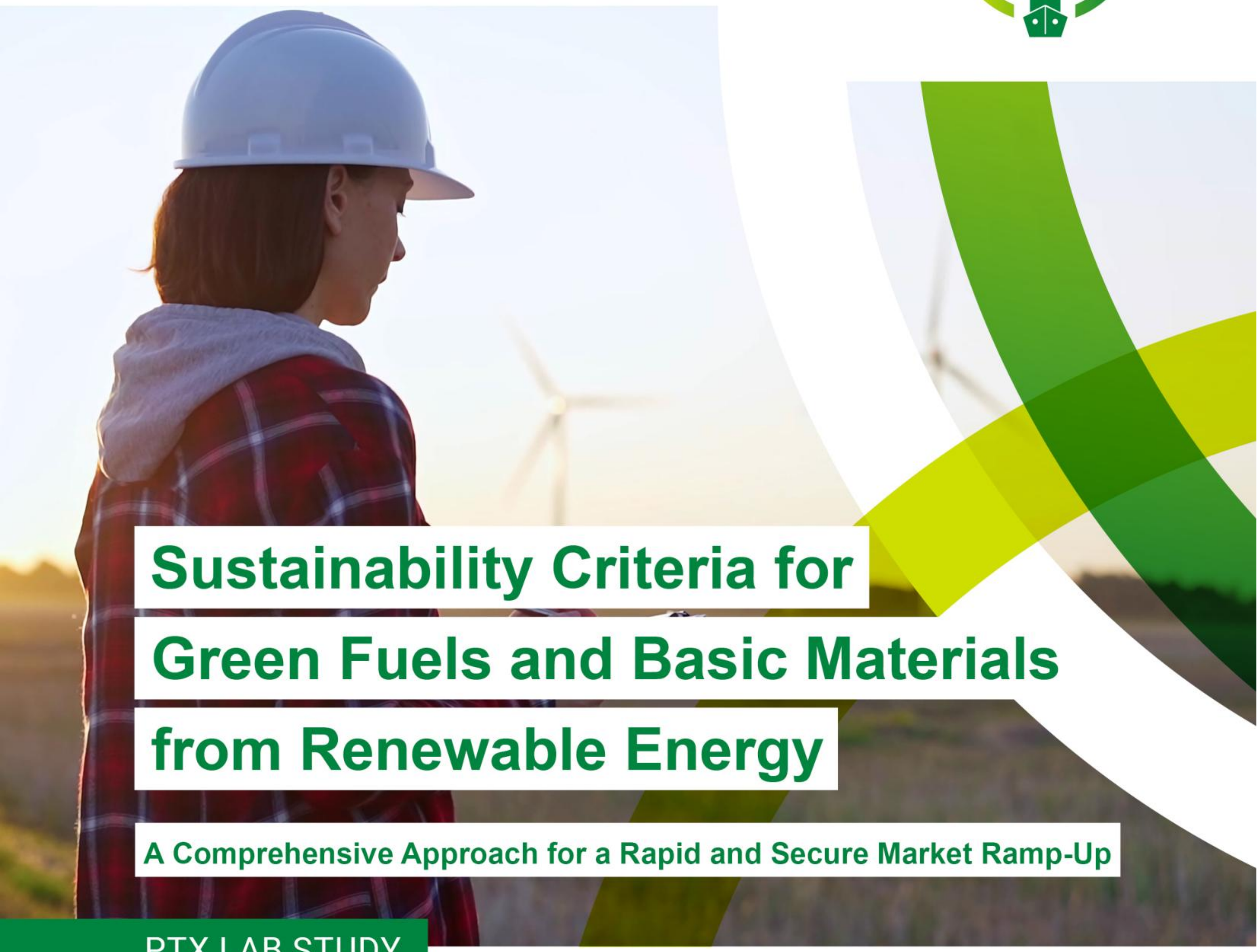

Sustainability Criteria for Green Fuels and Basic Materials from Renewable Energy

A Comprehensive Approach for a Rapid and Secure Market Ramp-Up

PTX LAB STUDY

PtX Lab Lausitz (Publisher)

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Publication: September 2025

Imprint

Publisher
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PtX Lab Lausitz would like to thank LBST, ifeu and RSB, as well as Baltahasar Kirchgäßner (BDEW e.V.) and Prof Sebastian Voswinckel (Hochschule Nordhausen) for their expertise in the preparation of this study. The team would also like to thank Josephine Götze, Lorena Tafur and Sepideh Rabiee Talkhouncheh from PtX Lab Lausitz.

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September 2025

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About PtX Lab Lausitz
The 'PtX Lab Lausitz – Think and Do Tank for Fuels and Basic Materials from Green Hydrogen' is developing the technical basis for the market ramp-up of environmentally compatible and sustainable production and utilisation of Power-to-X (PtX) products based on green hydrogen. Based in Cottbus (Brandenburg), the competence centre is a knowledge platform, source of inspiration and the partner of choice for business, government, research, and the general public.

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Foreword

The global market ramp-up of electricity-based green fuels and basic materials, known as Renewable Fuels of Non-Biological Origin (RFNBO), requires more than just technological solutions. It requires confidence in political stability, clear guidance and a robust sustainability architecture. Pragmatic sustainability criteria are needed to create confidence and certainty in the planning, financing and implementation of production capacities. Geopolitically challenging times require **pragmatic and robust sustainability criteria** to enable diversified domestic projects and partnerships for imports, and to create a broad market that prevents unilateral dependencies and uncertainties.

Especially in geopolitically challenging times, **pragmatic and robust sustainability criteria** are needed to create trust, enable diversified domestic projects and partnerships for imports, and create a broad market that prevents unilateral dependencies and uncertainties. **Effective and practicable sustainability criteria** for electricity-based green fuels and basic materials are therefore becoming an important **resilience factor** in the development of a climate-neutral and competitive economy.

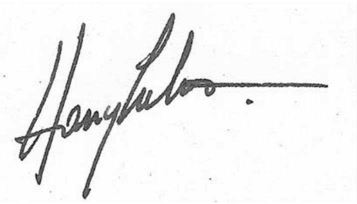
The market ramp-up of electricity-based green fuels and basic materials faces a double challenge: on the one hand, it must happen quickly and on an industrial scale in order to still meet the climate targets of the Paris Agreement. On the other hand, this transformation process must not create new social or ecological problems – for example, through unfair distribution of basic materials, uncontrolled consumption of resources or a lack of social acceptance.

With this study, PtX Lab Lausitz presents a concept for **dynamic sustainability criteria** designed to make the market ramp-up of electricity-based green fuels and basic materials **fast, fair and ecologically responsible**. The proposed criteria are based on three overarching guiding principles:

1. **Minimisation of risks (do no harm):** The protection of ecological systems, respect for human rights and the limitation of resource consumption form the ecological and social basis for any sustainable economy.
2. **Generating added value (benefit sharing):** Sustainability also means fairness. Only when social participation and local development opportunities are ensured along global value chains can a resilient relationship of trust emerge – the basis for social acceptance.
3. **Accelerating market ramp-up:** Sustainability criteria must be **simple, understandable and practicable** – not bureaucratic hurdles, but **clear guidelines**. This allows projects to be financed and implemented quickly.

The concept uses **dynamic criteria** based on technological maturity: in the early phase, simplified standards apply, which are gradually tightened as the market grows – without slowing down innovation. This creates a clear framework that reduces complexity, achieves impact and mobilises investment in a way that is compatible with climate neutrality – the basis for a resilient, climate-friendly and economically viable energy and basic materials economy.

The PtX Lab Lausitz sees this publication as **an impulse and an invitation**: to discuss, to develop further and to jointly build a market that is not only climate-neutral but also future-proof in the broadest sense.



Cottbus, September 2025
Dr Harry Lehmann
Head of PtX Lab Lausitz

Abstract

The transition to a greenhouse gas-neutral economy requires the rapid expansion of renewable energy and the substitution of fossil fuels with sustainable alternatives. Electricity-based, green fuels and basic materials – known as renewable fuels of non-biological origin (RFNBO) – play a central role in this, especially in sectors that are difficult to electrify, such as aviation, shipping and industry. However, the necessary market ramp-up of these technologies is caught between ecological and social sustainability requirements on the one hand and the need for investment and planning security on the other.

This study by PtX Lab Lausitz develops a **dynamic criteria system** for **assessing the sustainability of RFNBO along ten key** aspects – from **electricity consumption and greenhouse gas reduction to social standards, resource and water use**. The study proposes **differentiated, time-phased criteria** for different phases of the market ramp-up – based on the S-curve model – and develops recommendations for action for an effective and resilient sustainability architecture. This aims to maintain the **balance between a pragmatic, rapid and sufficiently robust sustainable market ramp-up of RFNBO**. To this end, the criteria were developed based on **three guiding principles**: (1) minimisation of ecological and social risks (**do no harm**), (2) equitable distribution of opportunities and added value (**benefit sharing**), and (3) **acceleration of the transformatio**n through practicable requirements. The aim is to create a regulatory framework that is both ecologically sustainable and aligned with industrial policy, in order to enable a globally fair and climate-friendly market for green hydrogen derivatives.

The criteria developed provide a technical basis for discussions on sound and pragmatic sustainability criteria for funding instruments, international harmonisation and the upcoming review of the European Union (EU) rules for RFNBOs.

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List of abbreviations

Abbreviation	Meaning of abbreviation
BAT	Best Available Techniques
CCU	Carbon Capture and Utilisation
DA	Delegated Act
DAC	Direct Air Capture
ESG	Enviromental, Social and Governance
EU	European Union
FID	Final Investment Decision
FPIC	Free Prior Informed Consent
GHG	Greenhouse gas
HNV	High nature value areas
ILO	International Labour Organisation
ISCC	International Sustainability and Carbon Certification
ISO	International Standard Organisation
IUCN	International Union for Conservation of Nature
LCA	Life Cycle Assessment
LCF	Low Carbon Fuels
PPA	Power Purchase Agreement
PtL	Power-to-Liquid
PtX	Power-to-X
RSB	Roundtable on Sustainable Biomaterials
RED	Renewable Energy Directive
SDG	Sustainable Development Goals

1 Introduction: Green hydrogen derivatives (RFNBO) caught between market development and sustainability requirements

In view of global efforts to combat climate change and reduce dependence on fossil fuels, the use for sustainable energy sources is becoming increasingly urgent. In this context, renewable fuels of non-biological origin (RFNBO) are increasingly coming to the spotlight. RFNBO are particularly important for the defossilisation of sectors that are difficult to electrify, such as aviation, shipping and the chemical industry. These sectors are responsible for a significant proportion of global CO_2 emissions and therefore require fitting solutions to achieve ambitious climate targets.

RFNBO can basically be understood as renewable fuels (see EU Commission 2024b:3), "*whose energy content is derived from renewable energy sources with the exception of biomass*" (see RED Article 2 Point 36 (EU, 2023a). To produce RFNBOs, renewable electricity and water are used, along with carbon dioxide (CO_2) depending on the end product. The basic process for producing RFNBO consists of the electrolysis of water, which produces hydrogen. This hydrogen can then be used directly or converted with CO_2 into synthetic hydrocarbons or other carbon-containing products (e.g. methanol or dimethyl ether) or into carbon-free follow-up products (e.g. ammonia), which serve as substitutes for fossil fuels and basic materials. In this context, the term "power-to-X" (PtX) is often used. RFNBOs can include a wide range of electricity-based products, including hydrogen, methanol, methane, ammonia, aromatics and olefins, and synthetic liquid fuels such as e-fuels. The key criteria for classification as an RFNBO is that the electricity required for production must come entirely from non-biogenic renewable sources such as wind or solar. Only then can it be guaranteed that these fuels make a genuine contribution to reducing greenhouse gas emissions.

Despite the promising advantages of RFNBOs, there are considerable challenges to both their widespread use and market penetration, as well as to ensuring their sustainability. A key challenge is the current legal framework, which is often insufficient to ensure that RFNBOs are truly sustainable. While the European Union has created a regulatory framework with the Renewable Energy Directive (RED) and the two associated Delegated Acts (DAs)(EC, 2023a) to promote the use of RFNBO, its requirements are not sufficient to completely avoid negative environmental impacts. This is because the current legal requirements focus mainly on reducing greenhouse gas emissions and electricity procurement. However, other environmental and social criteria are not sufficiently considered. For example, there are no clear guidelines on land use, water use or the social impacts of RFNBO production. The existing gaps in the legal and policy framework could result in RFNBOs failing to achieve their intended sustainability and potentially causing undesirable negative impacts on the environment and society, comparable to the negative effects observed when many biofuels were introduced to the market.

The current situation makes it clear that, despite increasing regulatory incentives such as quotas for electricity-based sustainable aviation fuels (SAF), the necessary Final Investment Decisions (FIDs) for the large-scale deployment of RFNBOs are not being made. (IEA, 2023a, 2023b). Investors are hesitant to invest in the large-scale production of RFNBOs because of uncertainty about long-term profitability and the regulatory framework. This uncertainty about future market developments and the lack of clarity about government subsidies and incentives are major factors holding back the necessary investments. There is therefore an urgent need to clarify the legal requirements and create incentives that increase investment security. RFNBOs are also needed in the short term: as part of ReFuelEU Aviation, the European Union has introduced binding quotas for sustainable aviation fuels for 2025 (EU, 2023b). This also includes a sub-quota specifically for RFNBO with a minimum share of 1.2 per cent by 2030. The quotas represent an important step towards greenhouse gas neutrality in aviation. However, this will only be possible if the production of RFNBO is ramped up quickly.

To ensure a rapid and sustainable market ramp-up of RFNBO, clear and comprehensive sustainability requirements are therefore necessary, considering a specific timeline. Although there are currently a large number of publications on sustainability criteria for RFNBO[1], there is no yet a set of criteria for RFNBO that takes a holistic view of a rapid and sustainable market ramp-up, taking into account the time component. The aim of this study is therefore to define a set of short- and long-term criteria for RFNBO. To this end, a distinction is made between short- and long-term criteria based on the S-curve market introduction model, as the various market phases have different impacts on the environment and people. The early phase of market introduction is initially characterised by higher uncertainties and low production volumes. In the following phase, strong growth in capacity can be expected. At this stage, the technologies are more mature; hence, sustainability requirements must be tightened.

The criteria themselves are based on our 2022 PtX Lab Study "Development of PtX Sustainability Standards and Indicators" (Altmann et al., 2022)[2]. Additional sustainability standards were also examined, which are to be understood as best practice. In this context, best practice means that the criteria go beyond the minimum legal requirements of the DAs. Furthermore, the defined criteria are based on the principle of compatibility with the concept of Planetary Boundaries by Rockström et al. (2009), the 17 Sustainable Development Goals (SDGs) of the United Nations (UN), the Paris Climate Agreement and international agreements under international law.

This is followed in **Chapter 2**, **Basics**, by the definition of guiding principles for the development of the criteria and the determination of the time horizon. **Chapter 3** will focus on the **sustainability criteria** developed for each individual sustainability aspect. For each sustainability aspect, the criteria from the PtX Lab Study of 2022 will first be presented. This is followed by an overview of the criteria from best practice standards and other relevant literature. New PtX Lab Lausitz 2025 sustainability criteria are then formulated. **Chapter 4, Policy Recommendations**, follows. Here, recommendations that are important for successful implementation are made based on the set of criteria. The **conclusion** in **Chapter 5** concludes the study.

[1] See meta-analyses:(Altmann et al., 2021; Blohm and Dettner, 2023; Heinemann et al., 2022; International Renewable Energy Agency (IRENA), 2023; Krieger et al., 2024; Sailer et al., 2022; Schwalfenberg et al., 2023; Seebach et al., 2023)

[2] LBST and ifeu conducted a study on sustainability criteria for e-kerosene in 2022 on behalf of the PtX Lab Lausitz, following the guidance of the PtX Lab Lausitz for a holistic approach.

2 Basics: A dynamic and systemic perspective for the further development of sustainability standards for RFNBOs

Three guiding principles (2.1) are established as the basis for the development of sustainability criteria and the time horizon for the application of the sustainability criteria is derived from the S-curve model (2.2).

2.1 Three guiding principles

In the following, three guiding principles for the development of sustainability criteria for RFNBOs are proposed to support and secure a rapid and sustainable market ramp-up of RFNBOs:

1. **Minimisation of social and environmental risks** (do no harm)
2. **Generation of added value** (benefit sharing)
3. **Accelerating transformation/market ramp-up**

With the help of these guiding principles, the global market ramp-up of RFNBO production and imports should avoid or minimise negative impacts on the environment, economy and society (**1: minimisation of risks**) while at the same time fairly exploiting opportunities for development and value creation (**2: creation of added value**) (Altmann et al., 2022; Demuth et al., 2025). In addition, significant amounts of RFNBO are needed quickly in order to achieve climate neutrality and thus also climate targets such as the 1.5 °C target set out in the Paris Climate Agreement (Horndasch et al., 2025). Therefore, the implementation of ambitious sustainability standards should not slow down a rapid market ramp-up if possible. For this reason, sustainability criteria should also be practical and easy to implement, with only limited additional effort and costs (**3: Accelerating the transformation**) (Akhmetova et al., 2025; Horndasch et al., 2025).

The aim is to examine how sustainable production can be achieved within Planetary Boundaries[3] and in line with sustainable development goals (SDGs). Furthermore, RFNBO production can only be sustainable in the long term if there is social acceptance (**social licence to operate**) and if production is economically viable (**acceleration of market ramp-up**). Sustainability criteria should therefore keep an eye on issues of justice and fairness in order to maintain social acceptance and economic viability (Blohm and Dettner, 2023; Horndasch et al., 2025). Countries such as Germany will be particularly dependent on imports of RFNBO in the long term to meet their needs (Bundesregierung, 2024; Merten and Scholz, 2023). Countries that will mainly export RFNBO in the future due to their high production potential are also located in Africa and Latin America (Pfenning et al., 2021). In these countries, it is important to avoid creating unfair extractivist, neocolonial structures when establishing a hydrogen economy. Instead, fair distribution and the participation of all stakeholders in risks and added value should be encouraged and promoted (Demuth et al., 2025; Horndasch et al., 2025).[4]

[3] The concept of Planetary Boundaries defines thresholds for human activities that, if exceeded, will lead to permanent damage to the planet. These were first quantified and analysed in 2009 by Rockström et al. (Richardson et al., 2023; Steffen et al., 2015) .

[4] See also:(Amouzai and Haddioul, 2023; Hermanus, 2023; Kalt et al., 2023; Kalt and Lekalakala, 2023; Kalt and Tunn, 2022; Müller et al., 2022)

2.1.1 Minimisation of social and ecological risks

The production of RFNBOs can have significant negative social and environmental impacts, particularly on people and the environment (Altmann et al., 2022; Demuth et al., 2023a, 2023b). These are primarily linked to the high energy requirements and the significant consumption of metallic and non-metallic resources, water and land along the value chain. However, further impacts on geopolitics and human rights must also be taken into account in the interests of sustainable development (Horndasch et al., 2025)[5]. Therefore, sustainability criteria for RFNBO should aim to minimise risks to people and the environment in line with a do-no-harm approach (Demuth et al., 2025). These could be based on the 17 SDGs. The do-no-harm approach is a fundamental principle of sustainable development that aims to avoid negative impacts of technologies, projects or policies on people and the environment. In relation to the production of RFNBO, this means that the production and use of these technologies must be designed in such a way that they do not cause harmful effects on the environment, society or human rights. The integration of this approach is particularly important when it comes to new and emerging technologies such as the production of RFNBO, which could have potentially far-reaching ecological and social consequences (Demuth et al., 2025).

To enable sustainable development for all, the United Nations (UN) has established 17 SDGs. These cover the five core areas ("five Ps") of sustainability: people, planet, prosperity, peace and partnership (Thiele, 2024).In order to protect all five core areas, it is particularly important to preserve the ecological foundation, biodiversity and intact ecosystems (Rockström and Sukhdev, 2016). Therefore, sustainability criteria for RFNBOs should be designed to take into account compliance with Planetary Boundaries(Demuth et al., 2023a; Horndasch et al., 2025). The Planetary Boundaries define thresholds for human activities that, if exceeded, can lead to permanent damage to the planet. To assess the extent of the impact on Planetary Boundaries, it can be looked at how much of the safe operating space (SOS) is taken up by the activity (Galán-Martín et al., 2021; Rockström et al., 2009).

When designing sustainability criteria for RFNBOs, it is important to ensure that the demand for energy, water, land, and metallic and non-metallic resources does not result in excessive global consumption of the SOS or cause significant local damage to people or the environment.

2.1.2 Generation of added value

In order to minimise negative effects and exploit potential positive effects and added value along the RFNBO value chain, sustainability criteria can also take these into account (Demuth et al., 2025; Horndasch et al., 2025; Villagrasa, 2022). Sustainability criteria should therefore help to ensure a fair distribution of risks and added value along the RFNBO value chain. This will also help to achieve and maintain social acceptance of hydrogen projects (Dünnwald and Winkelmann, 2023; Pepe et al., 2023). Broad acceptance of hydrogen projects is particularly necessary at planned production sites for RFNBO in order to enable a rapid market ramp-up. Various dimensions of justice should be considered, as described, for example, in the concept of hydrogen justice (Kalt et al., 2023; Müller et al., 2022). In the interests of epistemic justice, local knowledge and values should be given equal consideration when developing sustainability criteria (Kalt and Tunn, 2022; Müller et al., 2022; Villagrasa, 2022; Waters-Bayer and Tadicha Wario, 2020). Overall, the added value of RFNBO production should be shared in a way that

[5] See also: (Cassidy and Quitzow, 2023; Eicke and Blasio, 2022; Morgen et al., 2022; Pepe et al., 2023) .

benefits all parties, and asymmetrical distribution into extractive neocolonial structures to the disadvantage of local communities should be avoided (Kalt and Tunn, 2022).

2.1.3 Accelerating the transformation

While sustainability criteria for RFNBOs should minimise risks and generate added value, they must also be practical enough not to slow down a rapid market ramp-up. To this end, they should above all be as simple, understandable and implementable as possible (Akhmetova et al., 2025; Horndasch et al., 2025).

This gives investors and project developers planning security.
Currently, only a few RFNBO projects have secured final financing (Final Investment Decision: FID) (Ueckerdt and Odenweiler, 2023). To create investment security, sustainability criteria should be as simple, consistent and transparent as possible. The market ramp-up must be accelerated, as the transition to a climate-neutral economy within Planetary Boundaries is necessary by 2045 in order not to exceed the Planetary Boundaries of global warming (max. 1.5 °C) in the long term.

2.2 Time horizon: Dynamic sustainability criteria for the market ramp-up of RFNBO

During the initial phase of the market ramp-up (formative phase), less rigorous sustainability criteria should apply to avoid slowing down the learning curve (3: Acceleration of the transformation). As soon as the market ramp-up moves from the formative phase to the growth phase, the cumulative negative environmental and sustainability impacts of RFNBO production also increase. Therefore, **stricter sustainability criteria should apply in the growth phase** to minimise risks (1. Do no harm) and ensure the fair sharing of products (2. Benefit sharing). The following section therefore derives a time-based differentiation of sustainability criteria based on the S-curve model of technological innovation. According to this model, less stringent sustainability criteria should apply in the formative phase (until 2035/40) and more stringent criteria should only apply once the growth phase begins (from 2036/41) (see Table 2-1 and Table 2-2). The S-curve model is one of many possible market growth models, but its simplicity and clarity make it well suited as a basis for dynamic sustainability criteria that reflect the dynamics of the market ramp-up of RFNBOs.

Table 2-1: Time horizon for sustainability criteria for RFNBO.

Sustainability aspects	Short-term criteria	Long-term criteria
Time horizon	In formative phase Until 2035/40	From growth phase From 2035/40
Production capacities/volumes RFNBO	Still low	Strongly growing
Social impacts	Still low Mainly at project level	Larger projects also increase potential social impact at project level. In exporting countries, questions of fair distribution and profit sharing are increasingly being raised at the societal level
Environmental impacts	Production capacities are still low, so the environmental impact of H_2, EE and CO_2 requirements as well as water and land consumption **is still low.**	Production capacities are still rising sharply, which means that **potential environmental impacts are also rising sharply** due to increased demand for H_2, renewable energies and CO_2, as well as increased water and land consumption
Proposed **Scope of social standards**	No restrictions on do-no-harm social standards, co-benefits still limited	No restrictions on social standards' do-no-harm principle, criteria for fair distribution of co-benefits
Proposed **Scope of environmental standards**	Avoid lock-ins. **Focus on the greatest risks.** Collect data and experience for more tailored regulation in the growth phase**.** **As simple and practical as possible**	Differentiated, based on data and lessons learned during the formative phase

2.2.1 From start to scaling: Market ramp-up of RFNBO based on the S-curve model

The S-curve model is a concept from innovation and technology management theory that describes the typical course of the introduction and maturation of new technologies. It shows how the production capacity of a technology or innovation develops over time, from the initial slow growth phase to later maturity. The curve resembles the shape of an "S", which is why the model bears this name (see Figure 2-1). The S-curve model of technological innovation/transformation distinguishes between three phases, see (Odenweller et al., 2022):

I. Formative phase
II. Growth phase
III. Maturity phase

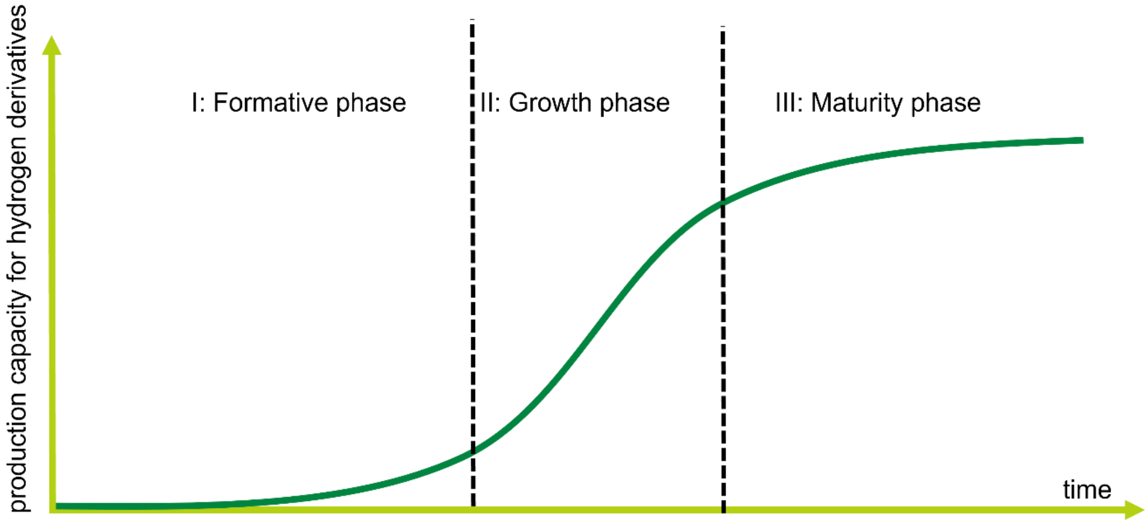

Figure 2-1: Schematic representation of the S-curve model.

