White Paper

Navigating PtX Certification Challenges:

Qualitative Assessment of Sustainability Requirements and Cost Dynamics for Exports from the SADC-region

CONTENT

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Executive Summary

This whitepaper provides a qualitative overview of the impacts and challenges of Power-to-X (PtX) certification on the development of PtX export hubs. We use the SADC (Southern African Development Community) as an exemplary PtX export region due to its abundant renewable sources, refinery infrastructure, as well as PtX policy frameworks and initiatives. We evaluate the European Union (EU), the United Kingdom (UK), South Korea and Japan as potential importing markets. We first provide an overview of the fundamentals of PtX certification, including an analysis of importing markets' legal frameworks, certification schemes and market incentives for importing PtX from the SADC region (such as the EU Renewable Energy Directive (RED III); H2Global, atmosfair fairfuel, UK RFTO and SAF Mandate). From these regulations and standards, we identify relevant PtX sustainability criteria for the SADC region. We then give an overview of the efforts in the SADC region to support the development of a PtX market. Next, we qualitatively evaluate which technical and regulatory requirements can affect system design and levelized cost of PtX production systems. When then take a closer look at challenges arising from two exemplary sustainability criteria from the EU RED III. Industrial and political feedback on RED III criteria as well as stakeholder discussions in South Africa are presented subsequently. As a synthesis of our results, we conduct a SWOT analysis of the SADC region as a PtX exporting hub and present an outlook on future research needs.

Our main Findings at a Glance:

PtX sustainability criteria differ between potential import regions for the SADC region.

Regulatory sustainability criteria for PtX in the EU, the United Kingdom, South Korea and Japan are collected and qualitatively compared. Differences occur in the GHG emission threshold, system boundaries, eligible electricity and CO_2 sources, additionality, temporal and geographic correlation as well as other environmental and social aspects. The analysis shows that European regulations are the most stringent and detailed, whereas Japanese regulation are the least strict of the investigated schemes.

Sustainability criteria can have an impact on PtX system design and levelized cost of PtX production systems.

We conduct a literature review from which we identify that the eligible source of grid electricity and CO_2, temporal correlation for electricity use and the overall GHG-threshold and scope can have impacts on PtX system design and the levelized cost of PtX production system.

Regional differences in certification require early decision on export markets from PtX production hubs.

In the export market, regulatory misalignment between importing regions creates barriers: The technical configuration and economic viability of PtX plants depend on the regulatory requirements of the importer. Therefore, producers must choose their target export markets early. This early commitment significantly impacts critical aspects of plant configuration. We show the challenges arising from this commitment in detail for two exemplary sustainability criteria from the EU RED III (CO_2 sources and co-production).

1. Introduction

The need for power-to-X (PtX) products for CO_2 reduction in hard-to-abate sectors such as aviation, shipping and heavy industry, is well established in the scientific literature [1]. To ensure that PtX products are sustainably produced and contribute to CO_2 reduction, certification schemes are developed that certify compliance with sustainability criteria. These criteria can include power supply specifications such as temporal and geographical correlation of power and hydrogen production as well as environmental aspects such as eligible CO_2 sources. The criteria can potentially influence the economic performance of PtX products [2] and are therefore a critical factor in the establishment of an international PtX market.

This whitepaper evaluates the impacts and challenges presented by certification and associated sustainability criteria on potential future PtX exporting regions, including a qualitative analysis of how certification requirements affect the levelized cost of PtX products. For this work, we use the Southern African Development Community (SADC) region as an example as it is a promising candidate to produce PtX due to its renewable energy potential and existing refinery infrastructure [3, 4]. Furthermore, local emerging PtX policy initiatives, including Namibia's Synthetic Fuel Act [5], and South Africa's Hydrogen Society Roadmap [6] as well as large-scale PtX projects like Hyphen, are noteworthy developments in the region [7]. The built-up of a PtX market in the region is further supported by institutions like the PtX Hub South Africa as well as financial mechanisms such as SA H_2 fund [8] or the SDG Namibia One Fund targeting $1 billion for green hydrogen and PtX projects [9].

As exports are expected to be a key driver for the PtX development in the SADC region [10, 11], this analysis focuses on sustainability criteria in potential export markets, primarily based on regulatory requirements. We look at the European Union (EU), Japan, the United Kingdom (UK), and South Korea given their likely need for imports to meet their blending requirements [12–15] and advanced regulatory frameworks [16–19]. Regulation is especially advanced for exporting sustainable aviation fuels (SAF), e.g. with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) by the International Civil Aviation Organization (ICAO) [20].

Our analysis is structured as shown in the following figure:

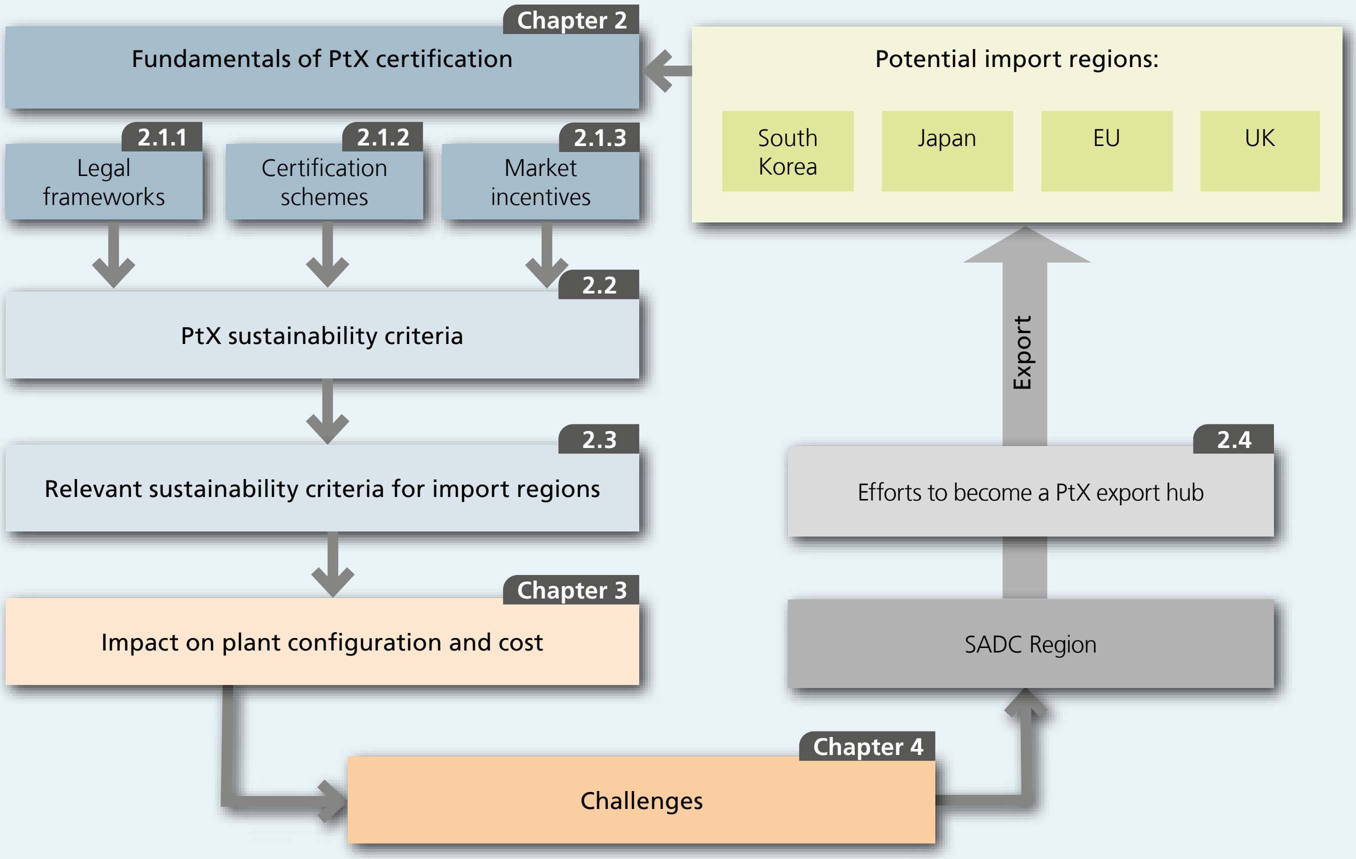

Figure 1: Structured analysis diagram

An overview of the fundamentals of the regulatory and certification landscape, as well as PtX sustainability criteria, is presented first (Chapter 2).

Subsequently, the impact of technical and regulatory requirements on plant configuration will be qualitatively analyzed (Chapter 3).

We will then discuss potential challenges and barriers arising from the sustainability criteria for PtX exporters in the SADC region (Chapter 4).
Then the findings are synthesized using a SWOT analysis (Chapter 5).

Finally, we will present an outlook on which challenges to monitor and prepare the ground for recommendations for future research (Chapter 6).

2. Fundamentals of PtX Certification

In this chapter, we provide an overview of the fundamentals of PtX certification with a focus on the EU, UK, Japan and South Korea as potential exporting markets for the SADC region. These regions have been chosen for the review based on the role of PtX imports in their respective hydrogen strategies [21–24], also taking into consideration insights on prospective net importers from studies projecting global PtX demand [14, 15, 25].

We will first introduce the regulatory and certification landscape in the exporting countries, distinguishing legal frameworks, certification schemes and market incentives, while showing how these elements are linked. We then provide definitions of the various PtX sustainability criteria originating from the regulatory and certification landscape and subsequently evaluate which of these criteria are relevant for PtX production in the SADC region. Finally, we provide an overview of the efforts in the SADC region to develop a PtX market.

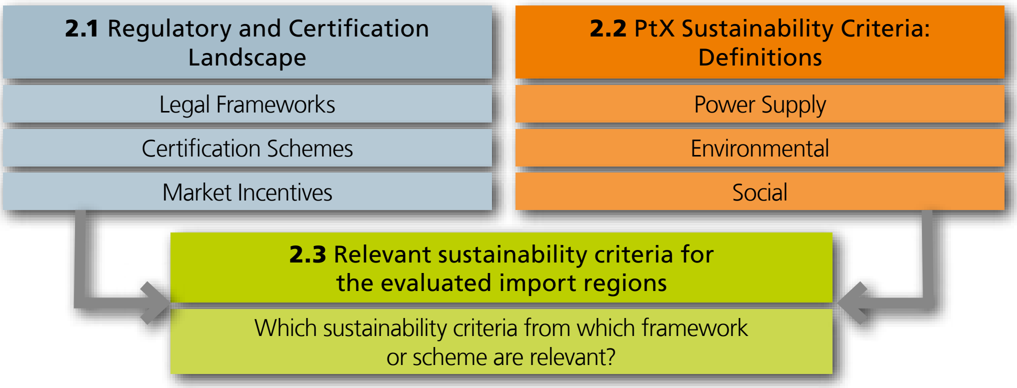

Figure 2: Chapter 2 overview: Fundamentals of PtX certification

2.1. Regulatory and Certification Landscape

The following section will provide a brief non-exhaustive overview of relevant legal frameworks, certification schemes and market incentives for selected PtX import regions. Their respective interrelations are visualized in Figure 3. An overview table with details can be found in Annex 2.

