part of the verified evidence base disclosed to the EU authorised reporting declarant.

The CBAM Registry guidance indicates structured reporting formats (XSD/XML and XLS templates[14]) that specify mandatory/optional fields and permitted values – an important practical signal that data exchange will become increasingly standardised (European Commission, 2025b).

[14]Direct link for download provided in section 4.5.1of https://taxation-customs.ec.europa.eu/document/download/47322ae4-27c9-49f1-bdb7-2a1fef73d647_en?filename=CBAM-UMN-UI%20manual%20for%20Declarants-Release%201.4.1.1-v1.81.pdf

4) Allocation and co-processing (how multi-output processes are treated)

Where installations produce multiple outputs or precursor chains, a consistent attribution is required so that "attributed emissions of production processes and embedded emissions of goods" can be used for reporting (Commission Implementing Regulation (EU) 2023/1773, 2023).

For hydrogen/PtX developers operating integrated plants (e.g., co-producing steam, oxygen, or intermediate chemicals), the key implication is that allocation of emissions to these different products need to be aligned with the CBAM process-route framework (Commission Implementing Regulation (EU) 2023/1773, 2023).

5) Monitoring, Reporting and Verification (MRV) guidelines and procedures

From 2026, importers importing more than 50 tonnes CBAM goods per year (de-minimis threshold) must apply for authorised CBAM declarant status and must buy and surrender CBAM certificates. The price of CBAM certificate is linked to the EU ETS allowance auction price - averaged quarterly in 2026 and weekly from 2027 (European Commission, 2025a). CBAM declarations for verification are due annually (not quarterly anymore as in the transitional period).

From a supplier standpoint, this raises the commercial stakes of embedded emissions quality: poor data can lead to conservative defaults, higher certificate needs, and tougher negotiations. It also makes internal monitoring systems (metering, calibration, data governance) more valuable because they reduce disputes with importers and auditors/authorities (European Commission, 2025a; European Commission, 2025b).

4.3.4 Roles and responsibilities

- **European Commission (DG TAXUD and others):** designs CBAM operational rules, maintains CBAM Registry infrastructure, publishes guidance and default values, and steers implementing/delegated acts. (European Commission, 2025a; European Commission, 2025b; European Commission, 2023)
- **National Competent Authorities (NCAs):** register declarants for registry access and manage authorisation and enforcement at Member State level; the registry documentation explicitly instructs parties to contact the NCA of the Member State of establishment for access/registration. (European Commission, 2025b)
- CBAM Accredited Verifiers: if importers use actual verified emissions data in their declarations, a verification must be carried out by independent verifiers accredited by EU national accreditation bodies. The accreditation process started; latest information can be found here: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism/cbam-verification_en#national-accreditation-bodies
- **Reporting declarant (EU importer / indirect customs representative):** legally responsible for timely reporting and certificate surrender. The implementing regulation defines "reporting declarant" categories and sets out mandatory reported fields. (Commission Implementing Regulation (EU) 2023/1773, 2023)
- **Third-country installation operators / suppliers (e.g., hydrogen producer):** not the legal declarant in EU law, but operationally responsible for providing credible installation and process emissions data to the declarant – often under contractual obligations. (Commission Implementing Regulation (EU) 2023/1773, 2023)

4.3.5 Consequences of non-compliance

From January 2026 onwards, CBAM-authorised importers ("authorised declarants") who submit their annual CBAM declaration but surrender fewer certificates than required face a penalty of €100 per tonne CO_2 not covered, along with the cost of purchasing and surrendering the missing CBAM certificates. The penalty is inflation-adjusted from the base year, meaning the nominal figure changes slightly over time.

Anyone importing CBAM goods without holding a valid "authorised declarant" status faces a penalty of €300–500 per tonne CO_2-eq. The exact amount within the range will be determined by the relevant NCA, depending on the

circumstances of the unauthorised importing. The penalties apply to the total embedded emissions of all non-compliant imports (https://cbamguide.com/compliance/penalties/).

4.3.6 Current status

CBAM has been operational since 2023 with a phased rollout: a transitional period from 2023–2025 and definitive regime since January 2026.

However, CBAM design and implementation rules will be subject to further development. In December 2025, the European Commission proposed a legislative package to strengthen the CBAM against circumvention, with a key proposal to expand its scope to downstream products starting January 1, 2028. This measure targets steel- and aluminium-intensive goods (e.g., vehicles, machinery) to prevent importers from bypassing CBAM financial adjustments by moving from primary materials to processed goods, alongside introducing anti-avoidance rules for re-routing and minimum transformation.

Other key decisions-to-come include the expansion of the CBAM scope to include other sectors – in particular organic chemicals, polymers (plastics) -, and potentially downstream products like automotive components by 2028.

4.3.7 Available support, resources and authorities

- **European Commission CBAM portal (DG TAXUD):** overview, timelines, guidance packages, and operational procedures for 2026. (European Commission, 2025a)

  Detailed information on reporting tools and requirements can be found here: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en
- **CBAM Registry & Reporting page:** registry access, manuals, quarterly report structures (XSD/XLS), and the list of NCAs: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism/cbam-registry-and-reporting_en
- **PtX Hub** has prepared a CBAM Readiness Toolkit: Preparing for the Definitive EU CBAM Period (https://ptx-hub.org/publication/cbam-readiness-toolkit-preparing-for-the-eu-carbon-border-adjustment-mechanism), and two specific guidance documents on hydrogen and ammonia, which can be accessed here:

  https://ptx-hub.org/wp-content/uploads/2025/12/Hydrogen_Guidance_Document.pdf

  https://ptx-hub.org/wp-content/uploads/2025/12/Fertiliser_Guidance_Document.pdf
- **Deutsche Emissionshandelsstelle (DEHSt**): https://www.dehst.de/DE/Themen/CBAM/cbam_node.html

4.4 Indian Green Hydrogen Certification Scheme

Indian Green Hydrogen Certification Scheme

Geographical or sectoral focus

- India — applies to domestic green hydrogen production facilities
- Currently two eligible production pathways: electrolysis and conversion of biomass
- So far limited to green hydrogen, but expansion to green ammonia and green methanol ongoing

MRV guidelines / procedures

- Project-level MRV: detailed records required for hydrogen output, energy, water, feedstocks, losses and process parameters
- Verification by a BEE-accredited Accredited Carbon Verification (ACV) agency; reports submitted via the Green Hydrogen Certification Portal (GHCP)
- MNRE and/or its designated agency may also conduct random or sample audits

Application: In which context relevant for PtX developer?

- Selling or using green hydrogen in India
- Accessing central or state incentives / concessions, incl. SIGHT-linked support under the National Green Hydrogen Mission
- Applicable to production facilities serving both Indian and export markets
- Exceptions: small plants of ≤ 10 t H_2/year are exempt unless they opt in voluntarily; 100% export-oriented producers not requesting Indian incentives or concessions

Authorised certification bodies

- ACV agencies must be accredited by the Bureau of Energy Efficiency (BEE)
- As of early 2026, BEE publishes a public register of accredited / provisionally accredited ACV agencies (e.g. VKU Certification Pvt. Ltd. and Bureau Veritas India Pvt. Ltd.)

Origin and legal framework

- MNRE Green Hydrogen Standard for India — core threshold of 2.0 kg CO_2eq/kg H_2
- March 2026: thresholds announced for green ammonia (≤ 0.38 kg CO_2eq/kg NH_3) and green methanol (≤ 0.44 kg CO_2eq/kg CH_3OH); MRV rules under development
- MNRE Green Hydrogen Certification Scheme of India (GHCI) — operationalises MRV and certification under the National Green Hydrogen Mission (NGHM)

Timelines & modalities of certification

- **Concept certificate:** voluntary; may be requested after design / concept / FEED approval
- **Facility-level certificate:** mandatory after consent to operate and before provisional or final certificates
- **Provisional certificate:** voluntary, auto-generated; available for periods of 1–11 months within the evaluation cycle
- **Final certificate:** ACV appointed by 31 March; verified data due 30 June. Certificate normally issued by 31 July. Clarification / resubmission round runs until 31 August / 30 September

Implementation status quo

- The scheme is operational
- Methodological refinement continues — in February 2026 MNRE published draft guidelines on emission calculation from off-site water drawal and treatment
- Elaboration of MRV standards for green ammonia and green methanol is ongoing

Benefits

- Creates a domestic compliance and credibility tool for incentives, concessions, public support and market standard
- Enables early-stage risk reduction through concept and facility-level certification before full annual production verification
- Final certificates state the product carbon footprint and support chain-of-custody tracking, with possible future use in India's Carbon Credit Trading Scheme

Key components of methodology

- **Scope / system boundary:** project-level boundary including direct emission sources and indirect emissions from electricity and/or fuel used in production. Onsite water treatment is included, while capital goods, business travel, employee commuting and renewable-electricity generation / transmission are excluded
- **Core metric / threshold:** reported in kg CO_2eq/kg H_2; the annual average non-biogenic emissions must be ≤ 2.0 kg CO_2eq/kg H_2. No sub-grades or tiers — if the annual average exceeds the threshold, none of that year's hydrogen from the facility is certified as green
- **Renewable electricity treatment:** RE may be direct, stored or banked with the grid; qualification is based on renewable sourcing and traceability — not additionality, temporal matching or geographic correlation. PPAs with load-dispatch certificates and green-exchange products, e.g. Green-Day Ahead Market G-DAM) or green tariffs are accepted, while claims based only on RECs or carbon credits are not
- **Allocation / co-products:** emissions allocated by energy content; co-products without calorific value are assigned no emissions

Challenges

- Domestic certification is not automatically sufficient for export markets — projects targeting the EU or other destinations must still comply with those markets' methodologies
- Verification and institutional infrastructure is still maturing
- MRV is data-intensive and operationally demanding, with strong emphasis on evidence for electricity sourcing, metering, process data and annual verification
- Currently centred on hydrogen production. Expansion to ammonia and methanol is under preparation - but current uncertainty for producers as detailed requirements are not finalised yet
- Non-compliance can trigger withdrawal of certificates and temporary loss of eligibility for domestic support

4.4.1 Application and purpose

The Indian Green Hydrogen Certification Scheme (GHCI) is the detailed implementation framework for measuring, monitoring, verifying and certifying green hydrogen under the National Green Hydrogen Mission (NGHM). The scheme is embedded within India's broader strategy to become a global hub for the production, usage, and export of green hydrogen and its derivatives under the NGHM. It operationalises the August 2023 Green Hydrogen Standard for India, which defines green hydrogen as hydrogen produced using renewable energy through electrolysis or conversion of biomass and sets a maximum non-biogenic greenhouse gas intensity of 2.0 kg CO_2-eq/kg H_2, averaged over the previous 12 months (MNRE, 2023; MNRE, 2025a). The scheme is currently under expansion for green ammonia and green methanol.

For PtX developers, the GHCI is relevant when hydrogen is intended for sale or use in India, when a project receives central or state incentives or concessions, or when a facility serves both domestic and export markets. Small facilities producing 10 tonnes per year or less are exempt unless they opt in voluntarily. Producers with 100% export capacity that do not receive incentives or concessions are exempt from the final certificate but must still report quantity and emissions in line with the importing country's requirements.

This implies that for export-oriented projects, GHCI certification alone will not be sufficient for export-market access, and compliance with the importing country's methodology is required. The scheme therefore functions as both a domestic market-access framework and a credibility tool for public support (MNRE, 2025a).

In March 2026, India announced thresholds for green ammonia (max. 0.38 kg CO_2 eq/kg NH_3) and green methanol (max. 0.44 CO_2 eq/kg CH_3OH) to advance implementation of the National Green Hydrogen Mission. Detailed methodologies for the measurement, reporting and verification will be developed by MNRE (MNRE 2026). As they were not yet available at the time of writing this report, the methodologies cannot be addressed in detail.

4.4.2 Legal base and implementation status

The GHCI is issued by the Ministry of New and Renewable Energy (MNRE) through an Office Memorandum under the NGHM, which defines the overall policy framework for green hydrogen development in India. The core threshold of 2.0 kg CO_2-eq/kg H_2 was established in the Green Hydrogen Standard (O.M. No. 353/35/2022-NT, 18 August 2023). The April 2025 revision (MNRE 2025) formally established the certification framework, including governance, MRV requirements, and verification procedures.

Publicly available official materials show that Bureau of Energy Efficiency (BEE) acts as Accreditation Body and has issued the accreditation procedure for Accredited Carbon Verification (ACV) bodies. BEE also maintains a public register of accredited or provisionally accredited ACV agencies under the Carbon Credit Trading Scheme (CCTS). This shows that the verification infrastructure referenced by the GHCI is now being operationalised (MNRE, 2025a; BEE, 2024; BEE, 2026).

To conclude, the scheme is formally established and in the process of full operationalisation, and certification is required for producers to qualify under government procurement programmes and the NGHM Production Linked Incentive (PLI) scheme. In parallel, it is being expanded to accommodate rules for green ammonia and green methanol.

4.4.3 Key components of the methodology

1) Product scope

The scheme operates at project level and currently recognises two eligible hydrogen production pathways: electrolysis and conversion of biomass. The functional unit is 1 kg of hydrogen, and the reporting metric is kg CO_2-eq/kg H_2. To qualify as green hydrogen under the Indian standard, average non-biogenic emissions must be at or below **2.0 kg CO_2-eq/kg H_2** over the applicable evaluation period. GHG performance is assessed over an "evaluation cycle", defined as one financial year (or shorter for new facilities). If the average for a financial year exceeds that threshold, none of the hydrogen produced by that facility during that year can be certified as green (MNRE, 2023; MNRE, 2025a).

2) System boundary

The GHCI adopts a project boundary that covers all direct emission sources and also includes indirect emissions from electricity and heat imported for hydrogen production. For electrolysis, the boundary includes water treatment, electrolysis, gas purification, drying, compression and on-site hydrogen storage. For biomass pathways, it includes biomass processing, heat or steam generation, conversion of biomass to hydrogen, gas purification, drying, compression and on-site storage. Producers may additionally report value chain emissions beyond the defined boundary, but those do not determine core GHCI compliance (MNRE, 2025a).

Several exclusions are explicit. Transport and storage outside plant boundaries, conversion into hydrogen carriers, reconversion and utilisation are outside the accounting scope. Capital goods, business travel, employee commuting, emissions from generation and transmission of renewable electricity, and emissions from withdrawal of water from the natural source are excluded. By contrast, on-site water treatment emissions are included, and off-site inputs brought into the facility boundary must be counted where relevant (MNRE, 2025a).

3) Renewable energy qualification and electricity treatment

Renewable energy under the scheme includes renewable electricity delivered directly, stored in an energy storage system, or banked with the grid in accordance with applicable regulations. Renewable power may be sourced from a renewable energy project and transmitted either through dedicated or common transmission lines. An important design choice is that claims based only on renewable energy certificates or carbon credits are not accepted. However, electricity procured through green tariff mechanisms and power exchange products such as Green Day-Ahead Market (G-DAM) can be considered renewable under the scheme (MNRE, 2023; MNRE, 2025a).

To count electricity as fully renewable, producers must demonstrate contractual linkage and actual generation, typically through PPAs and evidence by load dispatch certificates. Where electricity is not certified as fully renewable, emissions must be calculated using the latest available all-India weighted average grid emission factor (GEF) published by the Central Electricity Authority together with relevant transmission and distribution losses. This approach is materially less granular than the EU RFNBO framework as it does not define specific requirements related to additionality, temporal matching, or geographical correlation (MNRE, 2025a).

4) GHG accounting methodology and data needs

Annexure B sets out the Green Hydrogen Emission Calculation Methodology. For electrolysis, total emissions are calculated as the sum of feedstock supply, electricity supply, fuel supply, steam supply and other input materials, minus any emissions allocated to co-products. Water and steam are treated as feedstocks for the electrolysis pathway. For biomass pathways, the methodology separates upstream process emissions from production-process emissions and again deducts any allocated co-product share (MNRE, 2025a).

The scheme introduces a materiality threshold, whereby individual emission sources contributing less than 1% of the total emission threshold (2.0 kg CO_2-eq/kg H_2) may be excluded, provided that total excluded emissions do not exceed 5% of the threshold. The GHCI currently accounts for CO_2, CH_4 and N_2O emissions only, excluding other greenhouse gases.

The methodology requires robust activity data on hydrogen output, electricity consumption, fuel use, steam use, feedstocks, auxiliary materials, grid factors, losses and co-products. The scheme also states that where a calculation method is not specified in Annexure B, Indian standards and ISO standards such as IS/ISO 14064-1, -2 and -3 and ISO 19870:2023 may apply. This makes the GHCI a hybrid framework: it is nationally specific, but it is designed to remain interoperable with established international accounting practice (MNRE, 2025a).

5) Allocation and co-products

Hydrogen production may result in co-products, and the GHCI allocates emissions to those co-products using an energy-content allocation method. The allocation ratio is based on the energy content of each co-product relative to the total energy output. Co-products without calorific value are not assigned any emissions, e.g. oxygen. For integrated plants producing heat it is relevant, because the allocation rule affects the certified product carbon footprint of hydrogen (MNRE, 2025a).

6) Monitoring, Reporting and Verification (MRV)

The GHCI requires producers to establish a monitoring plan covering emission source streams, activity data, monitoring instruments, calibration procedures, data-control procedures, recording frequency and emission factors. Critical monitoring instruments must be calibrated and certified. Records must be maintained for at least five evaluation cycles, including daily production and energy consumption data as well as key physical and chemical parameters of hydrogen production (MNRE, 2025a).

Verification is carried out by an ACV agency, which producers must engage by 31 March for the respective evaluation cycle. The scheme contains four certificate types:

I. A concept certificate is voluntary and can be sought after design or FEED approval.
II. A facility-level certificate is required after the facility has obtained consent to operate and is effectively the commissioning-stage eligibility certificate.
III. A provisional certificate is voluntary, auto-generated and available for operating periods of at least one month and up to eleven months within the financial year.
IV. The final certificate is the definitive annual certificate; where applicable, it confirms green status for the year, includes the product carbon footprint, and is issued after ACV verification and technical-committee review (MNRE, 2025a).

The certificate may also be used to claim carbon credits under India's CCTS, subject to additional requirements.