Formative phase: In the formative phase, hardly any production capacity is built up. Initial projects are implemented, which contribute to the formation of the first lead markets and provide learning effects for subsequent projects. The S-curve is relatively flat.

Growth phase: In the growth phase, production scales up. Production capacities are increased and larger projects are implemented, which are usually based on the lessons learned from the pilot projects in the first phase and can therefore be produced at lower costs. Production costs fall slowly and markets become more differentiated (Gassmann et al., 2023; WEF, 2020).

Maturity phase: In the maturity phase, production capacities slowly stabilise and hardly grow at all. Old, uneconomical plants are replaced by more efficient ones with lower production costs. The market is saturated.

High levels of uncertainty and risk exist, particularly at the beginning of the market ramp-up (formative phase) of new technologies, including RFNBO (Ebner et al., 2024; Frankfurt School of Finance & Managment, 2023; Hunt and Tilsted, 2024; Odenweller et al., 2022). Investors are still very cautious about making final investment decisions(Odenweller et al., 2022; Ueckerdt and Odenweiler, 2023). Implementing regulations and sustainability criteria too early and too strictly could overwhelm companies and deter investors, thereby stifling the market ramp-up at an early stage or delaying it significantly (Pepe et al., 2023). However, once RFNBO scales up quickly, the environmental impact of RFNBO could also increase significantly. This poses the risk of exceeding Planetary Boundaries if sustainability risks are not regulated (Bachmann et al., 2023; Coppitters et al., 2024; Kätelhön et al., 2019). As soon as the production and export of RFNBO grows significantly, questions of fair and equitable social distribution of risks and benefits will also intensify (Pepe et al., 2023).

The formative and growth phase for the market ramp-up of hydrogen is likely to progress faster than for more complex downstream products such as PtL kerosene, ammonia or methanol (Odenweller et al., 2022; SkyNRG, 2023; Springer et al., 2023; Topsoe, 2023;

Transport & Environment, 2024). There are also regional differences, it is expected that in the EU the hydrogen deployment outpace the global average (Odenweller et al., 2022). In addition, the speed of the market ramp-up of hydrogen varies in different scenarios depending on climate protection ambitions, regulations and policy instruments to promote it (IEA, 2022; McKinsey, 2024; Odenweller et al., 2022; PwC, 2024).

Looking at optimistic and ambitious market deployment scenarios, the formative phase for hydrogen is expected to end between 2035 and 2040 (IEA, 2022; McKinsey, 2024; Odenweller et al., 2022; PwC, 2024). We therefore recommend applying the short-term criteria proposed here for hydrogen until 2035 and then the long-term criteria from 2035 onwards. In contrast, a slower market development is expected for hydrogen derivatives such as ammonia, methanol or PtL kerosene, with the formative phase ending between 2040 and 2050, depending on the scenarios and derivatives. Hence, we recommend applying the short-term criteria proposed here for hydrogen derivatives until 2040 and the long-term criteria from 2040 onwards (see Table 2-2). If the market ramp-up of certain hydrogen derivatives is significantly delayed, it may be advisable to evaluate whether the short-term criteria should be extended in order to prevent further delays or slowdowns in the necessary market expansion.

Table 2-2: Assumed market ramp-up phases for various RFNBOs and the recommended sets of criteria.

Market ramp-up phases	Hydrogen	Hydrogen derivatives	Recommended set of criteria
Formative phase	By 2035	By 2040	Short-term criteria
Growth phase	From 2036	From 2041	Long-term criteria

2.2.2 Possible grandfather clause (5 years, 2040-45)

Large-scale industrial plants for the production of hydrogen and RFNBO generally have an expected economic lifetime of around 20-30 years (Arnold et al., 2018; Joas et al., 2019; Pfenning et al., 2017; Seymour et al., 2024). If the sustainability criteria for RFNBOs become more rigorous during the lifetime of production facilities, this may result in the facilities no longer being able to serve the market. In the worst case, a plant ends up as a stranded asset without having amortized its investment costs. If the market for RFNBO also develops very heterogeneously on a global scale, this plant could potentially serve a market with weaker sustainability requirements as an alternative (Pepe et al., 2023).

This means that stricter sustainability criteria, which are only supposed to apply from the start of the growth phase (2035/40), could already have an impact on projects that are still in the formative phase of planning or construction. This would shift the impact of the stricter sustainability criteria further forward than intended and could potentially slow down or stall the formative phase. While it is conceivable that existing facilities could be retrofitted to comply with stricter sustainability requirements, the PtX Lab Lausitz assumes that such conversions in the first years after commissioning (0-5 years) are unlikely profitable.

We therefore propose temporary grandfathering (sunset clause). Existing plants at the beginning of the growth phase (2035/40) must first demonstrate that they comply with the increased sustainability criteria five years later (see Table 2-3 and Figure 2-2).

Alternatively, grandfathering could be extended to 10 years or complete grandfathering could be established for plants that went into operation before 2040 (see Table 2-4).

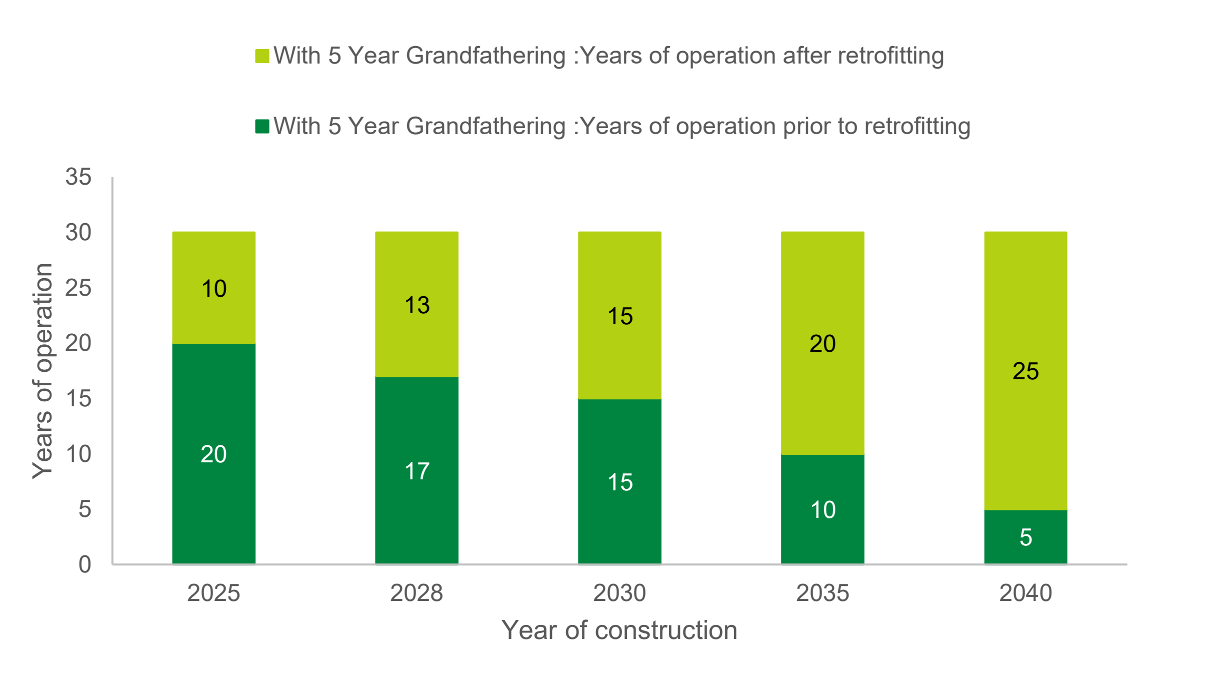

Figure 2-2: Years of operation for existing plants before and after a retrofitting in 2045, assuming a plant lifetime of 30 years and stricter standards from 2040 on with a 5 years grandfather clause.

Table 2-3: Example table showing remaining years of operation with a grandfather clause of 5 years for existing plants from 2040 onwards, assuming a lifetime of 30 years.

Plant construction	Retrofitting	Years of operation prior to retrofitting	Years of operation after retrofitting
2025	2045	20	10
2028	2045	17	13
2030	2045	15	15
2035	2045	10	20
2040	2045	5	25

Table 2-4: Example table showing remaining operating years with a grandfather clause of 10 years for existing plants from 2040, assuming a lifetime of 30 years.

Plant construction	Retrofitting	Years of operation before retrofitting	Years of operation after retrofitting
2025	2050	25	5
2028	2050	22	8
2030	2050	20	10
2035	2050	15	15
2040	2050	10	20

2.3 Sustainability criteria for PtL kerosene according to the PtX Lab Study 2022

The sustainability criteria for PtL kerosene were developed in the PtX Lab Study 2022 commissioned by us (Altmann et al., 2022). The criteria are based on the SDGs and Planetary Boundaries as well as on the legal requirements according to RED for RFNBO but go beyond the legal requirements for electricity and CO_2. In addition, further criteria for water, land and resource consumption as well as for social standards were formulated. Short-term criteria and ambitious long-term criteria were proposed (see Table 2-5).

For social standards, the 2022 PtX Lab Study proposed both do-no-harm criteria and criteria for positive effects to ensure that affected neighbourhoods and communities also benefit from local production.

Table 2-5: Overview of sustainability criteria for PtL kerosene proposed in the PtX Lab Study 2022 (Altmann et al., 2022).

Sustainability aspects	Short-term criteria (PtX Lab 2022)	Long-term criteria (PtX Lab 2022)
GHG reduction	No explicit limit value	No explicit limit value
Requirements for electricity	Compliance with RED delegated acts	• Compliance with RED delegated acts • **Renewability:** Fully renewable and energy source with limited land and resource consumption • **Additional requirements:** Compliance with RED and **initiation additionality as well as locality** (max. 150 km distance)

Sustainability aspects	Short-term criteria (PtX Lab 2022)	Long-term criteria (PtX Lab 2022)
Carbon source	• CO_2 from the air (DAC) • Biogenic sources that are not associated with negative effects • Industrial point sources in the EU ETS until 2035 • Geothermal sources	CO_2 from the air (DAC)
Resource efficiency	Cumulative primary energy consumption: < 3.5 MJ/MJ PtL	Cumulative primary energy consumption: < 3 MJ/MJ PtL
Water	• Water scarcity at the site not exceeding 60% or • Completely from seawater desalination	• Water scarcity at the site not exceeding 40% or • Completely from seawater desalination • If water scarcity at the site exceeds 60%, additional supply of desalinated water to the public
Country	No conversion of high nature value areas (HNV according to IUCN) (reference to criterion in ISO 13065)	No conversion of high nature value areas (HNV according to IUCN) (reference to criterion in ISO 13065)
Social standards	Do no harm Where applicable, the ESG criteria of the European Investment Bank must be met Positive effects Permanent creation of skilled jobs	Do no harm Where applicable, the ESG criteria of the European Investment Bank must be met Positive effects Permanent creation of skilled jobs If the regional supply of electricity/energy and/or water is underdeveloped, the project makes a relevant contribution to supplying the regional population

3 The 10 most important sustainability aspects: Development of dynamic sustainability criteria for RFNBO

The sustainability criteria and indicators for PtL kerosene developed by PtX Lab Lausitz in the PtX Lab Study 2022 (see Table 2-5) are discussed in greater depth below in order to derive a catalogue of expanded and updated sustainability criteria for RFNBO based on these findings (Altmann et al., 2022). Based on the current discourse and the examination of sustainability criteria that can be considered best practice, the sustainability aspects of the social dimension were subdivided into work, standard of living, society and legality.

The following discussion presents the old criteria for the respective sustainability aspect published by the PtX Lab Lausitz in 2022, followed by a comparison with other criteria from other standards (atmosfair, 2021; BMWi, 2021; CertifyHy, 2023; Climate Bonds Initiative, 2023; REDCert, 2023; RSB, 2023; TÜV SÜD, 2021). This is followed by the perspectives of other stakeholders (NGOs, science, business) based on references from grey literature (e.g. Villagrasa 2022; National Hydrogen Council 2021; PtX Hub 2021; Hornberg et al. 2021; Sailer et al. n.d.; Schwalfenberg et al. 2023; Blohm & Dettner 2023; BMWK 2022). The criteria will then be discussed in more detail, with a particular focus on the following aspects identified in Chapter 2:

1. Minimisation of risks
2. Generation of added value
3. Acceleration of the transformation

This results in the **proposal of new PtX Lab Lausitz 2025 criteria** for the 10 most important sustainability aspects.

3.1 Requirements for electricity

The EU defines the term "renewable liquid and gaseous fuels of non-biological origin" as "liquid or gaseous renewable fuels for transport of non-biological origin" and abbreviated as RFNBO, as "liquid or gaseous fuels used in the transport sector, excluding biofuels or biogas, whose energy content comes from renewable energy sources, excluding biomass" (RED Art.2 (36)) (EU, 2018). In general, the important criteria for green hydrogen derivatives is that the energy used must come entirely from renewable sources(Altmann et al., 2022; atmosfair, 2021; Germanwatch et al., 2022; Sailer et al., 2023; Schwalfenberg et al., 2023). In addition, the additionality of electricity has established itself as an important criterion for some cases for assessing the sustainability of green hydrogen derivatives (Kasten and Heinemann, 2019). The EU has also stipulated the **additionality** of renewable electricity for RFNBOs as a condition for some case and defined it precisely in a delegated act (DA to RED Art 27 (3)) (EC, 2023b; Scheyl et al., 2023)[6]. The additionality is intended to prevent the direct use of existing and developing renewable energies from being cannibalised by the production of hydrogen derivatives (Zabanova, 2023). Additional conditions such as temporal and spatial correlation are primarily intended to ensure grid- and system-friendly integration

[6] Additionally is not required in all cases. Only for the case of electricity procurement with PPA via the gird or via direct line additionality criteria are required in scope of EU regulations. See 3.1.2. and the EU regulations for more details.

and operation of hydrogen production and to prevent or curb emissions from additional fossil fuel power generation and rising local electricity prices (Ruhnau and Schiele, 2023; Schumm et al., 2024; Zabanova, 2023). The criterion of annual, monthly or hourly temporal correlation determines that the generation of renewable electricity fed into the grid must take place at the same time as the withdrawal of electricity from the grid for hydrogen production. The simultaneity is then further defined to ensure that the additional electricity demand from electrolysers is not covered by additional fossil fuel-based electricity generation. This would be the case if there were not enough renewable electricity available in the grid at that exact moment (Ruhnau and Schiele, 2023; Schumm et al., 2024; Zeyen et al., 2024).

However, different standards and stakeholders have different requirements regarding the design of the criteria for additionality. Some stakeholders from the business community fear that the criteria set by the EU are too strict. Consequently, the EU has already planned a review of these criteria by 2028 as part of RED III, focusing on whether RFNBO are sufficiently available at economic prices in the EU (BMWK, 2022; Butzengeiger et al., 2023; Zabanova, 2023). Meanwhile, another group of stakeholders, mainly from civil society, has introduced a broader understanding of additionality into the debate and is even advocating for stricter sustainability criteria for RFNBO electricity procurement (atmosfair, 2021; Villagrasa, 2022). In academia, flexible models of temporal correlation are being discussed, which are not strictly based on annual, monthly or hourly correlation, but allow for more flexible operation of electrolysers when electricity prices are low or negative (Ruhnau and Schiele, 2023; Zeyen et al., 2024).

3.1.1 Comparison of PtX Lab criteria and RED requirements for electricity procurement published in 2022

The short-term criteria for PtL kerosene in the 2022 PtX Lab Study take up the legal regulations of the RED regarding renewability and additionality and supplement them with further aspects in their long-term criteria (Altmann et al., 2022) (see Table 3-1).

The EU has established the criteria of **renewability** and additionality as the legal framework for RFNBO electricity procurement (EC, 2023b, 2023a; EU, 2018). Additionality is based on the criteria **of financial additionality** and **temporal and spatial correlation** of production. The legal criteria under EU legislation (RED) have already been discussed and described in detail in the literature (Sailer et al., 2023; Scheyl et al., 2023). In addition, the EU Commission has published a guidance document to facilitate understanding of the regulation (EC, 2023a).

The long-term criteria of the PtX Lab Study 2022 introduces the initiation additionality for renewable energy plants as a complementary concept. In addition, in the long term it propose,that there should only be a **maximum distance of 150 km** between renewable energy plants and PtX plants in order to reduce the load on electricity grids. The long-term criteria also address the aspects of **resource and land consumption** by renewable energy installations.

Table 3-1: Comparison of legal criteria for electricity procurement for RFNBOs according to RED and PtX Lab Lausitz 2022 criteria.

Criteria for electricity procurement	Short-term criterion (PtX Lab 2022)	Long-term criterion (PtX Lab 2022)
Renewability	Compliance with RED	Fully renewable Energy sources are associated with **limited resources and land use**.
Additionality	Compliance with RED	Compliance with RED **Initiation additionality**: The renewable energy power plant was initiated by the PtL itself and is located in **close proximity** (max. 150 km distance) to relieve the grid.

Excursus: RED compliance of standards

For renewable fuels to be counted towards RFNBO quotas such as the ReFuelEU Aviation quotas, the fuel must be certified as RFNBO. The certification system must also be recognised by the EU Commission. So far, only two voluntary certification schemes that can be used to certify RFNBOs have been recognised by the European Commission (as of 14 August 2025)[7]. (EC, 2025).

To date, standards developed for the global market have primarily focused on green hydrogen and green hydrogen derivatives (see CMS70, GHS) as well as low-carbon hydrogen (Climate Bonds Standard and Certification Scheme) (Climate Bonds Initiative, 2023; Green Hydrogen Organisation, 2023; TÜV SÜD, 2021). Although the two standards developed by global initiatives (GHS and Climate Bonds Initiative) contain more extensive sustainability aspects such as social standards or criteria for water consumption, the criteria for electricity, carbon source or GHG reduction are not sufficient to meet the RED criteria (Climate Bonds Initiative, 2023; Green Hydrogen Organisation, 2023). The RSB Standard for Advanced Fuels, in its version v2.5, explicitly refers to the term RFNBO and contains sufficient criteria for electricity, GHG reduction and carbon sources to comply with the RED criteria and goes beyond the RED requirements in some areas (RSB, 2023).

The RSB also defines no-go areas in which the installation of renewable energy plants for RFNBOs is prohibited. In addition, the RSB standard contains extended sustainability criteria based on the 12 RSB principles, covering areas such as land and water use and social standards (RSB, 2020).

[7] Two voluntary certification schemes that can be used to certify RFNBOs have been recognised by the European Commission (as of 14 August 2025): **CertifHy and ISCC EU.**
Still in the application phase but with a positive technical assessment by the EU: **CEE, RSB**, and **KZR INiG** (as of 14 August 2025).

However, the RSB Standard for Advanced Fuels is currently only applicable outside the EU. The RSB EU RED Standard for Advanced Fuels, which can be applied in the EU, currently only covers biofuels. However, it is expected that the EU standard will be expanded to include RFNBOs as part of the Impact Alliance with CertifHy, based on the global standard. For H2Global, RSB and CertifHy are planning a joint certification system, whereby CertifHy will certify RED compliance and RSB will certify the extended sustainability criteria of H2Global (RSB and CertifHy, 2022).

CertifHy has already developed a certification procedure designed to meet the RED criteria and certify RFNBO (CertifyHy, 2023).The CertifHy RFNBO standard has no sustainability criteria beyond those for electricity, GHG reduction and carbon sources.

With the CMS70 Green Hydrogen+ Standard, TÜV SÜD has established a standard for green hydrogen that demonstrates a high level of compliance with the RED criteria for electricity, GHG and carbon sources (TÜV SÜD, 2021). However, as a standard from a certifier (TÜV SÜD), i.e. a certification body, the standard cannot be recognised by the EU Commission as a voluntary certification system for RFNBO (Sailer et al., 2023). However, it is possible that other certification systems may recognise parts of CMS 70 certificates, for example for the verification of green hydrogen. TÜV Rheinland has expanded and adapted its hydrogen standard H2.21 at the beginning of 2023 so that the criteria now theoretically comply with the RED criteria(TÜV Rheinland, 2023). However, similar to the TÜV SÜD standard, it cannot be recognised by the EU Commission as a voluntary certification system because it is supported by a certifier. This means that the standards of TÜV Nord, TÜV SÜD and TÜV Rheinland are not sufficient certification systems for RFNBOs to be counted towards EU quotas (e.g. ReFuelAviation, REDIII).

TÜV Nord is currently developing a standard for hydrogen derivatives. It has been announced that this standard will be RED-compliant and will also include criteria beyond electricity, GHG reduction and carbon sources (Schwalfenberg et al., 2023). However, it is expected that, similar to the CMS 70 standard of TÜV SÜD, the TÜV Nord standard will not be recognised by the EU Commission as a voluntary certification system for RFNBO (Sailer et al., 2023; Schwalfenberg et al., 2023).

3.1.2 Comparison of electricity criteria of different standards

The RED defines four permissible reference cases for renewable electricity for RFNBO. One case for direct procurement via **direct line** (1.Direct) and three different cases for **grid procurement** (2.Electricity grid mix, 3.PPA, 4. Anti-curtailment). Different requirements are imposed on each of the four cases (EC, 2023b; Sailer et al., 2023; Scheyl et al., 2023). Only for the case of electricity procurement with PPA via the grid or via direct line additionality criteria are required in scope of EU regulations.

In all standards considered, the case for direct procurement (1.Direct) and procurement from the grid with PPA (3. PPA) is implemented. The **electricity grid mix case** (2. Electricity mix), which applies **when at least 90% of the grid electricity comes from renewable energies**, has been implemented in the RSB Standard for Advanced Fuel (RSB, 2023). The H2.21 standard, CMS70 Green Hydrogen and fairfuel do not implement this case (atmosfair, 2021; TÜV Rheinland, 2023; TÜV SÜD, 2021). It can be argued that with a high share of renewable energies in the grid, there is no longer any risk that additional fossil fuel-based electricity generation will be required to meet the electricity demand for electrolysers and that no increase in emissions from additional hydrogen production is to be expected (Schumm et al., 2024; Zeyen et al., 2024).

For **electricity procurement via PPAs** through the grid, the RED requires both **spatial/geographical correlation** and **temporal correlation**. Monthly correlation is required until 2030 and hourly correlation from 2030 onwards. The tightening to hourly correlation is to be reviewed in 2028 (EC, 2023b; Sailer et al., 2023; Scheyl et al., 2023). However, it is possible for EU Member States to implement the stricter hourly correlation before 2030 (Langenmayr and Ruppert, 2023). As an alternative to temporal correlation, an **exception** is formulated if the **day-ahead electricity price** for the respective bidding zone is lower than €20/MWh or lower than 0.36 times the EU ETS price for 1 t $CO_{2,eq}$ (EC, 2023b; Scheyl et al., 2023)[8]. For **geographical correlation,** EU regulations require electricity for the electrolyser to be sourced either from the same bidding zone or from a connected bidding zone with the same or higher day-ahead price. An exception applies to connected offshore bidding zones from which electricity for H_2 production can be sourced without restrictive day-ahead price rules (EC, 2023a; Scheyl et al., 2023).

The RED requires a form of **financial additionality** for renewable energies **in the case of PPAs and direct procurement**. This means that they must not have received any government subsidies (e.g. EEG subsidies). In addition, the RED requires that the renewable energy installations with which PPAs must cover at least the amount of electricity required to generate the RFNBO, plus that the renewable energy installations are **new**. It is specified that installations are considered **new** if they were **not** commissioned **earlier than 36 months before the RFNBO production installation**. In the case of repowering plants, the newly added capacity is considered additional (EC, 2023b; Scheyl et al., 2023).

The criteria of the PtX Lab 2022 study and the fairfuel standard go further and require **initiation additionality** (Altmann et al., 2022; atmosfair, 2021). This involves submitting planning documents and approval certificates for the renewable energy installations to prove that the operator or the service provider commissioned by them planned and built the renewable energy plants to supply the RFNBO plant with renewable electricity. This is to ensure that additional new installations are built instead of existing installations being mutually offset. While the PtX Lab 2022 study requires full additionality in its long-term criteria, fairfuel does not require proof of additionality in the case of surplus electricity use. The case where electricity from avoided curtailment (surplus electricity: redispatch case) can be used, which is possible according to RED (4. Anti-curtailment), has not yet been implemented in some (RSB, 2023; TÜV Rheinland, 2023; TÜV SÜD, 2021).

The standards examined deviate in part from the provisions of the RED or go beyond them. The criteria of H2Global are currently based entirely on the legal provisions of the EU under RED (BMWi, 2021) with regard to electricity procurement and GHG reduction. The RSB Standard for Advanced Fuels defines **no-go areas** (e.g. specially protected areas and habitats) based on its 12 principles where renewable energies may not be produced (RSB, 2023). The Fairfuel Standard stipulates that solar and wind energy should be used as a priority, although biomass and hydropower are not completely excluded (atmosfair, 2021). According to RED, the energy content of RFNBO may only be generated from non-biogenic sources, which means that all standards based on RED also completely exclude biomass as a renewable energy source (Altmann et al., 2022).

[8] With an EU ETS price of €55.55/t CO_2eq, the price cap would be €0.36*55.55 = €20.

3.1.3 Stakeholder perspectives on electricity criteria for RFNBO

System-friendly operation: geographical proximity and temporal correlation
The German Advisory Council on the Environment, which advises the German government, recommends that, in addition to the criterion of additionality, electricity procurement should also be based on **system-friendly operation** of electrolysers through **geographical proximity** to renewable electricity production, as does the Öko-Institut (Hornberg et al., 2021; Kasten and Heinemann, 2019). The proximity criterion has been included in the long-term PtX Lab 2022 criteria. If electrolysers and the renewable energy sources used to operate them are located in close geographical proximity, less grid capacity is required and the need to expand supra-regional transmission grids is reduced. Therefore, geographical proximity between the generation of renewable electricity and its use by electrolysis can relieve the burden on grids. Research indicates that overly strict geographical correlation leads to both higher economic costs and lower emissions savings (Brauer et al., 2022).