2.1.1. Legal Frameworks

Across jurisdictions, certain sustainability aspects of PtX products are addressed in legal provisions, often in connection with supply- or demand-side incentive instruments for the hydrogen ramp-up established in laws and regulations. In this context, the minimum sustainability requirements for PtX are defined that must be fulfilled to demonstrate compliance with the legal framework.

EU: In the EU, the uptake of renewable PtX products is incentivized by sectoral consumption quotas for renewable fuels of non-biological origin (RFNBOs) under the European Union's Renewable Energy Directive (2023/2413/EU), also known as RED III. Its delegated acts define how PtX

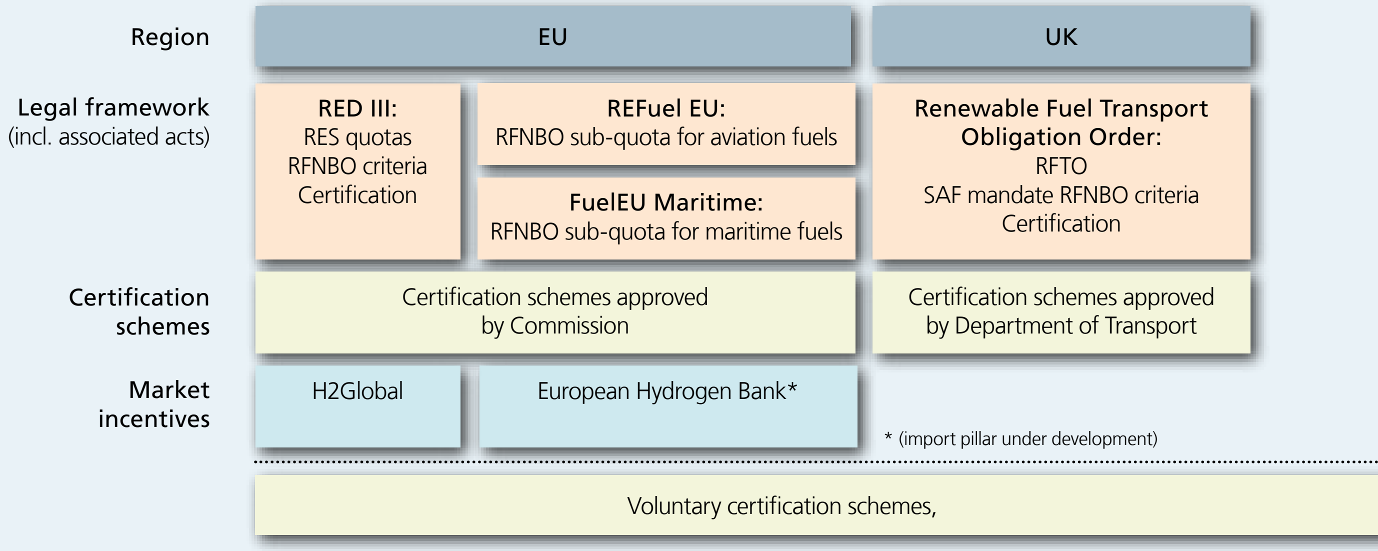

Figure 3: Legal frameworks, certification schemes and market incentives in selected import regions

products must be produced – whether domestically or overseas – to count towards the EU's renewable energy targets. ReFuelEU Aviation [26] sets an RFNBO blending mandate for aviation fuel, increasing from 1.2% in 2030 to 35% by 2050. Similarly, FuelEU Maritime [27] provides an RFNBO share for maritime fuel.

The Carbon Border Adjustment Mechanism (CBAM) imposes a carbon price on imports of certain products, including hydrogen and fertilizers to prevent carbon leakage. Importers have to pay a carbon price equivalent to the EU's carbon market price for embedded emissions of CBAM goods, whereas certified RFNBO enjoy zero-emission treatment [28]. This mechanism helps support the competitiveness of green hydrogen and PtX by disincentivizing hydrogen and ammonia imports with GHG emissions above RED III threshold.

UK: The UK's Renewable Transport Fuel Obligation (RTFO) [29] applies to fuels used in the transport sector, including maritime transport. Using certificate trading, fuel suppliers are required to meet a progressive renewable quota , with RFNBO being among eligible fuels. Since 2025, a separate SAF blending mandate [30] applies to aviation, including a power-to-liquid (PtL) obligation starting from 0.2% in 2028 and gradually rising to 3.5% in 2040. In addition, the UK has the Low Carbon Hydrogen Standard (LCHS), which supports the country's hydrogen strategy [23] by defining low-carbon hydrogen production. Based on the LCHS, the UK is currently developing a Low-Carbon Hydrogen Certification Scheme. While it is currently used under the Hydrogen Production Business Model (HPBM) – a support scheme for domestic production [31] – it may gain relevance for international trade [32–34].

South Korea: The Hydrogen Economy Promotion and Hydrogen Safety Management Act [35] establishes the Clean Hydrogen Portfolio Standard (CHPS) – a requirement to ensure a minimum share of hydrogen-generated electricity in the mix, which is underpinned by a bidding market [36]. The Act lays down corresponding eligibility criteria for clean hydrogen and derivatives, including certification requirement. In addition, a SAF blending mandate of 1% for departing international flights is envisaged from 2027 [16].

Japan: The Japanese Hydrogen Society Promotion Act (JHPA) lays the foundation for Japan's hydrogen economy [19], including definition of low carbon hydrogen and derivatives and introducing two support instruments – a CfD mechanism for the use of low carbon hydrogen and derivatives in hard-to-abate sectors and derivatives and support to hydrogen hubs for hydrogen infrastructure development [37]. For aviation, introduction of a 10% SAF mandate is planned by 2030, which is required to result in at least 50% GHG reduction [38].

Global: CORSIA is an instrument introduced by the ICAO for addressing CO_2 emissions in international aviation [39]. Use of SAF meeting sustainability criteria (among CORSIA eligible fuels) can be claimed towards the carbon offsetting obligation set to ensure carbon-neutral growth – alongside with eligible carbon offsetting programs.

South Korea	Japan	Global
Hydrogen Society Promotion and Hydrogen Safety Management Act: CHPS Clean hydrogen criteria Certification	Hydrogen Society Promotion Act: **CfD** Low-carbon hydrogen criteria Certification	**Annex 16 to Convention on International Civil Aviation** CORSIA Criteria for CORSIA eligible aviation fuels
Clean hydrogen certification scheme	Low-carbon hydrogen certification scheme	Certification schemes approved by ICAO
Clean Hydrogen Portfolio Standard (CHPS)	CfD-type supply subsidy	
e.g. TÜV Süd CMS70, CertifHy NGS, atmosfair fairfuel		

2.1.2. Certification Schemes

A certification scheme provides proof that certain sustainability requirements for a given product have been met. It demonstrates compliance with the legal frameworks previously discussed, but it can also be a voluntary scheme, independent of a legal framework and with its own sustainability criteria.

EU: To demonstrate compliance with the RED III in the EU, several certification schemes have been approved by the EU Commission: ISCC EU, CertifHy EU RFNBO and REDcert EU [40]. These mirror the »RED III« requirements exactly and contain no additional sustainability criteria.

UK: Compliance with the UK's Renewable Transport Fuel Obligation and SAF Mandate is to be demonstrated by a voluntary certification scheme [41]. While multiple eligible schemes operate for biogenic fuels, no certifications scheme for RFNBO or other types of renewable fuels is currently approved by the UK Department for Transport [42].

South Korea: South Korea's Clean Hydrogen Certification Scheme (SKCH) is a national scheme which sets out the criteria for sustainable hydrogen production. It can be used to demonstrate compliance with the Clean Hydrogen Portfolio Standard and the SAF mandate. The certification scheme is operated by the Korea Energy Economics Institute [43].

Japan: Clean hydrogen certification in Japan is embedded in the eligibility process for the state support schemes and ensured during business plan approval by METI with involvement of the schemes' administrator – JOGMEC [44]. The certification approach includes promotion of international harmonization and, in particular, adoption of international standards for GHG accounting [45, 46]. A low-carbon ammonia value chain developed by the Japanese utility company JERA is a first example of completed certification [47].

Global: Under CORSIA, three certification schemes are currently recognized: International Sustainability and Carbon Certification (ISCC CORSIA), Roundtable on Sustainable Biomaterials (RSB CORSIA) and ClassNK [48], which currently focus on biogenic SAF.

Atmosfair fairfuel is a voluntary certification scheme developed by atmosfair for e-kerosene and e-methanol for aviation and shipping, respectively.

Other examples of voluntary certification schemes applicable worldwide include the TÜV Süd Green Hydrogen certification standard CMS70, which defines sustainable hydrogen production in two tiers (Green Hydrogen and Green Hydrogen+). This Green Hydrogen Standard CMS70 initially focused solely on hydrogen, but has since expanded its scope to include ammonia, methanol and methane.

A further alternative is the CertifHy Non-Governmental Certification (NGC), an international certification scheme currently only applicable in the EU, the EEA and Switzerland, covering sustainability requirements to produce "renewable" and "low carbon" hydrogen.

2.1.3. Market Incentives (Incentive and Support Schemes)

There are various support mechanisms in place to help ramp-up the green hydrogen and PtX market. They can refer to legal frameworks and their respective sustainability requirements, often adding additional social or environmental aspects.

EU: H2Global is a German-Dutch [49] support scheme in the form of a two-sided market auction with contract-for-difference-like features. The production of hydrogen and derivatives can occur anywhere in the world (excluding Germany and the Netherlands), while consumption is limited to within the EU. During the supply-side auctions, PtX producers can apply and the lowest price offer wins. The product is purchased by HintCo, daughter company of the H2Global foundation. In the demand-side auctions, the products are sold to the highest bidding buyers [50, 51].

The European Hydrogen Bank operates using a fixed premium. Projects can apply for a fixed premium of their choice (€/kg H_2), and if their application is successful, they will receive that premium for 10 years. The only eligible product is hydrogen, and production must adhere to the requirements of the RED III. This mechanism applies to projects located within the EU, and the product must also be consumed within the EU. To attract imports, an international pillar is currently being developed by the European Commission.