4.4.4 Roles and responsibilities

The governance framework comprises MNRE, who acts as the nodal ministry for overall supervision, the Implementing Agency (IA) for operational execution, a Technical Committee chaired by the Mission Director of the NGHM for oversight and certification approval, and ACV agencies to perform independent verification. A Scheme Monitoring Committee (SMC), chaired by the Secretary of MNRE, periodically reviews implementation and recommends improvements to the scheme. Producers themselves remain responsible for registration, monitoring, evidence generation and timely submission of applications and supporting documents through the Green Hydrogen certification portal (MNRE, 2025a).

Non-compliance has explicit consequences: a certificate may be withdrawn if final verified emissions exceed the threshold after a provisional certificate has already been issued, or if a producer that has obtained a provisional certificate fails to apply for the final certificate within the deadline. A first occurrence leads to withdrawal of provisional certification for that cycle. A second occurrence within three years bars the producer from applying for a provisional certificate in the next evaluation cycle and cancels any such certificates already issued. A third or subsequent occurrence allows MNRE to impose additional measures, including barring applications for a defined period. The scheme also allows random or sample audits during or after the evaluation year (MNRE, 2025a).

4.4.5 Available support, resources and authorities

Key official support resources include:

- The Green Hydrogen Standard for India (baseline threshold and definition: https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/08/20230821267798802.pdf),
- The Green Hydrogen Certification Scheme of India (full methodology and procedures: https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2025/05/2025050521076474 02.pdf),
- BEE's ACV accreditation procedure and public ACV register, and
- The National Green Hydrogen Mission portals maintained by MNRE.
- For electricity-related calculations where power is not fully renewable, developers must also draw on Central Electricity Authority grid-emission-factor and transmission-loss data as referenced in Annexure B of the scheme (MNRE, 2023; MNRE, 2025a; BEE, 2024; BEE, 2026).

4.5 South Korea's Clean Hydrogen Certification Scheme

South Korea – Clean Hydrogen Certification Scheme

Geographical or sectoral focus

- National Korean compliance scheme, relevant for both domestic facilities and overseas imports
- Operationally hydrogen-centric: the reporting metric is kg CO_2eq/kg H_2

MRV guidelines / procedures

- Facility verification is required before initial certificate issuance
- On-site facility examination and on-site data examination, followed by review by the operating agency
- Initial certificate holders must submit sufficient verifiable site data within 6 months, then quarterly reports

Application: In which context relevant for PtX developer?

- PtX producers aiming to access the Korean hydrogen bidding market (incl. its price premiums) must comply with the scheme's certification-and-grading framework
- Clean hydrogen is effectively recognised up to 4.00 kg CO_2eq/kg H_2, with tiers 1–4 spanning 0.00–4.00 kg CO_2eq/kg H_2

Authorised certification bodies

- Certification Operating Agency: Korea Energy Economics Institute (KEEI)
- Certification Testing & Evaluation Agencies: Korea Testing Certification Institute (KTC) and Korea Testing & Research Institute (KTR)

Origin and legal framework

- Hydrogen Economy Promotion and Hydrogen Safety Management Act
- Public Notice on the Operation of the Clean Hydrogen Certification Scheme (MOTIE Public Notice No. 2024-39)
- Operational Rules for the Clean Hydrogen Certification Operating Agency (24 April 2025)
- Operational Rules for the Clean Hydrogen Certification Testing and Evaluation Agency (30 May 2025)

Timelines & modalities of certification

- Initial full verification (incl. physical facility inspection) to determine eligibility of the PtX production facility
- Overseas facilities also apply for initial certification and undergo essentially the same process, with some flexibility to accept equivalent forms of evidence (country-specific circumstances)
- During operation: monthly emissions calculation and operational-data documentation; annual inspection evaluation reporting

Implementation status quo

- Legally established and operational; original legislation issued in 2024, operating-agency rules revised April 2025
- Implementation support is active
- Linked to a functioning clean-hydrogen power bidding market — Korea opened the 2025 round with 3,000 GWh/year for hydrogen
- Guidance, support instruments and market practice are still being refined

Benefits

- Creates a clear Korean market-access route for qualifying low-carbon hydrogen and hydrogen-based fuels used in power generation and related applications
- Technology-neutral and tier / grade-based rather than limited to a single production route
- Open to provenly effective CCS
- Usable for domestic production and for overseas facilities / imported hydrogen — highly relevant for exporters

Key components of methodology

- **Scope / system boundary:** Well-to-Gate (feedstock production to hydrogen production). Includes electricity-consumption emissions (e.g. electrolyser) and upstream emissions (e.g. methane leakage / venting along the SMR gas supply). Embedded emissions from manufacturing electrolysers, SMR/ATR plant, pipelines, buildings or other capital equipment are excluded.
- **GHG emissions covered:** CO_2, CH_4, N_2O and HFCs
- **Electricity:** distinguishes direct off-grid low-carbon electricity, grid-transmitted low-carbon electricity under PPAs, and ordinary grid electricity; lifecycle emissions assigned accordingly (incl. transmission & distribution losses). RECs accepted only if on the same grid, generated in the same month and not used for Korea's renewable supply obligation — capped at 10% of monthly renewable-electricity use
- **Allocation of co-products:** multi-output processes use lower-heating-value (LHV) energy allocation
- **CCS:** creditable only if ≥ 90% of the GHG emissions from the hydrogen production facility are captured

Challenges

- High plant-level data burden: robust process data, monthly electricity-matching evidence, site-data verification and detailed documentation for facility changes and continued compliance
- Korea-specific methodology: exporters targeting the EU, Japan or other markets still face parallel compliance and transaction costs (not harmonised with RFNBO, CBAM or other foreign systems)
- Hydrogen-centric metric (kg CO_2eq/kg H_2) — does not by itself provide a full product-carbon-footprint method for derivatives such as ammonia or e-methanol
- Some methodological elements remain transitional or may evolve further

4.5.1 Application and purpose

As early as 2019, South Korea unveiled its Hydrogen Economy Roadmap. In subsequent years, the country introduced several laws to operationalise its targets in alignment with its updated Nationally Determined Contribution (NDC). The South Korean government defined clean power generation as a strategic priority and introduced the Clean Hydrogen Portfolio Standard (CHPS), which is best understood as a market-pull mechanism for hydrogen-based power generation, closely linked to the national Clean Hydrogen Certification Scheme.

The framework combines (i) a certification scheme that determines whether hydrogen or hydrogen compounds qualify as "clean" (i.e. the Clean Hydrogen Certification Scheme), and (ii) a competitive hydrogen power bidding market through which eligible generators can secure long-term contracted revenue for electricity produced with such fuels. This means the certification methodology is not only a carbon-accounting tool, but also an eligibility gate for participation in the hydrogen power market.

In 2024, Korea launched the world's first clean hydrogen power bidding market with 6,500 GWh/year and contract terms of up to 15 years. In 2025, the auction reopened with 3,000 GWh/year, again with 15-year contracts (Kim, 2025). Final selection is based on a combination of price and non-financial criteria, including clean hydrogen grade, fuel supply stability, and industrial/economic contribution. The compensation follows a contract-for-difference approach. In this sense, the principal financial benefit of certification is market access to a long-term, policy-backed revenue stream for qualified hydrogen generation (MOTIE, 2024; MOTIE, 2025).

4.5.2 Legal base and implementation status

The Korean framework rests on four linked laws. First, the *Hydrogen Economy Promotion and Hydrogen Safety Management Act* provides the statutory basis for clean hydrogen certification and related institutional roles. Second, the *Public Notice on the Operation of the Clean Hydrogen Certification Scheme* (MOTIE Notice No. 2024-39) sets the core certification architecture, including definitions, applications, grades, and institutional responsibilities. Third, the *Operational Rules for the Clean Hydrogen Certification Operating Agency* set out the detailed emission-calculation procedures, governance rules, forms, and data requirements. Fourth, associated enforcement instruments and annual hydrogen power bidding notices link certification outcomes to market access (Law.go.kr, 2025; MOTIE, 2024a; KEEI, 2025).

Implementation moved quickly from policy design to operation. MOTIE announced in late 2023 that the clean hydrogen certification system would be rolled out together with the clean hydrogen power market architecture; it designated KEEI as the Certification Operating Agency in December 2023. The Public Notice entered into force on 4 March 2024; and the detailed Operational Rules were enforced on 24 April 2025. In practical terms, the Korean scheme is therefore operational. Compliance is implemented through facility verification, certificate issuance, designated testing and evaluation bodies, and an electronic certification information system (MOTIE, 2023a; MOTIE, 2023b; MOTIE, 2023c; MOTIE, 2024a; KEEI, 2025).

4.5.3 Key components of the methodology

The Clean Hydrogen Certification Scheme is designed to identify and classify hydrogen and hydrogen compounds according to their lifecycle greenhouse gas (GHG) performance and to connect that classification to domestic market instruments.

1) Product scope

The legal scheme applies to the production and import of hydrogen and hydrogen compounds for use as fuels or feedstocks, and the law recognises **clean hydrogen** status through certification. The grading table published under the scheme defines four clean hydrogen tiers/grades, expressed in kg CO_2-eq/kg H_2: Tier 1 = 0.00–0.10; Tier 2 = 0.11–1.00; Tier 3 = 1.01–2.00; and Tier 4 = 2.01–4.00. Products above **4.00 kg CO_2-eq/kg H_2** do not meet the published clean hydrogen certification threshold (MOTIE, 2024a; KEEI, 2025).

For PtX producers, an important nuance is that the overall legal scope is broader than electrolytic hydrogen. H_2 produced from the **cracking of certified blue or green ammonia is eligible** for both general and clean H_2 auctions, making it a viable option across multiple applications (H2Tech, 2026).

2) System boundary and emissions included

As of today, the Operational Rules define the system boundary **as well-to-gate**, running from the procurement of hydrogen feedstocks to the shipment point at the hydrogen production facility. Kim (2026) notes that "emissions from (domestic) transportation are temporarily excluded; however, future policies may expand the scope to a cradle-to-grave approach" (Kim 2026, p. 4). Emissions are calculated at least monthly using global warming potentials from the IPCC Fifth Assessment Report (AR5) 100-year time horizon.

The methodology covers upstream feedstock supply, process fuel supply, electricity supply, heat supply, primary input material supply, direct process emissions, fugitive non-CO_2 emissions, by-product treatment, and carbon capture and storage related emission reductions. It also covers imported hydrogen and hydrogen compounds and includes international transportation in the certification architecture. For overseas facilities, equivalent documentation may be accepted where standard Korean documentation is not available (MOTIE, 2024a; KEEI, 2025).

3) GHG accounting and key emission factors

The master emission formula is:

$$E_{\underline{total}} = [(E_{feedstock\ supply} + E_{energy\ supply} + E_{input\ materials} + E_{process} + E_{fugitive\ non\text{-}CO2} - E_{C\text{-}credit} + E_{C\text{-}tracking}) * AF + E_{CCS\ process} - E_{CO2\ sequestrated}]$$

with:

E_{total}	Total GHG emissions calculated for the hydrogen product under the Korean scheme's overall formula.
$E_{feedstock\ supply}$	Upstream emissions from supplying feedstocks used for hydrogen production, including extraction, processing, storage, and transport.
$E_{energy\ supply}$	Upstream emissions from supplying process energy, i.e. electricity, heat/steam, and fuels used in hydrogen production.
$E_{input\ materials}$	Upstream emissions from non-energy input materials such as water, salt, acids, catalysts, solvents, and similar process inputs.
$E_{process}$	Direct process emissions from hydrogen production, including combustion and non-combustion emissions.
$E_{fugitive\ non\text{-}CO2}$	Fugitive non-CO_2 emissions released during production, such as methane, nitrous oxide, and refrigerants.
$E_{C\text{-}credit}$	Credit for carbon-containing by-products, using system expansion where such by-products displace other market products.
$E_{C\text{-}tracking}$	Emissions tracked from carbon-containing by-products when their carbon is ultimately emitted as GHGs.
AF	Energy allocation factor, used to allocate emissions between hydrogen and non-carbon by-products based on their lower heating value (LHV).
$E_{CCS\ process}$	Emissions from the carbon capture, transport, and storage chain, including capture-related energy use, compression, transport, and injection.
$E_{CO2\ sequestrated\ /\ sequestered}$	Deductible amount of CO_2 that is finally and permanently stored, subject to the scheme's conditions.
LHV	Lower Heating Value: energy content of a fuel excluding the latent heat of water vapour in combustion products.

The scheme combines developer-specific data with standardised default data. Applicants are required to use the "Basic Data Provided" (default emission factors) published by the KEEI. If no suitable Basic Data Provided exist, or if they do not fit the relevant process, applicants may either use adequate comparable data or develop their own

data, subject to prior submission and approval by the Operating Agency. Where sampling and laboratory analysis are used, the results must come from recognised ISO/IEC 17025 laboratories (KEEI, 2025).

Operationally, the required data package is substantial. Expected evidence includes process flow diagrams (PFDs) and/or piping and instrumentation diagrams (PIDs), heat and mass balances, monthly operating plans, efficiency data, input and output balances, information on captured carbon, transport and storage where relevant, and supporting documentation for electricity sourcing and by-product treatment. The quality of the result depends heavily on the project's metering, documentation and mass/energy balance discipline (MOTIE, 2024a; KEEI, 2025).

For pathways involving carbon capture and storage, GHG savings from CCS are recognised only if at least 90% of GHG emissions from the relevant production facility are captured and permanently isolated. The CCS transportation and storage process emissions are included in the system boundary.

The methodology draws on ISO 14040/14044, ISO 14067, ISO/TS 19870:2023, the IPHE Working Paper v3 (July 2023), and the GHG Protocol Corporate and Scope 3 Standards.

4) Electricity sourcing and temporal matching

Korea does not use a detailed additionality/temporal/geographic correlation framework for electricity qualification as the EU RFNBO framework. For electrolysis-based hydrogen, electricity sourced from low-carbon sources must be matched to production on a monthly basis (Article 9). The monthly consumption at the facility must match the monthly generation from the connected low-carbon source. REC-based renewable energy crediting is permitted but is capped at 10% of monthly renewable electricity consumption (Article 10), and only under specified conditions such as same-grid and same-month linkage. Renewable electricity is assigned a lifecycle emission intensity of zero (LCI), while grid electricity, nuclear electricity and other energy sources are handled through specified emission factors or formula-based calculations. Producers must submit supporting documentation and demonstrate that feedstock/fuel inputs and hydrogen outputs balance monthly (MOTIE, 2024a; KEEI, 2025).

5) Allocation, co-production and co-processing

Where by-products are produced simultaneously with hydrogen, emissions must be treated according to Form 1 of the Operational Rules. The methodology distinguishes between carbon-containing by-products and non-carbon by-products. Carbon-containing by-products are handled through a system-expansion and carbon-tracking logic, while non-carbon by-products are allocated using energy allocation based on lower heating value (LHV). For heat or steam sold outside the process, the methodology uses an existing concept that includes Carnot efficiency logic (KEEI, 2025).

The annex also includes specific treatment for projects directly linked to ammonia synthesis, including purity conditions and rules on energy returned from ammonia synthesis to hydrogen production. Accordingly, developers should expect Korea's scheme to scrutinise co-product handling (KEEI, 2025).

6) Monitoring, Reporting and Verification (MRV)

Independent Certification Testing and Evaluation Agencies, which are designated by the Certification Operating Agency, have to conduct on-site facility examinations, on-site data examinations, and issue an Evaluation Results Report. For projects at design stage, a preliminary review consulting process is available to test likely compliance before final investment and construction decisions. Annual certification applications must be accompanied by an Application Technical Description and supporting process data. Facility Verification Certificates specify the certified emission intensity; temporary changes to facility parameters must be promptly notified (MOTIE, 2024a; KEEI, 2025).

4.5.4 Roles and responsibilities

- **Ministry of Trade, Industry and Energy (MOTIE):** provides the statutory and administrative basis for the scheme, issues the public notice, designates the operating agency and testing/evaluation agencies, and links certification to related hydrogen power market instruments (MOTIE, 2023a; MOTIE, 2023b; MOTIE, 2023c; MOTIE, 2024a).
- **Certification Operating Agency (currently KEEI):** operates and manages the certification scheme, receives applications, issues facility verification certificates and clean hydrogen certificates, determines tiers, runs the committee and working body, develops and manages data and systems, and operates the certification information system (MOTIE, 2024a; KEEI, 2025).
- **Certification Testing and Evaluation Agencies:** review technical completeness, undertake on-site facility and data examinations, verify lifecycle calculations, and support maintenance and post-verification review functions (MOTIE, 2024a; KEEI, 2025).
- **Deliberation Committee / Working Body:** review major operational issues, issuance and changes of facility verification certificates, revocation-related matters, fee-setting questions, and amendments to operating rules (KEEI, 2025).
- **Applicants / producers / importers and counterparties:** must provide accurate and timely data, cooperate with evidence requests, maintain the verified operating conditions, and notify temporary changes that could affect verification or certification outcomes (MOTIE, 2024a; KEEI, 2025).

If compliance cannot be demonstrated, the project may be asked to supplement its application, may fail facility verification, or may be unable to obtain or retain clean hydrogen certification. In market terms, the most material consequence is likely loss of eligibility for Korean clean-hydrogen claims and loss of access to clean-hydrogen-specific demand channels such as the clean hydrogen power bidding market, where the 4 kg CO_2-eq/kg H_2 threshold is the entry gate. Non-compliance therefore has commercial consequences, even where the project remains technically operable (MOTIE, 2024a; MOTIE, 2024b; MOTIE, 2024c; KEEI, 2025).

4.5.5 Available support and resources

Key official support resources include:

- The Hydrogen Economy Promotion and Hydrogen Safety Management Act (statutory basis),
- The Public Notice on the Operation of the Clean Hydrogen Certification Scheme (full certification methodology and procedures),
- The Operational Rules for the Clean Hydrogen Certification Operating Agency,
- KEEI's certification portal, including its related laws and regulations, application procedure and certification criteria pages, together with the Basic Data Provided (default emission factors), fee schedules and certification guidance,
- MOTIE press releases for implementation updates and market context: rolling out the clean hydrogen certification system, launching the world's first clean hydrogen power bidding market and opening the hydrogen power bidding market for 2025, and
- The Korea Power Exchange (KPX) as the relevant authority for auction and market-operation information, including the KPX homepage (Law.go.kr, 2025; MOTIE, 2023a; MOTIE, 2023b; MOTIE, 2024a; KEEI, 2025).