Economic stakeholders criticise the electricity procurement criteria, particularly the additionality aspect, as being too strict and rigid. They fear that this will mean that only a few very expensive hydrogen projects that meet these strict criteria being implemented, resulting in insufficient quantities of affordable hydrogen derivatives being available (BMWK, 2022; frontier economics, 2021; Hydrogen Europe, 2021; US Camber of Commerence, 2024). The Expert Commission on Energy Transition Monitoring also points out that stricter sustainability criteria and the associated additional costs must be balanced (Löschel et al., 2024). In a letter to EU Energy Commissioner Kadri Simson in September 2024, Robert Habeck, Economics Minister in office at the time, advocated postponing the agreed introduction of stricter criteria for RFNBOs, as provided for in the delegated acts on the RED. According to Habeck's proposal, the **introduction of the additionality criterion** should be postponed **from 2030** to **2035**, and the **time correlation criterion** should **only** be tightened from monthly to hourly **from 2031 instead of 2030**. According to Habeck, this is intended to protect the market ramp-up of RFNBO. At the same time, some civil society organisations are calling for particularly strict rules on temporal correlation (Haywood and Tansini, 2023). In addition, there is criticism that the EU criteria refer in some detailed options to EU-specific concepts and systems that are difficult to transfer to non-EU countries (e.g. references to EU ETS, day-ahead prices, bidding zones), (Scheyl et al., 2023).

Research indicates that the requirement to prove hourly correlation between hydrogen production and renewable electricity generation leads to significant additional costs compared to a monthly correlation (Ruhnau and Schiele, 2023). The implementation of the strict electricity procurement criteria of the RED is estimated to be expensive (Hordvei et al., 2024; Langenmayr and Ruppert, 2023). Researchers at KIT estimate that in Germany in 2030, the CO_2 avoidance costs for achieving the RFNBO targets will be 14% higher than without these strict electricity procurement criteria (Langenmayr and Ruppert, 2023). Hordvei et al. estimate that the implementation of strict RED electricity procurement criteria for RFNBO in the EU will result in additional costs of €82 billion between 2024 and 2048 (Hordvei et al., 2024). This means that, compared to the base case without electricity procurement criteria, the costs for the energy system will increase by 3.7% (Hordvei et al., 2024).

Within the framework of RED III, a revision is also being considered, with particular focus on reviewing[9] and, if necessary, reforming the electricity procurement criteria for RFNBOs. This would be the case if hydrogen is not available in sufficient quantities and at an affordable price to meet EU targets and quotas due to overly strict and impractical criteria. Industry associations such as the Federation of German Industries (BDI), Hydrogen Europe and the Association of Industrial Energy and Power Management (VIK) criticise the one-hour time correlation as too strict and propose monthly correlation as sufficient (BDI, 2023; Hydrogen Europe, 2021; Klenke, 2023).

Excursus: Discourse on electricity criteria in the USA

In the USA, requirements for renewable electricity in the production of low-carbon hydrogen had been set as part of the tax credits provided by the Inflation Reduction Act (IRA) 45V tax credit (John, 2023; Natter, 2023; Tamborrino, 2023).However, tax credits for SAF and hydrogen are expected to be eliminated under the Trump administration's planned "One Big Beautiful Bill".

The tax credits had been granted depending on the GHG emissions of the hydrogen produced, with a maximum credit of $3 per kg H_2 granted for up to 0.45 kg CO_2/kg H_2, which is an initially technology-neutral approach. However, restrictive regulations had been considered for the specified GHG balance calculation method, which would impose additional requirements on the renewable electricity used so that it can be classified as CO_2-neutral (John, 2023; Natter, 2023). On 26 December 2023, the Internal Revenue Service (IRS) of the U.S. Treasury Department published the first leak of an initial official draft of regulations for hydrogen requirements that are eligible for tax credits (45V tax credits) under the Inflation Reduction Act (IRA) (IRS Treasury, 2023). In the draft, the U.S. Treasury Department presents a "three pillar" approach, which imposes three conditions on the renewable electricity used for hydrogen:

1. **Temporal matching**: § 1.45V–4(d)(3)(ii)(A) Annual correlation until 2028, hourly correlation from 2028 onwards

2. **Incremental** (Section 1.45V–4(d)(3)(i)(A)) Only newly built renewable energy facilities that went into operation no more than 36 months before the electrolyser

3. **Deliverability/geographical correlation** (deliverability: (§ 1.45V–4(d)(3)(iii))) The electrolyser must be located in the same bidding zone as the renewable energy generation of the electricity used

This approach has been and continues to be called for by many stakeholders in civil society, research and industry (Haley and Hargreaves, 2023; John, 2023). At the same time, the approach is also criticised as too restrictive by some industry stakeholders and fossil fuel lobby groups (John, 2023). Research indicates that the strict threshold of a maximum of 0.45 kg CO_2/kg H_2 in H_2 production can only be guaranteed if hourly correlation is demonstrated, while with only annual correlation, actual emissions could be significantly higher when using grid electricity (Ricks et al., 2023).

[9] The European Commission commissioned a review study on the status of the market ramp-up of RFNBO, including RFNBO criteria, that is currently conducted by ICF, Arelys and Fraunhofer ISI(ICF, 2025).

The outgoing Biden administration finalised the rules for the electricity procurement criteria for the IRA 45 V tax credits in January 2025. With the IRA 45 V tax credits, the US has thus set criteria similar to those of the EU in the delegated acts of the REDII in terms of temporal correlation, additionality and geographical correlation. This makes it more likely that these aspects will also become standards in the global international market. Now, the IRA 45 V tax credits for hydrogen are expected to be scrapped by the Trump administration.

The G7, G20 and an initiative of 35 countries within the framework of COP28, as well as a number of other initiatives such as the International Partnership for Hydrogen and Fuels in the Economy (IPHE), are increasingly advocating harmonised, mutually recognised minimum standards for renewable and low-carbon hydrogen. (COP28, 2023; G7, 2023; G20, 2023a, 2023b; International PtX Hub, 2023; ISO, 2023). Scientists have been able to show for various scenarios, such as for Germany and Morocco, that although hydrogen production prices rise slightly **when there is temporal correlation**, **local energy prices** can be **significantly reduced** and stabilised, by up to 31% with hourly correlation (Brauer et al., 2022; Schumm et al., 2024). Strict temporal correlation requires the addition of more renewable energies in order to achieve high electrolyser utilisation, which reduces prices for the entire electricity system due to the additional supply.

Further research indicates that temporal correlation can prevent emissions that would otherwise be generated by the additional fossil fuel-based electricity production required to meet the electricity demand for electrolysis. However, this comes with the expected disadvantage of higher hydrogen production costs (Ricks et al., 2023; Schlund and Theile, 2022; Zeyen et al., 2024). Some experts are therefore concerned that hourly correlation would stifle the market ramp-up and argue that, with high shares of renewable energy in the grid (e.g. >80% RE), no correlation or only a weaker one (e.g. annual correlation) would be sufficient. It is therefore proposed that **no or only a weak** (e.g. annual) correlation be required **in the short term**, **stricter requirements** (**e.g. hourly**) **in the medium term, and no or only a weak temporal correlation in the long term** (frontier economics, 2021; Giovanniello et al., 2023, 2024a; Zeyen et al., 2024). Other scientists, pointing to the higher costs of hourly correlation, recommend only requiring annual correlation or considering more flexible mechanisms that allow the correlation criterion to be waived in whole or in part when electricity prices are low or negative (Ruhnau and Schiele, 2023). In some cases, for reasons of practicability and compatibility with different electricity markets, it is also recommended to only use annual correlation (Pototschnig, 2021).

Some scientists therefore formulate this as **a regulatory dilemma** that must be weighed up between higher hydrogen costs with strict temporal correlation but rising emissions due to stimulated fossil electricity production with weak or no temporal correlation (Brauer et al., 2022; Schlund and Theile, 2022). However, in simplified terms, the higher the share of renewable energies in the electricity mix, the weaker the temporal correlation can be without significant additional emissions (Brauer et al., 2022; Zeyen et al., 2024). In addition, there are indications that, when demand is still low, an annual temporal correlation does not lead to a significant increase in emissions. Therefore, an annual correlation seems reasonable and practicable, especially at the beginning of the market ramp-up with low demand for hydrogen derivatives (Cybulsky et al., 2023; Giovanniello et al., 2023).

Brandt et al. suggest an alternative approach, allowing the EU grid electricity mix to be used for green hydrogen production at the start of the hydrogen market ramp-up, with the sole condition that at least 90% of the electricity comes from renewable sources (PPA or direct line) on an annual basis. Brand et al. argue that, with current electricity prices, which range from moderate to high (between €0.2/kWh to €0.6/kWh), there will be hardly any additional emissions even if the use of grid electricity without PPAs is allowed in some cases. According to modelling by Brandt et al. 2024, even with partial use of grid electricity mix, moderate to high electricity prices will result in almost the same greenhouse gas reduction as in the situation where temporal correlation and additionality would be applied in accordance with the stricter EU rule. At the same time, however, this could significantly reduce H_2 production costs (Brandt et al., 2024)

Additionality: Securing the expansion of renewable energies

The exclusion of renewable energy installations that receive state aid as well as old installations (e.g. those built more than 36 months before the electrolyser) could provide initial incentives to ensure that, as far as possible, new and additionally financed renewable energy installations are used for the production of hydrogen derivatives. In the political debate on EU regulation (RED DAs) on hydrogen derivatives, various additionality criteria based on different approaches (e.g. physical link (via direct pipeline), economic link (PPA), systemic link (merit order), project-based evaluation, initiation additionality, financial additionality (exclusion of state aid)) have been proposed and discussed (atmosfair 2021; European University Institute 2021; Bartlett 2022; de Veries et al. 2022).

While in markets such as the EU, where there is strong government support for renewable energies, the exclusion of government support is a good indicator that the renewable energy plant was built additionally, this criterion is less helpful in defining additionality in markets with a less pronounced support landscape. Approaches such as initiation additionality have therefore been proposed (Altmann et al., 2022; atmosfair, 2021). While proving additionality on a project basis and for PPAs seems straightforward, when using electricity from grids with a high share of renewable energy or surplus electricity (90% case or redispatch case), it is difficult to prove that the electricity comes from renewable energy plants initiated and implemented solely for the purpose of hydrogen production. Atmosfair therefore requires proof of additionality only for PPAs or direct purchases, but not for purchases of surplus electricity (residual electricity) (atmosfair, 2021).

However, NGOs from the Global South in particular criticise that the additionality criteria applied to date do not yet ensure that local access to clean energy is increased and that the energy transition is also promoted locally (Adow et al., 2022; Amouzai and Haddioul, 2023; Koppehel, 2023). Other authors demand that renewable energies required to produce green hydrogen should be built in addition to the national expansion targets of the respective countries. In other words, they should be additional to the renewable energy expansion plans set out in national climate targets (e.g. National Determined Contributions: NDCs or Integrated Resource Plans), meaning that renewable energies should not be counted towards national targets for renewable energy expansion (Cremonese et al., 2023; Germanwatch et al., 2022). While efforts should be made in the regular reports of the NDCs and the IPCC processes to ensure that renewable energies allocated to hydrogen production are not counted towards national renewable energy targets, it is difficult to demonstrate the exclusion of counting towards the NDCs at product level as a criterion for a standard.

It remains questionable whether these risks can be avoided by appropriate additionality criteria within the framework of product standards for hydrogen derivatives, or whether these challenges can only be addressed primarily through government measures and support from development cooperation. For example, the Hyphen project in Namibia is considering feeding surplus electricity into local grids, but this is currently hampered by a lack of grid infrastructure and adequate regulations.

Additionality 2.0: Additional positive effects through access to energy
Civil society actors are discussing expanded the additionality criteria (additionality 2.0) for electricity procurement. The aim is to expand access to clean and affordable energy for the local population (see SDG 7) as part of benefit sharing in the expansion of renewable energy capacities (Germanwatch et al., 2022; Morgen et al., 2022; Villagrasa, 2022). The H2Global criteria take up this idea of benefit sharing and positive contributions to the SDGs, but leave open the sectors in which these contributions are to be made (BMWi, 2021). The PtX Lab 2022 criteria integrate the approach of positive effects for the local population but then classify these under social criteria.

Resource and land use:
The production of RFNBO from hydrogen and CO_2 is very energy-intensive. Most of the social and environmental impacts therefore result from the provision of the necessary renewable energies. The expansion of renewable energies has significant impacts, particularly due to their consumption of resources and land (Villagrasa, 2022). The National Hydrogen Council therefore emphasises that recycling concepts for the renewable energies developed and the resources used in them should also be considered (Nationaler Wasserstoffrat, 2021). Hydropower in particular can have a high sustainability impact. Large-scale dam projects for hydropower can have a significant local impact on the environment and have often led to forced involuntary resettlement (Arantes et al., 2023; Randell, 2022). The provision of bioenergy is associated with high land consumption and conflicts of use. To avoid land use conflicts, areas with competing uses, such as fertile soils or areas of high biodiversity value, must be excluded. However, some emphasise that while agriculturally usable land should be excluded, it should be permitted where combined use is possible, such as in agri-PV (BMWK, 2022). By maximising energy efficiency, the amount of electricity required and thus the number of new renewable energy plants that need to be built can be reduced (Schlemminger et al., 2024). This means that fewer resources are needed to build renewable energy plants, which is why the PtX Lab 2022 study proposed a threshold value for energy efficiency as an additional criteria (Altmann et al., 2022). Further aspects of land and resource use are discussed in chapter 3.6. Only specific issues related to renewable energies were discussed here.

Grid suitability
The high volumes of additional renewable energy that must be supplied to electrolysers also pose considerable challenges for electricity grids (Kasten and Heinemann, 2019). To avoid high grid loads, some stakeholders propose defining criteria to ensure that the electricity used for electrolysers is as grid-friendly as possible (Hornberg et al., 2021; PtX Hub, 2021). The PtX Hub demands for local grid stability to be ensured (PtX Hub, 2021). The SRU calls to avoid grid bottlenecks by ensuring that renewable energy generation and electrolysis take place in close geographical proximity (Hornberg et al., 2021). Therefore, a maximum distance criterion, as already proposed in the PtX Lab 2022 study, appears to be a pragmatic and easy-to-measure criterion for reducing grid load. The geographical proximity between renewable electricity generation and electricity

consumption by electrolysers reduces the required grid capacity, thereby relieving the burden on the grids and reducing the need for additional transmission grid capacity.

3.1.4 Proposed sustainability criteria for electricity for RFNBO

The PtX Lab Lausitz advises keeping the electricity procurement criteria as simple as possible, initially requiring only RED compliance. Additionally, it is recommended to adjust the criteria for temporal correlation in line with research findings advocating for a phased approach: weak correlation in the short-term (e.g. only annual), stricter requirements in the medium-term (e.g. monthly to hourly) and returning to a weak or no correlation in the long-term (e.g. only annual) (Cybulsky et al., 2023; Giovanniello et al., 2023; Zeyen et al., 2024). Based on the findings of Giovanniello et al., the PtX Lab Lausitz propose introducing an annual correlation as a sufficient condition once renewable energies account for 60% of the electricity mix (Cybulsky et al., 2023; Giovanniello et al., 2024b, 2023). (See Table 3-2 and Table 3-3).

In the short term until 2030, it is assumed that the non-compete case applies and the demand for hydrogen derivatives will be so low that no relevant competition will arise even if grid electricity is purchased (Cybulsky et al., 2023; Giovanniello et al., 2023). Therefore an annual correlation is considered sufficient in the short term until 2030 as long as the share of renewable energy in the electricity mix remains below 60%. For Germany, the National Hydrogen Council expects a demand for climate-neutral hydrogen of 94-125 TWh in 2030, which could rise to 302-387 TWh by 2040 and 620-1288 TWh by 2050 (NWR, 2024). The update of the National Hydrogen Strategy anticipates a hydrogen demand of 95-130 TWh in 2030 (Bundesregierung, 2023). The EU has set itself the political target of producing 10 Mt (approx. 393 TWh) of renewable hydrogen in the EU and importing a further10 Mt by 2030 (EC, 2020)

In the medium term, **from 2030 to 2040**, once a higher share of renewable energies of over 80% of the grid's electricity mix has been achieved, the PtX Lab Lausitz proposes removing the requirement to demonstrate temporal correlation, as studies indicate that the protective effect against rising electricity prices and emissions will then hardly be necessary (Giovanniello et al., 2024a; Schumm et al., 2024; Zeyen et al., 2024). In the event that less than 80% of the electricity mix consists of renewable energies, the annual correlation should be replaced by stricter rules such as monthly or hourly correlation from 2030 (as soon as there is higher demand for hydrogen derivatives) (Cybulsky et al., 2023).

In the long term, **from 2040** onwards, particularly strict temporal correlation criteria should only apply where decarbonisation of the electricity mix has hardly taken place and where the risk of rising electricity prices and fossil emissions is particularly high due to additional electricity demand from electrolysers. Unlike the proposed EU regulation, this would not require hourly correlation in the long term everywhere except in systems with a renewable energy share of over 90%, but only at locations with a renewable energy share of less than 60%.

Table 3-2: Proposed gradation of the temporal correlation of renewable electricity for the production of RFNBO.

Time horizon	Proposed temporal correlation	Effect
Until 2030 (non-compete case, low H_2 demand in Germany/EU)	• If the share of renewable energy in the electricity mix is less than 80%, then **annual correlation** • If the share of renewable energy in the electricity mix is greater than 80%, **no temporal correlation is necessary**	Easy to implement, promotes market ramp-up
2030-2040 (Compete case Relevant increased demand for H_2 in Germany/EU)	• If the share of renewable energy in the electricity mix is less than 60%, then **monthly correlation** • If the share of renewable energy in the electricity mix is between 60% and 80%, then **annual correlation** • If the share of renewable energy in the electricity mix is greater than 80%, **no temporal correlation is necessary**	Stricter rules prevent increased electricity prices and emissions from additional fossil fuel-based electricity
From 2040 (Compete case Relevant high H_2 demand in Germany/EU)	• If the share of renewable energy in the electricity mix is less than 60%, then **hourly correlation** • If the share of renewable energy in the electricity mix is between 60% and 80%, then **annual correlation** • If the share of renewable energy in the electricity mix is greater than 80%, **no temporal correlation is necessary**	Stricter rules prevent socially unjust electricity prices and emissions from additional fossil fuel-based electricity

At the same time, it makes sense to work towards a revision of the electricity procurement criteria at the political level, particularly regarding the criterion of additionality and the required temporal correlation. Therefore, in preparation for the 2028 evaluation, information should be gathered in advance through research and monitoring in order to propose a reform of the relevant delegated act. With the adjustments to the time correlation presented here in this study (Renewables in the electricity mix), the PtX Lab Lausitz aims to contribute to this ongoing debate.

In the long-term criteria, the limited land and resource consumption of renewable energies should be based on the Best Available Techniques (BAT). In addition, a recycling concept for renewable energies should be demonstrated for the long-term criteria. This is not required for the short-term criteria in order to enable a quick and easy market ramp-up.

Initiation additionality should only apply in the case of direct lines or procurement via PPAs, but not in the case of procurement of surplus electricity (redispatch case) or procurement of electricity from grids with a high share of renewable energies (> 90%). While the PtX Lab 2022 criteria completely exclude hydropower, it has been decided here to allow the use of hydropower if an environmental impact assessment is provided. Depending on the existing infrastructure and structure of local grids and consumption patterns, different forms of integration and coordination of RFNBO production may be beneficial to the grid or the system. As this depends largely on local conditions and preferences, the local grid operator or local regulatory authority should verify the grid benefit of electricity procurement from the grid in the long term.

Since project developers can have a relatively large influence on how energy efficient the respective synthesis plants are designed, the energy efficiency criterion proposed in the PtX Lab Study 2022 was adopted (Altmann et al., 2022). Energy efficiency ensures that any additional renewable energy required is used as sparingly as possible, thereby indirectly reducing the need to expand additional renewable energy plants. This indirectly supports production that is as resource efficient as possible by minimising the need to build additional resource-intensive renewable energy plants.

Table 3-3: Proposed PtX Lab 2025 sustainability criteria for electricity procurement at RFNBO.

Proposed sustainability criteria	Short-term criterion (PtX Lab 2025)	Long-term criterion (PtX Lab 2025)
Renewability	Compliance with RED	Fully renewable
Additionality	Compliance with RED, but adjusted rules for temporal correlation: **Until 2030:** • If the share of renewable energy in the electricity mix is less than 80%, then **annual correlation** • If the share of RE in the electricity mix is greater than 80% RE, then **no temporal correlation** is necessary **2030-2040:** • If the share of RE in the electricity mix is less than 60%, then **monthly correlation** • If the share of RE in the electricity mix is between 60-80%, then **annual correlation** • If the share of renewable energy in the electricity mix is greater than 80%, **no temporal correlation** is necessary	RED compliance, but adjusted rules for temporal correlation • If the share of RE in the electricity mix is less than 60%, then **hourly correlation** • If the share of RE in the electricity mix is between 60-80%, then **annual correlation** • If the share of renewable energy in the electricity mix is greater than 80%, **no temporal correlation** is necessary

Proposed sustainability criteria	Short-term criterion (PtX Lab 2025)	Long-term criterion (PtX Lab 2025)
Initiation of additional renewable energies	None	Proof of initiation of renewable energy plants equal to the installed hydrogen production capacity[10] if electricity is purchased via PPA or direct line[11]
Resource consumption	None	• Proof of a **recycling concept** for newly installed renewable energies • Proof of **BAT** (Best Available Technique) for new installations of renewable energies. Proof of **limited resource and land consumption** in accordance with **BAT**
Grid suitability	Compliance with RED	• Compliance with RED • Proof/confirmation of system-compatible operation/grid-compatible integration by local grid operator or local regulatory authority[12]
Energy efficiency	Cumulative primary energy consumption < 3.5 MJ/MJ RFNBO	Cumulative primary energy consumption < 3 MJ/MJ RFNBO
Permitted energy sources	Renewable energies without biomass	• Renewable energies without biomass • Proof of environmental impact assessment when using hydropower

3.2 Greenhouse gas reduction

To positively impact climate balance, hydrogen derivatives must have a lower greenhouse gas balance than fossil reference processes. The scope of the balance sheet, i.e. which part of the value chain is considered, is particularly important here. Additionally, it is particularly relevant how the carbon or nitrogen source is accounted for in hydrogen derivatives such as methanol, ammonia or SAF. In addition to the accounting method, a

[10] Proof of initiation by the operator or a service provider commissioned by the operator by submitting planning and approval documents for the renewable energy installations.

[11] If the grid electricity is used from a grid with a high share of renewable energy (>80%) or surplus/residual electricity (redispatch case), proof of additionality is not required. The same applies if the electricity is sourced via local PPAs (max. 150 km design) and at least four times the total capacity of the production plant.

[12] Proof is only required for electricity purchased from the grid (e.g. PPA with grid connection), not for direct supply.

minimum GHG reduction must be specified that must be achieved to meet a selected sustainability criterion. The legal minimum requirement to be considered an RFNBO in the EU has been set by the RED at a minimum of minus 70% compared to the fossil reference value (94 g CO_2eq/MJ). The calculation method has been laid down in a Delegated Act by the EU (EC, 2024b).

3.2.1 PtX Lab 2022 Sustainability criteria for greenhouse gas reduction

The criteria proposed in the PtX Lab 2022 study stipulate that, in accordance with the legal requirements of the RED, a GHG reduction of at least 70% must be required (Altmann et al., 2022; EU, 2018). In the short term, the calculation method in accordance with the Delegated Act to RED Art. 25 (2) & Art. 28 (5) should be used, but in the long term, the stricter IS0 14067 standard should be applied. If industrial emissions (e.g. cement production, fossil fuel power generation) are to be used as a CO_2 source, the question arises as to who should be credited with the CO_2 emissions and who should include them in their balance sheet. The DAs of the RED choose the approach of allocating all emissions to the CO_2 source. Thus, a coal-fired power plant or cement manufacturer must continue to account for 100% of the CO_2 emissions in its own balance sheet. In return, the manufacturer of the hydrogen derivatives that uses the captured CO_2 may account for the CO_2 in its GHG balance sheet as a CO_2 removal from the air (with - 1kg CO_2eq/CO_2 kg).

The GHG accounting method according to ISO 14067 differs from the methodology in the DAs, in sense that it assumes an allocation of 50% of the GHG emissions from the CO_2 source to the GHG balance of the hydrogen derivative. The CO_2 emissions are thus divided equally between industrial CO_2 sources (e.g. cement plants or coal-fired power plants) and the production of hydrogen derivatives.

The two calculation methods therefore differ in terms of which CO_2 sources can be accounted for as CO_2 removals (creditable with - 1kg CO_2eq/CO_2 kg). In reality, according to calculations by Altmann et al. (2022), the required GHG reduction of 70% can only be achieved if a maximum of 38% of the greenhouse gas emissions from the CO_2 source are allocated to the hydrogen derivative and the rest is allocated to the CO_2 source. As a result, when accounting in accordance with ISO 14067 with an allocation of 50%, only DAC and biogenic sources achieve a GHG reduction for RFNBO of at least 70%. Industrial CO_2 sources cannot achieve a GHG reduction of 70% according to this accounting methodology, which means that they would implicitly be excluded by the GHG accounting methodology. According to the accounting method in the long-term ambitious GHG standard of the PtX Lab 2022 study, the required GHG reduction can therefore only be achieved with DAC and biogenic CO_2 sources. However, in the long-term standard of the PtX Lab 2022 study, biogenic CO_2 sources will also be explicitly excluded later and only DAC will be permitted as a CO_2 source.

Table 3-4: Comparison of legal criteria for RFNBOs for GHG reduction according to RED and PtX Lab 2022 criteria.