UK: While the Hydrogen Production Business Model (HPBM) supports the ramp-up of domestic production, no support schemes could be identified covering PtX imports to the UK.

South Korea: Through the CHPS tender for 15-year supply contracts, the Korean government subsidizes the difference between levelized cost of energy (LCOE) of hydrogen-generated electricity and the wholesale electricity price [52]. The bids are evaluated based on price (60%, subject to an undisclosed upper price limit) and non-price factors (40%), including the clean hydrogen tier. In the 2024 auction, assigned scores ranged from 14 points for Tier 1 to 0.4 points for Tier 4 clean hydrogen [53].

Japan: The CfD scheme is a price-gap subsidy under which the Japanese government covers the difference between the cost of supplying low-carbon hydrogen (strike price) and a reference price linked to conventional fuels. Support is granted to approved projects for 15 years and linked to a supply obligation for another 10 years. Targeted end-use includes electricity generation and hard-to-abate sectors such as steel, chemicals and transportation [54].

2.2. PtX Sustainability Criteria: Definitions

Through the legal frameworks and certification systems presented previously, sustainability criteria related to the production of PtX have been identified and classified into three main groups: power supply, environmental and social criteria. The power supply requirements define how hydrogen should be produced from a technical perspective. The environmental criteria refer to the environmental characteristics associated with the production of hydrogen and its PtX product. Finally, the social criteria address the aspects that must be considered in the communities where PtX production takes place. Table 1 presents the sustainability criteria associated with PtX production along with their respective definitions.

DEFINITION

Power Supply	
Renewability	Energy used to produce green hydrogen and PtX products must come from renewable sources
Additionality	Energy used to produce green hydrogen and PtX products must originate from newly established additional renewable capacities
Temporal correlation	Electricity production and power offtake for PtX occur during the same specified time interval
Geographical correlation	Electricity generation and PtX production take place in the same area (e.g., same bidding zone)
Environmental	
Greenhouse Gas (GHG) Emissions	Maximum permissible GHG emissions of the product, often defined in relation to a reference value (e.g., 70% less GHG emissions than conventional/non-green product). Given in [kgCO_2eq/MJ] or [kgCO_2eq/kgH_2]
GHG Emissions Methodology	Detailed specifications and instructions on how to calculate the GHG emissions value for a product, often either defined by the regulation itself or referencing another regulation (e.g., RED III)
Co-Processing/Co-production	In the context of the GHG emissions methodology under the RED III, co-processing is defined as the simultaneous processing of RFNBOs with biomass or fossil fuels. Co-production is a process with multiple outputs.
Carbon Sources	Definition of permissible carbon sources for carbon-based PtX products (e.g., industry point sources via Carbon Capture Utilization (CCU), Direct Air Capture) [56]
Water Conservation and Use	Definition of sustainable provision and use of water (as electrolysis needs fresh water, which can be especially scarce in regions with a lot of renewable energy potential)
Water Quality	Definition of sustainable provision of water regarding the availability of safe water, sanitation facilities and hygiene practices [57]. This sustainability criterion relates also to the use of purified water in electrolysis processes
Land Use	The space required for renewable energy generation units and PtX facilities must not compete with other land uses, such as food production
Biodiversity Conservation	Incl. biodiversity conservation, vegetation + species loss
Air Quality, Pollution	Consideration of waste exhaust/gas, definition of sources and thresholds
Noise Emissions	Prevention and control, definition of impact guidelines
Social	
	It considers various aspects, including community health and safety, protection of indigenous people, land acquisition and involuntary resettlement, access to resources and stakeholder engagement

Table 1: Identified sustainability requirements associated with the production of green hydrogen and PtX products. Brief general description of each criterion (further details given in upcoming chapters where needed) [55]

2.3. Thematic Scope of Relevant Sustainability Criteria for the Evaluated Import Regions

Using the taxonomy of sustainability criteria presented in the previous section, the thematic scope of the identified requirements for PtX products in the potential import regions is now discussed in comparison. A detailed overview of the sustainability criteria under the frameworks is provided in the Annex. Table 2 summarizes the aspects addressed in each scheme.

While the RED III mandates fulfilment of technical criteria for the power supply and environmental criteria on GHG emissions, including sustainable carbon sources, it poses no requirements for other environmental and social sustainability dimensions of PtX products. The H2Global support scheme proposes more extensive sustainability requirements, incorporating the sustainability criteria outlined by RED III along with additional environmental and social standards. Furthermore, the voluntary standard atmosfair fairfuel contains as well partially stricter requirements compared to RED III and complements them with other sustainability criteria. The South Korean and Japanese frameworks focus on the GHG footprint. CORSIA contains a comprehensive list of sustainability aspects formulated for SAF of all eligible production paths.

Most environmental and social criteria in the atmosfair fairfuel standard refer to the European Investment Bank (EIB) Environmental and Social Standards. The respective EIB standards focus on procedures and are not hydrogen-specific and, thus, difficult to reflect generically in the techno-economic modelling on the energy system and project level. CORSIA Sustainability Criteria for CORSIA eligible fuel formulate principles along a broad range of sustainability aspects without detailing indicators to assess compliance with those principles. At the same time, eSAF-specific aspects regarding eligible electricity were added recently.

Overall, H2Global offers the most comprehensive sustainability catalogue in terms of covering aspects in all three main categories. Moreover, its sustainability criteria are detailed enough, so that they can be quantified and/or otherwise reflected in project-level and/or energy system modelling. Finally, in light of announced international cooperations on facilitating green commodity markets, the sustainability framework under H2Global may be adopted in other geographic markets, also beyond Europe [58]. Therefore, while the GHG-related methodology criteria are assessed based on the relevant country-specific framework, the H2Global initiative also incorporates additional environmental and social criteria that we consider best practice. These criteria are assumed to be met, regardless of the targeted export market, in future analyses.

Table 2: Overview on Legal Frameworks, Certification Schemes and Market Incentives relevant for Export of PtX from the SADC region and which sustainability criteria they implement

		Legal Frameworks						Certification Schemes				Market Incentives	
		REDIII	CHPS	LCHS	RTFO	JHPA	CORSIA	CertifHy	TÜV	GHS	fairfuel	H2Global	H2Bank
SUSTAINABILITY CRITERIA	**POWER SUPPLY**												
	Renewability	x	-	x	x	x	-	**3**	x	-	x	x	REDIII
	Additionality	x	-	-	x	-	x	**4**	x	-	REDIII	REDIII	
	Temporal Correlation	x	x	x	x	-	x	**4**	x	-	x		
	Geographical Correlation	x	x	-	x	-	x	**4**	x	-	x		
	ENVIRONMENTAL												
	GHG emissions	x	x	x	x	x	x	x	REDIII **[1]**	IPHE	REDIII	x	REDIII
	Land use	**2**	-	x	-	-	x	-	-	x	-	x	-
	Wastewater, Ambient water quality	**2**	-	x	x	-	x	-	-	x	x	x	-
	Water conservation	**2**	-	x	x	-	x	-	x	x	x	x	-
	Air Emissions, Ambient Air quality	-	-	x	x	-	x	-	-	x	-	-	-
	Hazardous material management	-	-	x	-	-	-	-	-	-	x	-	-
	Waste management	-	-	x	-	-	x	-	-	x	x	x	-
	Noise and vibration	-	-	-	-	-	-	-	-	x	-	-	-
	Energy conservation, Resource use	-	-	x	-	-	-	-	-	x	-	-	-
	Biodiversity conservation, quality	-	-	x	x	-	x	-	-	x	-	x	-
	SOCIAL												
	Land acquisition, Involuntary resettlement	-	-	-	-	-	x	-	-	x	x	x	-
	Labor conditions	-	-	-	-	-	x	-	-	x	x	x	-
	Affected communities	-	-	-	-	-	x	-	-	x	-	-	-
	Indigenous people	-	-	-	-	-	x	-	-	x	-	-	-
	Cultural heritage	-	-	-	-	-	-	-	-	x	-	-	-
	Modern slavery, Child + forced labor	-	-	-	-	-	x	-	-	x	x	x	-
	Stakeholder engagement	-	-	-	-	-	-	-	-	x	x	x	-
	Anti-corruption, Transparency	-	-	-	-	-	-	-	-	x	-	-	-
	No poverty (incl. food security)	-	-	-	-	-	x	-	-	-	x	x	-
	Gender equality, Fewer inequalities	-	-	-	-	-	-	-	-	-	x	x	-

-	No specifications given
x	Specifications given
	Specifications given with reference to other sources

1 Lower threshold for "Green H2+", **2** "Issues such as water and land use, other environmental impacts, and social impact are regulated by other legal sources in the EU and its Member States." (International PtX Hub, 2023), **3** Proof of GO cancellation must be provided according to the consumed electricity, **4** Still on development

IPHE - International Partnership for Hydrogen and Fuel Cells in the Economy's *Methodology for Determining the Greenhouse Gas Emissions Associated With the Production of Hydrogen*, **GO** – Guarantee of Origin


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3. Impact of Regulatory Requirements on PtX Plant Configuration

The intermittent electricity supply from renewable sources, such as wind or solar power, can be a challenge when producing hydrogen and its derivatives [59]. While electrolyzers for hydrogen production can be operated in a fairly flexible way, the synthesis processes for derivative production require a preferably steady, non-interrupted energy and feedstock supply. Regulatory frameworks on renewable hydrogen influence this area of conflict and can have an impact on the system configuration of a PtX production plant and consequently on the levelized cost of the product. This chapter describes which of the criteria defined in chapter 2.2 may have an impact on the system design and highlights the respective differences across existing frameworks.

3.1. Regulatory Requirements with Possible Impact on System Design and Levelized Cost

Several regulatory requirements can have a direct impact on the system configuration and the resulting levelized cost of the respective Power-to-X product (LCOX) such as hydrogen or its derivatives.

Brandt et al (2024) [60] investigated the influence of the electricity source on the Levelized cost of hydrogen (LCOH) and the CO_2 footprint of the produced hydrogen. The authors compared a RED III - conform system using a direct connection and a power purchase agreement (PPA) with a scenario, in which a share of the electricity is purchased from the grid, depending on the grid electricity price. Allowing a mix of renewable electricity via direct connection and PPA, and the use of grid electricity, reduced the LCOH. Depending on the grid electricity price, it could either result in a significantly lower or higher CO_2 footprint compared to hydrogen produced from natural gas. The grid electricity price also has an impact on the amount of installed renewable capacity. Thus, their research shows, that the eligibility of grid electricity or the scope of which processes must fulfill the requirement of temporal correlation has an influence on the system configuration and the LCOH. Electricity supplied to auxiliary processes for the downstream production of hydrogen derivatives, like the compressors for synthesis processes, are excluded from the restrictions applying to renewable electricity in some regulatory frameworks [61]. This might reduce storage demand and thus also affect the system configuration and possibly the LCOX.