4.6 Japan's Hydrogen Strategy & Framework

Japan was the first country to formulate a national hydrogen strategy, adopting the Basic Hydrogen Strategy in 2017. In the revised 2023 strategy, the government set concrete scaling targets. Japan aims to use up to 3 million tonnes of hydrogen and ammonia by 2030, 12 million tonnes by 2040, and approximately 20 million tonnes by 2050. The Hydrogen Society Promotion Act of 2024 operationalises this strategic approach.

4.6.1 Application and purpose

Japan's hydrogen strategy can be seen as a low-carbon hydrogen and derivatives eligibility and market-creation regime rather than as a standard. Its central purpose is to strategically accelerate large-scale hydrogen supply chains for securing safe energy supply, for bringing down costs, for achieving carbon neutrality and for transitioning to a hydrogen-based society (METI, 2003). It offers public support for PtX products meeting carbon-intensity thresholds.

For PtX producers, the framework is relevant where hydrogen, ammonia or other hydrogen-derived fuels are intended for the Japanese market, where price premiums can be achieved under an approved supply-demand chain (Ministry of Economy, Trade and Industry, 2024; Agency for Natural Resources and Energy, 2025). The Japan Organisation for Metals and Energy Security (JOGMEC) administers the contracts-for-difference (CfD) scheme. The CfD Scheme tackles the price gap between low carbon hydrogen and conventional fuel by providing subsidies, covering the price gap for a term of up to 15 years. PtX products aiming at such CfD contracts must be below the defined maximum carbon intensities, differentiated by fuel.

4.6.2 Legal base and implementation status quo

The legal basis is the Act on Promotion of Supply and Utilisation of Low-Carbon Hydrogen and its Derivatives for Smooth Transition to a Decarbonised, Growth-Oriented Economic Structure, commonly referred to as the Hydrogen Society Promotion Act. The bill was approved by the Cabinet in February 2024. It establishes the basic policy framework, a business-plan approval scheme, support measures for approved projects and standards for suppliers of low-carbon hydrogen and derivatives (Ministry of Economy, Trade and Industry, 2024; Agency for Natural Resources and Energy, 2025; Agency for Natural Resources and Energy, n.d.).

In 2023, Japan's Organisation for Metals and Energy Security (JOGMEC) published the second version of the "Recommended Guideline for Greenhouse Gas and Carbon Intensity Accounting Frameworks for LNG/Hydrogen/Ammonia Projects" (https://www.jogmec.go.jp/content/300384406.pdf). It builds on ISO 14067, PAS 2050, the GHG Protocol Product Standard, the API Compendium, GIIGNL MRV guidance for LNG, IPHE hydrogen methodology work, and Japanese LCA guidance for hydrogen supply chains (JOGMEC, 2023).

4.6.3 Key components of the methodology and scheme

1) Product scope

Japan's Basic Hydrogen Strategy covers not only hydrogen itself but also hydrogen derivatives - including ammonia, e-methane and e-fuels. Qualification as "low-carbon" hydrogen / PtX has two elements: first, the amount of CO_2 emitted during production must remain below a fuel-specific threshold; second, use of the fuel must contribute to reducing CO_2 emissions in Japan. This second criterion is particularly important for fuels such as e-methane and e-fuels that may still emit CO_2 at the point of use (Ministry of Justice, Japan, n.d.; Agency for Natural Resources and Energy, 2025).

2) Carbon-intensity thresholds and system boundary

For low-carbon hydrogen, Japan's Basic Hydrogen Strategy sets a target carbon intensity of **max. 3.4 kg CO_2 /kg hydrogen**, measured from **well-to-gate**. For ammonia, a threshold of **0.84 kg CO_2-eq / kg NH_3** applies, for e-methane 49.3 g CO_2-eq/MJ , and for other e-fuels 39.9 g CO_2-eq/MJ (Norton Rose Fulbright, 2025).

The Strategy also notes that these definitions may be revised in light of future technological progress. In parallel, these standards are intended to be aligned with international levels, broadly equivalent to an approximate 70% reduction from grey hydrogen produced from fossil fuels (Ministerial Council on Renewable Energy, Hydrogen and Related Issues, 2023, p. 16; Agency for Natural Resources and Energy, 2025).

4) GHG accounting

The Guideline for Greenhouse Gas and Carbon Intensity (CI) Accounting applies a product carbon footprint logic. CI is obtained by dividing net product GHG emissions by the product energy content or weight (JOGMEC, 2023):

$$CI_{\text{product}} = \frac{E_{\text{product}} - R_{\text{GHG}}}{Q_{\text{product}}}$$

With

$CI_{product}$ = Carbon Intensity of product

$E_{product}$ = GHG emissions of production, covering feedstock production, feedstock transport and production processes

R_{GHG} = Reductions of GHG

$Q_{product}$ = Product energy content or product weight

Product GHG emissions are grouped into feedstock production, feedstock transport and production processes. GHG emissions in each process between the production of feedstock and the shipping point (**well-to-gate**) in the product manufacturing facility are included in the system boundaries. Contrary to this storage, transportation, and supply after the shipping point (gate) of the product manufacturing facility, and processes related to the consumption area are not covered. JOGMEC recommends reporting CI on both an LHV energy basis (for example MJ or MMBtu) and a mass basis (metric ton) to improve transparency and comparability.

If natural gas-based hydrogen production involves CCS, emission reductions from CCS can be considered if done methodologically correct. By contrast, potential emission reductions from Carbon Capture and Utilisation (CCU) are not eligible. The methodology also discusses the option to acknowledge carbon credits in the CI calculation but does not yet conclude – further studies will be done. The general view is that "carbon credits that are created based on appropriate methodologies and management, such as international credit mechanisms, are legalised in many countries and regions and may be given a certain degree of credibility (JOGMEC, 2023, p. 52).

3) Quantification of indirect emissions / electricity consumption

For hydrogen, the guideline distinguishes two main production routes: hydrogen from natural gas feedstock and hydrogen from water electrolysis using renewable energy-derived electricity. For natural gas-based hydrogen, the emissions from natural gas generation through SMR or ATR and all conversion steps to obtain the hydrogen product are to be considered. For electrolysis-based hydrogen, indirect emissions from electricity, heat and steam are included in the accounting framework. Where available, project-specific supplier emission factors are preferred; otherwise, general emission factors based on the production process of electricity, heat and steam may be used (JOGMEC, 2023).

4) Certification and approval requirements

It should be noted that the JOGMEC CI Guideline is a "recommended guideline" for calculating GHG emissions and carbon intensity, and one aims for cooperation with Guarantee of Origin and certification mechanisms in different countries or regions. But it does not itself establish a mandatory independent certification/audit regime for CI calculations.

However, under Japan's Hydrogen Society Promotion Act a government approval / certification process for suppliers and business plans is foreseen. The Act creates a business-plan approval scheme for suppliers and users of low-carbon hydrogen and derivatives, and support measures are tied to businesses that receive that approval. The law also provides for METI to set conduct standards for hydrogen suppliers.

5) Current status

As of March 2026, Japan's framework is operational. The Hydrogen Society Promotion Act is in force, and the administration is publishing information on approved supply plans and updated support rules. In February 2026, JOGMEC announced that the first price-gap subsidies were granted to JERA for supplying low-carbon ammonia produced in Louisiana to Hekinan Thermal Power Station (Agency for Natural Resources and Energy, n.d.; Japan Organisation for Metals and Energy Security, 2026).

4.6.4 Responsibilities and information sources

The Ministry of Economy, Trade and Industry (METI) and the Agency for Natural Resources and Energy (ANRE) set the overall policy framework, while Japan's Organisation for Metals and Energy Security (JOGMEC) administers the main financial support instruments. Suppliers and users are expected to cooperate in preparing the joint plan where support is sought, and suppliers must be able to demonstrate that the relevant fuel chain qualifies as low carbon under the applicable criteria.

Further information can be obtained at:

https://www.jogmec.go.jp/content/300384406.pdf

https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/20230606_5.pdf

4.7 Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation

Geographical or sectoral focus

- Global sectoral scheme for international civil aviation
- Applies to international flights between participating States; does not cover domestic aviation
- ca. 130 States participate in 2026

MRV guidelines / procedures

- Annual CO_2 monitoring, reporting and verification with fixed timelines:
- Verified Emissions Report sent from operator to State by 30 April of the following year
- State submits annual verified emissions data to ICAO by 31 July
- State informs operator of annual offsetting requirements by 30 November
- Offsetting with eligible carbon credits done in 3-year intervals
- Use of CEF reduces the number of carbon credits the operator must cancel, not the gross reported flight emissions
- CEF claims use a supplementary CEF reporting template; claim information must be verified

Application: In which context relevant for PtX producer?

- Relevant for e-SAF / biogenic SAF / synthetic jet fuel producers targeting airlines or aviation fuel suppliers
- Not a general hydrogen / ammonia product standard
- Relevant where airlines want to reduce CORSIA offsetting requirements through verified fuel use (CORSIA eligible fuels, CEF)
- Project must fit an eligible pathway and certified supply chain

Authorised certification schemes / bodies

- Fuel certification runs through ICAO-approved Sustainability Certification Schemes (SCS)
- SCSs work through certification bodies / auditors and batch-level chain-of-custody processes
- Approved SCSs published by ICAO: ISCC, RSB, ClassNK SCS

Origin and legal framework

- CORSIA aims to achieve carbon-neutral growth of international aviation; operators must monitor, report and verify CO_2 emissions from covered flights and offset emissions above the baseline via eligible carbon credits. Using low-carbon CORSIA eligible fuels (CEF) reduces this offset obligation.
- **ICAO Assembly Resolution A42-22** — political mandate and high-level design (phasing, baseline/offsetting, participation, review)
- **CORSIA SARPs** — binding technical standards implemented in national rules (MRV, offsetting, eligible fuels & emissions units, reporting, compliance)
- **Environmental Technical Manual, Doc 9501 Vol IV** — detailed implementation guidance for demonstrating compliance
- **ICAO Documents 04, 05, 06, 07** — operationalise CEF certification & crediting; Document 07 provides the methodology for actual life-cycle emissions values

Timelines & modalities

- Pilot phase: 2021–2023
- First phase: 2024–2026
- Second phase: 2027–2035
- Three-year compliance periods in second phase: 2027–2029; 2030–2032; 2033–2035
- Reporting timelines for 2025 emissions: operator to State by 30 Apr 2026; State to ICAO by 31 Jul 2026; operator notified by 30 Nov 2026

Implementation status quo

- MRV system has been in operation since 2019
- Offsetting phase started in 2021
- Fuel sustainability and LCA implementation documents were updated in November 2025 and are in effect

Benefits

- Direct aviation-sector compliance relevance
- Can support airline offtake and bankability for e-SAF projects
- For offtaker: reduces an airline operator's total final offsetting requirement within a compliance period
- The lower the carbon intensity of the PtX, the higher the economic benefit

Key components of methodology

- **Overall logic:** GHG performance of the CEF is expressed as a life-cycle emissions value (LCEF) in gCO_2e/MJ, LHV basis
- **Calculation routes:** a) ICAO default value or b) actual value under the actual-LCA methodology (ICAO Doc 07)

  Formula: LCEF = core LCA value + ILUC − emission credits, with LCEF = life-cycle emissions (gCO_2e/MJ), LCA = life-cycle-assessment emissions, ILUC = induced land-use change.
- **System boundary:** well-to-wake
- **GHGs covered:** CO_2, CH_4 and N_2O using 100-year GWPs
- **Electricity:** electricity for fuel synthesis, hydrogen intermediates and carbon capture is included
- **Threshold:** at least 10% life-cycle GHG reduction versus the 89 gCO_2e/MJ aviation-fuel baseline to qualify as CEF

Challenges

- Applicable only for aviation fuel pathways, not for PtX products more broadly
- Certification and documentation effort is high at operator- and PtX-producer level

4.7.1 Application and purpose

CORSIA is the International Civil Aviation Organisation (ICAO) market-based measure for international aviation. Its primary purpose is to address the growth in CO_2 emissions from international aviation beyond 2019 levels, in support of the sector's long-term aspirational goal (LTAG) of achieving net-zero CO_2 emissions by 2050.

CORSIA is not a GHG calculation standard for PtX production per se, but it defines the lifecycle GHG accounting rules under which low-emission fuels can generate CORSIA Eligible Fuel (CEF) credits that airlines use to fulfil their offsetting obligations. CORSIA differentiates between "CORSIA Sustainable Fuels (SAF)" – renewable or biogenic/waste-derived aviation fuels – and "CORSIA Lower Carbon Aviation Fuels (LCAF)" – fossil-based aviation fuels with lower life-cycle emissions than regular fossil fuels. Precondition for acceptance as CEF is a reduction of at least 10% compared conventional jet fuel on a life-cycle basis.

For PtX producers targeting aviation markets, CORSIA is the key compliance framework governing the commercial value of e-kerosene and other drop-in eSAF. Fuel certified as CEF under a recognised sustainability certification scheme can be used by airlines to reduce their CORSIA offsetting obligations on a tonne-for-tonne basis, creating a direct price premium for low-carbon SAF.

4.7.2 Legal base and implementation status

CORSIA was adopted by the ICAO Assembly in 2016. Implementation follows a phased structure: a Pilot Phase (2021–2023) with voluntary participation; a First Phase (2024–2026), also voluntary; and a Second Phase (2027–2035) which is mandatory for states accounting for ≥0.5% of international revenue tonne-kilometres (RTKs) in 2018. Ca. 130 states, accounting for more than 85% of international aviation activity, participate as of early 2026. CORSIA applies only to international aviation; domestic aviation is excluded.

The lifecycle GHG methodology for SAF is defined in *ICAO Document 10011 (CORSIA Sustainability Criteria, CSC)* and the associated *CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels*, updated periodically. The SAF LCA methodology was developed in alignment with ISO 14040/14044. As of 2024, ICAO has approved dedicated lifecycle values for multiple Power-to-Liquid (PtL) pathways, including those using CO_2 from direct air capture (DAC) and industrial point sources.

4.7.3 Key components of the methodology

1) Product scope

CORSIA applies to aviation fuels used on international flights covered by the scheme. SAF categories eligible under CORSIA include all ASTM[15]-approved SAF routes: Hydroprocessed Esters and Fatty Acids (HEFA); Fischer-Tropsch synthetic kerosene (FT-SPK), which includes PtL routes; alcohol-to-jet (ATJ); and co-processed fuels. In July 2026, ASTM also approved the Methanol-to-Jet (MTJ) pathway.

For PtX producers, the primary pathways are FT-SPK via the Power-to-Liquid route - renewable hydrogen combined with captured CO_2 to produce synthetic jet fuel via the Fischer-Tropsch process – and the MTJ pathway – using e-methanol or bio-methanol for eSAF production.

2) System boundary

The CORSIA LCA methodology uses a **well-to-wake system boundary**, covering feedstock acquisition/production (including electricity generation and CO_2-capture); fuel conversion and processing; transport and distribution to the airport fuelling point; and combustion on board the aircraft.

The functional unit is expressed in **g CO_2-eq/MJ** of fuel (LHV basis). For PtL, the fate of the CO_2-feedstock upon combustion is central: if sourced from direct air capture (DAC), combustion re-releases the same CO_2-previously removed from the atmosphere, resulting in near-zero net CO_2-emissions. If CO_2 is sourced from an industrial point source, only a partial credit applies, as the origin of the CO_2 was fossil.

[15] American Society for Testing and Materials

3) GHG accounting and threshold

Under CORSIA, the fossil fuel baseline for aviation fuel is 89 g CO_2 eq/MJ (LHV). To qualify as a CORSIA Eligible Fuel (CEF), a SAF must achieve lifecycle GHG emission savings of at least 10% compared to this baseline – i.e., a maximum lifecycle GHG value of **80.1 g CO_2-eq/MJ**. CEFs include both SAF and LCAF; the latter is specifically fossil-based aviation fuel that meets the CORSIA sustainability criteria.

GHGs covered include CO_2, CH_4, and N_2O (using GWP100 per IPCC AR5). Non-CO_2 aviation climate effects (contrail forcing) are excluded. For PtL using DAC-sourced CO_2 and near-zero-carbon electricity, CORSIA default lifecycle values are typically in the range of 5–15 g CO_2 eq/MJ, representing savings of over 80% compared to fossil jet fuel. For PtL using industrial point-source CO_2, lifecycle values are higher, depending on the emission intensity of the source.

SAF suppliers can use approved default values for a given production pathway instead of installation-specific values without penalties (unlike CBAM, which imposes an escalating mark-up on default values to incentivise actual data). However, the defaults are chosen conservatively, so that a producer of bio-based SAF with a cleaner-than-average supply chain has a commercial incentive to calculate actual values, since a lower LCEF generates more offsetting credit per tonne for the airline buyer, commanding a higher price.

Default values are provided for many feedstock pathways, but not yet for Fischer-Tropsch (FT) based PtX. Although CO_2-FT is a recognised ASTM D7566 Annex A1 conversion process, ICAO has not yet assigned a default lifecycle value for this pathway (approval expected in 2026–2027). Producers must use actual lifecycle values calculated per the ICAO methodology for actual LCA values, verified through an approved CORSIA certification scheme. The same applies to innovative approaches such as Methanol-to-Jet (MtJ) fuels.

In short:

- **Actual values** must be calculated in line with the ICAO document **CORSIA Methodology for Calculating Actual Life Cycle Emissions Values**
- **Default values** are set in the separate ICAO document **CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels**
- The technical background for adding or maintaining default values sits in the ICAO supporting document **CORSIA Eligible Fuels – Life Cycle Assessment Methodology**

4) Electricity sourcing

CORSIA has a detailed, standalone electricity sourcing framework (Section 10 of the "CORSIA methodology for calculating actual life cycle emissions values"). The rules are structured around three requirements – deliverability, temporal matching, and additionality – and are similar to the EU RFNBO framework.