	Short-term criterion (PtX Lab 2022)	Long-term criterion (PtX Lab 2022)	Legal minimum requirement
GHG accounting method	DA according to RED Art. 25 (2)/Art. 28(5) (EC, 2023c, 2023d)	ISO14067 Allocation: 50% to RFNBO	DA according to RED Art. 25 (2)/Art. 28(5) (EC, 2023c, 2023d)
GHG reduction	At least -70%: 28.2 gCO_2eq/MJ	Min. -70%: 28.2 gCO_2eq/MJ	Min. -70% according to RED Art 25(2): 28.2 gCO_2eq/MJ
CO_2 sources that may be accounted for as CO_2 removals - 1 kg CO_2eq/CO_2 kg	• DAC • Biogenic sources • Industrial point sources in the EU ETS until 2035 • Geothermal sources	DAC and biogenic sources	• DAC • Biogenic sources • Industrial point sources in the EU ETS by 2040, from fossil point sources for electricity generation (these only until 2035) • Geothermal sources
CO_2 sources that achieve at least a 70% GHG reduction	• DAC • Biogenic sources • Industrial point sources in the EU ETS by 2035 • Geothermal sources	• DAC and biogenic sources	• DAC • Biogenic sources • Industrial point sources in the EU ETS by 2040, from fossil point sources for electricity generation (these only until 2035)

3.2.2 Comparison of GHG reduction criteria for different standards

For most standards, a GHG reduction of at least 70% compared to the fossil reference has been established based on the RED requirements. The RED sets the fossil reference at 94g CO_2eq/MJ, which means that GHG emissions of a maximum of 28.2g CO_2eq/MJ are permitted. The CertifHy RFNBO Standard, the RSB Advanced Standard and H2.21 adopt the criterion for a maximum GHG intensity of 28.2 gCO_2 (CertifyHy, 2023; RSB, 2023; TÜV Rheinland, 2023).

These standards account for GHG reductions in the same way as specified in RED and not in accordance with ISO 14067. RED and ISO 14067 differ in how they account for the CO_2 sources used and where their CO_2 emissions can be allocated. RED allows CO_2 from industrial and geothermal sources as well as from fossil combustion to be fully attributed to the CO_2 source, so that the CO_2 used for RFNBO can be calculated with -1kg CO_2eq/kg CO_2 in the GHG balance. From 2036, ETS-regulated sources may also no longer be accounted for under RED with -1 kg CO_2eq/kg CO_2 but must be accounted for with 0 kg CO_2eq/kg CO_2.

Global standards that are more focused on hydrogen, such as the Global Hydrogen Standard or the Hydrogen Criteria of the Climate Bonds Initiative, set intensity limits based on the mass of hydrogen (kg CO_2eq/kg H_2) (Climate Bonds Initiative, 2023; Green Hydrogen Organisation, 2023). The fairfuels standard for PtL kerosene from atmosfair does not require a specific minimum GHG reduction, but explicitly excludes certain CO_2 sources or restricts their use (atmosfair, 2021).

H2Global also fully complies with the legal regulations of RED with regard to GHG reduction and electricity procurement (BMWi, 2021). This enables RSB and CertifHy to join forces to form an Impact Alliance, which will jointly develop a certification system for H2Global. CertifHy will certify RED compliance and eligibility, while RSB will certify H2Global's extended sustainability criteria that go beyond electricity procurement and GHG reduction(RSB and CertifHy, 2022).

3.2.3 Stakeholder perspectives on GHG reduction

Various methods for accounting for GHG emissions are being discussed at national and international level. In the H2Global market consultation, for example, few companies called for clear, uniform accounting standards for GHG accounting to enable product comparability. Only one company criticises the GHG reduction threshold of -70% and calls for GHG reductions of 50% to be allowed in the short term in order to enable a simplified and accelerated market ramp-up (BMWK, 2022). In addition, it is pointed out that the accounting of co-processing is not clearly regulated and that clarity is needed (BMWK, 2022)

Internationally, further harmonised approaches and standards for calculating the GHG balance of hydrogen and its derivatives are being discussed. Further standardised methods such as the methodology of the International Partnership for Hydrogen and Fuels in the Economy (IPHE) or the draft ISO standard ISO/DTS 19870:2023 presented at COP28 are under discussion and could help to shape the development of harmonised international standards (COP28, 2023; Heinemann et al., 2023; ISO, 2023).

In LCA research, the EU's GHG accounting methodology (RED) and similar approaches are criticised for not accounting for the full life cycle emissions. EU regulations set the emission factor for renewable electricity at 0 CO_2eq/kg H_2 in GHG accounting, even though the current GHG balance for renewable energies is higher than 0 (De Kleijne et al., 2024). This means that, mainly due to the production of renewable energy plants using partly fossil electricity, for example for the production of PV modules in China, the embedded carbon from the emission-intensive production of renewable electricity would have to be accounted for with emission factors greater than zero. In addition, EU regulations do not take into account emissions generated during the transport of hydrogen (De Kleijne et al., 2024). Hydrogen leaks in particular could have a significant impact on the climate during transport. Hydrogen is not a direct greenhouse gas but can increase methane and ozone concentrations through chemical reactions in the atmosphere. As a result, leaked H_2 can have a much stronger short-term warming effect than CO_2 (De Kleijne et al., 2024; Warwick et al., 2023).

The National Hydrogen Council emphasises that GHG accounting across the entire value chain is important (Nationaler Wasserstoffrat, 2021). It is not entirely clear what impact hydrogen leaks along the entire supply chain may have on the climate balance of hydrogen derivatives (Warwick et al., 2023). Possible disadvantages for human health must also be considered and analysed. For this reason, further investigation is needed into the extent to which hydrogen leaks along the supply chain and in the production plant should be monitored.

Research findings indicate that RFNBOs such as ammonia can be produced in compliance with strict GHG reduction criteria without significant additional costs (Mingolla et al., 2024). Therefore, in the long term, GHG reduction requirements of more than 70% could be demanded without significant additional costs. In addition, the question may be raised as to whether different GHG reductions should apply to different RFNBOs depending on the technological possibilities.

3.2.4 Proposed sustainability criteria for GHG reduction

To demonstrate simple compatibility and compliance with RED, it is proposed not changing the calculation method for GHG reduction to ISO14067. In practice, this allows for concepts like those used by the Impact Alliance, which certifies RED compliance and additional extended criteria. In addition, instead of implicitly excluding certain CO_2 sources by choosing the GHG accounting method, we propose explicitly allowing certain sustainable CO_2 sources and explicitly excluding non-sustainable CO_2 sources (see 3.3. on sustainability criteria for CO_2 sources). To maintain compliance with RED, the PtX Lab Lausitz proposes a GHG reduction of at least 70% in the short term. In addition, we consider important that the accounting of co-processing be simplified and accounted for in the future. In the long term, GHG reductions should be increased in stages from -70% to -80% and up to -90% by 2050. (See Table 3-5).

During initial phase of the market ramp-up, emissions are underestimated due to simplified accounting assuming 0 CO_2eq/ kg H_2 as the emission factor for the production of hydrogen from renewable (De Kleijne et al., 2024). In the short term, this is acceptable in order to enable a rapid market ramp-up with simple regulation. It is hoped that, as the RFNBO market ramps up, the upstream chain of renewable energies will also become increasingly decarbonised, so complex accounting will not be necessary in the long term. However, if the decarbonisation of the upstream chain of renewable energies does not occur quickly enough, the GHG accounting methodology may need to be revised in the long term to take this into account.

A tracking procedure and reporting of greenhouse gas emissions, particularly for hydrogen and methane from leaks during storage and transport, must be demonstrated and published on a mandatory basis. Initially, this should only apply to long transport distances (over 1000 km), but in the long term it should apply to the entire supply chain.

Table 3-5: Proposed PtX Lab 2025 sustainability criteria for GHG reduction in RFNBO.

Proposed sustainability criteria	Long-term criterion (PtX Lab 2025)	Short-term criterion (PtX Lab 2025)
GHG accounting method	DA according to RED Art25 (2)/Art28(5) (EC, 2023c, 2023d)	
GHG reduction	By 2050: At least -80% 24.8 gCO_2eq/MJ From 2050: Min. -90% 9.4 gCO_2eq/MJ	Min. -70%: 28.2 gCO_2eq/MJ
Monitoring and reporting of GHG leaks during transport and storage	Mandatory monitoring and reporting of GHG leaks along the entire value chain (H_2 production with RFNBO use)	Mandatory monitoring and reporting of GHG leaks during transport over 1000 km.

3.3 Carbon and nitrogen sources

In addition to the primary energy source, water requirements and land use, the carbon source is a key factor influencing the environmental balance and social impact of RFNBO production. The RED does not specify any direct criteria for the CO_2 source in the DAs. However, industrial point sources will be excluded in the long term from 2041 onwards via the GHG accounting methodology (see chapter 3.2.2). Overall, the debate has so far focused primarily on carbon sources. Now, due to the increasing relevance of ammonia as a potential renewable fuel for ships, it is becoming increasingly important to also consider the sustainability of nitrogen sources (Ammonia Energy Association, 2021; Green Hydrogen Organisation, 2023; Hubatova, 2022; Naturschutzbund Deutschland (NABU) e.V. and Klünder, 2021; Zerta et al., 2023). Standards have now increasingly included ammonia as a hydrogen derivative in their scope (CertifyHy, 2023; Green Hydrogen Organisation, 2023; RSB, 2023; TÜV Rheinland, 2023). However, no explicit criteria for the nitrogen source have been specified.

3.3.1 PtX Lab 2022 Sustainability criteria for carbon sources for PtL kerosene

The PtX Lab 2022 study only considers carbon sources for PtL kerosene. Among the long-term criteria, only DAC is acceptable. Sources that do not represent a closed carbon cycle and would lead to additional emissions were excluded. Industrial and fossil point sources were excluded from the long-term criteria due to expected lock-in effects and are only permitted in the short-term standard if they are subject to effective CO_2 pricing, e.g. EU ETS. Biogenic carbon sources were excluded in the long term in the PtX Lab 2022 study in order to avoid competing uses and negative sustainability effects from intensive biomass use (Altmann et al., 2022). In addition to DAC, the PtX Lab 2022 study also allows biogenic carbon, carbon from industrial point sources subject to the EU ETS until 2035, and geothermal sources in its short-term criteria. In the long-term standard, only carbon from DAC is permitted (Altmann et al., 2022). In addition, the PtX Lab 2022 study requires in its long-term criteria that the electricity for DAC comes from renewable energies.

3.3.2 Comparison of criteria for carbon sources in different standards

The GHS and CMS70 standards do not specify criteria for carbon sources. The CMS70 standard can only certify green hydrogen that does not require a carbon source for its production(Green Hydrogen Organisation, 2023; TÜV SÜD, 2021). The Climate Bonds Initiative's Hydrogen Criteria also apply only to hydrogen, but exclude its use for carbon capture and utilisation (CCU) for fuels (Climate Bonds Initiative, 2023).

The RFNBO standard of TÜV Nord (TNE) and the ISCC EU RFNBO and REDCert EU RFNBO standards are not yet public, so it is unclear how criteria for carbon sources are implemented (Schwalfenberg et al., 2023). However, it is expected that the criteria will be very closely aligned with the RED requirements. The standards that have already adopted the RFNBO term (RSB v2.5 CertifHy RFNBO, H2.21) are very closely aligned with the RED in terms of criteria for carbon sources. This means that they all allow biogenic carbon and carbon from direct air capture (DAC) without exception, as well as carbon from geothermal sources. According to the RED, only the proportion of carbon from waste incineration that comes from biogenic waste is permitted.

Carbon from fossil fuel power generation and industrial point sources is only permitted under RED if an effective CO_2 price has been paid by the CO_2 point source. In addition, under RED, carbon from industrial point sources is only permitted until 2040 and from fossil fuel power generation only until 2035. The RED does not explicitly exclude any carbon sources but merely distinguishes how they can be accounted for in GHG accounting. While the H2.21 standard also directly implements the RED requirements in this respect, the RSB and Certify RFNBO standards stipulate a phase-out of industrial point sources from 2035 onwards.

The fairfuel standard categorises different carbon sources (sustainable, conditionally sustainable, non-sustainable) (atmosfair, 2021). It includes a phased-out schedule that defines carbon sources classified as non-sustainable (waste incineration, industrial point sources: cement, steel, glass, biomass class C) by 2030 and conditionally sustainable carbon sources by 2040 (waste incineration biogenic share, biogas, biomass class B). From 2040, up to 50% of carbon may come from carbon sources classified as sustainable (sewage sludge, paper, biomass class A). From 2040, at least 50% of the carbon must come from DAC. Carbon from fossil sources and geothermal energy is always completely excluded. In general, carbon from energy crops or waste from animal food production is excluded.

3.3.3 Stakeholder perspectives on carbon and nitrogen sources for RFNBOs

The NGO Transport and Environment (T&E) proposes that the following biomass should be excluded from the feedstocks permitted under the RED (Annex IX) for advanced fuels as unsustainable: biomass from mixed waste incineration, straw, glycerine, bagasse, residues from palm oil production, wood residues from forestry and animal fats (McQuillen et al., 2022). Palm oil residues are excluded in particular if they are linked to unsustainable palm oil cultivation methods. Certain wood residues (saw logs and veneer logs) are excluded so that they can be used for other, higher-quality material applications. According to T&E, other biogenic residues such as tree stumps or leaves should not be used in order to maintain the nutrient balance of the soil. In addition, T&E sees competition for use between residues from forestry and other types of use, which is why they are classified as completely unsustainable (McQuillen et al. 2022). Therefore, of a total of 915 Mt of biogenic CO_2theoretically available in Europe, T&E classifies only 130 Mt (14%) as sustainable according to its stricter criteria, of which only 26 Mt (8%) were classified as sensibly exploitable (McQuillen et al. 2022). While fairfuel excludes manure as an animal waste product from food production, presumably to avoid misguided incentives that would lead to an increase in livestock farming, T&E considers manure to be a sustainable feedstock (atmosfair, 2021; McQuillen et al., 2022)).

3.3.4 Proposed sustainability criteria for carbon and nitrogen sources in RFNBO

Although the potential of biogenic CO_2 sources will remain limited in the future, it still seems sensible to use the biogenic CO_2 produced during the energy use or recycling of biogenic sustainable residues (waste incineration). It is to be expected that biomass will continue to be used for energy purposes in the future. Therefore, it should remain permissible to use biogenic CO_2 that has been proven to be a by-product (residual material) for RFNBO in the long term. Contrary to the fairfuel standard and the PtX Lab 2022 criteria, we now propose to allow DAC and biogenic CO_2 that has been generated as waste to be used as a carbon source for RFNBO in the long term. However, as stated in the RED, only biogenic CO_2 from waste should be used.

In the long term, the permitted biogenic CO_2 should be based on substrate classes A & B in accordance with the Fairfuel standard as set out in Annexes 1 & 2(atmosfair, 2021). In this context, the special requirements for proof of origin should also apply (See Table 3-6 and Table 3-7).

Table 3-6: Long-term permissible CO_2 sources for RFNBO.

Permitted CO_2 sources
Biogas plants with permitted substrates
From (energetic) use of sewage sludge
From (energetic) use of residual biomass, with permitted substrates
Residues from paper and pulp production
Biogenic fraction of waste incineration, with biogenic content from permitted substrates and non-recyclable plastic content
Direct air capture (DAC)

For simplicity, all biogenic household waste (animal and vegetable food waste) is permitted. Only animal waste from food production is excluded in order to prevent false incentives to increase animal products. In addition, plastic waste has been permitted for municipal and industrial waste if proof of origin or expert reports demonstrate that it is non-recyclable. In contrast to fairfuel, animal manure and slurry are also permitted as feedstock in line with T&E. Manure is an important feedstock for biogas, whereby CO_2 is produced during fermentation, which can be used. As part of the REPowerEU plan, the EU plans to increase biogas production in Europe to 35 bcm by 2030 (EC, 2022a, 2024c). Therefore, against the backdrop of cascade utilisation, which is to be enshrined as a guiding principle in the German biomass strategy, it seems sensible to allow manure and animal dung as permissible biomass substrates (BMEL, 2022).

Origin	Permissible substrates/ Permissible biogenic residual materials	Restrictions
Forestry	Wood residues	• Wood only at the end of the utilisation cascade, proof of forest use without loss of biodiversity • Proof of non-recyclable plastic • No energy crops (NaWARo) • No waste from animal food production
Agriculture	• Cereal straw, • harvest residues, • Feed residues • Green waste, • Roadside grass • Manure, animal dung	
Municipal waste	Sewage sludge Wood residues Non-recyclable plastic Food waste Household (plant and animal) Food production waste (vegetable only)	
Industrial waste	• Wood waste • Black liquor • Non-recyclable plastic	

In the short term, biogenic CO_2 should be limited to substrates permitted under Annex IX Part A of the EU Renewable Energy Directive. However, due to the limited potential of biogenic CO_2 as a residual material, political support should be given to research and market ramp-up of DAC. It seems sensible to discuss special quotas and/or incentive systems for DAC-based RFNBOs. Contrary to RED, it seems sensible to exclude industrial point sources from 2035 rather than from 2040. Regarding sustainable nitrogen sources, the PtX Lab Lausitz proposes – as with DAC – that the renewability of the electricity used for this purpose be made a condition for the long-term criterion (see Table 3-7).

Table 3-7: Proposed PtX Lab 2025 sustainability criteria for carbon and nitrogen sources for RFNBOs.

Proposed sustainability criteria	Short-term criteria (PtX Lab 2025)	Long-term Criteria (PtX Lab 2025)
Renewability of electricity for nitrogen and CO_2 production	None	Gas separation processes for CO_2 or nitrogen extraction (e.g. DAC or Linde process) **Completely with renewable electricity**
CO_2 sources	• DAC • Biogenic CO2generated as waste/secondary product from[13], including sewage sludge and waste incineration • CO2 from the incineration of non-recyclable plastics • Industrial point sources in the EU ETS until 2035 • Geothermal sources	• DAC • Biogenic CO_2 generated as a waste product/secondary product from[14] , including sewage sludge and waste incineration • CO_2 from waste incineration of non-recyclable plastics
Restriction of biomass and non-recyclable plastic sources for biogenic and waste-based CO_2	Permitted substrate classes for biomass according to RED Annex IX Part A.(EU, 2018) The origin of biogenic CO_2 must be verified by an expert opinion.	Permitted substrate classes based on the fairfuel standard. The origin of biogenic CO_2 must be verified by an expert opinion.

[13] Biomass or biogenic residues may not be burned/used for the primary purpose of CO2 capture. The CO2 may only be used as a secondary product of a primary use (e.g. energy production).

[14] Biomass or biogenic residues may not be burned/used for the primary purpose of CO2 capture. The CO2 may only be used as a secondary product of a primary use (e.g. energy generation).

3.4 Resources (metallic and non-metallic minerals)

Natural resources, including metallic and non-metallic minerals (M&M), are crucial for today's economies and societies. Global economic growth, technological innovations, and a growing world population are driving the increasing demand for raw materials worldwide. This trend raises questions about the sustainability of such significant growth, both from a human and an environmental perspective.

The value chain for the production of hydrogen and hydrogen derivatives requires various metallic and non-metallic materials, some of which are in short supply and are classified as critical (Grohol and Veeh, 2023). Significant quantities of critical resources are needed, especially for the construction of renewable energy sources, electrolysers and catalysts (Chardayre et al., 2023, 2022; Garacia et al., 2023; PtX Hub, 2021). The extraction of raw materials required for this purpose poses considerable risks to the environment and human rights due to intensive mining (Chardayre et al., 2023, 2022; Garacia et al., 2023). There are also concerns that resource scarcity could lead to increased dependencies and conflicts over resources or exacerbate existing ones (Eicke and Blasio, 2022; Pepe et al., 2023). In order to minimise risks to the environment and human rights, conflicts over raw materials and geopolitical impacts of the supply chains, aspects of resource consumption and efficiency are increasingly being included in the sustainability discourse on hydrogen derivatives (Altmann et al., 2022; PtX Hub, 2021; Villagrasa, 2022). Some countries have even begun to restrict raw material extraction or exports (Gholz, 2014; Press et al., 2023). In order to maintain access to important raw materials for the energy transition and for the production of hydrogen derivatives, it is crucial to maintain social acceptance for raw material extraction (social licence to operate) and to reduce resource requirements and the environmental and social impacts of mining (Albrecht, 2023; Komnitsas, 2020; Lindman et al., 2020)

3.4.1 Comparison of criteria for resources in standards

Resources in standards for hydrogen derivatives

The PtX Lab 2022 study on the development of sustainability criteria and indicators for PtL kerosene weighs up various metrics as possible criteria for resource consumption and resource efficiency. Various metrics for material efficiency, such as raw material consumption (RMC), raw material input (RMI) and cumulative raw material demand, as well as raw material criticality, recycling rates and energy efficiency, as cumulative energy demand, are discussed as possible indicator metrics (Altmann et al., 2022). Material efficiency (e.g. RMC or RMI) and raw material criticality are classified as inappropriate and impractical and rejected as indicators for a standard. Recyclability is also excluded from the standard as difficult to implement. The PtX Lab 2022 study further argues that cumulative energy demand (CEC) can be a suitable proxy for resource efficiency in the production of PtL kerosene, as significant resource requirements arise from the provision of renewable energies (e.g. wind and PV) and energy-intensive synthesis processes (e.g. Fischer-Tropsch), and these variables are therefore linked.

High energy requirements lead to increased expansion of renewable energies and thus to increased resource requirements. For this reason, PtX Lab 2022 proposes a KEA limit of < 3 MJ/MJ PtL for the long-term standard and < 3.5 MJ/MJ PtL for the short-term standard (Altmann et al., 2022). Furthermore, in the long term, only energy sources with **limited resource and land consumption** should be accepted according to the PtX Lab 2022 criteria (Nationaler Wasserstoffrat, 2021).

Until now, the standards for hydrogen derivatives such as the fairfuel standard, RSB, ISCC EU, the Green Hydrogen Standard, CertifHy RFNBO, H2.21 or the criteria for H2Global have not integrated any clear criteria or indicators related to resource consumption (atmosfair, 2021; BMWi, 2021; CertifyHy, 2022; Green Hydrogen Organisation, 2023; RSB, 2023; TÜV Rheinland, 2023).

However, H2Global includes minimum requirements for waste and pollutant management in its criteria. According to these, RFNBOs must at least comply with ISO 14001 for environmental management and provide evidence of (BMWi, 2021). RSB requires a minimum standard for waste management in accordance with its criterion 11e (RSB, 2020). Beyond that, no other criteria regarding resource consumption or efficiency have been included in standards for hydrogen derivatives to date.

Standards for measuring resource flows and impacts

A set of standardised methods and indicators at regional and product level have been established to measure and quantify resource flows and their impacts. In order to monitor the impacts of the upcoming expansion of PtX technology on the availability of natural resources, it is crucial to select a set of indicators that are suitable for this purpose. In the area of material flows in national economies, the most widely accepted method is described in *the* UNEP *Manual on Economy Wide Material Flow Accounting* (2021) (UNEP, 2021). In this context, it makes sense to mention some indicators that are widely accepted and used in the analysis of regional or global economies, such as in the Germany Resource Report 2022 or the RESCUE Study 2019 (Lutter et al., 2022; Purr et al., 2019).

Raw Material Consumption (RMC, also known as the material footprint) measures the total amount of raw materials required to produce goods used by the economy (including imports and excluding exports). Indirect material flows are also considered, i.e. the raw materials contained in intermediate products.
The RMC indicator is also used as a reference indicator for monitoring and reporting on sub-targets of SDG 8 (sub-target: 8.4. Improve resource efficiency) and SDG 12 (sub-target: 12.2.: Sustainable management of natural resources) (Lenzen et al., 2021). On the other hand, *Total Material Requirement* (TMR) and *Total Material Consumption* (TMC) are better suited to assessing environmental impacts at the regional level rather than the volume of material flows. TMC and TMR consider the amount of materials moved, regardless of whether they are later used or only end up as waste or spoil during the extraction of the materials used. If a large amount of material has to be moved to obtain a small amount of usable material, the environmental impact of extraction is greater than if only small amounts of unused material are produced. Unlike RMC, TMC and TMR also include unused necessary material flows and therefore provide a more realistic picture of the total quantities of material that need to be moved, which correlates approximately with the intensity of extraction and its environmental impact. An overview of regional resource indicators can be found at Table 3-9.

Table 3-10: Overview of regional resource indicators categorised by direct vs. indirect material flows and by geographical domains. DEU (DM): Domestic Extraction Used; UDE: Unused Domestic Extraction; DMI: Direct Material Input; DMC: Domestic Material Consumption; RME: Raw Material Equivalent; RMI: Raw Material Input; RMC: Raw Material Consumption; TMR: Total Material Requirement; TMC: Total Material Consumption; MF: Material Footprint.

<table>
<tr><td colspan="2" rowspan="3"></td><td colspan="5">Value chain</td></tr>
<tr><td colspan="2">Direct</td><td colspan="3">Direct + indirect</td></tr>
<tr><td>Used</td><td>Unused</td><td colspan="2">Used</td><td>Used + Unused</td></tr>
<tr><td rowspan="3">Region</td><td>Domestically sourced and used</td><td>DEU (or DM)</td><td>UDE</td><td colspan="2"></td><td></td></tr>
<tr><td>Domestically produced and used + imports</td><td>DMI</td><td></td><td rowspan="2">RME</td><td>RMI</td><td>TMR</td></tr>
<tr><td>Domestic production + imports - exports (consumption)</td><td>DMC</td><td></td><td>RMC (MF)</td><td>TMC</td></tr>
</table>

In recent years, several studies have proposed the development of a range of methods for assessing the material footprint of products. Depending on the scope of the analysis and the data available, there are various methods for evaluating different indicators. (Liedtke et al. 2014). Life cycle assessment (LCA methodology), as described in ISO 14040 and ISO 14044, is currently the state of the art in quantifying the environmental impacts and material resource consumption over the life cycle of products. Life cycle assessment is widely used to perform material flow analyses for products and services. In the area of resources, approximately 30 different indicators, each with its own category, have been proposed and applied in life cycle assessments, each of which assesses a specific environmental impact. A comprehensive overview can be found in Berger et al. (2020) and UNEP, 2019 (Berger et al., 2020; UNEP, 2019).

3.4.2 Stakeholder perspectives on resource consumption for RFNBOs

As part of the discourse on corporate due diligence for their supply chains, the risks to the environment and human rights arising from the resource requirements for renewable energies are also discussed in detail (Chardayre et al., 2023, 2022; Denter and Friess, 2023; Garacia et al., 2023; Steinwandel and Schnittker, 2022). There is also increasing discussion of the resource requirements for the production of hydrogen derivatives, which arise from the construction of renewable energy sources (e.g. wind and PV), electrolysers (e.g. PEM or AEL) or catalysts in synthesis (e.g. in Fischer-Tropsch synthesis) (Garacia et al., 2023).

The scientific discourse on the sustainability of hydrogen derivatives is also increasingly addressing the high demand for critical raw materials, which results primarily from the high demand for renewable energies (Buizza et al., 2023; Gabrielli et al., 2023; Heinemann et al., 2021).