The criterion of temporal correlation, when using grid electricity, between the electricity generation and its use in the electrolyzer addresses the mismatch between the intermittent character of wind and solar electricity generation and the more continuous energy demand of the downstream production processes. Possible measures to link electricity generation to the electrolysis and synthesis processes are the combination of wind and solar power to stabilize electricity supply, the oversizing of renewable and electrolyzer capacity, and the implementation of hydrogen and battery storages [59]. The balancing interval for temporal correlation influences the system configuration in terms of the chosen renewable electricity sources, the ratio of installed renewable capacity and the rated power of the electrolyzer, and the installed storage capacities. Ruhnau and Schiele (2023) [2] compared an hourly with an annual (no temporal correlation required) balancing interval and stated that the more flexible, annually balanced scenario resulted in a significantly lower LCOH and in lower storage demands. Additionality as a criterion for green hydrogen and its derivatives can have an impact both at the production plant level and at the energy system level. If additionality is applied, the full LCOE of non-funded renewable energy plants can be considered as the minimal electricity purchase cost. If it is ignored, existing plants that are no longer receiving subsidies can provide electricity, possibly lowering the cost. Frontier Economics [62] stated that the LCOH for a renewable hydrogen plant in Germany can be lowered by 1.1 €/kg when additionality is not applied. On a system level, additionality can have positive and negative impacts. Hordvei et al. (2024) [63] name it as the most expensive of the RED III criteria to comply with, but also the most effective to accelerate the green energy transition, as removing it would increase the use of fossil sources in the electricity market. Although, the opposite effect could be observed, as new installations could be preferably used for hydrogen production, slowing down the transition of the electricity system [64, 65].

The CO_2 threshold and the scope of CO_2 emissions considered may define the share of grid electricity that can be used and have an influence on the heat source for downstream processes with a heat requirement, such as the distillation of crude methanol.

For the production of hydrocarbons, the eligibility of CO_2 sources can also have a great influence on the LCOX, given that CO_2 from renewable sources is either limited in volume (biogenic) or very cost and energy intensive (direct air capture), as described in chapter 4.2.

3.2. Differences Across Regulatory Frameworks

Bube et al (2025) [61] reviewed existing sustainability regulations for PtX production. Across the existing legal frameworks, certification schemes, and market incentives for green hydrogen and its derivatives, a variety of regulatory requirements can be found as shown in the Annexes. In the following, legal frameworks from the EU (Renewable Energy Directive 2023/2413/EU, RED III), the United Kingdom (Renewable Transport Fuel Obligation, RTFO), Japan (Japan Hydrogen Society Promotion Act, JHPA), and South Korea (South Korea Clean Hydrogen, SKCH, under the Hydrogen Economy Promotion and Hydrogen Safety Management Act) are investigated to compare the requirements of temporal correlation and the GHG emissions threshold.

It can be stated that the two European regulations, RED III and RTFO, are the strictest and most detailed of the schemes investigated. They have the temporal correlation criteria with the shortest balancing intervals (RED III: hourly from 2030 onwards, RTFO: 30 minutes) and the broadest scope for the GHG emissions threshold (RED III: Well-to-Wheel, RTFO: Well-to-Point of Delivery). While the temporal correlation criterion requires a shorter balancing period for the RTFO, its GHG emission threshold is less ambitious than the EU RED III regulation, regardless of the narrower scope (32.5 gCO_2eq/MJ compared to 28.2 gCO_2eq/MJ). The Japanese regulation is the least strict of the schemes investigated. No temporal correlation criterion is given and the GHG emissions threshold only includes the Well-to-Gate emissions. The SKCH has the lowest CO_2 threshold, however, only Well-to-Gate emissions are accounted for in the first Phase. Tier 2 (8.3 gCO_2eq/MJ) allows for higher emissions compared to Tier 1 (0.83 gCO_2eq/MJ), expecting a share of mixed electricity from the grid. The electricity used has to be balanced on a monthly basis [66].

Radek et al (2024) [67] investigated the impact of the RED III requirements on hydrogen imports and domestic renewable electricity installations in the European power sector. They stated that the RED III requirements would increase the system cost for hydrogen production and reduce the electrolyzer installation within EU, as a larger part of the demanded hydrogen would be covered by imports. This shows that stricter regulations have an impact on the system design of green hydrogen production and increase the focus on PtX production in regions with a high potential for renewable energy sources, preferably complementing each other to a continuous generation profile. However, the study only compared RED III regulation to a scenario without any hydrogen regulation criteria on a system level and did not analyze individual criteria or the effect on the configurations and costs at plant level.

4. Deep Dive into Challenges from Certification Requirements

Compliance with the certification criteria described in the previous section can present significant challenges for fuel producers, a topic that will be explored in detail in this chapter. First, the challenge of deciding on suitable markets is described. Second, the challenges of two exemplary RED III criteria – CO_2 sources and co-production - are discussed in detail.

4.1. Fragmented Global and Regional Regulatory Frameworks and Certification Schemes

Regulatory Framework and Certification Schemes in the SADC-Region

Currently, the SADC region lacks a dedicated regional regulatory framework and certification schemes for green hydrogen, unlike the comprehensive frameworks found in the EU or ECOWAS. Instead, hydrogen development is addressed indirectly through existing strategic instruments, particularly the SADC Climate Change Strategy and Action Plan, which promotes renewable energy and supporting regulatory structures [68].

Within the region, South Africa leads with the most sophisticated green hydrogen regulatory framework (Table 3). Additionally, Namibia, often cited as a frontrunner in Africa's green hydrogen transition, has released a comprehensive Green Hydrogen Strategy, supported by significant international interest and bilateral cooperation agreements. However, key regulatory instruments, including sustainability definitions, GHG accounting rules, and certification mechanisms, are still under development [69].

In Table 3, the analysis of South Africa's regulatory frameworks uses a color-coding system: red (no sustainability criteria), yellow (partial criteria), and green (extensive criteria). The results show that while existing legal frameworks contain relevant sustainability criteria – such as the National Water Act regulating water use, biodiversity, and resource management – others like the National Energy Act only partially address sustainability. The National Energy Act focuses on power supply criteria and renewable energy promotion (shown in yellow) but lacks comprehensive climate and environmental criteria. Notably, none of the regulatory frameworks in this table specifically address green hydrogen production with integrated power supply criteria (temporal and geographical correlation) [70–73].

Although the regulatory frameworks mentioned in Table 3 do not directly address green hydrogen production and its green characteristics, South Africa has various initiatives, including strategic policies, certification and standards development, and regional as well as international collaborations. They encompass the green hydrogen market, e.g.:

Table 3
Current regulatory frameworks landscape and sustainability criteria in South Africa.

Colors
red: sustainability criteria not included
yellow: partially included,
green: included

		Power Supply (renewable energy sources, additionality, temporal, geographical correlation)	**Climate and Environmental** (Water, protected areas, biodiversity, resource management, air quality)	**Social** (Just transition)
National Water Act, 1998	Legal framework	red	green	yellow
National Environmental Management Act	Legal framework	red	green	green
Climate change Act, No. 22 of 2024	Legal framework	red	green	green
Climate Change Bill 2021	Legal framework	red	green	green
National Energy Act	Legal framework	yellow	yellow	green
Electricity Regulation Act	Legal framework	yellow	red	red
Occupational Health and Safety Act	Legal framework	red	red	green
Environmental Impact Assessment (EIA) Guideline:	Guideline	red	green	green
SGS Company	Certification scheme	green	green	green
ISO TS 19870 / SATS 19870:2024	Technical Standard	GHG Assessment: It standardizes the calculation of GHG footprints across the entire hydrogen value chain (well-to-consumption gate).		

- Hydrogen Society Roadmap (HSRM) [6]: A comprehensive green hydrogen roadmap that outlines the strategic development of a hydrogen-based economy in South Africa
- Green Hydrogen Commercialisation Strategy (GHCS) [74]: South Africa's official strategy designed to develop a green hydrogen economy for both domestic consumption and international export markets.
- Renewable Energy Certificate System of South Africa (RECSA): A system that manages the country's voluntary renewable energy certificate (REC) market to promote clean energy adoption
- South African Renewable Energy Masterplan (SAREM) [75]: A strategic plan aimed at boosting clean power generation, energy storage capacity, and green hydrogen production
- Rebel Group Project (under development): Led by RebelGroup, LBST, and TÜV Süd Africa, this project provides practical guidelines for regulations, standards, and certification systems for both export and domestic green hydrogen/PtX products [76].
- Regional Collaborations: Africa Green Hydrogen Alliance, Southern African Green Hydrogen Corridor, and IPHE promote harmonized standards and unified PtX certification approaches, enhancing investment attraction and global value chain integration.
- Regarding certification schemes, SGS Company, a South Africa-based global certification body, was recognized in 2025 for CertifHy EU RFNBO certification, exemplifying regional collaboration with international schemes [77]. Additionally, SABS[11] established the technical committee TC 197 to align with international hydrogen standards, introducing "SATS 19870:2024" for GHG emissions methodology in hydrogen production and transport [78].

[11] South African Bureau Standard
[12] SADC Cooperation in Standardization
[13] SADC Cooperation in Accreditation
[14] Development Finance Institutions
[15] Development Finance Resource Centre

Regional Quality Infrastructure in the SADC-Region

To ensure international competitiveness, the SADC region has established a comprehensive Certification Quality Infrastructure (QI) that ensures products and services meet international benchmarks for trade facilitation and regional industrial growth. This framework encompasses:

- SADCSTAN[12] – Standard harmonization across the region
- SADCA[13] – Regional accreditation systems

While this QI framework does not directly address green hydrogen and PtX sustainability requirements, it provides the foundational structure for developing harmonized certification standards for PtX products that align with international requirements.

Market instruments in the SADC-Region

Some regional market instruments supporting green hydrogen development include the SADC Finance and Investment Protocol (FIP) – a legally binding treaty promoting investment harmonization through the DFI[14] network and DFRC[15] capacity building initiatives [79, 80]. Further market instruments to ramp-up the market can be found in [73].

GAP-Analysis for the SADC-Region:

The SADC region's green hydrogen regulatory landscape reveals significant structural deficiencies that hinder effective market development. The current regulatory environment is characterized by fragmented and partial frameworks that address sustainability criteria in isolation rather than as integrated components of a comprehensive green hydrogen governance system.