- *Deliverability* requires that the electricity generation facility and the CEF production facility are in the same transmission network (managed by the same TSO), or in the same or a neighbouring interconnected electricity market region with equal or higher electricity prices. This is broadly equivalent to RFNBO's geographic correlation rule.
- *Temporal matching* starts at annual matching (until 31 December 2029) and transitions to hourly matching from 1 January 2030 – but only if the network meets specific "readiness conditions" (the presence of an EAC scheme with hourly issuance/clearing capability and hourly metering at both the generation and CEF production facility). If the network is not ready, annual matching continues until readiness is achieved. There is also a de minimis exemption: if electricity is less than 7.5% of total input energy, the matching period is the lifetime of the sourcing arrangement or annual, whichever is longer.
- *Additionality* requires that electricity generation or storage capacity came into operation no earlier than 36 months before the CEF production facility – the same ⩽36-month rule as RFNBO. Subsidised capacity earmarked for other end uses (e.g. grid decarbonisation) cannot be claimed as additional. CEF facilities coming into operation before 2028 are exempt from additionality requirements until end of CORSIA Phase 2 (31 December 2035) – a transitional relief equivalent to RFNBO's deferred additionality elements for plants starting before 1 January 2028.

- If electricity is sourced from a highly decarbonised grid, the document notes that strict hourly matching and additionality requirements may not be necessary, but details for these rules have yet to be developed. Grid average emissions can also be claimed as a fallback, in which case deliverability, temporal matching, and additionality requirements do not apply, but the grid's emission factor is used in the LCA calculation.

5) Monitoring, Reporting and Verification (MRV)

CEFs shall come from fuel producers that are certified by a Sustainability Certification Scheme (SCS) authorised by the ICAO Council. CORSIA does not operate its own direct verification infrastructure. Instead, ICAO approves sustainability certification schemes through which producers demonstrate conformity.

Approved schemes include:

- International Sustainability and Carbon Certification (ISCC), approved 10/2020, Website: https://www.iscc-system.org/about/sustainable-aviation-fuels/corsia/.
- Roundtable on Sustainable Biomaterials (RSB), approved 10/2020. Website: https://rsb.org/rsb-corsia-certification/
- **ClassNK** Approved: 10/2024 Website: https://www.classnk.or.jp/hp/en/authentication/scs/index.html.

These schemes verify feedstock sustainability, chain of custody, and lifecycle GHG calculations. Only SAF certified under an ICAO-approved scheme qualifies as a CORSIA Eligible Fuel. Airlines report SAF use to their national civil aviation authority, which reports to ICAO. SAF volumes are cross-checked against the ICAO CORSIA Fuel Monitoring System (CFMS).

4.7.4 Roles and responsibilities

- **ICAO:** governs CORSIA through its Assembly and Committee on Aviation Environmental Protection (CAEP); maintains the CORSIA Implementation Elements; updates eligible fuel documents, including SAF life-cycle values; and approves Sustainability Certification Schemes (SCSs).
- **National civil aviation authorities:** register airlines, collect annual emissions reports, review verified reports, notify operators of their CORSIA offsetting requirements, and enforce compliance under national implementing rules.
- **SAF producers and other CORSIA eligible fuel economic operators:** obtain certification under an ICAO-approved SCS, demonstrate compliance with the applicable CORSIA sustainability criteria and life-cycle emissions methodology, and provide batch-level and chain-of-custody documentation to airlines so that CEF-related emissions reductions can be claimed.
- **Sustainability Certification Schemes (SCSs):** ICAO-approved SCSs certify CORSIA eligible fuel economic operators for compliance with the *CORSIA Sustainability Criteria for CORSIA Eligible Fuels* and ensure that the methodology for calculating actual life-cycle emissions values has been applied correctly. The currently ICAO-approved SCSs are ISCC, RSB and ClassNK SCS, with the scope of approval depending on the scheme.
- **Certification bodies and auditors:** conduct the independent conformity assessments under the rules of the relevant ICAO-approved SCS. They audit fuel producers and other economic operators in the supply chain, check sustainability and chain-of-custody evidence, verify the data used for CORSIA eligible fuel certification, and issue or support the issuance of certificates in accordance with the approved SCS procedures.
- **Aeroplane operators:** purchase and use CORSIA eligible fuels, retain the required sustainability and chain-of-custody documentation, report CEF claims in their annual CORSIA reporting, and use certified CEF emissions reductions to reduce their CORSIA offsetting requirements.

4.7.5 Available support and resources

- CORSIA SAF Sustainability Criteria and Lifecycle Values is the primary technical reference, available at https://www.icao.int/environmental-protection/CORSIA,
- CORSIA Methodology for Calculating Actual Life Cycle Emissions Values: https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Fuels/ICAO-document-07-Methodology-for-Actual-Life-Cycle-Emissions-November-2025.pdf
- CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels: https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Fuels/ICAO-document-06-Default-Life-Cycle-Emissions-November-2025.pdf
- CORSIA Eligible Fuels - Life Cycle Assessment Methodology: https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Fuels/CORSIA_Supporting_Document_CORSIA-Eligible-Fuels_LCA_Methodology_V8.pdf
- The ICAO CORSIA FAQ page also contains a dedicated section on eligible fuels, which addresses a number of practical LCA boundary and calculation questions, available at: https://www.icao.int/CORSIA/FAQ-SCS-Evaluation.

- The most relevant contact point for questions is the **ICAO CAEP Secretariat**, specialised on LCA methodology and GHG calculation topics. Questions regarding the LCA methodology document can be directed to the CAEP Secretary at ICAO via caep@icao.int.

4.8 International Maritime Organisation (IMO)

IMO: Life Cycle GHG Intensity of Marine Fuels & Net-Zero Framework

Geographical or sectoral focus

- Global framework for international maritime shipping
- The LCA Guidelines cover fuels and energy carriers used on board ships for propulsion and power generation — they do not themselves set a ship-size threshold
- Under the draft NZF, mandatory ship compliance is expected to apply to large oceangoing ships over 5,000 GT; discussions on smaller ships remain separate
- Relevant fuel scope includes fossil fuels, biofuels, PtX fuels (e-ammonia, e-methanol, hydrogen, synthetic methane/e-LNG) and electricity for shore power

MRV guidelines / procedures

- The LCA Guidelines are a lifecycle accounting framework, not yet a standalone mandatory MRV regime for ship operators
- Current mandatory IMO reporting remains primarily under MARPOL Annex VI instruments such as DCS, EEXI and CII
- Future NZF implementation is expected to rely on lifecycle fuel information, including Fuel Lifecycle Label (FLL) data and a fuel certification ecosystem similar to CORSIA or RFNBO

Applicability: In which context relevant for PtX producer?

- Relevant for producers of marine PtX fuels targeting the shipping market
- Provides the methodology for demonstrating lifecycle GHG intensity of hydrogen and hydrogen-derived marine fuels such as e-ammonia and e-methanol
- Likely to become the technical basis for future compliance with the IMO Global Fuel Standard and related market mechanisms
- Relevant for comparison and potential overlap with EU FuelEU Maritime, which also regulates the annual well-to-wake GHG intensity of energy used on board ships

Authorised certification schemes / bodies

- The draft Sustainable Fuels Certification Schemes (SFCSs) guidelines focus on certifying the well-to-tank (WtT) stage of the fuel supply chain. Ship-side compliance verification and FLL operationalization sit outside the SFCS guidelines
- No finalized IMO list of authorised certification schemes or verification bodies is yet in force; the recognition system and reporting requirements remain under development

Origin and legal framework

- **2023 IMO Strategy on Reduction of GHG Emissions from Ships** (adopted at MEPC 80, July 2023)
- **2024 Guidelines on Life Cycle GHG Intensity of Marine Fuels**, adopted by Resolution MEPC.391(81)
- **Draft IMO Net-Zero Framework (NZF)** approved as draft legal text at MEPC 83 in April 2025; adoption remains pending. The current draft combines a Global Fuel Standard and an economic mechanism with tiered compliance and incentives for zero or near-zero (ZNZ) fuels
- In short, ships must reduce their GHG fuel intensity (GFI) over time. Ships emitting above GFI thresholds must acquire remedial units to balance their deficit emissions, while those using zero or near-zero GHG technologies are eligible for financial rewards

Timelines & modalities of compliance

- Concrete MRV / certification timetables for fuel producers are not yet defined
- The draft SFCS guidelines foresee annual reporting by recognized SFCSs to IMO, but the reporting deadline and final data list remain under development
- If a producer claims a project-specific actual value that is lower than the IMO defaults, that actual value may only be used after third-party verification (SFCS guidelines)

Implementation status quo

- The LCA Guidelines are adopted and operational as guidance,
- The SFCS guidelines provide default pathway values and allow verified actual values
- The broader legal architecture for certification, scheme recognition and compliance remains under development within the NZF process. The NZF yet must be adopted (originally scheduled for October 2025, now end of 2026 earliest).

Benefits

- Creates a common international lifecycle methodology for marine fuels
- Improves comparability of competing fuel pathways through a well-to-wake approach
- Allows use of default values or project-specific actual values
- Expected to support commercial positioning of low-carbon PtX fuels in future shipping compliance markets.
- Certification approach is under development but relies on many architectural elements from the CORSIA and RFNBO certification ecosystem

Key components of methodology

- **Overall logic:** attributional well-to-wake methodology covering well-to-tank plus tank-to-wake emissions
- **System boundary:** feedstock extraction/cultivation/recovery, processing, conversion, transport, storage, bunkering and onboard fuel use
- **GHGs covered:** CO_2, CH_4 and N_2O
- **WtT term:** feedstock, land-use, processing/conversion and transport, minus eligible soil-carbon and CCS credits
- **TtW term:** technology-specific; accounts for combustion/conversion emissions, methane slip and fugitive losses where relevant
- **Values:** default emission factors per fuel pathway code; actual values may be used subject to verification/certification
- **Allocation:** energy allocation is the default for co-products; mass or economic allocation may be used case by case where appropriate

Challenges

- No fully operational IMO recognition system for certification schemes / bodies is in force yet
- Some methodological parameters, especially for certain TtW elements and credits, remain subject to further IMO development
- Commercial value depends on the final NZF design, general adoption / entry into force and future demand from shipping actors

In July 2023, the IMO adopted a strategy on reduction of GHG emissions from ships (MEPC 80) that significantly sharpened decarbonisation ambitions compared to its initial 2018 framework. The core target is to reach net-zero GHG emissions by or around 2050. To ensure progress, the strategy established specific indicative checkpoints for total annual GHG reductions (compared to 2008 levels):

- 2030: Reduce emissions by at least 20%, striving for 30%.
- 2040: Reduce emissions by at least 70%, striving for 80%.
- Aim for zero or near-zero GHG emission technologies and fuels to represent at least 5% (striving for 10%) of the energy used by 2030.

To implement these goals, the IMO is developing the **Net-Zero Framework (NZF)**, which was adopted in draft form at MEPC 83 (April 2025). It consists of two primary measures:

- **Global Fuel Standard (GFS)**: A goal-based technical standard that mandates a phased reduction in the life-cycle (well-to-wake) GHG intensity of marine fuels through annual **GHG Fuel Intensity (GFI)** limits. There are two tiers: the "Base Target", representing a less-ambitious GHG reduction, and the "Direct Compliance Target", which is a more ambitious GHG emission reduction. Both are derived from the 2008 baseline value of 93.3 g CO_2-eq/MJ (well-to-wake basis). The base target has modest annual reduction targets, starting in 2027 and reaching 65.3% of the baseline value in 2035. The direct compliance targets also start in 2026 and reach 53.2% in 2035 (King & Spalding, 2025).
- **Economic Mechanism**: A global pricing and incentive mechanism for maritime GHG emissions. Under the current draft, ships exceeding GFI thresholds would have to balance deficits through buying remedial units (RU) from the Net-Zero Fund, or through using surplus units from other ships. Ships using zero or near-zero emission fuels may qualify for financial rewards from the IMO Net-Zero Fund.

The NZF was originally scheduled for formal adoption in October 2025, with entry into force in 2027. However, the extraordinary MEPC session in October 2025 adjourned adoption discussions for one year. At MEPC 84 (April/May 2026), the Committee established further intersessional work to resolve concerns and drive convergence ahead of MEPC 85 (December 2026). If adopted, the MARPOL tacit acceptance procedure means entry into force would be expected around 16 months after adoption. At the time of writing, the NZF remains a draft framework, pending adoption. Once in force[16], it is expected to provide the overarching framework for the GHG-intensity requirements of international shipping, drawing on the IMO LCA Guidelines and envisaging certification of fuels through recognised Sustainable Fuel Certification Schemes (SFCS) – both described in more detail below.

4.8.1 Application and purpose

The International Maritime Organisation (IMO) **2024 Guidelines on Life Cycle GHG Intensity of Marine Fuels** (LCA Guidelines) provide the international framework for assessing the lifecycle GHG intensity of fuels and energy carriers used on board ships for propulsion and power generation - including alternative fuels derived from hydrogen (ammonia, methanol, hydrogen itself) and Power-to-Liquid fuels (e.g. synthetic methane, e-LNG). The Guidelines are relevant to PtX producers because they define the lifecycle GHG accounting methodology that may underpin IMO's market-based measures and fuel standards for shipping, including the prospective goal-based fuel standard (GFS) being developed by the Marine Environment Protection Committee (MEPC).

The IMO LCA Guidelines are currently advisory (non-mandatory); their regulatory application is being determined by the IMO Committee as part of the mid-term GHG reduction measures package under the 2023 IMO GHG Strategy. They are also relevant for comparison with EU FuelEU Maritime, which regulates the annual well-to-wake GHG intensity of energy used on board ships calling at EU ports. The IMO methodology is expected to form an important technical foundation for future mandatory fuel GHG intensity requirements for international shipping.

[16] Note that also the overall design of the NZF is currently under discussion. See more information here: Countdown: Assessing proposals to meet the 2023 IMO GHG Strategy

4.8.2 Legal base and implementation status

The legal basis is Resolution MEPC.391(81), which adopted the 2024 LCA Guidelines and revoked the earlier 2023 version adopted under Resolution MEPC.376(80). The Guidelines themselves are not a standalone mandatory certification regulation; Resolution MEPC.391(81) expressly states that any regulatory application and implications are to be determined by the Committee when developing regulatory provisions (IMO, 2024a).
As of October 2026, the IMO LCA methodology is therefore best understood as an adopted and operational guidance framework whose full legal effect is still being integrated into the wider IMO framework.

4.8.3 Key components of the methodology

1) Product scope

The scope of the *IMO 2024 Guidelines on Life Cycle GHG Intensity of Marine Fuels (2024 LCA Guidelines)* covers fuels and energy carriers used on board of ships for propulsion and power generation, including fossil fuels (HFO, MGO, LNG), biofuels, PtX fuels (e-ammonia, e-methanol, hydrogen, synthetic LNG/e-methane), and electricity (for shore power). The Guidelines include an initial non-exhaustive fuel list with Fuel Pathway Codes (Appendix 1), covering the main current and anticipated future marine fuel types (IMO, 2024a).

Onboard fuel use is not new as an IMO reporting subject: under the IMO Data Collection System (DCS), ships of 5,000 GT and above already report fuel-oil consumption data, which supports calculation of associated GHG emissions and operational carbon intensity. What the 2024 LCA Guidelines add is a fuel/energy-converter-specific Tank-to-Wake (TtW) factor, including CH_4 and N_2O and relevant slip or fugitive terms, and its integration with Well-to-Tank (WtT) data into a Well-to-Wake (WtW) GHG-intensity result, also see Figure 2.

2) System boundary

The methodology is built around an attributional **Well-to-wake (WtW)** system boundary that spans feedstock extraction, cultivation, acquisition or recovery; feedstock processing; transport to conversion; conversion into fuel; transport, storage, delivery and bunkering; and final onboard fuel use. The guidelines do not include capital-goods or manufacturing emissions. The included greenhouse gases are CO_2, CH_4 and N_2O. Other short-lived climate forcers, refrigerants and cargo-related emissions are outside the scope of the LCA Guidelines (IMO, 2024a).

If the NZF is adopted as currently designed, ship operators are likely to be regulated against a WtW-based metric in future IMO rules[17], which sum up Well-to-Tank (WtT) emissions and Tank-to-Wake (TtW) emissions.

Well-to-tank (WtT) methodology

WtT emissions are calculated as **GHG_WtT = e_fecu + e_l + e_p + e_td − e_sca − e_ccs**, where e_fecu covers feedstock extraction/cultivation/acquisition/recovery, e_l covers direct land-use change, e_p covers processing/transformation and conversion (including electricity generation where relevant), to final fuel, e_td covers feedstock and fuel transport, storage, delivery and bunkering, minuse_sca covers recognised soil-carbon accumulation credits, and e_ccs covers eligible CCS credits. Embedded emissions from manufacturing machinery/equipment are not included.

For the initial default factors, the Guidelines currently set Direct Land Use Change (DLUC), soil-carbon accumulation and several CCS-related parameters to zero pending further methodological development, which is an important limitation for interpretation (IMO, 2024a).

Tank-to-wake (TtW) emissions

TtW emissions are calculated using an equation that accounts for combustion or conversion emissions, methane and nitrous oxide conversion factors, and fuel slip or fugitive losses between tank and energy converter. TtW values are therefore technology-specific and can differ by energy converter. Methane slip is especially important for gaseous fuels such as LNG, while several terms relating to fugitive emissions, CCU-derived credits and onboard CCS remain subject to further IMO methodological guidance. GWP100 factors are according to latest IPCC values (IMO, 2024a).

[17] The current 2024 LCA Guidelines do not by themselves impose a final mandatory WtW reporting duty on operators yet.

Well-to-wake (WtW) emissions

WtW emissions are the sum of WtT and TtW emissions. For PtX fuels this means that not only process energy and conversion efficiency, but also the documented origin of carbon and hydrogen affect the resulting lifecycle profile (IMO, 2024a).

Appendix 2 of the 2024 LCA guidelines provides initial default emission factors by fuel pathway code, while the Guidelines also permit project-specific actual values subject to verification and certification. The IMO LCA workstream therefore already distinguishes between generic pathway defaults and certified site-specific data.