Accordingly, civil society and development cooperation actors have now also integrated aspects of resource consumption into their positions on the sustainability of hydrogen derivatives (Chardayre et al., 2022; Klima Allianz Deutschland, 2021; PtX Hub, 2022; Steinwandel and Schnittker, 2022; Villagrasa, 2022). In addition, Brot für die Welt demands that materials used for renewable energies and electrolysers in the process chain must meet minimum standards and proposes that only resources from countries that are signatories to the Extractive Industries Transparency Initiative (EITI) may be used (EITI, 2019; Villagrasa, 2022). [15] Signatory states of the EITI commit to complying with the EITI's minimum standards, which include civil society participation, transparency and access to information (EITI, 2019). Other relevant sustainability initiatives in the mining sector include the Towards Sustainable Mining (TSM) initiative by the Mining Association of Canada and the CSR framework of the Global Reporting Initiative (GRI) (Lindman et al., 2020).

In addition, Brot für die Welt calls for recyclability to be increased and ensured (Villagrasa, 2022). The Climate Alliance also demands that the raw material requirements of electrolysers be significantly reduced in order to ensure security of supply and minimise environmental and social impacts in mining countries(Klima Allianz Deutschland, 2021). The NGO PowerShift is calling for renewable energies and electrolysers to reduce their demand for critical raw materials and be designed in such a way that recycling and closed-loop recycling are possible (Chardayre et al., 2023, 2022). Increased recycling rates and recyclability should reduce the demand for virgin materials and thus also the necessary mining activities. In addition, PowerShift advocates that companies comply with due diligence obligations along the value chains for the extraction of necessary metallic and mineral materials (Chardayre et al., 2023).

Excursus: Raw materials flow indicator

Material indicators for the sustainability of products

The extraction and use of raw materials can have a significant impact on the environment. Two aspects are particularly important for the sustainability of resource use. The first relates to the overall impact on the natural environment. The total amount of natural material that is extracted, moved and processed is a suitable indicator for assessing the overall environmental impact, such as soil degradation, water pollution and greenhouse gas emissions. Understanding trends in resource use can help identify areas where these impacts are most severe and where intervention is most urgently needed. The second aspect relates to the risk of resource depletion associated with products or specific production methods and the risk to future supply. It is therefore important to quantify and assess the relative contribution of a product system to resource depletion.

We propose using the **Total Material Requirement (TMR)** and **Abiotic Depletion Potential (ADP)** indicators as initial parameters for assessing sustainability performance in the context of resource use. The TMR indicator is a measure of the total environmental impact associated with the extraction of the materials required. The ADP indicator, on the other hand, provides information on the availability of the materials required to manufacture a specific product and on the impact that specific production pathways may have on the future availability of resources. These two indicators are described in detail below.

[15] The EITI is an international organisation that provides sustainability certificates for the oil, gas and mineral sectors on a voluntary basis. Website: https://eiti.org/.

Total Material Requirement (TMR) and Raw Material Input (RMI)

TMR measures the amount of all direct and indirect raw materials extracted, moved and processed (including unused extraction) and therefore describes important impacts of human activities on the environment. All mining activities have significant consequences for the local ecosystem, e.g. on flora, fauna, groundwater and surface water systems, the risk of drought or the occurrence of radioactivity. The extraction of raw materials that occur only in a very small percentage of the earth's crust and in mineral ores would therefore require extensive excavation work and a large amount of material movement, resulting in a generally high environmental impact. In addition, the extraction process disrupts or destroys the supporting and supply functions of the material that is moved and consumed, e.g. when dredging sand in coastal areas, which can lead to land erosion, damage to the ecosystem and an increased risk of flooding. Therefore, in terms of the environment, the TMR is an indicator of potential environmental impacts and effects associated with resource extraction.

Mostert and Bringezu (2019) and Pauliuk (2022) applied TMR and Raw Material Input (RMI) in LCA using the Ecoinvent database (Mostert and Bringezu, 2019; Pauliuk, 2022). To do this, they developed a new LCIA method called the PMF Product Material Footprint. Since there is no internationally agreed standard for measuring the product footprint, both indicators should be used to provide two pieces of information about cumulative raw material use and total primary material demand. While TMR can be considered an average indicator of environmental impact at the point of extraction, RMI is an average indicator of environmental impact potential along the production chain up to final disposal. The RMI is also required for calculating the TMR (see 3.4.2). Both indicators therefore provide complementary information. The footprint calculated using these two indicators quantifies both the material used and processed and the total extraction of primary material from nature. According to the life cycle assessment framework, raw material extraction is an input-oriented process and therefore a good basis for measuring resource efficiency. TMR and RMI have been used in recent case studies to measure the material intensity of chemical products, building structures and electrical energy storage technologies (Sameer and Bringezu, 2019).

Life cycle assessment was originally developed to measure environmental impacts based on output-oriented indicators (impacts of a product on the environment, such as GHG emissions). For the application of TMR and RMI to product assessment, a new LCIA method based on two input-oriented indicators (requirements on nature for the production of the product) was introduced.

The Abiotic Depletion Potential (ADP) indicator

Analysing trends in resource use can help identify patterns of scarcity and overuse that can serve as a basis for conservation and management strategies. The best-known indicator for assessing the relative scarcity of abiotic resources is the Abiotic Depletion Potential (ADP) and, in particular, the $ADP_{ultimate\text{-}reserve}$[16] (not to be confused with, for example, the $ADP_{economic\text{-}reserve}$[17]), which was only established in 1995 (Guinée and Heijungs, 1995). The ADP introduces the concept of "depletion": once a resource is extracted from the Earth's crust, it is considered depleted. The characterisation model has been controversially discussed, and the data used to calculate the impact indicator covers around 50 materials. Since the ADP indicator assesses resource depletion in relation to the rate of extraction and availability of natural resources, it is not an impact indicator that refers to the natural environment. The $ADP_{ultimate\text{-}reserve}$ model expresses resource depletion as the ratio of the current extraction rate to the size of the natural stock. The ultimate reserve considered in the ADP is the only relevant stock estimate in terms of reducing natural reserves (Van Oers and Guinée, 2016).

However, this will never be known with certainty, as it depends on future technological developments. Therefore, final resources (crustal content) are considered a better substitute than fluctuating resource estimates or economic reserves as defined by the U.S. Geological Survey (USGS), which tend to offer a medium-term perspective (several decades). Van Oers et al. have shown how averaging production data over different time intervals can significantly reduce the impact of fluctuating or inaccurate data on the ADP (Van Oers et al., 2020).

Regarding the depletion of total (natural and anthropogenic) resources calculated using the ADP method, further limitations should be noted. The extraction of a substance whose remaining estimated reserves are very low could have a relevant impact on the ability of future generations to extract the same substance from natural or other deposits. For this reason, a material with low estimated reserves and high extraction rates could or should be considered critical from an environmental sustainability perspective. However, it can be argued that anthropogenic stocks must be included so that resources already extracted are not deducted from the final reserves. However, by taking extraction rates into account, the method cannot distinguish between the part of the resource that is currently being used (anthropogenic stock) and that which could be reused in the future (recycling). The AADP (anthropogenic stock extended abiotic depletion potential) methodology has attempted for the first time to explicitly quantify and take into account geological (ADP) and, in addition, (estimated) anthropogenic stocks and reserves. However, this extended indicator AADP is not yet widely used (Schneider et al., 2011).

[16] ADP ultimate reserve = the reserves that can be extracted using current technology.
[17] ADP economic reserve = the reserves that are economically recoverable today. This in turn varies depending on prices.

Another problem that currently limits the informative value of the ADP indicator is the concept of material dissipation and its significance for the future availability of resources (Berger et al., 2020; Beylot et al., 2020). The approach developed by the European Commission's Joint Research Centre for dealing with the dissipation of mineral resources proposes taking dissipative resource flows into account. This method was applied in the study by Beylot et al. (Beylot et al., 2021). The most recent attempt to include anthropogenic stocks and dissipation processes in the use phase of a product is described by Mankaa et al. with the conceptualisation of the expected dissipation potential of the abiotic resource (AEDP) (Mankaa et al., 2024). The lack of updated crustal contents and fluctuating annual production data, together with incomplete coverage of elements, may also highlight the need for new calculation methods. An overview of different methods for taking dissipation processes into account in ADP assessments can be found in Lai and Beylot (Lai and Beylot, 2023).

All these new approaches to improving the quality of the original ADP are currently being discussed further in the scientific community. As a result, there is still no method that could be recognised and applied in international legal frameworks. Nevertheless, as things stand at present, the ADP $_{\text{ultimate-reserves}}$ method is considered the best available proxy for the decline in total resource stocks and is therefore recommended as a method by the Task Force on Mineral Resources as part of the *Global Guidance for LCIA Indicators and Methods* project of the *Life Cycle Initiative of the UN Environmental Programme* (UNEP, 2019) following the findings of Berger et al. (Berger et al., 2020; UNEP, 2019). ADP is also recommended by the Joint European Research Centre as part of the Environmental Footprint to assess the impact of mineral and metal use (European Commission. Joint Research Centre., 2020).

3.4.3 Proposed sustainability criteria for resources for RFNBO

Below, two indicators for resources, TMR and ADP, are described in more detail as the basis for our proposed sustainability criteria. Based on these two indicators, the PtX Lab propose sustainability criteria for resources for RFNBO (see Table 3-8).

Application of TMR and ADP for the sustainability assessment of RFNBO products

The methodological approach to measuring TMR and ADP for products is relatively new and the discussion among experts is still ongoing. As seen so far, this is not only related to the definition of the indicator itself, but also to the development of databases and calculation methods. Since all RFNBOs have not reached maturity, ADP and TMR values for these fuels are only sporadically available and they are not uniform in terms of methodological approaches and database quality. All these factors mean that the possibility of calculating TMR and ADP and using these values to assess the sustainability level of RFNBOs is still in early stages in some cases. Nevertheless, some authors have already presented preliminary TMR and ADP values that could form the starting point for further improvement of the methods and for initial comparisons between fuels and chemicals (Bicer, 2017; Sameer and Bringezu, 2019; Suleman et al., 2015).

Decisions by regulatory authorities at national and international level are needed to harmonise methodological approaches and define databases and input data. In this context, the Product Environmental Footprint (PEF) at European level aims to ensure that all products entering the European market in future are environmentally certified (EU

Green Buisness, 2024).The life cycle assessment proposed in connection with the PEF comprises 16 environmental categories, for each of which a set of indicators can be used. ADP belongs to the category of resource consumption, minerals and fossil fuels. The PEF rules therefore apply not only to ADP, but also to all other impact or environmental categories and indicators. In this programme, a set of rules for measuring the environmental impact of products using the life cycle assessment must be developed and established by experts, business circles and politicians. In the context of ADP, this includes, among other things, which minerals are to be included, or which database versions must be used. The decisions will be based on the specific characteristics of the individual products, e.g. which material is particularly important for the product in question or whether critical materials are required. Defining these rules ensures that all manufacturers follow the same rules and that all products are assessed uniformly and are therefore comparable. We therefore propose that the Product Environmental Footprint, which is being continuously expanded and refined by the EU Commission, should consider the TMR in addition to the impact indicator ADP for the impact category "resource consumption and fossil fuels". Together, they are suitable for a comprehensive sustainability assessment for the use of materials, and specially for metals and non-metallic minerals. Further information on the PEF, the EU procedure, the scope and the timetable can be found on the European Commission's Product Environmental Footprint website (EU Green Buisness, 2024). The development of the PEF by the EU Commission is an ongoing process and will be gradually incorporated into the relevant legal acts.

ADP and TMR as a starting point

Apart from the large amount of data that needs to be researched, compiled and evaluated, the difficult part of the analysis is to create a proxy for sustainability performance that takes into account demand versus the availability of all critical materials and their relative weight. In the first phase, which is the sustainability assessment between two or more products/production processes, a comparison of TMR or ADP values can be carried out instead of assigning absolute sustainability levels. To enable meaningful comparisons, both indicators must be normalised to a unit of product (e.g. 1 kg RFNBO) or energy delivered (e.g. per kW). In a second phase, absolute limits for these two indicators should be set for all RFNBOs to ensure their sustainability. There are various ways in which this phase could be implemented. One option would be to compile a set of thresholds for classifying performance into different categories, such as gold, silver and bronze standards. The implications of these different performance levels for production authorisation and trade need to be discussed. Exclusion criteria above the defined material use can also be set for certain critical materials. This would mean, for example, that the production of RFNBOs for which the demand for a certain material exceeds the limit value would not be eligible for certification. Alternatively, it could be stipulated that if ADP or TMR limits are exceeded, certain conditions must be met, such as that a minimum proportion of 50% of the newly extracted material for electrolysers, catalysts, synthesis plants and newly built renewable energy plants (e.g. in accordance with the Extractive Industries Transparency Initiative). The same could apply to the use of recycled materials, provided that the use of secondary materials is not already included in the ADP calculation (e.g. ADP).

Setting thresholds would not only ensure sustainable RFNBO production but also put pressure on the market by discouraging resource-inefficient methods or practices for RFNBO production and promoting research and investment in best practice technologies. The threshold system can be updated regularly based on new information (e.g. list of raw materials, updated databases, resource requirements due to technological innovations, etc.) to take account of technological advances and data on resource availability. It must also be considered that very high standards cannot be proposed at an early stage, as they would not be practicable in many developing countries and would therefore run counter to the interest in developing a RFNBO value chain and stimulating a global market.

Table 3-8: Proposed PtX Lab 2025 sustainability criteria for RFNBO resources.

Proposed sustainability criteria	Short-term Criteria (PtX Lab 2025)	Long-term Criteria (PtX Lab 2025)
Environmental impact (TMR)	• **Publication of an LCA study** including: ○ **TMR values** based on LCA *best practices*[18] and databases must be provided (see Mostert and Bringezu, 2019) ○ **Comparison of TMR** results from the production of different RFNBOs	• **Proof** that **TMR < X**[19] • If TMR > X, then ○ **Proof that > 50% of newly extracted materials** (virgin material) are **certified** for electrolysers, catalysts/synthesis plants and newly built renewable energy sources. E.g., the Extractive Industries Transparency Initiative (EITI) ○ **or proof that > 50% recycled materials** were used
M&M availability (ADP)	• **Publication of an LCA study** including: ○ **ADP values** based on LCA *best practices*[20] and databases must be provided (see Mostert and Bringezu, 2019) ○ **Comparison of ADP** results from the production of different RFNBOs	• **Proof** that **ADP < X** [21] • If ADP > X, then a recycling concept or a plan for secondary material utilisation must be presented

[18] It must be ensured that the same framework is used for the TMR calculation (e.g. system boundaries, minerals considered, etc.).
[19] Based on the data collected, TMR benchmarks must be defined that set TMR limits for different production methods and technologies for each RFNBO.
[20] It must be ensured that the same framework is used for the ADP calculation (e.g. system boundaries, minerals considered, etc.).
[21] Based on the collected data, ADP benchmarks must be defined that specify ADP limits for different production methods and technologies for each RFNBO.

Calculation of indicators

Total Material Requirement (TMR)

According to Mostert and Bringezu, the TMR for products is calculated as (Mostert and Bringezu, 2019) :

$$TMR = \sum_{i=0}^{n} m_{\text{material } i} \cdot CF_{TMR \text{ material i}}$$

"The TMR considers both used and unused extraction. The unused extraction includes all natural material that is moved and dumped to enable the extraction of raw material." (Mostert and Bringezu, 2019)

The $CF_{TMR_{material\ i}}$ is calculated as following:

$$CF_{\text{TMR}_{\text{material i}}} = CF_{RMI \text{ material i}} \cdot (1 + coeff_{\text{extraction material i}}$$

"The $coeff_{extraction\ material\ i}$ is the extraction coefficient of the material i calculated by the ratio of the mass of the unused extraction and the mass of the extracted primary material for production of the material measured in kg per kg." (Mostert and Bringezu, 2019)

$$coeff_{\text{extraction material i}} = \frac{m_{\text{unused extraction}}}{m_{\text{extracted primary material for prodcution of material i}}}$$

CF_{RMI}: Ratio between the mass of the extracted raw material, i.e. the extracted consumption and the mass of substance i in the extracted raw material (->concentration of material i in the extracted raw material).

$Coeff_{em}$: Ratio between the mass of the unused withdrawal and the mass of the primary material withdrawn for the production of material i

Abiotic Depletion Potential $_{Ultimate\text{-}reserve}$

The ADP model relates annual withdrawal rates to stock estimates. Depletion is assessed as the withdrawal rate (E) divided by the stock estimate (R), and this ratio is multiplied by 1/R to account for differences in stock size, as shown in the following equation (see Guinée and Heijungs for a detailed discussion of the modelling decisions) (Guinée and Heijungs, 1995). In addition, the ADP is defined relative to the reference substance antimony (Sb) and includes indirect material flows. Antimony was chosen as the reference substance because it is the first element in the alphabet for which a complete set of required data (extraction rate and ultimate reserve) is available. The choice of reference substance is arbitrary. Choosing a different reference does not change the relative sizes of the stocks. (Van Oers and Guinée, 2016). The equation below shows the calculation of the ADP Characterisation Factor (CF) for a resource i in relation to the reference substance antimony. For $ADP_{Ultimate\text{-}reserve,}$ the inventory estimate R is the ultimate reserve (crustal content).

$$\text{ADP}_i = \text{CF}_i = \frac{\frac{E_\text{i}}{R_\text{i}}}{\frac{E_\text{ref}}{R_\text{ref}}} \cdot \frac{\frac{1_\text{i}}{R_\text{i}}}{\frac{1}{R_\text{ref}}} = \frac{\frac{E_\text{i}}{R^2{}_\text{i}}}{\frac{E_\text{ref}}{R^2{}_\text{ref}}}$$

The specified ADP coefficient (CF) for a particular mineral in kg of antimony equivalents is multiplied by its extracted quantities (in kg). The total ADP of a particular product is therefore the sum of these multiplications, where m_i is the quantity of the required mineral $_i$ in kg. The formula is shown (Van Oers et al., 2020) :

$$AD = \sum_i \mathrm{ADP}_i \cdot m_i$$

3.5 Water use

In addition to electricity, water is also required for electrolysis. Water is therefore an essential input factor in the production of RFNBO. In addition to electrolysis, water may also be required at other stages of the value chain. For example, water is needed to clean PV systems or to cool hydrogen production facilities. Water is therefore an important sustainability aspect of RFNBO, particularly in regions that are already affected by water scarcity or will be affected in the future.

3.5.1 PtX Lab 2022 Sustainability criteria for water use for PtL kerosene

In the PtX Lab 2022 study, the sustainability aspect "water availability" encompasses both the social and ecological impact of water use in the production of PtL in aviation (Altmann et al., 2022). Water can be used at several points in the PtL value chain, with electrolysis requiring the most water, at around 13 kg of fresh water to produce 1 kg of PtL. Water may also be needed to clean the PV panels. However, this is not yet clear whether this refers to the entire value chain or whether the aspect relates exclusively to electrolysis according to the PtX Lab 2022. In order to assess the water situation in the region, the PtX Lab 2022 study recommends using the SDG indicator 6.4.2 "Degree of water stress" (Altmann et al., 2022; atmosfair, 2021), in line with the fairfuel standard (2021). "*If, at the planned location, water scarcity according to UN Water17 SDG indicator 6.4.2*

1. *No further measures are required; Note: Since future developments in water scarcity must also be taken into account in order to ensure continuous compliance with the standard (in the course of regular audits), it may be the case that the 40% threshold is only exceeded after the plant has been commissioned. This would mean retrofitting with seawater desalination. It is therefore always advisable to invest in seawater desalination if the limit is only slightly exceeded.*
2. *If the limit is exceeded by more than 40%, the required water must be obtained, e.g. through seawater desalination, and must not be taken from fresh water reserves.*
3. *If the limit is exceeded by more than 60%, the required water must be obtained, e.g. through seawater desalination, and a quantity of desalinated water commensurate with the total investment must be made available to the public at socially acceptable prices."*

For the short-term standard, the limit can initially be set at 60% according to the PtX Lab 2022 study. Table 3-9 summarises the proposals again.

Table 3-9: Criteria for water availability for the long-term and short-term criteria according to the PtX Lab 2022 study.

Criterion	Short-term criteria (PtX Lab 2022)	Long-term criteria (PtX Lab 2022)
Water availability	• Water scarcity at the location not exceeding 60% Or • Completely from seawater desalination	• Water scarcity at the location not exceeding 40% Or • Completely from seawater desalination • If water scarcity at the site exceeds 60%, additional supply of desalinated water to the public

SDG 6.4.2. "Level of water stress" is defined by the UN as the ratio between total freshwater withdrawal by all important sectors (agriculture, forestry and fisheries, industry, electricity generation, and services, including water withdrawal for households) and total renewable freshwater resources, taking into account ecological water requirements (UN, 2023). This means that the indicator can only be used to draw indirect conclusions about the social component of sustainability in terms of water supply to the local population. Rather, the indicator describes the competing uses of water by different sectors and their influence on sustainable water use.

In addition, countries report on the indicators at most annually and exclusively on the basis of national data within the framework of the SDGs. The annual recording of water stress at national level therefore does not allow any conclusions to be drawn about regional characteristics. Such differences can be significant, particularly in the case of indicators such as SDG 6.4.2, which looks at the degree of water stress, as water availability is highly dependent on local conditions. Furthermore, water availability is subject to seasonal fluctuations that may not be fully captured by annual reporting (Heinemann et al., 2021; Thomann et al., 2022). It is therefore important to consider both regional and seasonal differences when assessing water availability in order to make informed decisions regarding PtL production and other similar processes.

Exceeding the water stress thresholds does not directly rule out a location. Nevertheless, the PtX Lab Study 2022 still recommends that water should be obtained from seawater desalination plants in such cases. This measure is already practised in some countries, but it is more of an example and cannot be regarded as a general norm. It should be noted that no further criteria have been established for seawater desalination plants themselves, although they have environmental impacts that should be taken into account when formulating criteria (Labunski, 2024; Panagopoulos and Haralambous, 2020; Roberts et al., 2010). In addition to electricity consumption, it is particularly important to consider the handling of waste materials such as brine.

3.5.2 Comparison of water consumption criteria for different standards

The RSB, GH2 and H2Global standards all emphasise sustainable water management, but their requirements and priorities vary (BMWi, 2021; Green Hydrogen Organisation, 2023; RSB, 2023, 2020). The RSB standard emphasises the development and implementation of a water management plan that aims to use water efficiently and maintain or improve the quality of the water resources used (RSB, 2023, 2020). This should be monitored on an annual basis. It includes the integration of rainwater harvesting practices, irrigation techniques and measures for the reuse or recycling of wastewater. In addition, a prior impact assessment is required in order to assess potential social and environmental impacts. As a general rule, it must be ensured that operations do not contribute to the depletion of surface water or groundwater resources – water extraction must therefore not exceed replenishment capacities(Hinicio, 2024; RSB, 2020).

The Green Hydrogen Standard (GH2) requires a publicly available assessment of water use and the concept for wastewater treatment and water pollution, with reference to applicable national standards where applicable (Green Hydrogen Organisation, 2023). Furthermore, it emphasises the need to consider the risk of reducing access to water or exacerbating water scarcity. Measures to improve water efficiency and minimise water pollution are also required, including the provision of drinking water, irrigation and/or water treatment for local communities. Specific requirements are also set for seawater desalination plants, based on the principle that the company must provide evidence that the plant has no negative impact on the water source.

H2Global defines sustainable water sourcing as ensuring that there is no foreseeable impairment of quality or scarcity at the site throughout the entire life cycle of the project. This excludes the use of fossil water resources in arid regions and requires proof of sustainable management of residues from desalination if such facilities are used (BMWi, 2021; Hinicio, 2024).

The Climate Bonds Initiative also requires a water management plan and a local assessment of water resource availability. It is important to make sure that water extraction for hydrogen production does not compromise access to water for human use and agriculture. It is recommended that hydrogen production facilities not be located in regions with high water scarcity without alternatives such as seawater desalination (Climate Bonds Initiative, 2023).

3.5.3 Further perspectives on water consumption for RFNBO

The Öko-Institut emphasises that water production for hydrogen production should not put additional pressure on water resources, either in the short term, seasonally or in the long term (Heinemann et al., 2021). It is reiterated that water is needed not only for electrolysis, but also as an input at other points in the value chain. This is to ensure that there are no negative impacts on the ecosystem and biodiversity and that water scarcity for local communities and water costs do not increase. For the use of seawater desalination plants, the criteria must ensure that they meet high environmental standards in terms of salt disposal, efficiency and the use of renewable energies for power supply. Projects should also aim to increase local water availability by making surplus fresh water from desalination plants available to communities and providing water reservoirs (Heinemann et al., 2021).

Researchers from the HyPat project discuss the impact of the hydrogen production chain on local water supply and highlight the need to avoid negative effects such as water scarcity and price increases (Thomann et al., 2022). They emphasise that demand along the entire value chain must be taken into account, especially with regard to groundwater and surface water, where scarcity and seasonal fluctuations must be considered. The study suggests that, in the event of water scarcity, additional seawater desalination plants should be built to meet the needs of hydrogen production facilities. It points out that existing seawater desalination plants should not be used for production and that alternative solutions are needed to minimise potential negative impacts on local water supplies. Water availability is considered not only at the national level but also at the regional level, using the WRI indicator "Baseline Water Stress" to identify areas at high risk of water scarcity (Hofste et al., 2019). The study also emphasises the need to consider the additional energy required for seawater desalination and to minimise environmental impacts on coastal marine ecosystems. It recommends maintaining a minimum distance of 4 km from marine protected areas to avoid harmful effects from salt wastewater. (Thomann et al., 2022).

Dena emphasises that hydrogen production should not put additional pressure on local water availability, whether in the short term, seasonally or in the long term (Weiß et al., 2023). Hydrogen production should respect existing water rights and be coordinated with existing water management plans to minimise conflicts with other water uses, such as irrigation. Besides, it is emphasised that hydrogen production must not impair the quality of the water source used. It is crucial to ensure that wastewater from hydrogen production, such as salt wastewater or wastewater from the production of PtX materials, does not negatively impact the quality of the source. In regions where seawater desalination is an option, it is important to ensure that desalination plants meet high environmental standards, particularly regarding brine disposal. Furthermore, it is pointed out that water is also used as a coolant or for cleaning photovoltaic systems. For these applications, efforts should be made to maximise water efficiency and minimise the additional water required beyond the volumes used as raw materials. As a first step towards achieving a sustainable hydrogen product, basic water management practices should be integrated into hydrogen certification schemes to increase transparency and comparability. This would include specifying the origin, use, volume and recovery of suitable water sources, surface water or groundwater, or, in the case of seawater, details on the operation of desalination plants. A subsequent step would be for hydrogen certification schemes to include additional requirements, e.g. benefits for local communities through improved access to water and improved supply infrastructure (Weiß et al., 2023).