A critical gap exists in the absence of specific green hydrogen legislation across the region. While countries like South Africa have established various environmental and energy laws with sustainability elements, none directly address the unique requirements of green hydrogen production, certification, and trade. This regulatory void creates uncertainty for investors and developers seeking clear operational guidelines.

Furthermore, the region exhibits asymmetric regulatory development between member states. South Africa demonstrates a more mature but fragmented approach with multiple existing laws containing partial sustainability criteria, while Namibia, despite its strategic leadership ambitions, remains in early-stage regulatory development with frameworks still under construction. This disparity complicates regional harmonization efforts and creates potential barriers for cross-border collaboration.

Beyond regional regulatory fragmentation, Chapters 3.1 and 3.2 revealed that each major import market maintains distinct and non-interoperable requirements. This dual-level fragmentation (both regional and global) creates several critical implications:

- Export Market Challenges: The region lacks regulatory frameworks that comply with diverse international sustainability and traceability requirements, complicating harmonization efforts due to substantial jurisdic-tional differences such as EU, Japan and South Korea.
- Domestic Market Barriers: Absence of recognized national or regional sustainability standards prevents the development of bankable projects targeting local offtake.
- For project developers and operators: Regulatory fragmentation forces early, inflexible market commitments that increase misalignment risks and challenge resourcelimited developers.
  The resulting export focus undermines domestic market development. Without harmonized regional certification systems, developers face high strategic risks navigating divergent international requirements, highlighting the critical need for coordinated regional and global certification frameworks.

4.2. Availability of compliant CO_2 Sources

Fossil CO_2 sources:

Fossil CO_2 sources can be eligible under RED III in PtX projects until 2036 if the CO_2 comes from electricity production and until 2041 if it comes from other industrial sources, such as cement plants. These CO_2 sources must also be part of a CO_2 pricing system to qualify as eligible. If these conditions are met, the CO_2 industrial sources can be subtracted from GHG emissions accounting. If ineligible industrial CO_2 sources are used, the required 70% GHG reduction threshold mandated by RED III cannot be achieved. Therefore, these two conditions are essential for industrial CO_2 sources to be considered "carbon-neutral" under RED III, and they pose some challenges.

A crucial aspect of using CO_2 sources from industrial sites is the requirement for an effective upstream carbon pricing system. A technical definition of what constitutes an "effective" carbon pricing system is not provided by the European Commission [81]. According to a non-binding document from the European Commission [82], an effective CO_2 pricing system must fulfill specific minimum criteria. These include having a robust monitoring, reporting, and verification (MRV) process, being binding on its participants, and ensuring that the carbon price effectively contributes to emission reductions aligned with climate neutrality. Currently, the following systems are deemed to meet the requirement for upstream accounting within an effective carbon pricing system: EU ETS, Swiss ETS, and UK ETS. Other CO_2 pricing systems where RFNBOs and RCFs are anticipated to be produced may seek to undergo assessment.

Most countries in the SADC region lack Carbon Pricing Systems or an Emission Trading System [83]. South Africa currently implements carbon pricing mechanisms through a Carbon Tax (Carbon Tax Bill). This carbon pricing framework encompasses emissions from various sectors, including fuel combustion in energy industries and transportation, fugitive emissions from solid fuels and oil, industrial processes in the mineral, chemical, and metal industries, as well as livestock emissions in agriculture and land use. However, the carbon tax rate is capped at approximately 12 EUR/tCO_2 [84], which is relatively low compared to the EU ETS, where prices range between 60-120 EUR/tCO_2 [85]. It is not clear if these conditions can be accepted by the European Commission. According to VDMA [81], an effective carbon pricing strategy must encompass all sectors of the economy, with a recommended pricing level based on European carbon prices. This indicates a barrier, as there are currently few ETS-comparable systems outside the EU, although some countries are considering implementing their own ETS. As a result, RFNBO projects that source CO_2 from industrial sites outside of Europe may not be feasible under the regulations established by the delegated acts [86].

Biogenic CO_2 sources:

In the context of the SADC region, Namibia's local biomass, particularly from bush encroachment, offers a significant opportunity to use this resource as a sustainable CO_2 source for producing RFNBOs, especially e-fuels. Biogenic CO_2 sources are permitted under the requirements of the Delegated Acts Art. 28. However, there are two requirements that must be addressed to effectively use this CO_2 for PtX products: compliance with sustainability and GHG savings according to the RED III and use of a mechanism to prevent double counting.

The biofuel from which the CO_2 is derived must satisfy the sustainability and GHG savings criteria specified in RED III, which include considerations such as land use change, biodiversity, and GHG accounting for biofuels. To validate adherence to these sustainability criteria, it is required that the biofuel used for CO_2 sourcing is certified by a voluntary scheme approved by the European Commission [40]. This requirement can pose a barrier due to the complexity and potential costs and processes associated with obtaining such certifications in the SADC region [87].

Additionally, biogenic CO_2 should not receive credits for emissions saved through CO_2 utilization on the biofuel side under RED III, as the regulation aims to prevent double counting. This presents a challenge, as there is currently no effective mechanism in place to address this issue. Without such a mechanism, there is a risk that a biofuel producer could receive emission credits simultaneously with a PtX producer, leading to inconsistencies and undermining the integrity of the emissions accounting process [87].

Further eligible CO_2 sources:

The Delegated Acts (DA) of the RED III allow the use of further CO_2 sources, such as the combustion of RFNBOs, CO_2 from geological sources, and CO_2 captured through Direct Air Capture (DAC). However, there are important requirements to consider. For example, the combustion of RFNBOs must comply with the sustainability criteria specified in the delegated acts (first DA, Article 27 and second DA, Article 28). Additionally, geological CO_2 must be released naturally to qualify for CO_2 deductions. While DAC technology holds promise, it is not yet fully developed and also energy-intensive, which means it is likely to remain expensive [88].

4.3. Co-Processing and Co-Production Rules impact Brownfield Plants

Co-processing and co-production regulation

Article 28 of the second DA specifies the GHG emission accounting rules for RFNBOs [89]. These rules include regulations on co-processing, where RFNBO inputs are mixed in with conventional (fossil) inputs; and co-products, where multiple outputs are produced (see Figure 4). The DA generally allows co-processing of renewable and fossil products in the same installation. If an RFNBO input partially replaces a fossil fuel input, the GHG emissions must be calculated proportionally based on the energy value of inputs. The RFNBO content is calculated by dividing the renewable energy input by the total relevant energy input. For a process with multiple co-products, the allocation of GHG emissions is done by energy content, if the ratio of co-products is fixed. If the ratio is not fixed, GHG emissions are allocated with a physical causality approach: It must be calculated how GHG emissions of the process change if the output of one product is increased, while the others are kept constant.

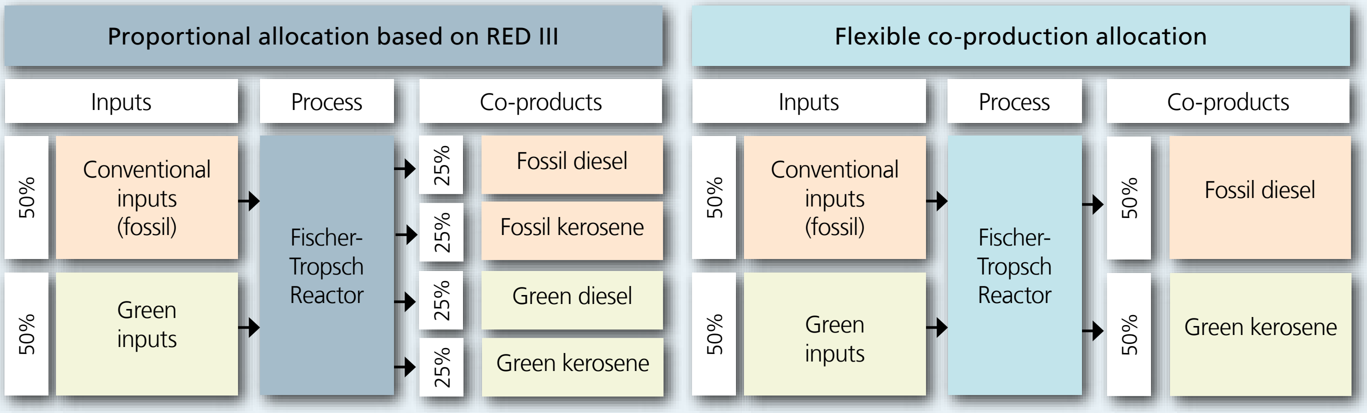

Figure 4: Example of current co-production allocation rules based on the RED III (left hand side) and flexible production allocation (right hand side).

Co-processing and co-products in practice: refineries

An exemplary process for which this regulation is relevant is the production of eSAF. eSAFs, such as synthetic kerosene, are expected to be a vital component of the PtX market because of their potential to decarbonize the aviation sector [90]. Synthetic kerosene can be produced in refineries using the Fischer-Tropsch (FT) process. In the FT process, co-processing would be feasible by mixing renewable H_2 and CO feedstocks with conventional inputs to produce syncrude [91]. The co-production regulation then states that the green attribute must be allocated to all products from the FT process. For example, a 50% share of green inputs into a process yielding 50% kerosene would lead to 25% of the overall output being green kerosene (see Figure 4). Only a small number of global refineries employ the FT process [92, 93]. Large commercial plants are operated by Sasol in Secunda, South Africa. Most other refineries in the world are crude oil fractional distillation plants [94]. These refineries are not eligible to co-process renewable H_2 and CO_2 directly as feedstocks, only as a finished imported syncrude. Therefore, a complete green transformation for crude oil refineries is not feasible without significant investments to change the process (e.g. installing a FT reactor). However, existing equipment could be partially reused [90]. Nonetheless, crude oil refineries can use green hydrogen in hydrocracking and hydrotreating processes, where it acts as a reactant and not as a feedstock to the fuel [95, 96].

Criticism of co-processing and co-production regulation and demand for flexible allocation

The current proportional allocation rules for co-products do not allow allocating the green attribute flexibly to the product that yields the highest green premium or has subsidies, e.g. kerosene (see Figure 4). According to the H2Global auction results, the current co-production rules of the DA were one of the reasons why no bids were submitted for eSAF production [97]. Allowing flexible allocation would create an economic advantage for FT plants. With incremental increase of green H_2 into the process, the green attribute would be allocated to kerosene. While there is still some conventional kerosene in the product mix, additional green hydrogen would not incentivize shifting the production to a higher share of kerosene. However, once all kerosene is green, adding additional green H_2 could incentivize a shift in the production mix to more kerosene.