6) Allocation of emissions to co-products

Where more than one product results from a conversion process, the default rule is energy allocation. If energy allocation is not appropriate – for example where a co-product has no meaningful energy content, such as oxygen from electrolysis – other allocation methods such as mass or economic allocation may be used on a case-by-case basis. This is highly relevant for PtX plants with multiple outputs (IMO, 2024a).

7) Certification and verification

The Guidelines specify elements of the Fuel Lifecycle Label (FLL)[18] subject to verification/certification and provide a general procedure for identifying appropriate certification schemes. The FLL is a standardised information carrier for marine fuels that records: fuel type; feedstock (nature/carbon source and feedstock type); production process; GHG emission factors; information on fuel blends; and sustainability themes/aspects[19].

Currently, the LCA Guidelines provide a common calculation basis; a certification approach is being developed through a SFCS working group. Relevant stakeholders have been consulted, but the SFCS guidelines have not yet been officially adopted, which is foreseen at MEPC 85. The draft SFCS guidelines foresee annual reporting by recognised SFCSs to IMO, with the final deadline and data requirements still under development.

Under the draft IMO Net-Zero Framework, ship compliance is expected to be annual: ships would report their GHG Fuel Intensity each year. This means fuel producers/suppliers will likely need to provide verified lifecycle fuel data also on an annual basis, but the exact producer-side submission calendar remains under development.

4.8.4 Roles and responsibilities

- **IMO / MEPC**: sets and updates the methodology, decides how the Guidelines are translated into regulatory instruments, and continues to develop associated implementation guidance. Member Governments were requested to bring the Guidelines to the attention of stakeholders across the marine fuel value chain (IMO, 2024a).
- **Fuel producers and suppliers**: must identify the applicable fuel pathway, compile the underlying pathway and emissions data, and provide either default values or verified actual values. In practice, this means robust pathway documentation, process data, energy sourcing evidence, transport chain information and sustainability information suitable for certification or equivalent assurance (IMO, 2024a; IMO, 2025c).
- **Verification and certification** bodies: draft IMO materials foresee fuel-supply-chain information being certified through recognised Sustainable Fuel Certification Schemes (SFCSs). Under the draft SFCS guidelines, SFCSs would certify the WtT stage of the fuel supply chain, certification bodies would conduct audits and issue certificates to economic operators, and recognition of SFCSs by IMO/MEPC would be subject to periodic review and renewal.

[18] Proposals of updating the FLL's scope and functionality have been submitted to IMO and are currently under discussion.

[19] The sustainability aspects in the LCA Guidelines cover 10 themes: GHG emissions; carbon source; electricity/energy source; direct land use change (DLUC); indirect land use change (ILUC); water; air; soil; waste and chemicals; and biodiversity conservation. Specific metrics and indicators are defined for each theme.

4.8.5 Available support and resources

The 2024 LCA Guidelines (MEPC.391(81)) are available at https://www.imo.org/en/OurWork/Environment/Pages/GHG-Emissions.aspx. The IMO GHG strategy documents, MEPC session outputs, and intersessional working group (ISWG-GHG) submissions provide ongoing methodological developments.

The most relevant legal documents can be found here:

- **International Maritime Organization (2023)** *2023 IMO Strategy on Reduction of GHG Emissions from Ships*. Available at: https://www.imo.org/en/ourwork/environment/pages/2023-imo-strategy-on-reduction-of-ghg-emissions-from-ships.aspx.
- **International Maritime Organization (2025)** *The IMO Net-Zero Framework - FAQs*. Available at: https://www.imo.org/en/mediacentre/hottopics/pages/faqs-the-imo-net-zero-framework.aspx.
- **International Maritime Organization (2025)** *IMO approves net-zero regulations for global shipping*. Available at: https://www.imo.org/en/mediacentre/pressbriefings/pages/imo-approves-netzero-regulations.aspx.

The University Maritime Advisory Services (UMAS) and CE Delft have published analyses relevant to maritime decarbonisation, marine fuels and lifecycle-emissions assessment, see e.g. here:

- UMAS shipping insights page, including IMO decarbonisation analysis: https://www.u-mas.co.uk/the-implications-of-the-imo-revised-ghg-strategy-for-shipping/
- CE Delft study on sustainable alternative fuels in maritime transport: https://cedelft.eu/publications/assessment-of-impacts-from-accelerating-the-uptake-of-sustainable-alternative-fuels-in-maritime-transport/
- CE Delft study on FuelEU Maritime and lifecycle fuel incentives: https://cedelft.eu/publications/fueleu-maritime-and-eu-ets/

Last but not least, the Mærsk Mc-Kinney Møller Center provides excellent summaries of latest developments in its IMO-blogs – available at: https://www.zerocarbonshipping.com/news/countdown-assessing-proposals-to-meet-the-2023-imo-ghg-strategy

4.9 International Organisation for Standardisation (ISO)

In a first step, one needs to understand the differences and dependencies between ISO 14067 and ISO/TS 19870. **ISO 14067:2018 is the generic product carbon footprint standard**. The standard is part of the ISO 14060 family of GHG standards and builds on the life cycle assessment (LCA) framework of ISO 14040 and ISO 14044. **ISO/TS 19870:2023** is more operational for **hydrogen-based PtX chains**: it quantifies GHG emissions from production, conditioning, conversion and transport to consumption gate.

Once can understand ISO 14067:2028 as the "parent" generic standard, from which ISO/TS 19870 resulted as a "child" sector-specific application – it was written to apply ISO 14067's framework to the particular complexities of the hydrogen supply chain. ISO 19870 references ISO 14067 extensively; ISO 14067 knows nothing about hydrogen. The structural hierarchy of the different ISO standards is illustrated in Figure 10 below.

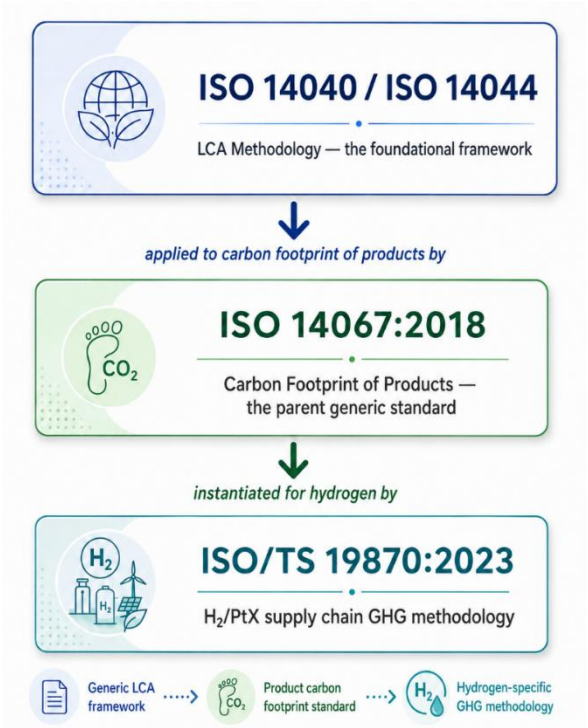


Figure 10: Parent–instantiation hierarchy of ISO standards in the context of PtX

Source: authors' own illustration

For PtX producers aiming to apply an ISO standard, it therefore makes sense to use ISO 19870, otherwise one would need to reinvent the wheel. Exceptions are: i) specific offtaker needs to comply with ISO 14067, or production cases not covered by ISO 19870.

Among the schemes reviewed, South Korea's Clean Hydrogen Certification scheme explicitly applies ISO, as it references ISO 14040, 14044, 14067 and ISO/TS 19870. EU RFNBO also builds upon and integrates international ISO standards. By contrast, IMO uses its own LCA guidelines (though it references ISO 14040 concepts); GH_2 builds on IPHE rather than ISO directly, and the Indian GHCI refers to but does not explicitly adopt ISO.

4.9.1 ISO 14067 I Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification

1) Application and purpose

ISO 14067:2018 – *Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification* – is the internationally recognised generic standard for quantifying the **carbon footprint of any product**. Published in August 2018, it replaces the earlier technical specification ISO/TS 14067:2013. A working draft revision (ISO/WD 14067) is currently in preparation (ISO, 2024). Its single focus is the climate change impact category: all other environmental dimensions fall outside its scope.

This section provides a brief summary of what ISO 14067 itself defines. A more detailed summary of the most relevant ISO 19870 standard can be found below.

2) Products covered and thresholds

ISO 14067 is product-scope universal: it applies to any good or service, regardless of sector or technology. All emissions and removals are expressed relative to a clearly defined functional unit – the quantified measure of what the product delivers (ISO, 2018, §6.3.1). For hydrogen, this is typically 1 kg H_2 or 1 MJ (lower heating value); for ammonia, 1 tonne NH_3. The choice of functional unit determines the denominator of the carbon intensity figure and must be reported explicitly.

Most importantly, ISO 14067 does not define GHG intensity thresholds, product classifications, or colour labels such as 'green' or 'low-carbon'. It is a measurement ruler, not a pass/fail gate.

3) System boundary and emissions included

ISO 14067 requires that the system boundary encompass all relevant unit processes within the product system. The standard mandates a **cradle-to-grave** boundary for complete **Carbon Footprint (CFP) studies**, covering raw material acquisition, production, transport and delivery, use, and end-of-life. Where specific stages are demonstrably insignificant or data is genuinely unavailable, **a partial CFP (e.g., cradle-to-gate) is permitted** – but excluded stages and the justification for their exclusion must be explicitly disclosed (ISO, 2018, §6.3.6 and Annex A). All six IPCC AR6 GHGs are covered (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6), expressed as CO_2-eq using GWP100 of the IPCC.

4) Consideration of electricity related emissions

Under ISO 14067, electricity consumed in the product system carries an indirect GHG emission that must be quantified using the most specific data available, following a strict data quality hierarchy:

(1) site-specific measured data;
(2) supplier-specific data;
(3) industry averages;
(4) generic defaults.

For dedicated off-grid renewable installations, the emission factor reflects the lifecycle GHG intensity of the renewable plant itself – i.e., CAPEX-embedded manufacturing emissions – which is non-zero but low (typically 4–50 g CO_2-eq/kWh depending on technology and location) (Leire et al., 2022). ISO 14067 does not contain a blanket zero-emission-factor rule for renewable electricity, which is for example applied in EU RFNBO.

5) GHG accounting principles

ISO 14067 is a generic methodology standard: it provides no sector-specific numerical defaults. Data must come from primary measurements, recognised databases (e.g. IEA, national inventories), or sector-specific supplementary frameworks. CAPEX emissions must be included or explicitly justified as insignificant.

The general calculation principle (§6.4 and §6.5) can be summarised as follows:

$$\mathbf{CFP = \Sigma\,(E_i \times GWP_i) - \Sigma\,(R_j \times GWP_j)}$$

where E_i are GHG emissions from unit process i, R_j are GHG removals from unit process j, and GWP is the 100-year global warming potential characterisation factor.

6) Allocation of co-products

Allocation is required whenever a process produces more than one output. ISO 14067 inherits a mandatory three-step hierarchy from ISO 14044 (ISO, 2018, §6.5): (1) avoid allocation through system expansion – credit the product system for the avoided production of a substitute; (2) physical allocation – partition on mass, energy, or stoichiometry; (3) economic allocation – last resort only, using market value.

7) Current status (in planning / operational / under review)

ISO 14067:2018 remains the operative published reference and is under revision, similar as the ISO 19870 standard (see below).

4.9.2 ISO 19870 I Hydrogen technologies – Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate

ISO/TS 19870:2023 — Hydrogen Technologies: GHG Methodology Summary

Geographical or sectoral focus

- Internationally applicable — not jurisdiction-specific
- Production pathways covered: electrolysis, SMR+CCS, chlor-alkali co-production, steam cracking co-production, coal gasification+CCS, biomass/waste, ATR+CCS
- Conditioning and conversion covered: compression, liquefaction, ammonia (NH_3), liquid organic hydrogen carriers (LOHC)
- Transport modes covered: inland waterways, pipelines, rail, road, sea

MRV guidelines / procedures

- No built-in pass/fail threshold
- PtX producers seeking certification need to identify and engage an independent verifier
- Reporting at multiple delivery gates along the supply chain is permitted

Applicability: In which context relevant for PtX producer?

- Provides a pathway-neutral, international framework for structuring hydrogen GHG accounting across complex supply chains
- Modular delivery-gate logic is directly useful where H_2 is produced in one country, converted to a carrier (e.g. ammonia, LOHC), shipped internationally and delivered to a downstream user
- Functions as an analytical bridge between project design, offtake negotiations and jurisdiction-specific certification requirements
- Relevant for documenting GHG performance of the production, conditioning and transport stages — independently of the regulatory framework applied at the import destination

Authorised certification schemes / bodies

- No authorised certification body or accreditation pathway defined within ISO/TS 19870 itself
- Intended as a quantification methodology that can underpin third-party verification and certification schemes

Origin and legal framework

- Not legally binding; persuasive and standard-setting value only
- Positioned within the ISO LCA / product carbon footprint family: draws on ISO 14040, ISO 14044 and ISO 14067; transport accounting linked to ISO 14083
- Does not define 'green', 'clean' or 'low-carbon' hydrogen thresholds — provides a common accounting framework that jurisdictions may use or adapt
- Practical force depends on voluntary adoption by market actors or incorporation into compliance schemes

Timelines & modalities of compliance

- No mandatory compliance timeline — voluntary adoption instrument

Implementation status quo

- ISO/TS 19870:2023 is the operative version as of early 2026, but currently under active revision — transitioning from a single technical standard to a more granular multi-part standards architecture
- ISO 14067 (carbon footprint of products) remains the generic umbrella
- Voluntary adoption by market actors and certification bodies is the primary implementation pathway

Benefits

- Harmonised, internationally recognised methodology enabling like-for-like comparison of hydrogen supply pathways
- Pathway-neutral: applicable to all major production routes
- Modular delivery-gate structure supports complex, multi-country PtX supply chains
- Supports interoperability between different national and regional certification systems
- Analytical bridge between project documentation, investor due diligence and offtake negotiation

Key components of methodology

- **Thresholds:** no pass/fail GHG thresholds established
- **Reporting metric:** kg CO_2e
- **System boundary:** well-to-tank
- **Covered gases:** CO_2, CH_4, N_2O (IPCC GWP100)
- **Total inventory:** $E_{total} = E_{production} + E_{conditioning} + E_{transport}$
- **Stage emissions:** $E_{stage} = E_{combustion} + E_{fugitive} + E_{industrial\ process} + E_{energy\ supply} + E_{upstream}$
- **Electricity accounting:** on-site generation vs. purchased electricity
- **CAPEX emissions:** must be reported separately if not immaterial
- **CCS/CCU:** captured CO_2 with CCS does not have to be accounted; CCU accounting depends on situation and duration of storage
- **Upstream methane:** explicitly required for natural-gas-based hydrogen pathways

Challenges

- Voluntary instrument: no mandatory enforcement mechanism
- Currently in transition from single TS (2023) to a multi-part series — creates uncertainty for implementers; not yet published

1. Application and purpose

ISO/TS 19870:2023 provides a harmonised methodology for determining the GHG emissions associated with hydrogen production, conditioning and transport up to the consumption gate. Its practical purpose is to make hydrogen pathways comparable on a life-cycle basis, thereby supporting policy design, certification frameworks, investor due diligence and commercial decision-making in international hydrogen markets (ISO, 2023; ISO and UNIDO, 2024).

ISO 19870 focuses on hydrogen as a product rather than on individual production labels. In other words, it does not define what counts as "green", "clean" or "low-carbon" hydrogen in legal terms. Instead, it establishes a common accounting framework that jurisdictions and certification systems may use or adapt when they apply their own thresholds and eligibility rules (ISO, 2023; ISO and UNIDO, 2024).

2. Legal status and normative positioning

The instrument is an ISO Technical Specification (TS), not an ISO International Standard and not a legally binding regulation. It was published as Edition 1 in November 2023 under ISO/TC 197/SC 1; building on the *Methodology for Determining the Greenhouse Gas Emissions Associated With the Production of Hydrogen* developed by the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE).

ISO/TS 19870 has reputational power and standard-setting value, but its practical force depends on whether it is adopted voluntarily by market actors or incorporated by reference into public or private compliance schemes (ISO, 2026a; ISO and UNIDO, 2024).

Methodologically, ISO/TS 19870 is positioned within the wider ISO life-cycle assessment and product carbon-footprint family. It draws particularly on ISO 14040, ISO 14044 and ISO 14067, while transport-related accounting is linked to ISO 14083. This positioning is important because it anchors the hydrogen methodology in an established LCA logic rather than creating a sector-specific accounting approach from scratch (ISO and UNIDO, 2024; ISO, 2006a; ISO, 2006b; ISO, 2018).

It shall be noted that, although not very old, ISO/TS 19870:2023 is currently being revised. ISO indicates that the Technical Specification will be succeeded by a multi-part series. This reinforces the point that ISO/TS 19870 should be understood as a foundational transition document: highly relevant now but already being translated into a more granular standards architecture (ISO, 2026a; ISO, 2026b; ISO, 2025).

3. Scope and system boundaries

The scope of ISO/TS 19870 is a partial carbon-footprint assessment from **"well-to-tank"**: the methodology covers upstream resource extraction and supply, hydrogen production, conditioning or conversion, and transport until the point at which hydrogen or a hydrogen carrier is delivered for use. End-use emissions and downstream applications beyond the consumption gate fall outside the scope (ISO, 2023; ISO and UNIDO, 2024).

A major strength of the specification is its modular structure. It allows reporting at multiple delivery gates along the supply chain, which is particularly relevant for international PtX chains involving separate producers, conditioning facilities, exporters, shippers, import terminals and off-takers. The functional unit is defined as 1 kg of hydrogen or hydrogen carrier at the conditions and purity required for the next stage in the chain, allowing consistent comparison across different supply configurations.

A broad set of production pathways is covered, including electrolysis, steam methane reforming with CCS, chlor-alkali co-production, steam cracking co-production, coal gasification with CCS, biomass waste pathways and auto-thermal reforming with CCS. For conditioning and conversion, ISO 19870 includes compression, liquefaction, ammonia and LOHC pathways, while transport coverage extends to inland waterways, pipelines, rail, road and sea, but not air transport. The methodology explicitly considers upstream methane emissions for natural-gas-based hydrogen and requires CAPEX emissions to be reported separately when they are not immaterial (ISO, 2023; ISO and UNIDO, 2024).