3.5.4 Proposed sustainability criteria for water consumption in RFNBO

Principle

The use of water in the production of RFNBOs should not have a negative impact on water availability in the affected region. This requires consideration of the entire water demand along the value chain as well as regional and seasonal factors. It is important to consider ecological impacts and competing uses, with the social dimension addressed in the context of the sustainability aspect Standard of living (see 3.8.1). Where possible, an impact assessment should be carried out and a water management plan drawn up to assess the ecological and possibly also social consequences in terms of the price, quantity and quality of water. The water management plan should be reviewed regularly, ideally annually, to ensure efficient water use and maintain the quality of the water resources used.

Criteria

Before implementing the project, an impact assessment should be carried out if possible[22]. The aim of the impact assessment is to be able to estimate the effects on the quality, quantity and price of water. It is also advisable to draw up a water management plan[23] and to review it regularly on an annual basis (Hinicio, 2024). The aim of the water management plan is to ensure efficient water use and maintain the quality of the water resources used. In addition to providing a basis for decision-making on project plans, both the impact assessment and the water management plan serve to identify and eliminate risks. They also form a basis for transparent communication and promote dialogue with affected stakeholders in the region.

In order to ensure water availability in regions that suffer from severe water scarcity and to rule out competition for water use with private households, it is proposed to use the water stress indicator[24] according to the World Resource Institute (Kuzma et al., 2023). This indicator can be used to assess both regionality and seasonality on the basis of the data. For the long-term scenario, the water stress according to WIR in the region of the planned site should not exceed the threshold value of 20% (corresponding to the low to medium category) in any month over a three-year period prior to the application. If the threshold value is exceeded in one or more months of the three-year period, a site is not automatically excluded. However, further evidence must be provided to rule out a deterioration in local water availability:

1. **No use of fossil water**: No fossil water may be used to ensure that water resources are not excessively depleted.
2. **No use of water intended for human consumption:** No water intended for human consumption[25] may be used.
3. **No use of water beyond replenishment capacity:** The use of water must not exceed the natural replenishment capacity of the groundwater table, watercourse or reservoir from which the water originates. This is to ensure that water resources are managed sustainably and their availability for future generations is guaranteed.[26]

For short-term criteria, the threshold value for water stress can be set at 40% (corresponding to the medium to high category). However, if the threshold value is exceeded, the same criteria should apply as for long-term criteria. The criteria for water consumption can be found in Table 3-10.

If a seawater desalination plant is used as a water source, further criteria should be considered in both the short-term and long-term criteria sets. One key aspect is the impact assessment process, which evaluates the specific effects of the plant on the environment. In particular, the impact on marine ecosystems, the coastline and the marine environment should be analysed. Another important element is the waste management concept, which also includes the disposal of brine, a waste product of

[22] Hinicio (2024) provides an example of an impact assessment for water.
[23] Hinicio (2024) provide an example of how to create a water management plan.
[24] Water stress measures the ratio of total water demand to available renewable surface and groundwater resources. Water demand includes household, industrial, irrigation and livestock use.
[25] Reference is made here to EU Directive 2020/2184, which lays down the framework for the protection of water resources and the protection of drinking water quality in the European Union (EU, 2020) .
[26] In this case, this refers to the total amount withdrawn (including by other users). This means that the total amounts withdrawn must not exceed the replenishment capacities. Conversely, this means that a percentage must be allocated to the specific project (this requires an overarching agreement between the various stakeholders).

seawater desalination. This concept aims to make brine disposal environmentally friendly and minimise negative impacts on the environment. According to Hypat (2022), it is also necessary for the seawater desalination plant to maintain a minimum distance of 4 km from marine protected areas (Thomann et al., 2022). This serves to protect sensitive marine habitats and contributes to the preservation of biodiversity. Furthermore, the electricity procurement criteria in accordance with RED should also be met for the electricity procurement of the seawater desalination plant, which means that the electricity must come from renewable energy sources (EC, 2024b). This is crucial in order to minimise the environmental impact and ensure the sustainability of the seawater desalination plant's operations. In principle, an environmental and waste management system must be in place to prevent harmful emissions. Reference is made to DIN ISO 14001 for this purpose. In particular, criteria relating to emissions, land use (see aspect Land use and land use change), waste and wastewater are all important points for the sustainability aspect of water use.

Table 3-10: Proposed PtX Lab 2025 sustainability criteria for water consumption by RFNBO.

Criteria	Short-term criteria (PtX Lab 2025)	Long-term criteria (PtX Lab 2025)
Water scarcity or competition for use	Same logic as for long-term, but with a threshold value of 40% for the WRI Water Stress Indicator	• WRI Water Stress at the location/region not exceeding 20% in any month of the last 3 years Or • WRI Water Stress at the location/region in one (or more) month(s) of the last 3 years above 20%, then proof that: ○ No use of fossil water + ○ No use of water intended for human consumption (see EU Directive 2020/2184) + ○ No use of water in excess of the replenishment capacity of the groundwater table, watercourse or reservoir from which the water originates
If seawater desalination (SD) is used	• Impact Assessment Process (specific environmental impacts) • Waste management concept including brine • SD plant at least 4 km distance from marine protected areas (see HYPAT) • Electricity procurement criteria according to RED	• Impact assessment process (specific environmental impacts) • Waste management concept including brine • SD plant at least 4 km distance to marine protected areas (see HYPAT) • Electricity procurement criteria according to RED

Criteria	Short-term Criteria (PtX Lab 2025)	Long-term criteria (PtX Lab 2025)
Environmental and waste management system	Environmental and waste management according to ISO 14001	Environmental and waste management according to ISO 14001
Preliminary where possible	• Impact assessment (effects on price, quality, quantity and biodiversity) • Water management plan with regular monitoring	

3.6 Land use and land use change

Land is required not only for the production of RFNBOs, but also for other parts of the value chain. In particular, the land consumption to produce renewable electricity for electrolysis is proportionally very high. Careful site selection is crucial to avoid negative impacts on ecosystems and local communities. The planning of site selection and land use must therefore be carried out carefully in order to minimise negative impacts on the environment and local communities.

3.6.1 PtX Lab 2022 sustainability criteria for land use and land use change for PtL kerosene

The sustainability criteria for land use and land use change in the PtX Lab 2022 study address the so-called "land-critical" part of the value chain (Altmann et al., 2022). This refers to electricity production. If DAC or seawater desalination is used, the criteria should also apply to these parts of the value chain. The PtL plant itself (electrolysis and synthesis) is not taken into account because it can be compared to conventional industrial plants in terms of space requirements (Altmann et al., 2022), see Table 3-11.

Unlike the RED criteria for biomass, which focus on agroforestry zones, the RFNBO framework must be expanded. This includes additional areas to be protected, such as arid and semi-arid ecosystems. For this reason, the PtX Lab 2022 study refers to the ISO 13065:2015 standard on bioenergy (ISO, 2015) for the criteria for land use and land use change. The set of criteria is listed in Annex E. An essential criterion is biodiversity within the area of activity. This must be protected in particular in the context of land use and land use change. In addition, an environmental impact assessment should be carried out for PtL projects in both the short and long term (Altmann et al., 2022).

Table 3-11: Criteria for land use change for the long-term and short-term criteria of the PtX Lab 2022 study.

Criterion	Short-term criteria (PtX Lab 2022)	Long-term criteria (PtX Lab 2022)
Land use or land use change	No conversion of high nature value areas (HNV according to IUCN) (reference to criterion in ISO 13065)	No conversion of high nature value areas (HNV according to IUCN) (reference to criterion in ISO 13065)

3.6.2 Comparison of criteria for land use or land use change in different standards

The sustainability aspect of land use or land use change is taken into account in various forms in most of the standards considered (BMWi, 2021; Climate Bonds Initiative, 2023; Green Hydrogen Organisation, 2023; RSB, 2023). With the exception of the Fairfuel Standard from atmosfair (atmosfair, 2021). No criteria are listed there. The Climate Bonds Initiative standard only requires that the project assess land use and land use change (Climate Bonds Initiative, 2023). H2Global requires a social and environmental impact assessment in accordance with the USVP of the Kreditanstalt für Wiederaufbau (KfW) [27] (BMWi, 2021). Furthermore, land use conflicts should be ruled out. In addition, project areas in or directly adjacent to areas worthy of protection (listed as nature reserves, marine protected areas, Special Protection Areas[28] (SPAs), areas of high biodiversity, wetlands and cultural sites) should also be excluded. Besides, ecological damage should be avoided and biomass should be used without adversely affecting local food production. The Green Hydrogen Standard requires the protection of biodiversity(Green Hydrogen Organisation, 2023). This is to ensure that healthy and functional aquatic and terrestrial ecosystems exist in the long term. The impacts of project activities on biodiversity must be managed responsibly, and ongoing and new issues must be continuously identified and addressed. For GH2 accreditation and certification, biodiversity issues must be identified through a competent assessment process and appropriately monitored during project implementation.

In the RSB standard, the aspect of land use and land change can be found in principle 7, "Conservation" (RSB, 2023, 2020). In general, operations that have negative impacts on biodiversity, ecosystems and conservation values should be avoided. In addition, operations should contribute to the protection of carbon storage. RSB introduces the terms "no-go areas" and "no conversion areas". No-go areas may not be used for any activities unless the areas in question are expressly approved by the legislator. No-go areas include nationally, regionally or internationally protected areas such as wetlands under the Ramsar Convention or areas protected under IUCN categories I-V. So-called Key Biodiversity Areas according to IBAT and areas in the IUCN Red List of Ecosystems are classified as no conversion areas. These areas may not be converted for activities. In addition, requirements for the protection of ecosystem functions, buffer zones and ecological corridors are defined.

3.6.3 Stakeholder perspectives on land use and land use change for RFNBOs

Blohm and Dettner (2023) emphasise that in countries with informal land use rights, particular attention must be paid to respect these rights (Blohm and Dettner, 2023). However, only the social component is presented here: no individual or community should be forced to sell land for production if it is used for cultural or traditional purposes. In addition, productive farmland should not be used for production in order to secure agricultural production. Blohm and Dettner (2023) recommend using already sealed areas in industrial zones to avoid conflicts between energy and food production and to protect the landscape(Blohm and Dettner, 2023).

[27] KfW provides for social and environmental impact assessments and has various sustainability guidelines for different parts of the organisation (DEG, KfW IPEX-Bank, KfW Development Bank). These often refer to further international standards such as the World Bank's ESS or the IFC PS (KfW, 2024; KfW IPEX-Bank, 2020)

[28] Special Protection Areas are, for example, bird sanctuaries under the EU's Natura 2000 regulation (EU, 1992)

Brot für die Welt (2022) also proposes implementing more multifunctional land use in the future to avoid competition for land (Villagrasa, 2022). Agri-photovoltaics is cited as an example here. This technology enables land to be used simultaneously for agriculture and energy production. Brot für die Welt (2022) also points out the various influences and risks to land along the value chain that must be taken into account in hydrogen production and electricity generation (Villagrasa, 2022). National governments are being called upon to take action, as part of a national hydrogen strategy, the organisation is calling for comprehensive zoning to identify priority areas for large-scale development of renewable energies for hydrogen production.

3.6.4 Proposed sustainability criteria for land use and land use change for RFNBOs

Principle
The proposed sustainability criteria for land use and land use change are based on Principle 7 of the RSB Standard (RSB, 2020). Compared to the rest of the literature reviewed, the criteria listed therein represent a robust sustainability assessment and protection with regard to land. In line with RSB, operations should avoid negative impacts on biodiversity, ecosystems and conservation values, and contribute to the protection and/or enhancement of carbon stocks. It is therefore also recommended that impacts on the land affected be integrated into the environmental impact assessment preceding the project.

Criteria
It is recommended to avoid sealing new areas wherever possible and, ideally, to locate production sites in existing industrial areas. In addition, priority should be given to areas where the preliminary environmental impact assessment identified the lowest risk of impact on conservation values. Furthermore, there are areas that are designated as no-go areas and no conversion areas in line with RSB. The use of areas designated as "no-go areas" for operational purposes is prohibited. This applies to both long-term and short-term criteria, unless production is legally permitted within the framework of nature conservation management for the area in question. These no-go areas include regionally, nationally or internationally protected areas. These include, among others:

- Protected areas classified in categories I-IV by the International Union for Conservation of Nature (IUCN)[29]
- Wetlands of international importance designated under the Ramsar Convention[30]
- World Heritage Sites designated under the United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage Convention
- Biosphere reserves designated under the UNESCO programme "Man and the Biosphere".

Other legally protected areas include:

- Primary forests (i.e. naturally regenerated forests with no significant signs of human activity and where ecological processes are not significantly disturbed)
- Areas of cultural or spiritual significance to indigenous peoples, including their rights to subsistence, land management and tradition.

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[29] An area of land and/or sea specially dedicated to the protection and maintenance of biological diversity and natural and cultural resources and managed through legal or other effective means.
[30] The Convention on Wetlands of International Importance, especially as Waterfowl Habitat.

These no-go areas include both ecological and cultural assets. In principle, prioritisation is conceivable, with the highest priority being given to nature conservation. It would therefore also be conceivable to impose an unrestricted ban on the use of the above-mentioned areas with ecological relevance. However, the regulations on designated no-go areas could continue to apply to areas with cultural relevance.

Areas with significant nature conservation value at global, regional or local level or which contribute to its preservation fall into the category of no conversion areas. These areas may not be converted. This criterion applies to both short-term and long-term considerations. No conversion areas include, among others:

- Key biodiversity areas[31] as specified in the Integrated Biodiversity Assessment Tool (IBAT) for Business Tool, including Alliance for Zero Extinction Areas[32] (AZEs), Important Bird Areas[33] (IBAs) and IUCN Key Freshwater Biodiversity Areas
- Natura 2000 areas[34] in accordance with the European Birds and Habitats Directives
- Areas with high carbon stocks, e.g. wetlands and peat bogs
- Areas listed on the IUCN Red List[35] of ecosystems.

Another criterion is the preservation and protection of ecosystem functions[36] and ecosystem services[37]. Both short-term and long-term measures must be implemented to preserve and maintain ecosystem functions and services such as biodiversity and carbon stocks. This applies to areas both inside and outside the company site that are directly affected by the company's operations.

Furthermore, ecological corridors must be protected in both the long-term and short-term criteria. According to RSB, an ecological corridor is a continuous strip of land or water that differs from the adjacent landscape on both sides and allows the movement of individuals and ecological processes between two or more habitats, thus contributing to connectivity. It is important to ensure that existing ecological corridors within the operating site are considered and protected. In addition, ecological corridors must be created by the operator if the operating site impairs connectivity between the surrounding ecosystems.

Another criterion for land use and land use change is the long-term protection of buffer zones. Buffer zones are areas that serve to intercept pollutants and manage other environmental issues. Existing buffer zones should be taken into account in order to

[31] Places that make a significant contribution to global biodiversity conservation. They represent the most important areas for global biodiversity protection and are identified nationally using globally standardised criteria and thresholds.

[32] Key areas identified by the Alliance for Zero Extinction, each of which represents the last remaining refuge for one or more endangered or critically endangered species.

[33] Important areas for the protection of global bird populations, identified by the Important Bird Areas (IBA) programme of Bird Life International.

[34] It is an EU-wide network of nature reserves established under the 1992 Habitats Directive to ensure the long-term survival of Europe's most valuable and threatened species and habitats. It consists of Special Areas of Conservation (SACs) designated by Member States under the Habitats Directive and includes Special Protection Areas (SPAs) designated by them under the 1979 Birds Directive.

[35] The categories and criteria of the IUCN Red List of Ecosystems are a global standard for assessing the conservation status of ecosystems, applicable at local, national, regional and global levels. The Red List of Ecosystems assesses whether ecosystems have reached the final stage of degradation (a state of collapse), whether they are classified as critically endangered, endangered or vulnerable, or whether they currently do not pose a significant risk of collapse (not endangered).

[36] According to the RSB, ecosystem functions are characteristic processes of an ecosystem, such as decomposition, production, nutrient cycling and flows of nutrients and energy, which result from interactions between organisms and the physical environment and ensure the integrity of the ecosystem.

[37] Ecosystem services are, according to RSB, the benefits that humans derive from ecosystems. These include provisioning services such as food and water, regulating services such as flood and disease control, cultural services such as spiritual, recreational and cultural benefits, and supporting services such as nutrient cycles that maintain the conditions for life on Earth.

avoid negative impacts on adjacent areas. In addition, new buffer zones should be designated if this is indicated by the environmental impact assessment. Furthermore, as already mentioned in relation to the sustainability aspect of water use, reference is made here once again to DIN ISO 14001. This should be considered to protect the environment from emissions, as this contributes to safe environmental and waste management.

Table 3-12: PtX Lab 2025 sustainability criteria for land use and land change for RFNBOs.
[1]See criterion 8 Standard of living and https://whc.unesco.org/en/renewable-energy.
[2]May only be used if appropriate management methods preserve or improve the identified nature conservation values.

Criteria	Short-term criteria (PtX Lab 2025)	Long-term criteria (PtX Lab 2025)
Preliminary	Impact assessment where possible	

No-go areas	Complies with long-term criteria	• Exclusion of the following areas:
		  ○ "IUCN" Category I-IV protected areas
		  ○ Wetlands of international importance designated under the Ramsar Convention
		  ○ World Heritage Sites designated in the UNESCO World Heritage Convention[1]
		  ○ Biosphere reserves designated by the UNESCO Man and the Biosphere Programme[1]
		  ○ Primary forests
		  ○ Natural or non-natural grasslands with high biological diversity
		  ○ Areas of cultural or spiritual significance to indigenous peoples, including their rights to subsistence, land use and tradition[1]
		• Exception: Use of the area is legally permitted within the framework of the protection management for the area concerned

No Conversion Areas[2]	Complies with the long-term criterion	• The following areas may not be converted:
		  ○ Key Biodiversity Areas (KBA) as defined in the IBAT for Business Tool, which includes Alliance for Zero Extinction Areas (AZEs), Important Bird Areas (IBAs), and IUCN Key Freshwater Biodiversity Areas
		  ○ Natura 2000 areas (as defined in the European Birds and Habitats Directives)
		  ○ Areas with high carbon stocks, e.g. wetlands or moorlands
		• Areas listed in the IUCN Red List of Ecosystems

Criteria	Short-term criteria (PtX Lab 2025)	Long-term criteria (PtX Lab 2025)
Preservation/ improvement of ecosystem function	Complies with the long-term criterion	Maintaining and improving ecosystem functions and services, such as biodiversity and/or carbon stocks, both within and outside the company premises, on land directly affected by the activities→ Where possible, based on an impact assessment of the influence on biodiversity
Protect ecological corridors	Complies with the long-term criterion	• Existing corridors must be protected • If corridors improve wildlife connectivity, they must be created
Protect buffer zones	Applies only in the long term	Where possible, buffer zones should be protected and designated where necessary to avoid negative impacts of activities on areas adjacent to the site.
Environmental and waste management system	Environmental and waste management according to ISO 14001	Environmental and waste management according to ISO14001

3.7 Labour

Considering social standards, the human well-being approach is a good starting point for classifying and aligning the individual aspects that fall within the social domain.

Key components of human well-being include areas such as health, happiness, meaningful work and social relationships, freedom and self-determination. In particular, work organisation is one of the determining factors that can provide human well-being, partly through direct or indirect effects on the constituent elements. On the one hand, certain aspects of work contribute to the achievement of general well-being, such as adequate remuneration that enables people to buy enough food. However, on the other hand, the realisation of human well-being requires certain aspects, directly related to work, namely safety in the workplace, the quality of work accommodation or self-determined influence through freedom of assembly and organisation in the work context. Furthermore, work must be considered in the broader context of direct and indirect effects of work and the working environment on human well-being. A social standard should therefore take into account elements such as equal opportunities, promotion and responsibilities to protect. At a minimum, decent work for workers should be ensured (SDG 8).

The aspect of work is deeply rooted in the concept of human well-being. A socially sustainable working environment must therefore be designed to promote human well-being as far as possible.

A standard relating to work in a company should consider the real circumstances at company level. The company's sphere of influence is an important factor to be considered. Where and how can a company positively influence working conditions in terms of human well-being, and what is economically reasonable? Certain requirements must therefore apply, demanding a certain level of reasonable effort. However, absolute certainty cannot be demanded, because the further the risks and actions are removed from the company's direct sphere of influence, the more difficult and costly it is to achieve certainty.

Essentially, minimum labour standards reflect the fact that work must be carried out in a manner that is humane. These minimum standards, which complement human rights and fundamental rights, have been laid down in the ILO's core labour standards. These are also often directly referred to or form the basis of existing sustainability standards.

These include the following areas:

- Freedom of association and the right to collective bargaining
- Elimination of forced labour
- Abolition of child labour
- Prohibition of discrimination in employment and occupation
- Occupational health and safety

3.7.1 PtX Lab sustainability criteria for labour standards for PtL kerosene

The PtX Lab 2022 Study (Altmann et al., 2022) fundamentally refers to existing legal frameworks such as the UN Human Rights Convention and the ILO's International Core Labour standards (ILO, 2022, 1998). These are further expanded by the European Pillar of Social Rights (EU, 2017). This results in certain minimum requirements, which are formulated in the PtX Lab 2022 Study:

- Fair, non-discriminatory and equal treatment/opportunities
- Zero tolerance for forced labour and child labour
- Respect for freedom of association and collective bargaining
- Protection and promotion of safety and health
- A good relationship between employees and management
- The opportunity to raise concerns in the workplace

Regarding occupational health and safety and the protection of public health and safety, the PtX Lab 2022 Study requires that all relevant laws be complied with. The fundamental principles laid down in EU law should also apply extraterritorially, where relevant. In general, the project must also "be planned and operated in accordance with international good practice." (Altmann et al., 2022, p. 57)

Thus, the PtX Lab 2022 Study primarily refers to existing legal requirements that must be complied with within the project, thereby ensuring that working standards are in line with legal requirements.

3.7.2 Comparison of criteria for work under different standards

Since labour standards are widely established as social standards and are largely implemented, generally recognised frameworks such as the ILO core labour standards can be used. Most standards and legal regulations for hydrogen derivatives/RFNBO do not explicitly refer to social standards at all (Sailer et al., 2022; Schwalfenberg et al., 2023). The few standards related to RFNBO/hydrogen derivatives that discuss social standards (e.g. ISCC Plus, RSB or RedCert), mainly refer to frameworks such as the ILO core labour standards, and derive their criteria from them, either directly by indicating compliance with the established frameworks, or indirectly by using these frameworks as the basis for their own criteria. Only a few standards are very specific to working conditions (Sailer et al., 2023; Schwalfenberg et al., 2023). Another frequently chosen reference point is the reference to compliance with national legislation. These usually correspond to international frameworks or go beyond them. As a result, social standards and labour standards, in particular, are usually treated rather superficially in sustainability standards. In most cases, only general references are made to established regulations or standards. Further context-specific elements or clarifications are usually not included.

3.7.3 Stakeholder perspectives on labour standards for RFNBOs

Labour standards have a long history and are now universally recognised in many areas. Basic labour standards are widely accepted. However, violations are often raised by stakeholder groups.

What has recently received more attention from stakeholders in relation to labour is the extended companies' sphere of influence and the working conditions that prevail them. This concerns the control and influence of over supply chains and the extent to which companies have a responsibility for the working conditions that prevail them.

3.7.4 Proposed sustainability criteria for labour standards at RFNBO

When evaluating existing standards, it became clear that certain areas in the work context should be covered by a specific labour standard. Appropriate indicators were developed based on existing and most demanding standards. It was found that, as standards dealt with labour standards in greater depth, comparable areas were addressed in very similar ways. This facilitated the consolidation of sustainability criteria. Specific and demanding indicators from the standards were combined with corresponding principles in order to achieve the highest possible level of ambition. In addition, supplementary elements from national or international regulations, that went beyond those applied in the standards, were integrated and harmonised with the existing criteria. This resulted in a detailed and ambitious set of criteria.

However, it should be noted that the labour standards for the production of sustainable fuels do not differ significantly from general labour standards, as these mostly refer to business operations. For example, a generally high safety standard is required to protect the health of workers, rather than addressing production-specific risks. This means that the criteria are universal rather than specific. It, in turn, has advantages in terms of application, as production processes vary and the existing risks are not always identical. It is therefore advisable to establish a general commitment to minimise safety risks than to prescribe a context-specific application.

In this way, a wide variety of circumstances can be covered. This allows for efficient risk assessment on site in the specific work context, as a result of which, context-specific measures must be taken that adequately address the respective risk. Otherwise, there is a risk that certain risks will fall through the cracks of explicit use cases. It means that standards addressing work related standards more generally and at higher-level manner can also be included in the analysis.

The following areas have emerged from an overall review of labour standards:

- Wages/salaries/remuneration
- Duty to provide information/duty to disclose
- Trade unions and negotiations, collective agreements
- Complaints mechanism
- Employment contract and social security
- Safety
- Agreements/procedures
- Obligation to provide support
- Working hours/working conditions
- Dismissals and reductions
- Non-discrimination
- Responsibility to protect; prohibition of child labour, slave labour and forced labour
- Equal treatment of different employment relationships and working conditions
- Supply chains
- Extended due diligence
- Accommodation of work equipment and working environment

Wages/salaries/remuneration

Two aspects are of central importance when paying wages for work performed. Firstly, the amount of the wage must correspond to the work performed and thus cover the cost of living. Secondly, wages must be paid regularly and securely. Payments must be made at regular intervals so that employees can plan ahead and cover their living costs. In addition, special situations, such as overtime, must be clearly regulated so that there is a transparent relationship between the employee and the employer and the employer cannot take advantage of such special situations. This also enables the employer to clearly demonstrate that employees are treated fairly. Documentation and traceability can generally contribute to a better relationship between employer and employee.