4.4. Industrial and Political Feedback on RED III Criteria & Stakeholder Discussions in South Africa

Feedback from Hydrogen Europe in 2022:

While not related to the final version of the RED, Hydrogen Europe already pointed out in 2022 [98], that the additionality and correlation requirements are excessively stringent, potentially leading to complexity and rigidity that could hinder investments. They also recommend reevaluating the restrictions on CO_2 sources and redefining the criteria for acceptable CO_2 sources limited by carbon pricing requirements to produce e-fuels. This joint letter, which includes major European hydrogen technology providers, called for an extension of the transitional period and grandfathering to at least 2030, a shift from hourly to monthly time matching, and greater flexibility concerning Power Purchase Agreements (PPAs) and bidding zone alignment. Since this feedback has been published in 2022, the RED III has come into force in 2023, but none of the discussed requirements have been adjusted or changed, which makes the feedback still relevant today.

Feedback from the German Minister of Economic Affairs in 2024:

In his letter to the European Commission dated September 2024, German Minister Robert Habeck urged a revision of the DAs under the RED III concerning green hydrogen [99]. He argued that the current criteria for RFNBOs, particularly the strict "additionality", temporal and geographical correlation rules, pose significant barriers to scaling up green hydrogen production across the EU. Habeck emphasized the need for more flexible and pragmatic rules during the ramp-up phase of the hydrogen economy. He proposed a temporary relaxation of the additionality requirement, such as allowing electrolyzers to use grid electricity under certain conditions and extending the transition period beyond 2030. He also supported calls for an earlier review of the delegated acts, originally set for 2028, in order to reflect the evolving market and technological conditions more rapidly. Habeck’s appeal was aligned with concerns voiced by other EU Member States and industry stakeholders, who share the view that overly rigid regulations could delay hydrogen investments and jeopardize Europe’s climate and industrial goals.

Feedback from the European Parliament in 2025:

The European Parliament has asked the European Commission to review the requirements for producing green hydrogen outlined in the RFNBOs delegated act adopted in 2023. The Parliament noted that the strict criteria for additionality, as well as temporal and geographical correlation, are impacting production costs and hindering investment. They are advocating for “investment-friendly” requirements that maintain environmental standards while reducing regulatory burdens [100, 101].

Feedback from other EU-industry stakeholders:

Fertilizers Europe warned that stringent additionality (36-month window) and hourly correlation are especially burden-some for heavy-use industrial players in areas with limited renewables, calling for a postponement to at least 2035, conservative grandfathering extensions, and inclusion of low-carbon PPAs [102], emphasizing that the need for greater flexibility in the RFNBO production criteria is essential to simplify processes and reduce costs.

General feedback and perspectives from stakeholders in the SADC-Region:

- Source 1: "Implementation of EU rules on sourcing renewable electricity for RFNBO production: Perspectives of non-EU countries" [103]: In this source, an analysis was conducted to determine whether the requirements in the DA can be met by countries outside the EU. This involved interviews with project developers and other industry partners. The main feedback from the interviewees highlighted concerns regarding the additionality criteria, particularly for large-scale projects that require phased approaches, as stringent timelines may negatively impact their development. Additionally, the issue of temporal correlation was emphasized; allowing more flexibility in temporal correlation (specifically, less strict rules than the one-hour requirement) would enable better operation of electrolyzers and improve the LCOH.
- Source 2: "Shaping the Future: Industry Insights on Technical Standards and Certification for Green Hydrogen" [104]: Stakeholders in South Africa provided valuable feedback during this workshop. They emphasized the need for clear and practical certification criteria for green hydrogen, highlighting the importance of aligning these processes with market demands while considering environmental factors, particularly water consumption in hydrogen production. Although existing regulations like the Occupational Health and Safety Act and environmental legislation lay a foundation, they may not fully address the specific sustainability criteria for hydrogen technologies. Stakeholders expressed uncertainty about whether to develop a local certification scheme that focuses on regional needs or to adapt existing international standards to meet global market expectations. Additionally, regional collaboration was recognized as a potential avenue for developing a cohesive certification framework. Furthermore, stakeholders highlighted the importance of building local expertise to enhance the efficiency and accessibility of certification processes. Finally, they emphasized the lack of direct relationships with potential buyers and customers, which could impede efforts to expand the green hydrogen market internationally.
- Source 3: "HySecunda Stakeholder Workshop South Africa 1 – Protocol" [105]: During a HySecunda workshop conducted by Fraunhofer [106] in South Africa, stakeholders raised several concerns, which include the need to align with international standards, as current national standards are not a priority. The focus regions identified are Europe, Japan, Korea, the UK, and Singapore. Participants expressed fears that fragmentation will continue to grow, similar to the situation with biofuels. Furthermore, the workshop results highlight gaps in research and development, especially concerning strategies to encourage the government to adopt essential policies and regulations related to hydrogen. Additionally, a need to identify aspects or criteria within the RED III that may not be applicable or feasible for PtX projects was identified.

5. Synthesis of Findings: SWOT Analysis of the SADC Region as a Producer of PtX

To summarize the findings from Chapters 3 to 4, a SWOT (strengths, weaknesses, opportunities, threats) analysis of the SADC region as a producer of PtX fuels is presented in this chapter. It explores the strengths, such as internal capabilities and competitive advantages that support the development of certification schemes; weaknesses, including internal challenges or limitations that may impede progress; opportunities, referring to external trends, market demands, and policy shifts that could facilitate the adoption and scaling of PtX certification; and threats, encompassing external risks and uncertainties that could undermine success. This analysis seeks to provide a comprehensive perspective for operators, developers, and policymakers on the legal frameworks, certification schemes, and sustainability requirements (both global and regional) for green hydrogen and PtX. By examining these dimensions with special focus on identifying weaknesses and threats, this analysis aims to inform strategic decisions, enhance stakeholder alignment, and support the development of credible, scalable, and internationally recognized PtX certification frameworks in the SADC region.

Strengths

- Competitive landscape: SADC has abundant renewables, refining infrastructure, and first developments of PtX policy frameworks (e.g., South Africa's Hydrogen Society Roadmap, Namibia's Synthetic Fuels Act).
- Large-scale PtX projects are underway (e.g., Namibia's ~2 Mt/year green ammonia via 3 GW electrolyser by 2030).
- Emerging certification collaborations: e.g., the certification company SGS in South Africa recognized under EU's CertifHy scheme.
- SABS is aligning national with international certification activities e.g., publication of SATS 19870:2024 for GHG assessment in hydrogen value chains.
- Presence of a well-established Standard and Quality Infrastructure (QI) that engages in activities such as standard harmonization and the establishment of accreditation bodies.
- Regional cooperation initiatives including the Africa Green Hydrogen Alliance and Southern African Green Hydrogen Corridor.
- Potential synergies among Biomass-to-X and PtX using local biomass for sustainable CO_2 supplies in e-fuel production.

Weaknesses

- Regulatory local frameworks are still fragmented without comprehensive green hydrogen governance integration.
- Uncertainty whether to adopt international schemes or develop local standards.
- Uncertainty about potentially complex regulatory frameworks hinder smaller developers.
- Stakeholders emphasize weak mechanisms for connecting producers with offtakers, which could limit market access.
- Local technical capacity (e.g., life-cycle assessment, certification processes) remains limited.
- Limited biogenic CO_2 and immature DAC technologies limit feedstock options, increasing cost and supply risk.

Opportunities

- High demand for PtX in global decarbonized energy markets through exports.
- Harmonized schemes tailored to regional priorities could unlock premium markets and elevate SADC's capability in low-carbon fuels.
- A unique chance to lead by integrating local environmental concerns into certification (e.g., water & land use).
- Certification growth can catalyze local value chains, industrial development, and skilled employment.
- The role of financing mechanisms is expected to be crucial for improving investment practices and lowering H_2 production costs. The creation of new instruments may facilitate the creation of the PtX market and boost investor confidence in the region.

Threats

- Competition from other PtX hubs (e.g., Chile, Uruguay) with strong renewables and CO_2 access.
- Global and regional fragmented regulations create market entry barriers, investment risks and require early decision on market prioritization.
- Strict rules (e.g., RED III's additionality, co-processing, CO_2-sources) raise compliance hurdles due to technical and design complexities and potentially higher cost.
- Lack of or limited environmental criteria and social criteria in import markets. International certification often neglects regional sustainability concerns (e.g., water use, biodiversity, community impact).
- Environmental and social impacts (e.g., water usage) of PtX projects may spark community backlash.

6. Outlook for Further Evaluation

The establishment of initial regulatory requirements represents a positive step toward achieving net-zero GHG emissions targets on national and international levels. Importing regions such as the EU, UK, Japan, and South Korea are at the forefront of creating legal frameworks for green hydrogen and PtX products. These frameworks lay the groundwork for regulatory development considering the specific needs of these regions and driving the currently developing market. Right now, regulatory requirements vary significantly across importing regions, while the SADC region either lacks existing regulatory frameworks or presents fragmented approaches, as seen in South Africa. While many existing frameworks focus on reducing GHG emissions, it is crucial to address the gaps regarding environmental and social sustainability criteria beyond carbon intensity (see Chapter 5). Including these aspects in certification is vital for promoting responsible market growth.

As sustainability criteria continue to diverge across major importing regions, the SADC region faces both opportunities and risks (see Chapter 5). The region's abundant renewable resources and international partnerships establish strong fundamentals for green hydrogen and PtX market growth. However, regulatory fragmentation at both international and regional levels undermines this potential by creating investor uncertainty, delaying capital deployment, and forcing developers to navigate costly, inflexible compliance requirements across multiple jurisdictions. Regional workshops and studies [107] have provided valuable opportunities for stakeholders to reflect on these challenges and engage with evolving regulatory frameworks. Successfully addressing these challenges will be critical for streamlining project implementation and expanding PtX market participation. Industry stakeholders have identified the need to adapt certain sustainability requirements – specifically the EU's RED III additionality and temporal correlation criteria – to better facilitate market access and participation.