4. GHG accounting methodology

ISO/TS 19870 follows the standard four-phase carbon-footprint logic of i. goal and scope definition, ii. life-cycle inventory analysis, iii. life-cycle impact assessment and iv. interpretation (ISO and UNIDO, 2024; ISO, 2006a; ISO, 2006b; ISO, 2018). The methodology is a partial product carbon footprint approach covering hydrogen production, conditioning/conversion and transport up to the consumption gate within a well-to-consumption-gate system boundary (ISO and UNIDO, 2024).

For calculating GHG emissions, the principal reporting metric is kg CO_2-eq. Carbon dioxide, methane and nitrous oxide are the principal gases considered (applying IPCC GWP100 values).

The overall GHG accounting logic is expressed in two steps. First, for each process, total emissions are calculated as the sum of each emitted greenhouse gas multiplied by its respective GWP100 factor. Second, total inventory emissions for the product system are calculated as the sum of emissions from the three main value chain stages: production, conditioning and transport (ISO and UNIDO, 2024).

$$E_{\text{total emissions inventory}} = E_{\text{emissions inventory production}} + E_{\text{emissions inventory conditioning}} + E_{\text{emissions inventory transport}}$$

Each of these stage inventories includes all direct and indirect emissions within the system boundary and may be broken down into combustion emissions, fugitive emissions, industrial process emissions, energy supply emissions and other upstream emissions (ISO and UNIDO, 2024).

$$E_{\text{emissions inventory (production/conditioning/transport)}} = E_{\text{combustion emissions}} + E_{\text{fugitive emissions}} + E_{\text{industrial process emissions}} + E_{\text{energy supply emissions}} + E_{\text{upstream emissions}}$$

The life-cycle inventory framework is therefore relatively comprehensive. Special methodological attention is given to electricity, steam, natural gas, transport services, co-product allocation and carbon capture. For electricity, the specification distinguishes between on-site generation and purchased electricity. Depending on the PtX project context, either grid data or PPAs may be used.

For multifunctional systems, the specification provides a structured hierarchy covering subdivision, virtual subdivision, allocation, and system expansion or substitution. For captured CO_2, it differentiates between CCS and CCU: if CO_2 is stored, no emissions are allocated to the stored CO_2, although the emissions from capture and storage remain within the production inventory; if CO_2 is utilised, treatment depends on the project context and the chosen attribution approach (ISO and UNIDO, 2024).

The interpretation phase then requires analysis of significant issues, data quality, sensitivity and uncertainty, together with transparent reporting. ISO/TS 19870 also recommends preparation of a life cycle assessment report and allows for critical review, thereby reinforcing the credibility and comparability of results (ISO and UNIDO, 2024; ISO, 2018).

5. Reporting, verification and implementation implications

The Technical Specification recommends the preparation of a life cycle assessment report and leaves room for critical review in line with ISO review practice. However, it does not itself establish a certification body architecture, an accreditation pathway or a pass-fail threshold.

Accordingly, ISO/TS 19870 is best understood as a quantification methodology that can underpin verification and certification, rather than as a complete certification scheme. This distinction is essential when comparing it with regulatory instruments such as the EU RFNBO framework or national hydrogen certification schemes (ISO, 2023; ISO and UNIDO, 2024).

6. Relevance for PtX projects and key limitations

For PtX project developers, ISO/TS 19870 provides a pathway-neutral and internationally acknowledged way to structure hydrogen GHG accounting across complex supply chains. Its modular delivery-gate logic is particularly useful where hydrogen is produced in one location, converted into a carrier such as ammonia or liquid hydrogen, transported internationally and then delivered to a downstream user. In that sense, the specification can function as an analytical bridge between project design, offtake negotiations and jurisdiction-specific certification requirements (ISO and UNIDO, 2024; ISO, 2023).

It is not a full sustainability framework, as it does not address environmental or social safeguards. IST TS 19870 does not set legal thresholds for market access, subsidy eligibility or trade recognition.

7. Current status

Important to note is that ISO 19870 is currently being revised. It will be moving from the single 2023 technical specification toward a more modular set of product-specific texts: ISO/FDIS 19870-1 for hydrogen production up to the production gate, ISO/DIS 19870-2 for conditioning and transport of gaseous and liquid hydrogen up to consumption gate, and ISO/DIS 19870-3 for the ammonia chain up to delivery gate and conversion back to hydrogen. This direction is important for PtX because it suggests that ISO 14067 will remain the generic umbrella, while PtX-relevant operational detail increasingly sits in sector-specific companion standards (ISO, 2026a; ISO, 2026b; ISO, 2026c; ISO, 2026d).

4.10 Green Hydrogen Standard (Green Hydrogen Organisation)

4.10.1 Application and purpose

The Green Hydrogen Standard™ of the Green Hydrogen Organisation (www.GH$_2$.org) is a voluntary, project-level accreditation and certification framework for green hydrogen and selected derivatives. For PtX producers, its practical purpose is to provide a credible, internationally recognisable benchmark for when hydrogen can be marketed as "GH$_2$ Green Hydrogen", while also supporting investor confidence, trade, and guarantees of origin. It is therefore most relevant where producers want to demonstrate robust voluntary green credentials in addition to, or alongside, market-specific regulatory compliance requirements.

Unlike legally binding market-access rules such as EU RFNBO or EU CBAM, GH$_2$ is not itself a statutory compliance regime. Rather, it is a voluntary certification architecture that combines greenhouse gas thresholds with broader environmental, social and governance (ESG) requirements. This makes the standard particularly relevant for export-oriented projects, corporate offtake arrangements, and financing contexts in which an independently verified green product claim adds commercial value.

4.10.2 Implementation status quo, origin and legal base

The standard was first published by the GH$_2$ Organisation in May 2022, updated to version 1.1 in January 2023, and further revised to version 2.0 in November 2023. Version 2.0 expanded the framework beyond hydrogen and ammonia to also include green methanol and synthetic methane. Hence, it is as an operational voluntary certification standard.

4.10.3 Key components of the methodology

1) Product definition and emissions thresholds

The Green Hydrogen Organisation defines green hydrogen as hydrogen produced through the electrolysis of water with 100% or near 100% renewable energy and close to zero greenhouse gas emissions. The operational threshold for certification is ≤1 kg CO_2-eq per kg H_2, averaged over a 12-month period. For green ammonia, the corresponding threshold is ≤0.3 kg CO_2-eq per kg NH_3. These thresholds are intended to anchor the standard's green claim in a quantitative emissions ceiling rather than a generic renewables claim.

The emissions benchmark of ≤ 1 kg CO_2/kg H_2 is ambitious, and de-facto excludes "blue" PtX (i.e. fossil fuel derived in combination with CCS).

2) System boundary and emissions treatment

The Green Hydrogen Standard™ states that it is committed to full life-cycle analysis of GHG associated with renewable hydrogen production and utilisation, including embedded emissions. However, its current certification thresholds are based on a "well-to-gate" methodology aligned with the IPHE 2023 approach. At the same time, project operators are expected to calculate and report emissions associated with storage, conversion and delivery of hydrogen and derivatives, and are encouraged to report embodied emissions as well.

3) Electricity sourcing rules

The Green Hydrogen Standard™ applies the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) electrolysis methodology as its foundational GHG accounting framework, with two explicit modifications. First, unlike IPHE, the GH2 Standard does not accept the assumption that renewable electricity carries zero emissions – it requires that emissions associated with renewable electricity generation are quantified. Second, it requires that fugitive hydrogen emissions are evaluated, monitored, and minimised. For on-site generation, only electricity produced and consumed within the facility boundary is counted. The standard allows up to 5% of annual electricity consumption from non-renewable sources where technical or market constraints can be reasonably demonstrated, with the resulting GHG contribution calculated using official national grid emission factors or CDM standardised baselines. The overall 1 kg CO_2-eq/kg H_2 threshold must still be met on an annual average basis.

4) Sustainability and disclosure requirements

A distinctive feature of the Green Hydrogen Standard™ is that it does not focus only on GHG accounting. The standard is structured around seven requirements covering project overview and outlook, stakeholder engagement, project location and design, social impact, environmental impact, health and safety, and governance, transparency and accountability. Across these themes, the Green Hydrogen Standard™ expects public disclosure and evidence that the project has addressed issues such as approvals, consultation, water use, biodiversity, pollution control, community impacts, and governance arrangements. This makes the Green Hydrogen Standard™ a broader sustainability certification standard rather than a narrow carbon-accounting protocol.

5) Verification, certification and guarantees of origin

The certification pathway is structured as a sequence of project development, independent assurance, stakeholder consultation and public comment, accreditation by the Gren Hydrogen Organisation's Accreditation Body, production certification, and annual review and renewal. Projects that meet the standard are licensed to use the "GH_2 Green Hydrogen" label and become eligible to obtain and trade GH_2 certificates of origin through the GH_2 Registry. The annual review element is important because it signals that accreditation is not conceived as a one-off approval, but as an ongoing compliance relationship.

4.10.4 Roles and responsibilities

- **Project developer / operator**: responsible for designing the project in compliance with the GH_2 Standard, producing the required public documentation, and maintaining the underlying measurement, reporting and evidence systems needed for certification.
- **Independent Assurance Provider:** conducts the assurance review, stakeholder consultation, and assessment that form the basis for accreditation. This actor is central to the credibility of the Green Hydrogen Standard™ because it relies on independent verification. The Green Hydrogen Organisation foresees the use of accredited Independent Assurance Providers, but a public consolidated list of accredited providers was not identified on the Green Hydrogen Standard™ pages reviewed.
- **GH_2 Accreditation Body and Registry**: decide on accreditation, authorise use of the standard's label, and issue, track and cancel certificates of origin. They also review accredited projects annually and may undertake spot checks and recommend refinements to the standard.
- **Host governments and stakeholders**: while the Green Hydrogen Standard™ is a voluntary scheme, its principles explicitly refer to sovereignty, subsidiarity, consultation and transparency. Demonstrating compliance with credible national requirements can therefore contribute to certification. Stakeholder concerns are expected to be addressed through project-level processes and, where relevant, national authorities.

If a project cannot demonstrate compliance with the required emissions threshold, documentation standards, or wider ESG requirements, it cannot receive or retain Green Hydrogen Standard™ certification and therefore cannot use the standard's label or associated certificates of origin. For producers, the main consequence of non-compliance is therefore commercial and reputational rather than a direct legal penalty: the loss of a voluntary certification claim that may otherwise support offtake, financing or positioning in premium green markets.

4.10.5 Current status

The Green Hydrogen Standard is currently in force in version 2.0. The 2023 update added green methanol and synthetic methane, addressed hydrogen leakage, introduced biomass-related sustainability criteria, and added a prequalification option for early-stage projects. The Green Hydrogen Organisation explicitly positions the standard as a complement to evolving regional and national rules, including the EU RFNBO framework, rather than as a replacement for such legal compliance schemes. This confirms the role of the standard as a voluntary, internationally oriented benchmark that may help projects demonstrate readiness for stricter regulated markets.

4.10.6 Available support and resources

The main practical sources are

- The Green Hydrogen Standard™'s page: https://www.greenhydrogenstandard.org/standard/introduction,
- The standard's requirements page: https://www.greenhydrogenstandard.org/standard/requirements, and the
- Standard's certification page (https://www.greenhydrogenstandard.org/standard/accreditation-and-certification).
- The latest standard version can be downloaded at: https://www.greenhydrogenstandard.org/standard

4.11 Carbon credit frameworks for PtX

Carbon credit markets can provide an additional revenue stream for PtX projects by monetising verified emission reductions on top of commodity sales. This can be particularly relevant where the green product itself does not yet receive a sufficient premium, where domestic offtake is not linked to a compliance fuel market, or where developers need supplementary cash flow to improve project bankability. In practice, carbon revenues are most plausible where the methodology can credibly show that a PtX project displaces a more carbon-intensive fossil pathway and that the project would not proceed in the same form without carbon finance (Perspectives Climate Research, 2026; UNFCCC, 2026a; Verra, 2023).

The baseline-and-credit logic differs fundamentally from the product carbon-accounting standards addressed above. Product standards such as RFNBO, CBAM, ISO/TS 19870 or the Green Hydrogen Standard™ Standard primarily ask: "What is the attributed GHG intensity of this product within a defined system boundary?" Their outputs are conformity statements, thresholds, product carbon footprints or certificates that support market access, disclosure or claims. **Baseline-and-credit methodologie**s ask a different question: "**How many tonnes of emissions were avoided relative to a counterfactual baseline scenario**?" Their outputs are tradable credits, which require baseline setting, additionality testing, monitoring, reporting and verification (MRV), and explicit treatment of leakage; they are therefore counterfactual and incentive-based rather than purely attributional (Perspectives Climate Research, 2026; UNFCCC, 2026a; UNFCCC, 2026b).

For PtX, the most relevant carbon crediting frameworks are currently the Article 6 of the UNFCCC's Paris Agreement Carbon Market Mechanism, the Gold Standard, Verra's Voluntary Carbon Standard (VCS) and the Global Carbon Council (GCC) – these mechanisms are in the process of approving PtX-relevant methodologies. As of October 2026, the first PtX-relevant methodologies have been approved by the Gold Standard and Verra. In addition, three PtX methodologies are in the approval process at the UNFCCC for the Art. 6.4 mechanism – the first ones may be approved end of 2026 or early 2027. (UNFCCC, 2026b; UNFCCC, 2026c; UNFCCC, 2026d; Gold Standard, 2025a; Gold Standard, 2025b; Global Carbon Council, 2025a; Verra, 2023).
That means PtX project developers can now start the registration process of their projects if the project matches the approved methodologies. Once a project is registered, the MRV process can start, and carbon credits can be generated. If a PtX producer wants to claim carbon credits where no applicable methodologies are available yet (e.g. e-methanol or synthetic methane), then they can develop and submit a new methodology for approval.

The choice of the carbon credit "standard" will impact the buyer segment of resulting carbon credits. Sovereign buyers often prefer Art. 6 as this is the UN-supervised standard. For private sector buyers, the picture is less clear: some may prefer UN-backed credits as well, other may target voluntary standards – it always depends on their objective.

It is important to note that a double-claiming under different standard is excluded. Nevertheless, carbon credits may be an interesting way of monetizing greenhouse gas reductions for the part of their production that is used domestically (i.e. where no benefits from export markets exist).

Table 2: Current status and coverage of the most relevant carbon crediting routes for PtX

Framework	Relevant methodology	Coverage	Status as of March 2026
UNFCCC Article 6.4	Proposed new methodologies A6.4-PNM001 and A6.4-PMM006, and PMM011 -- all currently in the approval process	• Green ammonia (A6.4-PNM001) • Fertiliser production with renewables-based ammonia (A6.4-PNM006) • Green hydrogen production (PMM011)	Approval of first ammonia methodology expected for end of 2026. Then, project registration can start, which is the precondition for generating carbon credits.
Gold Standard	Approved green ammonia methodology Proposed green hydrogen methodology	• Green ammonia and green hydrogen	**Approved in July 2026** Approval of gH_2 methodology expected early 2027
Verra / VCS	Existing CDM methodology AM0124 VM0053 – low carbon fuels for shipping	Green hydrogen to existing dedicated consumers • PtX and e-fuel use in maritime shipping	**Active since September 2023** **Active since June 2026**
Global Carbon Council	GCCNMT002 Methodology for the production of low-carbon ammonia	• Low-carbon ammonia using electrolyser, residual or blue hydrogen	Consultation draft published in December 2025; not yet an approved methodology

Source: author's compilation based on UNFCCC, Gold Standard, Verra and GCC sources (UNFCCC, 2026b; UNFCCC, 2026c; UNFCCC, 2026d; Gold Standard, 2025a; Gold Standard, 2025b; Global Carbon Council, 2025a; Verra, 2023).

4.11.1 Article 6.4 of the Paris Agreement: background and status

Article 6.4 created a multilateral crediting mechanism under the Paris Agreement, supervised by the Article 6.4 Supervisory Body. The mechanism is designed to approve methodologies, register activities, accredit validation and verification bodies, and operate the registry and issuance architecture for Article 6.4 emission reductions.

The institutional UNFCCC architecture is in place and operational after many years of UN negotiations and preparation. As stated above, the ecosystem is still in an early stage: first, a new methodology must be approved, before in a second step projects can be registered. Only upon registration of a project at the UNFCCC, it can start MRV and subsequent issuance of carbon credits.

Benefits of Art. 6.4 are that, due to its supervision by the UNFCCC, it can be considered the highest-quality standard – with positive reputational and commercial effects for PtX producers. Beyond these effects, Art. 6.4 credits may carry direct regulatory value under CBAM, if the EU's draft regulation on carbon price paid in third countries as of May 2026 (see section 4.3.2) is implemented: where a third-country carbon price mechanism allows compliance via such credits, the draft Implementing Regulation recognises the price paid for credits issued as ITMOs under Article 6.4 toward the effective carbon price deduction, up to a cap of 10% of reported and confirmed emissions in the third-country scheme.

A6.4 PNM001: Production of ammonia through electrolysis of water, air separation and synthesis of hydrogen and nitrogen

PNM001 is an early and comparatively expansive proposal for green ammonia. It applies to ammonia produced from electrolytic hydrogen and nitrogen from air separation, with the main process powered predominantly by renewable electricity from a greenfield renewable plant. The proposal allows residual grid use but caps the annual ratio of grid electricity to captive renewable electricity at below 10%, and it also restricts local drinking water use for electrolysis to no more than 5%.

In methodological terms, it attempts to cover the full production chain from hydrogen and nitrogen production to ammonia synthesis, and states that life cycle emissions are considered in both the baseline and project scenarios (AM Green Ammonia, 2025; CDM Executive Board, 2023).

For baseline setting, PNM001 chooses a complex combination of best available technology (BAT), an ambitious benchmark based on the top 10% best-performing ammonia plants, and consideration of existing actual or historical emissions. Conceptually, this is quite ambitious because it tries to combine all three baseline logics in one methodology instead of selecting one principal baseline approach for one activity type. The practical effect is a potentially tight crediting baseline, but also a relatively heavy data burden.