Short-term/long-term criteria (PtX Lab 2025)
Criterion: Wages/salaries/pay

- **Payments** to employees are made **on time** and **at regular intervals** that have been clearly communicated to and recorded for employees.
- All employees receive regular **pay slips** or equivalent documents clearly showing the salary earned, allowances, bonuses and overtime pay, with all deductions listed in detail. In addition, the requirements of national legislation and labour administration procedures must be observed.
- **Wages** must be commensurate with the level of comparable work in the country or region. It must be ensured that the wages paid comply with industry standards and the minimum legal requirements.
- **Overtime** must be compensated with an appropriate bonus; this can be in the form of financial compensation or time off in lieu. In doing so, the employer must comply with the applicable national legislation, the rates laid down in the collective agreement or in an agreement with the trade unions. If none of these principles apply, the employer must adhere to the following factors:
    - 1.5 times the normal rate for work performed outside regular working hours.
    - 2 times the normal rate for work performed under special circumstances. For example, on regional rest days, public holidays and night work.
    - The employer is free to choose the type of compensation and to determine the reduction of overtime in a period of time instead of overtime, which is equivalent to time off in lieu. However, the employer must ensure that the employee has the opportunity to reduce the overtime in the chosen period.

Duty to provide information

Within a company, the duty to provide information should cover two main aspects. The first aspect is the company's internal duty to inform itself, i.e. an obligation for the company and its managers to inform themselves about the applicable law and facts relevant to the work context. The second aspect is the duty to provide information to others, i.e. a level of obligation that is intended to contribute to awareness within the company. In other words, an obligation to inform all relevant individuals, in particular employees, about the current state of affairs. This information must be communicated in a transparent and appropriate manner. In this way, the company can facilitate access to relevant information, even if it is difficult to obtain. This prevents information asymmetry between employees and employers, which could potentially be exploited. This is supplemented by a duty to disclose information. This means that employees can also obtain certain information from their employer that is relevant to their employment relationship. This, in turn, should contribute to the equal treatment of employees.

Short-term/long-term criteria (PtX Lab 2025)
Criterion: Duty to provide information/ Duty to disclose information

- Employers must inform themselves about the **labour laws applicable** in the country and the fundamental ILO conventions. They must also communicate this **information about existing labour rights** to employees transparent.
    - If there are industry-specific and applicable ILO conventions, employers must inform themselves about these and implement and apply them accordingly. The status of these conventions must be reviewed at regular and appropriate intervals to ensure that they are still up to date. Employees must also be informed of this.
- At the start of the employment relationship and in the event of significant changes, employees must be provided with clear and **comprehensible information in a form and language they can understand**. This includes, among other things, the following information: rights relevant to the employment relationship, in particular the rights of employees under national law (labour law) and detailed information on the applicable collective agreement, including rights relating to working hours, remuneration, overtime, allowances and social benefits.
- There is a **minimum notification period** for significant operational changes. All upcoming significant operational changes must be effectively documented, and employees must be informed about the changes in an understandable manner.
- In addition to the **obligation to provide information** at the start of the employment relationship, the employer must inform employees about:
    - possible changes to working hours and the work schedule,
    - the currently applicable works agreement and any changes thereto,
    - the type of work to be performed by the employee,
    - the responsibilities of the employee in connection with the performance of their work,
    - changes to employment rights,
    - internal mechanisms of the workplace, such as existing guidelines and the procedures by which these are ensured.
    - Existing legal action, whistleblower and complaint mechanisms. It must be explained how the employer guarantees the confidentiality of such mechanisms and how they are made available to employees.
    - national or local legislation relevant to the employment relationship and any registration procedures (e.g. registration requirements, work permits, etc.)
    - Existing and associated trade union organisations and access to them.
- If the employer is aware that it will be making large-scale job cuts or is in financial difficulties that will lead to **job losses** for employees, it must inform the employees of this at an early stage.
- An employee may request information from the employer about the **salaries or salary increases** of comparable colleagues if this is related to the principle of equal treatment. For example, if the employee requests a salary increase on the basis of the principle of equal treatment. This information must be provided in abstract form and is used exclusively for the purpose of transparent and fair salary development and the prevention of discrimination. Therefore, the information may only be provided for this purpose and may only contain information relevant to it.

Trade unions and negotiations, collective agreements

An important and central right is collective employee representation and the negotiation of conditions directly with an industry or employer.

It is primarily important to ensure not restricting the right to freedom of association and collective bargaining. Secondly, the internal processes of such collective employee representation bodies must be free from employer influence. Eventually the results achieved must be recognised and implemented by the employer.

Short-term/long-term criteria (PtX Lab 2025) **Criterion: Trade unions and negotiations, collective bargaining agreement**
• The employer recognises the right of employees to **freedom of association**, to organise trade unions and to collective bargaining. • In countries where national legislation recognises the right of employees to establish, join and conduct collective bargaining without interference, the employer shall comply with this national legislation. • If national law prevents or significantly restricts the organisation of employees or collective bargaining, or if there is no clear relevant legal framework, the employer shall not restrict or hinder the employees' own efforts to develop and establish an **alternative mechanism for representation purposes**. Such mechanisms must have the possibility and authority to voice complaints and protect employees' rights regarding working and employment conditions. The employer must actively promote such mechanisms so that employees can contact employers without violating the law. The employer must not intend or attempt to influence or control these mechanisms.   ○ In general, the following applies: Any influence or obstruction of trade union activities by employer is prohibited, employees are free to decide which employee organisations or similar organisations will represent them in the existing mechanisms for collective bargaining, employee representatives must not be discriminated against and must be able to communicate with other employees without any restrictions or obstacles. • The employer must comply with **collective agreements** and generally create fair working conditions in consultation with existing employee organisations or using established alternative mechanisms.

Obligation to promote

Continuous improvement of one's own skills is an inherent part of the work process but may also require explicit support to achieve certain developmental milestones. The fact that this process takes place throughout life and is possible has also been recognised in SDG 4 (Quality Education) as the promotion of opportunities for lifelong learning. Companies should also work towards this process.

They should recognise and implement the added value of such support for their employees. It is important that companies empower their employees to learn and create suitable opportunities for their development. This also enables companies to improve internal processes and utilize their employees' skills efficiently and optimally.

Short-term/long-term criteria (PtX Lab 2025)
Criteria: Obligation to promote lifelong learning

- The company must act on the premise that its employees can take advantage of **learning activities for vocational training** and **lifelong development of skills** for long-term employability.
  - The company should develop a strategy for the professional development of its employees.
- The company must give employees the opportunity to expand and develop their skills. Such **support and development opportunities** must be communicated transparently and be easily accessible. Such measures for further training may only be suspended if there are compelling reasons.
  - The company can take various measures to promote the development of its employees, e.g. career information and counselling, orientation aids, gathering work experience for further development (e.g. job shadowing), evaluation, coaching, mentoring, professional networking, training to develop skills for further activities.
  - These measures should help to identify and shape career development opportunities for employees and develop their skills so that they can adapt quickly to current challenges in order to make the company resilient.
- The company should also validate informal and non-formally acquired skills and further promote them through on-the-job learning and support the exchange of such skills, e.g. by issuing qualified job references.

Working hours and working conditions

Working hours and prevailing working conditions are important aspects of decent work. If overtime is necessary, it must be ensured that employees receive appropriate compensation for it. It must also be recognised that employees are entitled to certain rest periods and holidays. The company should promote working hours and working conditions that are also socially acceptable for employees.

Short-term/long-term criteria (PtX Lab 2025)
Criterion: Working hours/working conditions

- **Working hours**, including breaks and **rest periods**, must comply with national legislation and relevant collective agreements or company agreements.
  - Following conditions must be met as a minimum: Employees are not regularly required to work more than 48 hours per week. After six consecutive working days, at least one day of rest must be granted. Deviations from these conditions are only permitted in exceptional circumstances. The application of this exception requires a derogation from a competent authority. In addition, these exceptional circumstances must be documented for subsequent justification.
    - Even under exceptional circumstances, the following conditions must be met: The maximum permissible daily working time is 14 hours or 72 hours per week or a maximum of 18 consecutive working days.
- **Overtime** is voluntary and is not regularly required or performed.

- With regard to overtime, national legislation or applicable agreements, whichever is more favourable to the employee, shall be complied with.
  - Notwithstanding other provisions, the following minimum requirement must be observed: Any overtime may not exceed a period of more than three consecutive months and/or 12 hours per week. The total working time within a week shall not exceed 80 hours. Only in exceptional and justified circumstances, which must be communicated to the employee in a transparent manner, may this minimum requirement be suspended.
- Break times are clearly defined and respected.
- There are clear and unambiguous rules governing regular absence from work due to illness and absence from work due to an accident at work. However, these rules must at least comply with national legislation or other agreements, whichever is more favourable to the employee.
  - Regardless of other provisions, the following minimum requirements must be met: The rules must guarantee employees that they will not be dismissed during a temporary absence due to illness or accident. In addition, adequate continued payment of wages must be provided. Absence from work due to illness shall not be deducted from the employee's holiday entitlement.

Employees are entitled to **at least 3 weeks of paid annual leave**. This applies to all employees in the company. If statutory provisions or collective agreements are more favourable to the employee these must be applied accordingly. After two consecutive months of employment with the company, paid annual leave is granted in proportion to the duration of the employment contract.

Dismissals and reductions

In principle, the employee's freedom to terminate the employment relationship must be recognised. There can be no general protection against dismissal, but the company should ensure that dismissals are carried out in a socially acceptable manner. This includes, in particular, compliance with notice periods and early notification of the employee. If a company is in a precarious economic situation, reductions or dismissals should be carried out in as socially acceptable manner as possible. The search for practicable alternatives is recommended.

Short-term/long-term criteria (PtX Lab 2025)
Criterion: Dismissals and reductions

- In principle, employees have the right to terminate their existing employment relationship with their employer in accordance with the contractually agreed or statutory **notice period**.
- If the employer terminates the employment relationship, they must also observe the specified notice periods.

- Upon termination of the contract by the employer,all relevant severance payments required by law and collective agreements must be made. If there are any outstanding wage payments, social security contributions or pension contributions and benefits, these must be paid either upon or before termination of the employment relationship, either in favour of the employee or according to a schedule agreed in the collective agreement. If payments are made in favour of the employee, the employees shall receive proof of these payments.
- Before resorting to mass redundancies for operational reasons, the employer must examine whether there are any alternatives to downsizing. If this analysis shows that there is no viable alternative to redundancies for operational reasons, a socially acceptable redundancy plan must be developed and implemented. This plan must aim to minimise the negative effects of the redundancies on employees as far as possible.
  - The following principles must be observed: The plan for job cuts must be drawn up in compliance with the principle of non-discrimination. Employees and organisations representing them must be involved in the process. The plan drawn up must reflect consultation with employees, their organisations and, where appropriate, the government, as well as existing provisions and requirements under collective agreements or works agreements must be observed. In addition, all legal and contractual requirements regarding the notification of authorities and the notice periods for employees, as well as the information and consultation of employees and their organisations, must be fulfilled.

Non-discrimination

A company should make every effort to provide its employees with the best possible protection against discrimination. The standards that are relevant and offer the most comprehensive protection should be applied. If such standards are not regulated externally, the company must establish internal rules and procedures that offer protection against all forms of discrimination. This begins with internal processes, which must be designed to be non-discriminatory. Overall, the corporate culture should be actively shaped in such a way that it is accepted by employees. Nevertheless, procedures and measures must be in place to ensure that any discrimination is stopped as quickly as possible. Gender equality and women's empowerment should also be recognised and realised in the context of work (SDG 5).

Short-term/long-term criteria (PtX Lab 2025)
Criteria: Non-discrimination

- The employer must comply with national legal **provisions on non-discrimination**. Where possible, the employer must comply with the non-discrimination principles set out here at the same time or as an alternative. The **principle of protection** that offers the best protection against discrimination applies. In cases where national law does not contain provisions on non-discrimination in employment, the standards set out here shall be applied where possible. In cases where national law does not comply with this standard, the employer is expected to conduct its activities in accordance with the standards set out here, if this does not violate applicable law.

- The employer is responsible for ensuring that all employees are free from discrimination on the basis of, among other things, sex, sexual orientation, gender or gender identity, caste, race, ethnic, social or indigenous origin, genetic characteristics, age, birth, disability, religion or belief, political or other opinions, activism, membership of a national minority, membership of a trade union or other form of employee organisation, nationality, marital or family status, health status or migrant, minority or economic status in the employment relationship or in the exercise of opportunities. The employer shall therefore create an enabling environment that ensures equal access to opportunities.
- The company shall ensure that its corporate policy and all employment management procedures are non-discriminatory and guarantee **equal opportunities**. In addition, measures must be taken that actively contribute to preventing and combating discrimination on the basis of gender.
- In addition to prohibiting discrimination, employers must also take **proactive** measures **against discrimination** within the company. To this end, the company must develop and implement a clear and transparent anti-discrimination policy and introduce procedures for dealing with potential problems. This includes training, **awareness-raising measures**, the dissemination of information and other **awareness-raising measures**. In addition, an individual may be appointed, who spends part of their working time as a contact person and at the same time promotes and enforces anti-discrimination measures.
- The employer is obliged to ensure that recruitment decisions or decisions relating to employment are made in a non-discriminatory manner, i.e. no recruitment decisions may be made on the basis of personal or socio-economic characteristics that are not related to the job requirements.
- The employer must organise working relationships in such a way that they are based on the principles of equality, equal opportunities and fair treatment. These principles must apply to all aspects of the employment relationship, such as recruitment and employment, remuneration (including wages and social benefits), working conditions, access to training, job assignment, promotion, termination of employment or retirement, and disciplinary measures. In all aspects, the employer is obliged to observe non-discrimination and to act accordingly.
- The employer must take measures to prevent and combat any form of harassment, intimidation, bullying and/or exploitation, in particular of women, and any form of gender-based violence and harassment. Measures must be taken to prevent discrimination within the company and, if it occurs, it must be dealt with immediately and decisively.
- Without prejudice to the principle of non-discrimination, the employer may take protective or supportive measures to eliminate past discrimination. Selection for a particular job based on the specific requirements of the job does not constitute discrimination. The employer is obliged to check whether such measures are compatible with national law.

The employer guarantees the right to maternity leave. The minimum requirements set out in ILO 183 must be met: maternity leave shall be at least 14 weeks, and the employment contract may not be terminated during this period. A return to the same job and the same salary is guaranteed.

Agreements and procedures

The internal organisation of the company should be governed by clear agreements, procedures and rules so that employers and employees have a common understanding of how the working relationship between the parties is organised. Such agreements should be reached by mutual consent and thus reflect a consensus acceptable to both parties. It may be beneficial for employees to be represented by an employee representative to facilitate the process. Care should be taken to ensure that the provisions are adopted on the basis of relevant principles and are as favourable as possible for the employees in the company.

Short-term/long-term criteria (PtX Lab 2025)
Criterion: Agreements, procedures and provisions

- The employer/company must develop and maintain a **written works agreement** as well as associated and necessary procedures. This agreement and the procedures must be appropriate for the size of the company. The employer is obliged to communicate this to employees in a culturally appropriate manner.
  - This works agreement must cover at least the following areas: Working conditions (including health and safety and data protection standards), recruitment and promotion practices, terms and conditions of employment including social benefits, entitlement to and payment of wages, maternity protection, protection against violence and harassment, capacity building and skills development, non-discrimination and equal opportunities, grievance procedures, disciplinary procedures and dismissals.
  - It should also be specified how the employer intends to comply with the requirements of national labour law and how any applicable collective agreements are implemented within the company. If the certification standard to be applied imposes higher requirements on the company, the company agreement must also cover how the company implements these higher standards.
- The employer must **document** the relevant works agreement and the associated **procedures and management system**, as well as the **work reports**, so that it can be verified whether these are in line with national legislation or other relevant agreements.
- Depending on the size of the company, a company should establish an internal **employee representation body t**hat acts as **a co-determination body** for operational matters (works council). This body should represent the interests of employees as set out in a works agreement.
  - In principle, employees should be free to determine this body, preferably through an election. However, employees should be free to decide how the body is formed. The employer must not hinder them in this.
  - The tasks and co-determination rights of such a body must be in accordance with and comply with national law.
- When determining maternity leave, social security provisions or other mandatory benefits, the employer must base the works agreement on the provisions most favourable to the employees. Depending on whether national laws, collective agreements or agreements with employee organisations offer better conditions, the employer is obliged to include these in the works agreement.
- The employer must establish and maintain a system for up-to-date **employment records**, while respecting the rights of employees to privacy and data protection.

Complaints mechanism

it is undeniable that grievances can arise a company. Hence, there must be a mechanism within the company so that affected individuals can report them. It is important that such a mechanism operates transparently, is easily accessible, and that complaints are dealt with efficiently.

Short-term/long-term criteria (PtX Lab 2025) **Criteria: Complaints mechanism**
• The employer must establish and maintain a transparent **complaints mechanism**. This must be easily accessible, and the employer must inform employees how they can use this procedure. This information must be provided at the beginning of the employment relationship and immediately after changes in the procedure. In addition, access to the complaints' mechanism must be made publicly available transparently and easily accessible. • The complaint mechanism must be effective and well organised. Complaints must be dealt with promptly and handled appropriately as part of a **transparent procedure**. The procedure must be completed quickly with appropriate feedback, and the complainant (if known) must be informed immediately. • The complaint mechanism must also allow for **anonymous complaints** and handle them accordingly. Even in the case of an anonymous complaint, any necessary steps must be taken to handle the complaint and remedy the grievance. • The complaint mechanism must not **impede access to other judicial or administrative remedies**. It must be ensured that access to statutory complaint procedures or other existing conciliation procedures remains possible. This mechanism must also not replace complaint mechanisms provided for in collective agreements. • Access must be granted to all persons who have a relationship with the employer, regardless of the form of employment or working relationship with that person, e.g. including temporary agency workers. • When a complaint is submitted, it must be documented in detail and a **record of the complaint process** must be kept. The reason for the complaint, how it was handled by, and the outcome of the process must be documented in detail.

Safety

In addition to the general protection of workers' rights, a safe working environment must also be ensured (SDG 8.8). Companies in particular must contribute to this, as they are responsible for implementing such a safe working environment. It is important that the company first identifies risks in the working environment and records them specifically for each workplace. Based on this, appropriate preventive measures must be taken and their adequacy regularly reviewed.

Short-term/long-term criteria (PtX Lab 2025) **Criteria: Safety**

- The employer must introduce a **health and safety policy** that applies to all employees, including contractors. These must be based on the highest applicable standards and at least meet these standards.
- The employer has a duty to ensure a safe and **healthy working environment**. In doing so, the employer must take into account the risks inherent in the specific work processes. **Hazards in the working environment**, such as physical, chemical and biological hazards, must be addressed, if they exist. Specific risks affecting women must also be taken into account by the employer.
- The employer must take measures to minimise and prevent accidents, injuries and illnesses that may occur at work.
    - These include: Employees must be trained for the activities and tasks they are expected to perform and be **aware of the health and safety risks** of the work to be carried out. In addition, employees must be trained and informed about how to deal with workplace-specific hazards and what preventive measures to take to reduce the risk (e.g. the correct transport, storage and handling of hazardous substances).
- Existing **preventive measures** must be designed in such a way that all employees can easily understand (e.g. signs, markings) and implement them (e.g. knowledge of assembly points in an emergency). If further training is necessary, the employer must ensure that this is provided.
    - The employer must continuously monitor that all employees are informed about the current preventive measures and that these have been understood.
- The employer is obliged to keep regular **records of all accidents at work**.
    - Based on this documentation, the preventive measures and procedures for emergencies and accidents must be continuously monitored. This continuous monitoring should contribute to further developments and additional measures that lead to an improvement in existing measures and procedures, thus reduce accidents at work.
- The employer shall ensure that important means of **hazard control** are available and accessible and can be used by all employees.
    - These include, for example, first aid kits, fire extinguishers and materials for dealing with leaks.
    - The materials must be available in sufficient quantity and quality.
    - Employees must be familiar with these resources and their use and must be trained accordingly.
- If necessary, the employer must ensure that employees are provided with personal protective equipment that is appropriate for the work to be performed and that this equipment is used regularly and properly. In addition, the quality of this protective equipment must be maintained to ensure adequate protection against hazards.

The employer must identify potential health risks in the workplace and monitor the health of employees who perform work that poses a risk to their health by regularly checking health indicators. In this way, the employer aims to prevent and reduce work-related health problems.

Responsibility to protect

To ensure that a company contributes to human well-being and does not adversely affect the well-being of others, companies have an enhanced responsibility to protect vulnerable groups. This extends beyond the immediate employment context, whereby the company has certain duties of care and obligations to act as soon as it becomes aware of or suspects any abuses. The company must therefore contribute to the achievement of SDG 8.7 and take immediate and effective measures to abolish forced labour, end modern slavery, and implement the prohibition of child labour.

Short-term/long-term criteria (PtX Lab 2025) **Criteria: Responsibility to protect Prohibition of child labour**

• There must be **no child labour** within the company. Furthermore, the company must not contribute to supporting or enabling child labour and must fulfil its duty of care in this regard.
  ○ In doing so, the company must comply with at least the age requirements of the ILO Convention on the Minimum Age for Admission to Employment 138 and those of the Convention on the Prohibition and Immediate Action for the Elimination of the Worst Forms of Child Labour 182. If national legal requirements are even stricter, the company must apply them.
  ○ Children above the legal minimum age and under 18 years old may be employed or recruited by the company, provided that an appropriate risk assessment is carried out before work commences. Under no circumstances may children be employed in a manner that is economically exploitative or dangerous or harmful to the child's education or harmful to the child's health or physical, mental, spiritual, moral or social development. Under no circumstances may children under the age of 18 be employed in hazardous work. The employer is obliged to regularly monitor the health, working conditions and working hours of children.
• If any form of child labour occurs in connection with the company (including all types of external work or work within supply chains), the company must take immediate and effective measures to eliminate it and remedy the situation. Depending on the existing relationship, compensation may be required.
  ○ The case must be referred immediately to the competent law enforcement authorities or the competent authorities. In addition, in the event of child labour, the company must take all measures required by national law.

Short-term/long-term criteria (PtX Lab 2025)
Criteria: Responsibility to protect, Prohibition of slave labour and forced labour

- There must be **no slave or forced labour** in the company.
  - Forced labour includes work or services that are not voluntarily performed and are required of a person under threat of violence or punishment, such as debt bondage or similar working arrangements, as well as human trafficking.
  - The following practices, among others, are strictly prohibited: The obligation to hand over and deposit the employee's identity documents to the employer or to third parties. The withholding of parts of the employee's salary. The obligation for family members (spouses, children) to work in the company. Restricting the worker's freedom of movement after the end of their shift, e.g. by prohibiting them from leaving the company premises.
- The employer must ensure that its contractors and suppliers do not use such labour.
- No form of physical punishment, psychological or physical coercion or abuse may be used or tolerated within the company, and the company is obliged to continuously monitor that none of these practices are used.
- If the company discovers that forced labour is being used, including by third-party employees (e.g. contractors or suppliers), immediate measures must be taken to end this practice. Where possible, forced labour-free working conditions must be offered immediately or the employment relationship based on forced labour must be terminated and/or compensation paid, with the choice of remedial measure being determined by the person concerned.
  - The case must be referred immediately to the competent law enforcement authorities or the competent authorities. In addition, in the event of forced labour, the company must take all measures required by national law.

The employer is obliged to continuously monitor working conditions and circumstances. Particular attention must be paid to the fact that certain employees may be at higher risk of human trafficking due to socio-economic characteristics such as age, disability, ethnicity and/or gender.They must ensure that unnecessary restrictions on the freedom of movement of their employees (exceptions may be made for security reasons and certain types of work) are avoided during the period of their employment.

Equal treatment

There are various types of employment relationships and working relationships within a company. For example, temporary or agency workers may be employed for certain tasks. In addition, employees may be employed who are only present at the place of work for the duration of their employment relationship (migrant workers) and are therefore exposed to certain risks. The company must act in such a way that people in employment relationships, other than permanent employment, are not unjustifiably disadvantaged and thus evade certain aspects of social responsibility through the use of other employment relationships.

The company must therefore exercise due care to ensure that certain standards are also observed when employees are not within the company's direct sphere of influence. In addition, the risks associated with certain employment relationships, such as the employment of migrant workers, must be taken into account and there must be no discrimination.

In the case of employment relationships that do not exist directly with the company itself, the company must ensure that the same entitlements and conditions apply during the period of hiring as if the temporary workers were directly employed, i.e. equal pay and equal treatment.

However, as a general rule, the creation of permanent jobs should always be a priority, and all regular work should be covered by such employment relationships.

Short-term/long-term criteria (PtX Lab 2025)
Criteria: Requirement for equal treatment of different employment relationships (temporary workers, agency workers and migrant workers)

- The company records all cases in which employees perform activities within the company's structures but are contractually outside the direct influence of the company because they are employed by third parties (subcontractors).
- The employer organises employment relationships in such a way that all regular work is performed by permanent employees. **Fixed-term contracts or subcontracting agreements** are only used if the permanent workforce is insufficient for a limited and specific period, if special tasks need to be performed or if other special circumstances exist. The employer must not attempt to circumvent employment based on permanent employment contracts or, under certain circumstances, fixed-term contracts by other means and precarious employment relationships.
    - Contracts with subcontractors shall only be concluded in the case of exceptional work or special circumstances or if it is not possible to conclude a direct contract.
- The employer must actively ensure that migrant workers are not disadvantaged in any way. The employer must ensure that migrant workers are employed under the same conditions as non-migrant workers performing similar work. Their treatment must not be in any way less favourable than that of non-migrant workers. This includes all aspects such as equal pay and equal rights, equal opportunities and equal treatment, and freedom from any form of discrimination.
    - The employer is obliged to ensure that migrant workers are not subjected to physical or psychological coercion. Under no circumstances may unnecessary restrictions on their freedom of movement or the retention of identity documents such as passports or personal belongings be tolerated. The company must develop procedures to monitor compliance with the requirements and prevent coercion from occurring in the course of the employment relationship. All economically reasonable measures and efforts must be taken to ensure that the company's suppliers also comply with these requirements.
- If the company employs temporary workers for an uninterrupted period of at least three months, it is obliged to sign a legally binding written employment contract in accordance with the performance standards. This must contain a precise job description.