The SADC region could draw lessons from other regional initiatives that harmonize certification schemes and reduce market access uncertainty by combining sustainability requirements of key importing regions with additional criteria tailored to local technical, environmental, and social contexts. For example, CertHiLAC [108] is a Latin American certification system initiative that provides dual certification to align with RED III requirements while reflecting regional sustainability priorities, including specific criteria for water, land use, and biodiversity. Specifically for the SADC region, it is recommended to consider the following aspects:

- Define what constitutes GH2 and derivative products (e.g. green ammonia, e-methanol) across production, storage, transport, and export
- Align definitions with export market requirements (EU, Japan, UK, South Korea)
- Streamline environmental, land-use, health and safety approvals
- Align hydrogen regulation with existing legal frameworks and programs relating to renewable energy in the countries and region e.g., integration of Renewable Energy Certificates (RECs) in South Africa into GH_2 certification, including power supply criteria such as temporal and geographical correlation
- Harmonize hydrogen standards and regulatory frameworks within the SADC region to reduce fragmentation and enable intraregional trade, while ensuring compatibility with continental market integration objectives under the African Continental Free Trade Area Agreement (AfCFTA), supported through regional cooperation and voluntary convergence facilitated by the Africa Green Hydrogen Alliance (AGHA)

Regional certification schemes could allow project developers to balance export readiness with local market necessities, while gradually reducing uncertainty over market prioritization. However, it is essential to assess how this flexibility may impose additional upfront engineering and certification costs on project developers, and whether these costs outweigh the benefits in terms of market access.

Moreover, despite growing attention to sustainability requirements, systematic analyses remain scarce on how specific regulatory criteria – such as temporal correlation, electricity and carbon sourcing, and CO_2 thresholds – influence plant configuration and the Levelized Cost of Hydrogen (LCOH) and its derivatives (LCOX). Filling this gap will be a central objective of our recommendation and future work. In particular, we recommend a focus on:

- Quantitative assessments to evaluate the impact of the criteria described in chapter 3 on the system design and the resulting LCOH or the respective derivative.
- Evaluating both individual criteria and entire frameworks.
- Developing guidance on tailoring PtX system configurations to meet evolving market demands.

By pursuing these research topics, we aim to provide a clearer understanding of how regulatory requirements shape the competitiveness of PtX projects in the SADC region and identify pathways toward aligning regional potential with global market access.

7. Annexes

Annex 1a: Sustainability requirements associated with legal frameworks, certification schemes and

Sustainability aspect	RED III	H2Global	Atmosfair fairfuel
References	RED III; DR 2023/1184; DR 2023/1185	Hydrogen Purchase Agreement, Annexes 3.1b, 9.1a and 9b[1]	atmosfair fairfuel – Catalogue of criteria[2]
GHG emissions threshold	28.2 g CO_2e/MJ	25.38 g CO_2e/MJ	28.2 g CO_2e/MJ
System boundary	Well-to-Wheel	Well-to-Point of Delivery (PoD); if PtX product were used at PoD; distribution from PoD not accounted for	as per RED III
Eligible electricity	RES, excluding biogenic sources	as per RED III; renewable electricity for seawater desalination	RES
Additionality	max. 36 months between RES and PtX plant operation start; exemption until 2038 for plants starting operation before 2028	as per RED III	as per RED III; no exemption (for plants starting operation before 2028)
Temporal correlation	monthly until 2029; hourly from 2030	as per RED III	hourly
Geographic correlation	same bidding zone	as per RED III	same bidding zone, within 500 km radius
Carbon source	DAC, combustion of RFNBOs or RCF Biogenic carbon, Geological sources if released naturally, Activities subject to EU ETS (power plants until 2035, other industrial processes until 2040)	as per RED III	growing DAC share up to 100% by 2050; no fossil or industrial point sources
Co-processing/ Co-production	proportional allocation	as per RED III	flexible allocation (under book-and-claim) unless another approach applies, e. g. mass balancing under another standard
Other environmental and social	NA	see Annex 1b	see Annex 1b

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4 Operating rules for Clean hydrogen certification operating agency, Korea Energy Economics Institute, 2025, https://www.keei.re.kr/boardDownload.es?bid=0024&list_no=124736&seq=1

5 Shirakawa, K., Tachiiri, H., Hydrogen Society Promotion Act and relevant orders and regulations, Mori Hamada Energy & Infrastructure Newsletter, January 16, 2025 (Vol. 47), https://www.morihamada.com/sites/default/files/newsletters/en/energy-infrastructure/20250116/01.pdf

6 CORSIA Methodology for calculating actual life cycle emissions values, ICAO, 2025, https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Fuels/ICAO-document-07-Methodology-for-Actual-Life-Cycle-Emissions-June-2025.pdf

market incentives

UK	South Korea	Japan	CORSIA
RTFO and SAF Mandate technical guidance[3]	Operating rules for Clean hydrogen certification operating agency[4]	Hydrogen Society Promotion Act and relevant orders and regulations[5]	CORSIA GHG methodology[6]; CORSIA sustainability criteria[7]
for RTFO: 32.9 gCO_2e/MJ; for SAF Mandate: 53.4 gCO_2e/MJ or lower (number of certificates accounts for actual reduction)	Tier 1[8]: 0-0.1 kg CO_2e/kg H_2; Tier 2: 0.1-1 kg CO_2e/kg H_2	for hydrogen: 3.4 kg CO_2/ kg H_2; for ammonia: 0.87 kg CO_2/ kg NH_3; for synthetic fuel: 39.9 g CO_2/MJ (hydrogen used as feedstock must meet hydrogen threshold above)	80.1 g CO_2e/MJ or lower (accounting for actual reduction compared to 89 g CO_2e/MJ)
Well-to-Wheel	Well-to-Gate (planned for phase 2: Well-to-Port; planned for phase 3: Well-to-Wheel)[9]	Well-to-Gate	Well-to-Wheel
for RTFO: RES (non-biomass); for SAF Mandate: RES (non-biomass) and nuclear	expected sources: Tier 1: 100% RES; Tier 2: RES with some grid electricity[10] [11] (plan to minimize use of grid electricity required; up to 10% of RES electricity may be used through REC, otherwise PPA)	RES (or CCS); use of non-fossil certificates (EAC) is allowed	NA[12]
new generation capacity at new, upgraded or recommissioned electricity production site curtailed electricity (same or later operation start as PtX plant); other satisfactory evidence	"additionality and feasibility of GHG emission reductions, when compared to alternative pathways"	NA	max. 36 months between PtX plant operation start and electricity generation installation and storage capacity; exemption until 2035 for plants starting operation before 2028
30-minute	monthly	NA	annually until 2029; hourly from 2030 given network readiness (hourly EAC[13] and/or hourly metering)
national grid; regional grid subject to regionalization criteria (physically separate or managed as such, systematic grid congestion)	same electrical grid as H_2 production facility	NA	RES and PtX facility in the same network: TSO area, country or bidding zone
DAC, water, biogenic, naturally occurring/ geothermal, waste CO_2 (industrial point sources)	NA	NA	no biomass obtained from land/aquatic systems with high biogenic carbon stock; direct land use change (DLUC) emissions considered in case of conversion
proportional allocation	NA	NA	proportional allocation
NA (applicable to biofuels only)	NA	NA	see see Annex 1b

7 CORSIA Sustainability criteria for CORSIA eligible fuels, ICAO, 2025, https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Fuels/ICAO-document-05-Sustainability-Criteria-June-2025.pdf

8 While four tiers of clean hydrogen are outlined in the Korean framework, only the first two are presented here, as they are supposed to be produced fully or predominantly from renewable electricity.

9 Notification of the operation of Clean hydrogen certification system, Kim & Chang, 29.12.2023, https://www.kimchang.com/en/insights/detail.kc?sch_section=4&idx=28649

10 Seokhwan, J., Not all hydrogen is clean: Key issues regarding South Korea's Clean Hydrogen Certification, 2023, https://content.forourclimate.org/files/research/CUXiFUe.pdf

11 Nuclear electricity is eligible for domestic but not overseas electrolytic hydrogen production.

12 No provisions regarding eligible electricity sources could be found in the CORSIA GHG methodology. CORSIA eligible fuels include two types: CORSIA SAF, defined as a renewable or waste-based fuel meeting the sustainability criteria, and CORSIA lower carbon fuels (LCAF), defined as a fossil-based aviation fuel that meets the sustainability criteria.

Annex 1b: Further environmental and social sustainability requirements associated with legal

Sustainability aspect	H2Global	Atmosfair fairfuel	CORSIA
Water use	For provinces with high or extremely high water stress according to WRI's Aqueduct 3.0: no use of fossil water or water intended for human consumption. RES electricity to be used for seawater desalination. Monitoring of water consumption impact on water stress	For site with high or extremely high overall water risk according to WRI's Aqueduct Water Risk Atlas: independent impact assessment of water utilization; measures for sustainable water use	Maintain or enhance water quality and availability; respect water use rights of local and indigenous communities
Land use: protected areas	Site at least 1 km away from IUCN Category I-IV protected areas, Ramsar Wetlands, UNESCO World Heritage Sites, UNESCO Biosphere Reserves, AZE Sites on the Global AZE map, and ecosystems listed by the IUCN Red List	EIB ESG[1] Standard 10 – Cultural Heritage (CH), incl. natural heritage: ESIA[2] in case of significant CH impact; avoid significant adverse effects on CH by project location and design; if unavoidable for reasons other than costs: ESIA incl. studied alternatives, direct and indirect IA and mitigation measures	Operational practices will be implemented to avoid adverse effects on areas that, due to their biodiversity, conservation value, or ecosystem services.
Land use: biodiversity	Site at least 1 km away from a place regularly visited by endangered or critically endangered species (bird or mammal) in case of material risk of mortality or injury; at least 1 km from carbon pools if there is risk of GHG release	No biodiversity loss (applies to biomass use); no biodiversity degradation as eligibility requirement for CO_2 from pulp and paper industry	Included in previous aspect (see above)
Air quality	NA	NA	Air pollution emissions will be limited.
Waste	No brine discharge as a general rule (e. g. a zero liquid discharge technology); in case of lacking economic, technical or regulatory viability: risk assessment, monitoring, prevention and mitigation to be performed	In case of seawater desalination, ensure that concentrated brine has no negative impact on the environment	Operational practice to ensure responsible storing, handling and disposal of waste and chemicals
Land use rights	No forced resettlement (up to 5 years prior)	EIB ESG Standard 6 – Involuntary resettlement	Respect existing land rights and land use rights, including indigenous people's rights, both formal and informal
Local and social development	Training for employed residents within 50 km from installations; min. 160 h p. a., incl. 80 h p. a. related to RES; min. 10.000 EUR to be invested in the training program	NA	In regions of poverty, strive to improve socioeconomic conditions of affected communities
Gender	Equal opportunities officer; qualified employment contracts with women	EIB ESG Standard 7 – Vulnerable groups, indigenous peoples and gender – applicability based on EIA/ESIA; incl. consideration of specific gender risks	NA
Food security	NA	Addressed in EIB ESG Standard 6 – Involuntary resettlement (livelihoods include means for securing food; requirements for relocation sites include food and water security)	In food insecure regions, strive to enhance local food security of directly affected stakeholders