Project emissions under PNM001 are built up from three blocks: electricity consumed from sources other than the renewable plant, fossil fuel use if any remains in the project configuration, and physical leaks of hydrogen and ammonia. The leakage treatment is also broad. The draft identifies four possible leakage channels: transfer of replaced baseline equipment, competition for scarce resources such as renewable electricity or water, diversion of existing production, and indirect environmental GHG releases. This makes the proposal environmentally comprehensive, but also quite complex for validation and monitoring because many potential off-site effects would have to be evidenced case by case.

For MRV, the draft relies on plant-level metering and monitoring systems such as SCADA, flow meters and leak-detection sensors, together with ex ante parameters for BAT, performance thresholds and downward adjustment.

Overall, PNM001 is conceptually wide-ranging and tries to anticipate future Article 6.4 requirements, but from a project developer's perspective it is still a draft with a relatively high methodological and data management burden. The approval level by the Art. 6.4 Supervisory Body is unclear.

A6.4-PMM006: Fertiliser production with renewables-based ammonia

PMM006 is a later and more structured proposal and is explicitly aligned with the newer Article 6.4 standards on baseline setting, additionality and leakage. Its scope is narrower: it covers fertiliser production using renewables-based ammonia, where the ammonia is produced from electrolytic hydrogen. Only the share used for fertiliser production within the host country is creditable to avoid double-counting with international incentive schemes or regulations.

PMM006 distinguishes between greenfield and brownfield projects. For greenfield activities and for brownfield activities after the end of the remaining lifetime of old equipment, the baseline follows a BAT approach. For brownfield activities during the remaining lifetime of existing equipment, the baseline is based on existing actual or historical emissions. The draft provides a default **global BAT value of 2.16 t CO_2-eq per tonne of ammonia** (based on research done by Gold Standard) and then applies explicit downward adjustment rules over time, including host-country net-zero target years where available. This creates a transparent and Paris-alignment-oriented baseline (Perspectives Climate Research, 2025a).

Project emissions under PMM006 are narrower and more operationally defined than under PNM001. They include grid electricity use, fossil-fuel combustion for non-electricity purposes, and transport emissions. For electricity, the draft uses conservative default grid-emission factors and a factor for transmission and distribution losses as an interim solution until the related Article 6.4 electricity tool is fully embedded. For transport, proponents may either monitor actual fuel use or apply conservative default freight-emission factors.

Additionality under PMM006 is structured in four layers: regulatory surplus, avoidance of carbon lock-in, investment analysis, and common-practice analysis. The draft excludes barrier analysis and relies instead on a comprehensive investment analysis supported by the approved Article 6.4 investment analysis tool, followed by a common-practice test based on market share of renewables-based ammonia in the host country. MRV is

correspondingly formalised: repeated validation and verification checkpoints are prescribed for the main applicability conditions, and the methodology requires monitoring of ammonia output, electricity and fuel use, transport activity and, where relevant, host-country policy parameters used for downward adjustment.

Last but not least, in September 2026, a **methodology for hydrogen production from electrolysis of water powered primarily by renewable electricity (PMM0011)** entered the public consultation process[20].

4.11.2 Gold Standard PtX methodologies

Green Ammonia: Gold Standard approved and published its green ammonia methodology in July 2026 (Gold Standard 2026), currently limited to fertiliser production. The baseline consists of avoided conventional ammonia production (including hydrogen and nitrogen production) and emissions from transport of fertiliser products. It uses a Best Available Technology (BAT) emission factor, the lowest of global vs. national benchmarks, with conservative country-specific and global defaults where project data are unavailable. The global default is 1.6 t CO_2-eq/tNH_3 (top-decile efficient SMR without CCS), well below the ~2.73 global average. Upstream methane is deliberately excluded to keep the baseline low. As a novel VCM instrument, the baseline is progressively lowered over time based on the host country's Net-Zero target, so a growing share of real reductions accrues (uncredited) to the host country rather than being monetised, corresponding to the "Downwards Adjustment" approach under Art. 6.4. Greenfield projects must use BAT; brownfield projects use historical emissions capped at the BAT benchmark (minimum of the two), transitioning to greenfield BAT once replaced equipment reaches end-of-life. Backup grid power is capped at ⩽10% annually, provided emissions are quantified. Eligible renewable energy is dedicated on-site RE or PPA-backed with hourly temporal matching, with detailed provisions for off-site supply including virtual PPAs and REC-like instruments meeting additionality, deliverability and temporal-matching requirements. Environmental safeguards include a 5% cap on potable water use plus a WRI Aqueduct water-stress assessment (stricter proof in high-stress regions). Project emissions cover electricity use, fossil-fuel combustion where applicable, transport of ammonia, and physical hydrogen/ammonia leakage. Additionality follows Gold Standard's stepwise "Requirements for additionality demonstration": regulatory surplus, lock-in risk, financial additionality (barrier test for microscale), and common practice. MRV centres on continuous monitoring of ammonia output, fossil-fuel use, electricity use and transport distances, with calibration, archiving and verifier-access requirements.

Green Hydrogen: Gold Standard published its draft green hydrogen methodology for public consultation in June 2026 (Gold Standard, 2026b), currently limited to hydrogen dispatched to eligible hard-to-abate end-uses (heavy industry, chemical synthesis, refining, maritime shipping, long-haul transport). The baseline uses a Best Available Technology (BAT) emission factor, the lowest of global vs. national benchmarks. The global defaults are 8.5 t CO_2-eq/t H_2 (top-decile efficient SMR without CCS), 18 for coal gasification, and 6.3 for naphtha reforming. Upstream methane is deliberately excluded to keep the baseline low. As with ammonia, the baseline is progressively lowered over time based on the host country's Net-Zero target, so a growing share of real emission reductions accrues (uncredited) to the host country rather than being monetised, corresponding to the "Downwards Adjustment" approach under Art. 6.4. Greenfield projects must use the BAT approach; brownfield projects use historical emissions capped at the BAT benchmark, transitioning to greenfield BAT once the replaced equipment reaches end-of-life. Use of backup grid power is capped at ⩽10% annually. Eligible renewable energy is dedicated on-site RE or PPA-backed with hourly temporal matching. As an environmental safeguard, there is a 5% cap on potable water use plus a WRI Aqueduct water-stress assessment (stricter proof required in high-stress regions). Physical hydrogen leakage must be considered as project emissions, quantified using a GWP_{100} of 14.4. Approval may be expected for end 2026/early 2027.

[20] https://unfccc.int/process-and-meetings/the-paris-agreement/article-6/article-64-pacm/mechanism-process/methodologies/A6.4-PMM011

4.11.3 Verra's Voluntary Carbon Standard

Verra lists the **CDM methodology AM0124**, **"Hydrogen production from electrolysis of water"**, as an active methodology (Verra, 2023; CDM Executive Board, 2023). AM0124 applies to hydrogen produced by electrolysis using electricity from a captive wind or solar plant, or from a mix of captive renewable electricity and residual grid electricity, provided the grid share remains below 10% annually. The hydrogen must be supplied to existing dedicated consumers in the host country, and the methodology is applicable only where the baseline consumer previously used hydrogen made from coal, natural gas or oil-based routes. The methodology also limits use of local drinking water for electrolysis to 5% to avoid displacement of other uses. These applicability conditions make the method relatively conservative and clearly focused on displacement of existing fossil-based hydrogen demand (CDM Executive Board, 2023).

Baseline setting in AM0124 is handled through the standard CDM approach: baseline emissions are calculated from the quantity of hydrogen supplied multiplied by the relevant baseline-emission factor. The draft text gives indicative default intensities of 19 t CO_2-eq per tonne of hydrogen for coal-based hydrogen and 9 t CO_2-eq per tonne for hydrogen from natural gas or oil-based reforming. Project emissions include electricity from non-renewable sources, fossil fuels used to operate the electrolyser plant, incremental transport emissions and physical hydrogen leaks. Notably, the methodology states explicitly that no leakage is considered.

MRV follows the CDM tool suite and requires metering of electricity, fuel use, hydrogen volumes and transport parameters (CDM Executive Board, 2023; Verra, 2023).

In June 2026, Verra approved **VM0053: "Alternative Low-Carbon Fuels for Shipping"** (Verra, 2026), which applies to GHG reductions from ships switching from conventional fossil fuels to alternative low-carbon fuels, such as green/e-hydrogen, green/e-ammonia, and electrofuels (e-LNG, e-LPG, e-diesel, e-methanol). It is globally applicable, covers propulsion and onboard power, and applies to new or existing ships of any gross tonnage. E-fuels must be produced with green and captured CO_2 from air or sustainable biomass. Eligibility requires that fossil fuel use is the most plausible baseline scenario: LNG for LNG/gas carriers, otherwise diesel. Additionality relies on an activity method: regulatory surplus plus a positive list justified by the very low market penetration of alternative marine fuels (~0.26% in 2023, against a 5% benchmark). Reductions equal baseline minus project emissions on a well-to-wake life-cycle basis, using conservative default baseline intensities of 3.277 t CO_2-eq/t LNG and 3.376 t CO_2-eq/t diesel. Project emission intensities are set through the IMO Life Cycle GHG Guidelines, an accepted regulatory-jurisdiction factor, or the GREET model, all third-party verified, with no use of renewable-energy or attribute certificates permitted. Upstream emissions are embedded in the WTW intensity factors so no separate leakage is calculated and retrofit/tank-manufacturing emissions are excluded as de minimis. Reductions already claimed under an IMO or MARPOL compliance scheme cannot be double-counted.

4.11.4 Global Carbon Council

GCC's draft methodology for low-carbon ammonia had reached stakeholder consultation in December 2025. Currently, is being revised by the GCC Operations Team, and is then subject to Regulatory Committee approval before being uploaded as an approved methodology (Global Carbon Council, 2025a; Global Carbon Council, 2025b).

The GCC draft is broader in technological scope than the Article 6.4 and Gold Standard ammonia drafts because it allows low-carbon ammonia to be produced from three types of low-carbon hydrogen: electrolyser hydrogen, blue hydrogen and residual hydrogen[21]. It distinguishes baseline treatment by project type: brownfield projects use a BAT baseline under paragraph 36(i) of the Article 6.4 logic, while greenfield projects use an ambitious benchmark under paragraph 36(ii).

Additionality discussion begins with regulatory analysis, then investment analysis, and finally common practice analysis. For common practice, the draft sets a stock-based threshold: the share of low-carbon ammonia production capacity must be below 16% of total ammonia capacity in the relevant geography, or 20% in LDCs and SIDS. Project emissions include emissions from the production and consumption of low-carbon hydrogen, transport of hydrogen, physical hydrogen leaks, fugitive CO_2 and seepage for blue hydrogen, and any increased

[21] Residual here means "Hydrogen generated as a residue at an existing processing plant (e.g., chlor-alkali plant)"

steam or electricity use in brownfield projects. The methodology therefore accommodates several hydrogen routes, but this technological breadth also makes the accounting more demanding (Global Carbon Council, 2025c).

Leakage treatment under GCCNMT002 is also broader than in the other ammonia drafts. It includes embodied emissions from manufacturing electrolyser plants, while upstream leakage from CO_2 capture material for blue hydrogen is considered negligible. MRV is detailed, with large parameter tables covering ammonia production, electricity, fuels, transport distances, hydrogen flows, utility increments and uncertainty treatment.

5 Comparative Framework

This section provides a high-level overview of the key commonalities and differences between the GHG emission calculation standards. The carbon credit standards are not included, as they are still in an early stage. Figure 11 compares the system boundaries of the selected PtX methodologies. Table 3 compares key aspects of the methodologies – including type of regulation type, PtX product scope and functional units, geographic applicability, current legal status, main benefit for PtX producers and threshold values. Finally, Table 4 summarises rules for electricity accounting, acknowledgement of PPAs and/or GOs, allocation of co-products and embodied emissions in the GHG calculations, and sustainability requirements.

Figure 11: Comparison of system boundaries across selected PtX methodologies



Table 3: Methodology types and legal aspects of key GHG calculation standards for PtX

Methodology	Regulation type	Product scope / functional unit	Geographic applicability	Legal status	Main benefit for PtX producer	Threshold	System boundary (2026)
EU RFNBO	Renewable fuel regulation: Defines when a fuel qualifies as renewable	H_2 and PtX fuels; g CO_2-eq/MJ and savings %	PtX exported to EU	Not generally mandatory for export to EU. But mandatory if product wants to achieve "RFNBO-status" for EU targets or quotas (price premiums)	Access to EU renewable fuel markets; eligibility for quota counting and premium offtake	Pass/fail: 70% savings vs. fossil comparator 94 g CO_2-eq/MJ – i.e. max 28.2 g CO_2-eq/MJ	Well-to-wake
EU CBAM	Carbon-pricing mechanism for imports: Quantifies embedded emissions and applies ETS-equivalent carbon cost	Covered goods incl. hydrogen and ammonia/fertilisers ; t CO2-eq/t goods	Selected PtX products exported to EU	Mandatory for CBAM covered goods imported to EU	Lower embedded emissions reduce CBAM financial adjustment	N/A Higher emissions lead to higher CBAM financial adjustments	Well to gate
India GHCI	National certification scheme: Certifies that hydrogen is "Green" under GHCI and eligible for support	Green hydrogen: kg CO_2-eq/kg H_2; Forthcoming: green ammonia and green methanol	India	Quasi-mandatory: relevant for domestic sale/use in India, incentives/concessions. 100% exporters without access to Indian support schemes can be exempt	Domestic recognition, access to India' H_2 support schemes, annual certification	Pass/fail: max. 2.0 kg CO_2-eq/kg H_2	Well to gate
South Korea Clean Hydrogen Certification	National certification scheme: determines eligibility to participate in (subsidised) power bidding market	Hydrogen / hydrogen compounds; kg CO_2-eq/kg H_2	PtX exported to South Korea or produced domestically	Not generally mandatory, but mandatory for access to power bidding markets (price premiums)	Eligibility within Korean clean hydrogen certification framework	Grading framework: max. 4.0 kg CO_2-eq/kg H_2 for recognition as clean H_2, with tiers 1-4 spanning 0.00-4.00 kg CO_2-eq/kg H_2.	Well-to-gate
Japan's hydrogen framework	Nation certification scheme, determines eligibility for governmental subsidies and support program	H_2 and PtX fuels; kg CO_2-eq/kg H_2, kg CO_2-eq/kg NH_3; e-fuels: g CO_2-eq/MJ	PtX exported to Japan or produced domestically	Not generally mandatory, but mandatory for access to power bidding markets (price premiums)	Eligibility for support under the Hydrogen Act's CfD Scheme	3.4 kg CO_2-eq/kg H_2 0.87 kg CO_2-eq/kg-NH_3 E-methane: 49.3 g CO_2-eq/MJ E-fuel: 39.9 g CO_2-eq/MJ	Well-to-gate for H_2 and NH_3; Whole supply chain for e-fuels
ICAO CORSIA	International sectoral scheme	Life-cycle emissions value (LCEF) in g CO_2-eq/MJ	PtX sold to aviation sector	Mandatory from 1/2027	Price-premiums for accredited eSAFs	Max. 80.1 g CO_2-eq/MJ to be acknowledged as CEF	Well-to-wake

Methodology	Regulation type	Product scope / functional unit	Geographic applicability	Legal status	Main benefit for PtX producer	Threshold	System boundary (2026)
IMO LCA Guidelines	International sectoral scheme	Marine fuels; g CO_2-eq/MJ (LCV)	PtX sold to maritime shipping sector	Draft guidance now; legal adoption in progress	Price-premiums for low carbon maritime fuels	No single pass/fail; total carbon intensity of all fuels used by operator determines its compliance; increase of ambition over time	Well-to-wake
GH_2 Green Hydrogen Standard	Voluntary international product standard / label for "green" H_2 and NH_3	Hydrogen and green ammonia; kg CO_2-eq/kg H_2 or NH_3	Global	Voluntary (premium product label)	Commercial credibility, voluntary premium markets, guarantee-of-origin use	Pass/fail: max. 1 kg CO_2-eq/kg H_2; max. 0.3 kg CO_2-eq/kg NH_3 as12-month average	Well-to-gate, with separate reporting of transport emissions
ISO/TS 19870	Voluntary international standard for GHG intensity of H_2 + NH_3	Hydrogen production, conditioning and transport to end-user	Global	Voluntary	Comparable product carbon footprint; reference method for schemes and policymakers	No pass/fail; methodology for GHG emissions intensity only	Well-to-tank

Table 4: Overview electricity accounting, allocation of co-products, embodied emissions and sustainability requirements

Methodology	Electricity accounting	PPAs / GOs acknowledged	Co-products / allocation	Embodied emissions (installations)	Sustainability requirements
EU RFNBO	Zero emissions from electricity can be assumed only if electricity qualifies under RED delegated rules (hourly matching from 2030); otherwise grid factors apply. Additionality and temporal and geographic correlation central	PPAs: yes, conditionally. PPA volumes must be at least equivalent to claimed renewable electricity. Associated GOs must be cancelled to prevent double-claiming.	Allocation for multi-output processes based on energy content. Reference to ISO 14067 for allocation approach.	Not included	N/a
EU CBAM	ETS-style electricity factors: actual or default emission factors; hourly matching	PPAs can allow the use of actual emissions instead of conservative default factors, provided that the criteria in Annex IV, point 6, of EU 2023/956 are met, and the evidence requirements[22] specified in EU 2025/2547 are fulfilled.	CBAM does not address co-product allocation (i.e. no oxygen allocation treatment). Only precursors for complex goods (e.g. H_2 for ammonia in fertilisers) may be relevant, depending on the specific case.	Not included	N/a
India GHCI	No explicit temporal matching requirement. Renewable electricity must be demonstrated via physical or contractual linkage (e.g. PPAs, green tariffs, G-DAM). If not fully renewable, national grid emission factors (incl. T&D losses) apply. Electricity banking allowed under regulations	PPAs: yes, to demonstrate actual renewable electricity consumption. Renewable electricity claims must be backed by contractual linkage and generation evidence. RECs and carbon credits explicitly excluded. GHCI certificates function as a form of GO	Energy-based allocation (energy content) applied to co-products. Co-products without calorific value are not allocated emissions	Not included	N/a
South Korea Clean Hydrogen Certification	Monthly matching required for electrolysis; low-carbon electricity proof needed.	PPAs acknowledged. REC use allowed but capped at 10% of monthly renewable electricity consumption, and must be from same grid	Energy allocation (LHV)	Not included	N/a
Japan's hydrogen framework	PtX producers shall use supplier-specific data where available; otherwise use recognised national/regional factors.	Use of Go acknowledged; no explicit information on PPAs found.	No specific information found.	Not included	N/a

[22] Direct PPA with the generator. Must use smart-meter data, proof of delivery, hourly matching, physical connection evidence, and verifier evidence.

Methodology	Electricity accounting	PPAs / GOs acknowledged	Co-products / allocation	Embodied emissions (installations)	Sustainability requirements
IMO 2024 LCA Guidelines	Tracks source of electricity/energy and its GHG intensity; no detailed rules on RE requirements adopted (yet)	Detailed rules under which PPAs or GOs are accepted to claim renewable electricity are still under development	Primarily energy allocation; case-by-case alternatives possible for some co-products	Not included	Water, air, soil, waste/chemicals, conservation, carbon source, DLUC/ILUC
CORSIA	Similar to EU RnfBO, with temporal & geographical matching and additionality requirements. Annual matching until 12/2029, hourly from 2030, but with exceptions.	PPAs are accepted. Energy Attribute Certificates (EACs): accepted without limits before 2033, up to 30% of consumed electricity afterwards.	Energy allocation for co-products according to lower heating value	Not included	CORSIA SAF: Do-no-significant-harm (DNSH) safeguards for carbon stock, biodiversity, water, soil, air quality, waste/chemicals, and land-use rights CORSIA LCAF: DNSH safeguards for GHG permanence, carbon stock, biodiversity, water, soil, air quality, waste/chemicals, seismic impacts, and land-/water-use rights.
GH2 Green Hydrogen Standard	Requires 100% or near-100% renewable electricity; allows up to 5% of annual electricity consumption from non-renewable sources in case of technical or market constraints - emissions must then be calculated using official national grid emission factors or CDM standardised baselines.	Explicitly acknowledged. Grid-connected producers may count electricity as fully renewable if they have concluded PPAs with renewable generators covering at least the equivalent volume of electricity claimed.	H_2: Oxygen can be treated as co-product; full allocation detail is not the main design focus in current excerpts. For green ammonia, GH_2 explicitly recommends alignment with IPHE methodology.	Inclusion of CAPEX emissions is encouraged but not mandatory. Separate to the current emissions threshold.	High requirements: ESG, stakeholder engagement, social impact, health and safety, transparency, water and environmental management.
ISO/TS 19870	For on-site generation, only direct generation emissions plus upstream fuel supply emissions are counted. For grid electricity: grid emission factor or contractual arrangements.	Yes, both are allowed, if quality criteria are met.	Detailed allocation logic; subdivision, virtual subdivision, joint production, and system expansion/substitution. A decision-tree algorithm guides practitioners through the allocation method selection	CAPEX emissions reported separately when material	N/a

6 Tools for calculating the carbon emissions intensity of PtX fuels under selected standards and insights from applying them to real projects

6.1 Tools for calculating the carbon intensity of PtX fuels under selected standards

To translate the complex regulatory landscape summarized in the previous chapters into operational guidance, three Excel-based GHG intensity calculator tools have been developed - one each for green hydrogen, green ammonia, and synthetic liquid e-fuels (covering e-methanol and e-SAF). The tools share a common input architecture, a central Project Data Sheet to define a specific project, specific calculation sheets for the applied methodologies, a results overview sheet and a compilation of parameters and default values.

For each product, the most relevant methodologies have been implemented in a dedicated calculator. In addition, an illustrative example has been prepared for each tool to show users how it is filled in practice without claiming to be real world examples. Table 5 lists each calculator next to its case study, so that both can be downloaded together.

Table 5: PtX GHG intensity calculators and illustrative case studies – download overview

PtX product	Methodologies covered	GHG intensity calculator (.xlsx)	Illustrative case study (.xlsx)
Green hydrogen (H_2)	EU RFNBO, EU CBAM, Indian GHCI, South Korean CHCS	Download hydrogen calculator	Download hydrogen case study
Green ammonia (NH_3)	EU RFNBO, EU CBAM, IMO LCA Guidelines	Download ammonia calculator	Download ammonia case study
E-methanol / e-fuels	EU RFNBO, IMO, CORSIA	Download e-fuels calculator	Download e-fuels case study

Source: authors

The tools are intended as feasibility-stage decision-support instruments for project developers to gain an initial understanding of which framework could be met, and how a given project configuration performs against each standard. They are explicitly not audit-grade decision tools or MRV substitutes - verified certification remains the responsibility of the producers with the involvement of accredited bodies under the applicable scheme. Furthermore, general applicability and full compliance of a specific standard cannot be checked with these tools.

A number of caveats should be kept in mind when interpreting the tools' outputs. Default emission factors in the tools' reference sheets are placeholders drawn from publicly available sources and shall be replaced with country-specific or project-specific values once site data becomes available. Several methodological elements are simplified or deliberately out of scope, notably co-product allocation and the full set of alternative allocation methods permitted by the various frameworks. With regard to renewable energy use, temporal- and geographical-matching requirements, renewable-energy credit (REC) caps, and the materiality thresholds applied by some schemes are not enforced at the calculation level; the user is responsible for ensuring compliance with the related standards.

The tools represent the current regulatory landscape as of the release date in October 2026. As such, any updates and future developments are not covered. Users should carefully check the version and date of the tools to assess any of such updates or developments in the regulatory frameworks.

6.2 Lessons learnt from applying the tools to real projects

Applying the tools to three real-life PtX projects – one producing ammonia, and two producing e-methanol – plus running similar project configurations through the tools' frameworks in parallel yields three substantive insights that are difficult to derive from the regulatory texts alone.

The real-world project case studies

The carbon intensity calculation tools were not developed in isolation. To test them under realistic conditions, they were applied to real PtX projects run by private developers in different partner-country contexts — one producing green ammonia and two producing e-methanol, one of the latter also targeting e-SAF. The three projects were drawn from a larger group of developers approached at the beginning of the work. Not every invited PtX project ultimately took part, which illustrates the sensitivities around sharing project-level data. Results were handled in anonymised form, as the underlying configurations are commercially confidential.

The projects shared a common technical backbone but differed in their downstream products and feedstocks. In each case, dedicated renewable generation - solar PV, in some configurations complemented by wind, battery storage and/or grid connection - powers electrolysis to produce green hydrogen, which is then converted into the final product. In the ammonia configuration, hydrogen is combined with nitrogen in a Haber-Bosch synthesis loop. In the e-fuel configurations, green hydrogen is reacted with biogenic CO_2 to synthesise e-methanol; in one case the methanol may be further upgraded to synthetic aviation fuel via a methanol-to-jet route.

The CO_2 feedstock in the e-fuel projects was biogenic throughout. In one configuration, high-purity CO_2 will be captured from the fermentation off-gas of an existing bio-based production process, which is currently vented to the atmosphere. In another project, the CO_2 derives from the treatment of organic waste streams. One of these biogenic CO_2 supplies is seasonal, tied to an annual processing campaign, which raises a continuity question for year-round fuel production. The water source for electrolysis often was not specified in the project information available and would need to be confirmed with each developer.

The standards relevant to each project reflected its product and target markets: EU RFNBO and CBAM across the board and the IMO LCA Guidelines and CORSIA for the marine- and aviation-fuel routes.

First, differences in how the **accounting boundary** is drawn and how emissions from electricity consumption are treated translate into materially different results for the same project. For electrolytic hydrogen, EU CBAM returns an embedded-emissions value close to zero regardless of grid intensity, because its Annex II direct emissions scope excludes indirect electricity emissions for hydrogen. The same project may nonetheless fail to meet the threshold of the RFNBO framework, depending on how its electricity supply is classified under Reg. (EU) 2023/1184, and again a different result under a national scheme, driven by the applicable grid emission factor and the treatment of transmission and distribution losses. A single project can therefore present itself as near-zero-carbon to one authority, marginally compliant to a second, and non-compliant to a third – without any change in the underlying installation or process.

For PtX producers, this has the following consequences. The **commercial benefit** offered by a given scheme must be weighed against both the likelihood of meeting its carbon intensity requirements and the effort required to do so. A regulatory framework with lower premiums or financial benefits may become more attractive than one offering higher premiums but imposing more challenging eligibility requirements for proving the required carbon intensity and general applicability and compliance. In addition, producers targeting multiple markets should plan compliance against the most stringent methodology in the project's offtake portfolio, rather than the most lenient one.

Downstream PtX products (ammonia, methanol) reveal **emission sensitivities** that are not visible when hydrogen is considered on its own. Even a fully renewable ammonia configuration can struggle to clear the 70 % RFNBO

savings threshold when end use N_2O emissions from ammonia combustion are occurring and included within the well-to-wake boundary. For CH_4 and N_2O emissions from end-combustion the approach is different to CO_2 from combustion that could be assumed zero if from biogenic sources or the atmosphere. Whether and how such end use emissions are to be accounted for ammonia and other PtX products is a regulatory question (see specific standards as described in this report), and the answer has significant consequences for whether green ammonia projects are eligible in practice. For e-fuels, the CO_2 source selected for synthesis – direct air capture, biogenic, or industrial point source – is often the decisive factor separating a passing from a failing verdict under the selected frameworks. The biogenic and DAC pathways consistently outperform industrial-point-source routes by a wide margin. For the use of the tools, the biogenic and DAC pathways are the assumed standard use case. Further information regarding accounting of different CO_2 Sources can be found here.

Generally, **product market mapping,** i.e. understanding different offtake markets and their related regulatory aspects, is as important as a process design aiming at lowest possible GHG emissions. The methodological frameworks are gated to specific product types – CORSIA applies to synthetic aviation fuels, the IMO LCA Guidelines to marine fuels – and a project's commercial route to market therefore determines which GHG thresholds apply. For producers of ammonia or methanol with multiple potential offtake channels, the most attractive single market option available (e.g. based on a less stringent GHG threshold) may not be the best across the whole offtake portfolio.

A positive experience was that generally key data required for populating the tools was available for the real case examples (but one needs to consider that the project selection specifically looked for projects in an advanced planning stage). Project developers had specific questions related to the certification process – e.g. regarding exact delineation of the accounting boundary, combination of production steps along the full value chain including preliminary products; and full applicability and compliance under a given standard.
As mentioned before, the tools were designed for initial estimation of the GHG intensity of a PtX product to understand if they are close to meeting a given standard's GHG threshold. They are not meant to check full applicability and compliance under a specific standard. This is a task that remains with the project developers.

7 Recommendations

This chapter translates the comparative analysis of GHG accounting frameworks (Chapters 3–6) and insights gained from the industry case studies into recommendations for the two primary audiences of this report: PtX project developers and national authorities in producing countries. The analysis shows that the standards differ fundamentally across system boundaries, electricity accounting rules, GHG thresholds, and functional units. As a result, the same physical plant can appear near-zero-carbon under one framework, marginally compliant under a second, and non-compliant under a third – without any change to the underlying installation or process. Standard's requirements therefore shapes market access, project design, electricity sourcing, and MRV architecture for producers. In addition, structure of the electricity market and data availability shape a country's ability to facilitate private-sector access to premium markets.

7.1 Recommendations for PtX project developers

For project developers, the following choices and decisions define the ability of a given PtX product to serve different offtake markets.

1. **Define the target export market(s) first**
   The first and most fundamental step is to establish which offtake markets – and therefore which frameworks – are relevant for the specific product. The "label" a product achieves (e.g. RFNBO status, Indian GHCI certification, a South Korean CHCS tier) determines market access and the price premium or carbon pricing relief available. For each PtX product, its intended offtake markets and plausible alternatives should be mapped. In parallel, it is important to understand the implications of these choices from a carbon accounting perspective. This report and the supporting calculation tools – available for download at https://ptx-hub.org/ publication /GHG intensity calculators PtX products– aim to support these decisions by providing an overview of the requirements and benefits of each framework. This can help to understand consequences for the technical configuration of PtX installations.
2. **Build the binding methodology into project design from the outset**
   For regulated markets, compliance is non-negotiable and shapes decisions that are costly to reverse later – site selection, electrolyser dispatch profile, and PPA and guarantee-of-origin contract structure. Electricity sourcing rules have the greatest divergence across frameworks and the largest cost implication. EU RFNBO is the most ambitious standard – it requires additionality, geographical correlation, and hourly temporal matching from 2030 for electricity use, which must be reflected in procurement and metering from day one.
3. **Where the offtake market requirements are uncertain or may shift, design to the strictest plausible standard**
   Building the MRV set-up – data granularity (e.g. hourly electricity metering), monitoring, and documentation – to satisfy the most stringent standard in the plausible offtake portfolio preserves flexibility in terms of market access. A project can always step down to a less demanding framework, but retrofitting to a stricter one is difficult. Producers targeting multiple markets should plan compliance against the most stringent methodology in their portfolio.
4. **Weigh each scheme's premium against the effort and likelihood of compliance**. A framework offering lower premiums but readily achievable eligibility may be more attractive than one offering higher premiums but demanding carbon intensity proof that a given site cannot reliably deliver. This trade-off should be assessed per site, using project-specific grid emission factors and electricity arrangements rather than generic assumptions.
5. **Use the carbon intensity calculator tools (https://ptx-hub.org/ publication /GHG intensity calculators PtX products) early but understand its limits**
   The product-specific GHG intensity calculators (hydrogen, ammonia, e-fuels) give an initial understanding of which frameworks a given PtX project can meet and how sensitive the result is to the grid emission factor if electricity is sourced from the grid. At the same time, the tools are not audit-grade tools or MRV substitutes. The placeholder default emission factors in the tools must be replaced with project-specific

values as site data becomes available. Also, temporal and geographical matching and limits for the use of renewable energy certificates caps cannot be checked in the tools – verified certification remains the producer's responsibility, with accredited bodies under the applicable scheme.

6. **Address product-specific emission sensitivities that hydrogen-level analysis conceals**
   For ammonia, end use N_2O emissions under a well-to-wake boundary can jeopardise the 70% RFNBO savings threshold even for fully renewable configurations. For e-fuels, the CO_2 source for synthesis – direct air capture or biogenic, versus industrial point source – is typically the decisive factor between a passing and a failing result. The CO_2 feedstock choice and the treatment of downstream emissions should be clarified early in project design.
7. **Explore monetisation of domestic emission reduction from PtX under international carbon markets**
   Instead of exporting PtX products and shipping them around the globe to harness green premiums in markets abroad, the Paris Agreement Crediting Mechanism (PACM) and its Article 6.4 offers PtX producers a way to harness green premiums for domestic use of PtX. For example, if green ammonia is used in domestic fertiliser production, one can create tradeable credits (ITMOs) that can be sold on top of the commodity and thus generates additional revenue. Both PACM and voluntary markets will be ready to credit emission reductions from PtX use – the initial methodologies for hydrogen and ammonia currently are being approved (some already are), meaning that project will soon be able to apply for registration.

7.2 Recommendations for policy makers and national authorities

National authorities in producing countries shape the enabling environment in which producers can demonstrate compliance with the various emerging international standards. Providing data and monitoring infrastructure supports PtX project developers to plan correctly and proceed towards project implementation. We also recommend avoiding creating additional standards – it would lead to a further fragmentation of an already crowded standards landscape.

1. **Provide the public-sector data on which private compliance depends for the emission calculation**
   Make authoritative, regularly updated data publicly available – such as national and bidding-zone grid emission factors (including transmission and distribution losses), and data on renewable generation, grid feed-in and consumption. These are decisive inputs across almost every framework's electricity accounting and are most credibly supplied and maintained by public institutions. It helps PtX producers to pass verification and saves them a lot of time and cost - which typically is a key challenge in developing PtX projects. An absence of such data forces producers onto conservative default values that can turn an otherwise compliant project non-compliant.
2. **Establish proof-of-origin and proof-of-production registries**
   Robust national registries for guarantees of origin / renewable electricity certificates and for proof of production allow producers to substantiate renewable electricity claims and prevent double-counting. Designing these registries to be interoperable with, or recognised by, the registries of key export markets materially reduces producers' transaction costs.
3. **Build certification and verification support infrastructure**
   Access to accredited verification bodies and recognised certification schemes is a precondition for domestic producers to obtain the third-party certification that export markets require. Public support for accreditation, capacity building, and recognition arrangements lowers a structural barrier to market access.
4. **Use and align with existing standards rather than creating new ones**
   With dozens of different PtX carbon accounting frameworks already in operation or emerging, additional national standards risk increasing fragmentation and compliance costs without commensurate benefit. Where national requirements are necessary, they can be based on established reference methodologies (e.g. ISO/TS 19870). Alternatively, one can align own standards with – or seek mutual recognition against – the frameworks of priority export markets.

5. **Signal readiness to use Article 6 and encourage PtX project developers to engage in international carbon markets**
   Instead of exporting PtX products and shipping them around the globe to harness green premiums in markets abroad, the Paris Agreement Crediting Mechanism (PACM) and its Article 6.4 offers PtX producers a way to harness green premiums for domestic use of PtX. For example, if green ammonia is used in domestic fertiliser production, one can create tradeable credits (ITMOs) that can be sold on top of the commodity and thus generates additional revenue. Both PACM and voluntary markets will be ready to credit emission reductions from PtX use – the initial methodologies for hydrogen and ammonia currently are being approved (some already are), meaning that project will soon be able to apply for registration. Therefore, policy makers and national authorities should clearly communicate their willingness to make use of Article 6 and encourage project developers getting involved in the mechanism accordingly.
6. **Pursue harmonisation and mutual recognition through international fora**
   Convergence and mutual recognition of methodologies are the most effective means of reducing the multi-standard compliance burden on producers – a public-good function that individual producers cannot perform. National authorities are well placed to advocate for this in the relevant international and sectoral bodies.
7. **Balance accuracy against practicability**
   In designing or endorsing requirements, weigh methodological rigour against administrative feasibility: overly complex MRV deters investment, particularly for smaller projects, while overly loose rules undermine credibility and acceptance in export markets. Requirements that are proportionate to project scale and aligned with destination-market rules strike the most workable balance.

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