[1] Environmental and Social Standards, European Investment Bank, 2022, https://www.eib.org/files/publications/eib_environmental_and_social_standards_en.pdf
[2] Environmental and social impact assessment

Human and labor rights	Freedom of association & collective bargaining; no forced or child labor; no discrimination; health & safety; respect international conventions	EIB ESG Standard 7 – Labor rights	Respect human and labor rights
Miscellaneous	Environmental management system to ensure sustainable waste and water management Adherence to international conventions on human rights and fundamental freedoms and environment protection	highest possible proportion of all solid and liquid starting products from PtX plant should flow into end products (cooperation with refineries); system must be controllable in a way that serves the grid; PtX plant must not exacerbate bottlenecks in the grid; if rural electrification rate < 75% or HDI < 55%, additional RES capacity to supply local population at socially acceptable prices; EIB ESG Standard 10 – Stakeholder engagement	Best practices to maintain or enhance soil health (for biogenic feedstock)

Annex 2: Legal Frameworks in major importing countries*

Legal Frameworks

Renewable Energy Directive (2023/2413/EU) - RED III	■ European Union ■ To incentivize the uptake of renewable PtX products by sectoral consumption quotas for renewable fuels of non-biological origin (RFNBOs), incl. H2 and derivatives (e.g. ammonia, e-SAF and methanol) ■ Delegated acts (DAs) define how RFNBOs must be produced to count towards the EU's renewable energy targets
ReFuelEU Aviation	■ Sets an RFNBO blending mandate for aviation fuel in the EU, increasing from 1.2% in 2030 to 35% by 2050
FuelEU Maritime	■ Provides an RFNBO share for maritime fuel in the EU
Renewable Transport Fuel Obligation – RTFO	■ United Kingdom ■ Applies to fuels used in the transport sector, incl. maritime transport ■ Starting in 2025, a separate SAF Mandate applies to aviation, incl. a power-to-liquid (PtL) obligation starting from 0,2% in 2028 and gradually rising to 3,5% in 2040
Low Carbon Hydrogen Standard – LCHS	■ United Kingdom ■ Supports the country's hydrogen strategy by defining low-carbon hydrogen production ■ Basis for a Low-Carbon Hydrogen Certification Scheme currently being developed ■ Used under the Hydrogen Production Business Model (HPBM) (support scheme for domestic production), may gain relevance for international trade
Clean Hydrogen Portfolio Standard - CHPS	■ South Korea ■ Policy tool initially designed to require power generators to include a minimum share of hydrogen-generated electricity in their overall mix ■ Support mechanism, see 2.1.3 Market Incentives. ■ SAF mandate blending of 1% for departing international flights is envisaged from 2027
Japanese Hydrogen Society Promotion Act - JHPA	■ Japan ■ Foundation for Japan's hydrogen economy, incl. definition of low carbon hydrogen and derivatives ■ Support mechanisms, see 2.1.3 Market Incentives ■ Aviation: introduction of a 10% SAF mandate planned for 2030, which is required to result in at least 50% GHG reduction
CORSIA	■ Global ■ Instrument introduced by the ICAO for addressing CO_2 emissions in international aviation ■ SAF[1] that meets sustainability criteria (among CORSIA eligible fuels) can be claimed towards the carbon offsetting obligation set to ensure carbon-neutral growth

[1] CORSIA eligible fuels (CEF) are defined by reference to American Society for Testing and Materials (ASMT) standards.
While Fischer-Tropsch synthetic kerosene (ASTM D7566 Annex 1) is covered, the inclusion of the methanol route is subject to its ASTM approval, which is currently outstanding.

[2] Japanese Ministry of Economy, Trade and Industry

[3] Japan Organization for Metals and Energy Security

[4] German non-profit organization focusing on climate protection through car-bon offsetting and financing renewable energy and energy efficiency projects

Annex 3: Certification schemes in major importing countries

Certification Schemes

RED III compliance: ISCC EU CertifHy EU RFNBO RED-cert EU	■ Demonstrate compliance with the REDIII in the EU ■ Approved by the EU Commission ■ Mirror the RED III requirements exactly and contain no additional sustainability criteria
RTFO compliance: To be developed for RFNBO	■ Compliance with the UK's Renewable Transport Fuel Obligation (RTFO) and SAF Mandate to be demonstrated by a voluntary certification scheme ■ Multiple eligible schemes operate for biogenic fuels ■ No certifications scheme for RFNBO other types of renewable fuels currently approved by the UK Department for Transport
CORSIA compliance: ISCC CORSIA RSB CORSIA ClassNK	■ Currently recognized under CORSIA ■ Focus on biogenic SAF
CHPS compliance: South Korea Clean Hydrogen Certification Scheme	■ National scheme, which sets out the criteria for sustainable H2 production and demonstrates compliance with the Clean Hydrogen Portfolio Standard (CHPS) and the SAF mandate ■ Certification scheme is operated by the Korea Energy Economics Institute
JHPA compliance: Japan Clean Hydrogen Certification	■ Under development ■ Includes promotion of international harmonization and adoption of international standards for GHG accounting ■ Eligibility for state support schemes is ensured during business plan approval by METI[2] with involvement of the schemes' administrator JOGMEC[3]
Atmosfair fairfuel	■ Voluntary certification scheme developed by atmosfair[4] for e-kerosene (aviation) and e-methanol (shipping)
TÜV Süd CMS 70	■ Voluntary, applicable worldwide ■ Defines sustainable hydrogen production in two tiers (Green Hydrogen and Green Hydrogen+)
CertifHy Non-Governmental Certification (NGC)	■ International certification scheme currently only applicable in the EU, the EEA and Switzerland ■ Covers sustainability requirements to produce "renewable" and "low carbon" hydrogen
Green Hydrogen Standard (GHS)	■ Voluntary, applicable worldwide ■ Initially focused solely on hydrogen, but has since expanded its scope to include ammonia, methanol and methane

Annex 4: Market incentives in major importing countries

Market Incentives (Incentive and Support Schemes)

H2Global	■ German-Dutch support scheme ■ Production (H2 and derivatives) can occur worldwide (excl. Germany and the Netherlands), Consumption: within the EU ■ Two-sided market auction with contract-for-difference-like (CfD) features: During the supply-side auctions, PtX producers can apply and the lowest price offer wins. The product is purchased by HintCo, daughter company of the H2Global foundation. In the demand-side auctions, the products are sold to the highest bidding customers.
European Hydrogen Bank	■ Production (hydrogen) must adhere to the requirements of the REDIII, project must be located within the EU, Consumption: within the EU ■ To attract imports, an international pillar is currently being developed by the European commission ■ Fixed premium: Projects can apply for a fixed premium of their choice (€/kg H_2), and if their application is successful, they will receive that premium for 10 years
Carbon Border Adjustment Mechanism (CBAM)	■ Carbon price on imports of certain products (incl. H2 and fertilizers) ■ Goal: prevent carbon leakage, promote sustainability ■ Importers have to pay carbon price equivalent to the EU's carbon market price for embedded emissions of CBAM goods ■ Certified RFNBO: treated with zero-emissions ■ Mechanism helps support the competitiveness of green H2 and PtX by disincentivizing imports with GHG emissions above REDIII threshold
Clean Hydrogen Portfolio Standard - CHPS	■ For more details, see section 2.1.1 Legal Frameworks ■ CfD mechanism: Korean Government purchases electricity generated by clean hydrogen/ammonia, subsidizes the difference between the contract price and the wholesale electricity price on the Korea Power Exchange (KPX)
Japanese Hydrogen Society Promotion Act - JHPA	■ For more details, see section 2.1.1 Legal Frameworks.Introduces two support instruments: a CfD mechanism for the use of low carbon hydrogen and derivatives in hard-to-abate sectors, and support to hydrogen hubs for hydrogen infrastructure development

Abbreviations

AfCFTA	African Continental Free Trade Are Agreement
AGHA	The Africa Green Hydrogen Alliance
ASTM	American Society for Testing and Materials
CBAM	Carbon Border Adjustment Mechanism
CCU	Carbon Capture and Utilization
CEF	CORSIA eligible fuels
CertHiLAC	Certification System for Clean and/or Low-Carbon Hydrogen and its Derivati-ves in Latin America and the Caribbean
CfD	Contract for Difference
CHPS	Clean Hydrogen Portfolio Standard
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DA	Delegated Act
DAC	Direct Air Capture
DFI	Development Finance Institutions
DFRC	Development Finance Resource Centre
ECOWAS	Economic Community of West African States
EEA	European Economic Area
EIA	Environmental Impact Assessment
ETS	Emissions Trading System
EU	European Union
FIP	Finance and Investment Protocol
FT	Fischer Tropsch
GH2	Green Hydrogen
GHCS	Green Hydrogen Commercialization Strategy
GHG	Greenhouse gas emissions
GHS	Green Hydrogen Standard
GO	Guarantee of Origin
H2Bank	European Hydrogen Bank
HPBM	Hydrogen Production Business Model
HSRM	Hydrogen Society Roadmap
ICAO	International Civil Aviation Organization
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
ISCC	International Sustainability and Carbon Certification
ISO	International Organization for Standardization
JHPA	Japanese Hydrogen Society Promotion Act
JOGMEC	Japan Organization for Metals and Energy Security
kgCO2eq	Kilogram of CO2 equivalent
LCHS	Low Carbon Hydrogen Standard
LCOE	Levelized Cost of Energy
LCOH	Levelized Cost of Hydrogen
LCOX	Levelized Cost of PtX Product
METI	Japanese Ministry of Economy, Trade and Industry
MRV	Monitoring, reporting, and verification
NGC	Non-governmental Certification
PPA	Power Purchase Agreement
PtL	Power-to-Liquid
PtX	Power-to-X
QI	Quality Infrastructure
REC	Renewable Energy Certificate
RECSA	Renewable Energy Certificate System of South Africa
RED III	Renewable Energy Directive III
RFNBO	Renewable Fuels of non-biological origin
RSB	Roundtable on Sustainable Biomaterials
RTFO	Renewable Transport Fuel Obligation
SABS	South African Bureau Standard
SADC	Southern African Development Community
SADCA	SADC Cooperation in Accreditation
SADCSTAN	SADC Cooperation in Standardization
SAF	Sustainable Aviation Fuel
SAREM	South African Renewable Energy Masterplan
SATS	South African technical specification
SDG	Sustainable Development Goal
SKCH	South Korea Clean Hydrogen
SWOT	Strengths Weaknesses Opportunities Threats
UK	United Kingdom

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