- If **temporary agency workers** perform work for the company, the company must make economically reasonable efforts to ensure that the temporary agency is a reputable and lawful company. As a hirer, the company must fulfil its duty of care and, as far as possible, check that the temporary employment agency fulfils its duty of loyalty towards the temporary workers. Among other things, it must be ensured that the temporary workers are able to perform the work in a manner that meets the applicable performance standards set out here and that all human and labour rights are respected.
    - If the company concludes contracts with subcontractors, suitable selection criteria must be defined in writing in advance. As a minimum, compliance with the performance standard should be taken into account. In addition, the subcontractor's references must be checked. Verification of compliance with the performance standard through audits by the relevant certification bodies should also be included in the contract or be possible in general.The company must establish procedures for monitoring compliance with the requirements set out in the performance standard in relation to third-party employers. Additionally, it should be specified in the contractual agreements with third-party employers, where possible, that the requirements of the performance standard must also be met by these third parties.
    - It must also be ensured that workers employed by third-party employers have access to a complaint procedure that can adequately record and process complaints about their employment relationship with the company. If the third-party employer is unable to provide a suitable complaint mechanism, the company must extend its own complaint mechanism to the workers employed by the third party and communicate this to those workers in a transparent and understandable manner.

Supply chain

The further away the potential abuses are from the company's sphere of influence, the more difficult it will be for the company to take direct remedial action. The company's own sphere of influence is particularly limited in the supply chain. This allows the company to carry out careful checks in advance so that it does not later find itself in a situation where its scope for action is limited but the need for action is great. When selecting suppliers, it is therefore important to check at an early stage whether they meet the set of standards. However, if abuses occur, the company must work to ensure that these abuses are eliminated and, as a last resort, terminate certain contractual relationships.

Short-term/long-term criteria (PtX Lab 2025)
Criteria: Supply chains – extended due diligence

- Where possible, the company must establish and apply selection criteria based on the requirements of this performance standard when selecting suppliers. Thereby, the company must make commercially reasonable efforts to verify that the supplier complies with the applicable provisions of the performance standard and make its selection based on these findings.

- The company shall make reasonable efforts to identify the likelihood of risks associated with the main suppliers of goods and materials that are essential to the company's core functions. If risks are identified, the company shall take appropriate measures to eliminate them.
    - If the risk assessment identifies the existence or a significant risk of child labour, forced labour, sexual exploitation or sexual abuse, discrimination and unequal treatment of migrant or foreign workers, discrimination and/or restriction of freedom of association, or other risks of violation of fundamental workers' rights, or if risks are known or reported at lower levels of the supply chain, the company shall use a main supplier that has demonstrated compliance with this performance standard.
    - If the risk assessment identifies a significant risk of serious safety issues for workers in the supply chain, the company must introduce procedures and measures to minimise the risk. These must aim to ensure that primary suppliers within the supply chain take steps to prevent or adequately address such high-risk situations.
    - The company is obliged to continuously monitor its main supply chains to identify potential risks or significant changes at an early stage. If risks or violations are identified, the company must take appropriate measures in accordance with this performance standard to eliminate them and, if necessary, take legal action.
- The company should, to the extent possible, work to ensure that its main suppliers also fully comply with the requirements of this performance standard.
    - The company should require compliance with the performance standard to the extent that it can control or influence its main suppliers. In situations where this is not possible, the company should work to ensure that the company's primary supply chains are restructured over time to include suppliers that can demonstrate compliance with this performance standard.

If there is evidence of misconduct on the part of a supplier, the company must request proof of the corrective measures taken by the supplier. If the supplier fails to provide such evidence or proves unable to take appropriate remedial action, or if the violation is very serious, the company must commission another supplier within a reasonably short period of time, taking into account existing contractual obligations, and terminate the relationship with other suppliers as soon as possible.

Accommodation and work equipment

Under certain circumstances, the company must provide employees with work equipment or work accommodation. Work equipment must meet certain quality and maintenance standards so that the risk of injury at work is not increased. Work accommodation must also meet certain standards. The human well-being of employees and, where applicable, their families must not be adversely affected by relocation to such facilities.

Short-term/long-term criteria (PtX Lab 2025)
Criterion: Accommodation of work equipment and working environment

- The company must provide all employees with suitable **work equipment**, e.g. tools or work clothing. The work equipment must meet the requirements of the task, and its quality must be checked regularly. If the quality is not satisfactory, the work equipment must be replaced accordingly.
- Certain facilities must be provided as required and in proportion to the number of employees:
  - Changing rooms, with lockable storage facilities if requested by staff.
  - Suitable rest areas must be provided.
  - The company shall provide catering facilities such as shops or a canteen. If this is not economically feasible for the company (e.g. due to the small size of the business), suitable areas shall be provided for employees outside the work area where food can be stored, consumed and, if possible, prepared.
  - The company provides its employees with clean toilets with hand washing facilities near the workplace. If necessary and appropriate, clean showers are also provided.
- All facilities shall be regularly maintained and kept in a condition that satisfactorily meets all the basic needs of employees. Legal requirements must be complied with, and safe and hygienic conditions must be ensured.
- Where appropriate, facilities for women and men must be separate and provided in sufficient numbers in relation to their respective numbers of employees.
- Where accommodation is provided for employees and falls within the scope of this performance standard, i.e. is under the influence or control of the company, the company must develop and apply guidelines for the quality and management of the accommodation. In addition, the basic needs of employees in relation to this accommodation must be met.
  - Accommodation shall be provided in a manner consistent with the principles of non-discrimination and equal opportunity. Accommodation arrangements for workers shall not restrict their freedom of movement, freedom of association and freedom of assembly.
  - **Accommodation** provided to persons working for the company (regardless of their contractual relationship with the company) must be designed, built and maintained in such a way as to provide good sanitary, health and safety conditions. This includes clean and adequate sanitary facilities (e.g. separate facilities for women and men, including toilets, showers, lockers, etc.), consistently adequate drinking water quality, suitable living conditions, heating, sufficient beds and cooking facilities.

If the conditions at the site make it necessary to relocate families, the facilities must be adequate for the needs of families. The facilities must then at least meet the basic needs of all family members, taking into account all relevant factors, such as age.

3.8 Standard of living

In addition to the aspect of work, the production of RFNBO can also have social impacts that go beyond the well-being of workers. These impacts are particularly related to the use of water, energy and land and thus to factors necessary for the maintenance of human life (Fuchs et al., 2024). In this respect, the individual sustainability criteria of the aspect "standard of living" can be derived from Article 25 of the Universal Declaration of

Human Rights (UDHR), which gives it its name, and from Article 11 of the International Covenant on Economic, Social and Cultural Rights (ICESCR), which enshrines the right to an adequate standard of living. According to Article 11 of the ICESCR, this right includes "the right of everyone to an adequate standard of living for himself and his family [...] including adequate food, clothing and housing, and to the continuous improvement of living conditions." There is a broad agreement that this implicitly includes the right to access (affordable) water in sufficient quantity and quality (UN-CESCR, 2020) . Furthermore, it is argued in academia that the right to an adequate standard of living also entails access to energy services that are essential for cooking, lighting, heating and cooling and are therefore crucial for the realisation of other socio-economic rights (Bradbrook et al., 2008) . The scope of Article 11 IPwskR also raises a number of land-related issues, particularly in cases where individuals, families and/or communities are temporarily or permanently displaced against their will from the land they inhabit (UN-CESCR, 1997) and where land used for agricultural purposes, for example, is converted. It should be noted that land issues particularly often affect indigenous peoples and can also have cultural significance (Fladvad, 2023; Waters-Bayer and Tadicha Wario, 2020) .

According to sustainability aspect of living standards, minimizing negative social impacts on project-affected communities is one of the objectives. Furthermore, some of the above-mentioned sub-aspects also offer opportunities for improving the social situation. This applies to improving local water availability and access to electricity by supplying the local population with additional water and/or electricity. There are also opportunities regarding the socio-economic status of local actors, e.g. through creating minimum number of jobs, providing training measures and the involvement of local companies in the value chain. Consequently, the sustainability aspect of living standards is aimed at leveraging positive social effects.

3.8.1 PtX Lab 2022 sustainability criteria for living standards for PtL kerosene

In the PtX Lab 2022 Study (Altmann et al. 2022), the criteria relating to living standards fall under the social or socio-economic criteria (Altmann et al., 2022). The exception is the social impact of water use in the production of PtL in aviation, which falls under the sustainability aspect "water availability".

Regarding social and socio-economic criteria, the PtX Lab 2022 Study proposes a distinction between criteria that avoid or reduce harm ("do-no-harm") and criteria that lead to an improvement in the social situation (positive effects). The do-no-harm requirements are based on the European Investment Bank's framework for environmental and social sustainability (EIB, 2022). With regard to living standards, this primarily includes standards on involuntary resettlement and the protection and preservation of cultural heritage. No distinctions are made between long-term and short-term standards to avoid massive losses of credibility in negative practical cases. The do-no-harm requirements are therefore to be understood as minimum criteria.

EIB Standard 6 on involuntary resettlement refers to physical and/or economic (i.e. including loss of income or livelihoods) displacement as a direct result of project-related land acquisition or restricted land use. These should be avoided as far as possible from the outset or, if unavoidable, minimised to the lowest possible level. Those affected shall be consulted and adequately compensated.

EIB Standard 10 on cultural heritage applies to natural heritage that local communities and people consider to be part of their history, values and beliefs, their knowledge and/or traditions, which is valuable to them and which they wish to preserve and pass on to future generations. The project must avoid significant adverse impacts on cultural heritage. The affected communities must be consulted appropriately.

Concerning positive effects, the minimum requirements for the short-term standard include the permanent creation of skilled jobs. In the long-term, positive effects on local or regional infrastructure are also to be expected in cases of energy and water shortages. In this case, it is important to ensure that the neighbourhood's supply needs are met before a plant goes into operation. With respect to water availability, for example, if the long-term standard is that water scarcity at the site exceeds 60%, the local population must also be supplied with desalinated water at socially acceptable prices if a seawater desalination plant is planned.

Case-specific social impacts may also be relevant, requiring criteria to be designed dynamically. The PtX Lab 2022 Study proposes a bonus point system and variable criteria to describe further positive effects of a PtL project. These could include, for example, the proportion of skilled jobs created filled by women, or contributions to the local community, such as the construction or maintenance of clinics, homes, hospitals and schools.

3.8.2 Comparison of criteria for living standards of different standards

Most of the standards considered include both risk-minimising and positive impact criteria with regard to living standards.

Like the PtX Lab 2022 Study, the Fairful Standard draws on the EIB's ESG criteria (atmosfair, 2021). In addition, if water scarcity exceeds 60% at the planned location, the required water must be extracted, e.g. through desalination, and a quantity of desalinated water commensurate with the total investment must be made available to the public at socially acceptable prices. This is to be validated by the submission of a concept that sets out how the local population will benefit from the desalinated water.

The Green Hydrogen Standard contains requirements on involuntary resettlement, public health and safety, and improving the livelihoods of communities affected by the project (Green Hydrogen Organisation, 2023). Involuntary resettlement must be avoided where possible and the impact on displaced persons minimised through compensatory measures such as fair compensation and improved living conditions. Active community engagement throughout the process is essential. Furthermore, relevant public health issues must be identified and monitored during project implementation. Additionally, project operators must commit to identifying, assessing and mitigating human rights issues and providing access to legal remedies through effective grievance mechanisms.

Another requirement of the GHS aims to improve the livelihoods and living standards of communities affected by the project and to protect their lives, property, assets and resources from the project’s impacts. Certification requires an impact assessment and the proactive involvement of communities in the project. The impacts of the project must also be monitored. Finally, the standard requires project operators to assess the project's contribution to the SDGs. If commitments to additional performance have been made, the project operator is expected to have a system in place to monitor and report on the fulfilment of these commitments throughout the project's lifetime.

On the subject of site selection, H2Global requires not only an environmental impact assessment but also a social impact assessment (BMWi, 2021; Hinicio, 2024). This should also rule out land use conflicts. The participation of local and civil society actors should be ensured, e.g. by securing that local actors gain expertise and by actively involving local SMEs in the project. In addition, women should be actively involved in the implementation of the project. Proof of compliance with these requirements must be provided. Besides these minimum criteria, a statement is required on how the project supports the implementation of the SDGs in the respective partner countries. Validation is carried out via an action plan that contains targets on aspects such as the registration of employees in the social security system, the availability of childcare facilities and training programmes for local workers.

The ISO standard 13065 "Sustainability Criteria for Bioenergy" includes both a principle on respect for land use rights and a principle on respect for water use rights (ISO, 2015). According to this, the economic operator must provide information on how land use rights are handled, or in water-scarce countries, how the availability of water for human consumption and food production is taken into account.

The RSB standard also contains requirements for land rights and land use rights (RSB, 2023, 2020). According to these requirements, existing formal and informal land rights and land use rights must be assessed, documented and determined. The right to use land for a project is only established once these rights have been defined. This may require a land rights assessment. Furthermore, land that is the subject of legitimate disputes must not be used until these disputes have been resolved through Free Prior Informed Consent (FPIC) and a negotiated agreement with the affected landowners. FPIC is also considered by RSB to be the basis for all negotiated agreements on compensation, acquisition or voluntary surrender of rights by land users or owners. Involuntary resettlement is not permitted, and the local population must be compensated fairly, equitably and in a timely manner in the event of voluntary surrender of land rights.

As it relates to water, the company must maintain or improve the quality and quantity of surface and groundwater resources and respect formal or customary water rights. The company must respect the existing water rights of local and indigenous communities and, among other things, water resources that are the subject of legitimate disputes may not be used for operations until the disputes have been resolved.

Ultimately, the RSB standard requires that projects in poverty-affected regions contribute to the social and economic development of local, rural and indigenous people and communities. The definition of poverty-affected regions is based on the UN Human Development Indicators. The socio-economic status of local actors affected by the projects must be improved through measures such as job creation and skills training. Moreover, at least one measure must be implemented to significantly optimise the benefits for local stakeholders based on a needs analysis, e.g. through investments and the implementation of socially oriented projects. Additionally, special measures must be developed and implemented to promote and encourage the participation of women, young people, indigenous communities and socially disadvantaged groups in the project.

3.8.3 Stakeholder perspectives on living standards for RFNBOs

The Öko-Institut (Heinemann et al., 2021) distinguishes between minimum criteria, which are intended to ensure that no harm is caused by the production of hydrogen (derivatives), and additional optional criteria, which are defined to support sustainable development in the exporting countries. Concerning the input factor land, local and informal land rights must not be violated, which must be ensured through consultation with local interest groups. Optional goals include win-win situations, for example through the financial participation of the local population in the income from land use. In the case of PV and wind installations, shared land use could continue to be made possible, as these installations do not lead to exclusive use of the land. Extensive agriculture can be practised beneath wind farms, for example, and PV panels can shade agricultural land.

In reference to water, the Öko-Institut further proposes that local water prices shall be monitored, and countermeasures shall be taken if prices rise as a result of hydrogen production. Targeted investments in more efficient local water infrastructure to reduce losses and evaporation, as well as additional water production through seawater desalination, could also support local sustainable development. To avoid competition for water or price distortions, seawater desalination plants should be built along with existing plants. The aim should be to increase local water availability by either increasing the total amount or improving the seasonal water availability balance.

With regard to electricity, additional renewable energy capacities could contribute to the decarbonisation of local energy systems. Furthermore, additional investments in local infrastructure (e.g. energy grids, electricity storage systems) could support local sustainable development. In any case, competition for renewable energy sites between exports and local decarbonisation must be addressed as a minimum criterion.

Lastly, according to the Öko-Institut, socio-economic participation could be promoted by ensuring a certain proportion of local workers, establishing a local supply chain for technology, direct investment in research and development, and initiatives to build local capacity. Economic participation in the exporting country should therefore be ensured at two levels: hydrogen projects should increase local employment, and a significant part of the value added should be generated in the exporting country.

Researchers at Arepo GmbH on behalf of the Rosa Luxemburg Foundation (Morgen et al., 2022) go beyond a pure "do-no-harm" approach and divide possible criteria for the production of hydrogen (derivatives) into risk-minimising and positive impact criteria. Under the heading "Additionality 2.0", accompanying measures are described that ensure the expansion of the hydrogen export infrastructure and guarantees added value for the supplying countries.

In connection with water and renewable energies, it must first be ensured that the infrastructure built directly benefits local communities and that additional capacity is created on a relevant scale. For instance, existing desalination plants should not be repurposed for the production of green hydrogen, but should primarily serve drinking water supply, agricultural purposes or existing industry. The capacity of newly built plants should be high enough to meet the needs of all different stakeholders before water is made available for electrolysis. It must also be ensured that desalination plants are built and operated in such a way that there are no harmful effects on the environment or the people living in the surrounding area. Existing renewable energy infrastructure should also not be used for the production of green hydrogen for export. International hydrogen producers should bear the full cost of installing the necessary renewable energy power generation capacity and maintaining it. No part of the hydrogen value chain (including the generation of electricity from renewable energies) should be developed on land with disputed (including informal) land rights.

With a view to socio-economic participation, Arepo GmbH researchers believe that local labour, content and production should be used wherever possible. Economic opportunities for the local workforce in hydrogen-exporting countries should be ensured along the value chain, taking into account different levels of education, age, gender and skills. Additional infrastructure, business models and appropriate training for local communities for newly created jobs should be provided by local and international project partners, both in the renewable energy sector and in the hydrogen sector, and along the entire value chain of hydrogen and its derivatives.

The International PtX Hub (PtX Hub) argues that the production of PtX products should primarily contribute to the creation of economic value and jobs at the local level(PtX Hub, 2021; Venjakob, 2024). To this end, it is important that PtX production is well integrated into local production networks in order to exploit their potential. Furthermore, the potential for job creation at the local and regional level should be exploited, which requires capacity building and (re)training opportunities for various target groups. According to PtX Hub, it is also recommended that the production of PtX does not negatively impact local people's access to electricity or other vital resources such as water and land. This must be ensured and monitored along the entire value chain. PtX projects could instead generate co-benefits through the construction of new renewable energy or desalination plants, for example by improving the water supply to local communities and, in the long-term, to agricultural businesses.

3.8.4 Proposed sustainability criteria for living standards in RFNBOs

In relation to the aspect of "standard of living", the basic principle is that the operation must avoid negative social impacts (do-no-harm) on the communities affected by the project, particularly regarding their access to water, electricity and land, both in the short and long-term. In addition, the social situation of the communities affected by the project must be improved under certain conditions. For the criteria falling under this aspect, it is recommended to follow the RSB standard, which is supplemented in some areas.

With regard to the criterion of land rights and land use rights, in line with RSB Principle 12, it is recommended that existing formal and informal land rights and land use rights be respected and that no land be used that is the subject of legitimate disputes until these have been resolved through free, prior and informed consent (FPIC) and negotiated agreement with the affected land users. This requires an assessment and documentation of existing land rights and land use rights. Furthermore, involuntary resettlement is not permitted. If negotiated agreements are reached on the surrender or acquisition of land, the FPIC principle must also serve as a basis for this. In such cases of voluntary surrender of land (use) rights, compensation must be fair and equitable and must be paid in a timely manner. In any case, the compensation measure must enable the person or persons affected to earn their livelihood autonomously and in dignity. If PV or wind power plants are to be built, win-win situations should be sought, e.g. through joint land use.

As already discussed in section 3.2.6.4, areas where UNESCO World Cultural and Natural Heritage Sites are located, are considered "no-go areas", meaning that their use for operational purposes is prohibited. Different levels of strictness concerning the use of natural and cultural heritage sites are conceivable in principle but cannot be recommended without reservation, due to the special significance of the latter for the global community. In the case of other natural and cultural heritage sites not designated under the UNESCO World Heritage Convention, a decision on their use or removal in the case of reproducible cultural heritage may only be taken with the prior consent of the local communities affected on the basis of FPIC.

If chance finds occur during project implementation, the chance find procedure must be applied. According to this procedure,the competent authorities must be informed about any objects or sites found. Chance finds must not be touched until they have been examined by commissioned specialists and further measures have been determined.

When the water rights criterion is concerned, similar to the land (use) rights criterion and in accordance with RSB Principle 9a, water resources that are the subject of legitimate disputes may not be used until these disputes have been resolved according to FPIC. Furthermore, water must not be used at the expense of using the water required for communities' livelihood.

There must be no deterioration in the short or long-term for water availability. Water prices must not change as a result of RFNBO production. The conversion of existing desalination plants for electrolysis instead of drinking water supply, agriculture or existing industry is not permitted. In the long-term, if there is a shortage of water for the local population, they must first be supplied with additional water at socially acceptable prices. Whether such a shortage exists can be determined, for example, using SDG indicator 6.1.1, which measures the proportion of the population with access to safely managed drinking water. If the proportion is less than 50% based on the most recent year reported, an undersupply is assumed.[38] The additional water to be provided must correspond to 5% of the water used in the production of RFNBO and must be made available to the population within a 50 km radius of the water source used. In view of evaporation and losses – especially during dry periods – it must be ensured that the local population has access to this additional water. To this end, the efficiency of the local water infrastructure must be improved, e.g. through targeted investments. A decision on how to invest must be made on the basis of joint decision-making with the local population.

The same applies to the criterion of energy availability. Accordingly, RFNBO production must not lead to any deterioration in the short term. In the long-term, in the case of energy poverty, the regional population (NUTS 1 level) must first be supplied with 1% of the electricity required for the production of RFNBO at socially acceptable prices. SDG indicator 7.1.1, which measures the proportion of the population with access to electricity, can be used to determine energy poverty. Similarly, energy poverty is assumed to exist if the proportion is below 50% based on the most recent year reported. Furthermore, it must be ensured that the local population has year-round or continuous access to this additional electricity, e.g. through investments in the grid infrastructure.

For the final criterion of the standard of living aspect, "investment in the common good", alignment with RSB principle 5 is recommended. It only applies to regions affected by poverty, which are defined using the UN Human Development Index, as proposed by RSB. For countries listed in the inequality-adjusted Human Development Index, the threshold value is 0.59. If no data is available, the Human Development Index can be used with a threshold value of 0.74. In poverty-affected countries, the socio-economic status of the local actors affected by the project must be improved in the short term through a minimum proportion of (skilled) jobs to be created, a minimum number of training courses for local employees, and a minimum percentage of local companies to be involved. To determine who belongs to the local population or local actors, H2Global suggests a radius of 50 km around the project or, in the case of sparsely populated areas, the inclusion of the nearest large town with a certain number of inhabitants. There is also room for manoeuvre depending on the size of the project with regard to the minimum proportion of jobs to be created and the minimum number of training courses

[38] It should be noted that SDG indicator 6.1.1 does not have data for all countries. The use of an alternative indicator should therefore be discussed.

for local employees. H2Global, for example, proposes 500 hours per year as the minimum number of hours for training. It is still open to debate whether the requirement for a minimum proportion of jobs to be created should also apply outside regions affected by poverty, particularly regarding regions affected by structural change. In any case, special measures to promote the participation of women and vulnerable persons or groups must continue to be developed and implemented in the short term.

In the long-term, at least one measure to significantly optimise the benefits for local actors should be included and implemented in poverty-affected countries, as is the case for RSB, based on a needs analysis. The needs analysis should pay particular attention to vulnerable groups. The measures to be considered may include opportunities for participation, joint ventures and partnerships with local communities, or investments in or implementation of socially oriented projects; investments in education (e.g. the construction of schools), culture or health.

Table 3-13: Criterion for land (use) rights, cultural and natural heritage, water and energy availability and invest in the common good for the long-term and short-term criteria of the PtX Lab 2025 study.

Criteria	Short-term criteria (PtX Lab 2025)	Long-term criteria (PtX Lab 2025)
Land rights/ land use rights	• Respect for existing formal and informal land rights and land use rights • No use of land that is subject to legitimate disputes until these have been resolved through FPIC and negotiated agreement with the affected land users • No involuntary resettlement • FPIC as the basis for all negotiated agreements on compensation, acquisition, etc. • Fair, equitable and timely compensation for voluntary surrender of land (use) rights	
Cultural and natural heritage	• Exclusion of UNESCO World Cultural and Natural Heritage Sites (see Chapter 3.2.6) • For other cultural heritage sites: ○ Chance discovery procedure ○ FPIC for decisions on the use or removal of (reproducible) cultural heritage	
Water rights	• Use of water not to the detriment of the water needs of communities that depend on these water sources for their livelihoods • No use of water resources that are the subject of legitimate disputes until these have been resolved (FPIC)	

Criteria	Short-term criteria (PtX Lab 2025)	Long-term criteria (PtX Lab 2025)
Water availability	• No conversion of existing desalination plants for electrolysis • Water prices must not change • No deterioration in water availability	• In the event of undersupply (= SDG 6.1.1, < 50% - based on the most recent year reported) of local water supplies to the population: First, supply the local population with additional water (5% of the water used in the production of RFNBO) at socially acceptable prices) • Ensure that the local population has access to the additional water (e.g. through investment in infrastructure)
Energy availability	• No deterioration in energy availability	• In the case of energy poverty (= SDG 7.1.1, < 50%, based on the most recent reported year): First, supply the regional population with 1% of the electricity required for the production of RFNBO at socially acceptable prices • Ensuring that the local population has access to the additional electricity provided (e.g. through investments in grid infrastructure)
Invest in the common good	• In countries affected by poverty (UNHDI < 0.59) Improve the socio-economic status of local stakeholders affected by the project: • Minimum proportion of (skilled) jobs to be created • Minimum number of training courses for local employees • Minimum percentage of local companies involved • Development and implementation of special measures to promote the participation of women and vulnerable persons/communities	• In countries affected by poverty, implementation of at least one measure to significantly optimise the benefits for local stakeholders based on a needs analysis (with particular attention to vulnerable groups), e.g.: ○ Opportunities for participation, joint ventures and partnerships with local communities ○ Investment in or implementation of socially oriented projects (education, culture, health)

3.9 Society

To round off the social sustainability aspects of "labour" and "standard of living" already outlined above, the sustainability aspect "society" aims to identify and prevent the specific risks and impacts of a particular project on society. It should therefore be understood as an overarching (social) sustainability aspect and, as such, relates in particular to procedural aspects and fair operating practices.

3.9.1 PtX Lab 2022 Sustainability criteria for society for PtL kerosene

In the PtX Lab 2022 Study (Altmann et al., 2022), the criteria relating to society also fall under the social or socio-economic criteria, which in turn are based on the EIB's framework for environmental and social sustainability.

EIB Standard 2 describes the responsibility of project promoters to engage in transparent and regular dialogue with project stakeholders. It serves to ensure respect for the rights of access to information, public participation in decision-making processes and access to justice. The standard aims to involve persons or communities directly or indirectly affected by the project in a constructive dialogue and to ensure that they have access to information about the environmental, climate and/or social risks and impacts of the project in a culturally appropriate and understandable manner. Furthermore, opportunities for stakeholders to participate in an appropriate and independent manner in project decision-making processes that may affect them should be promoted, and effective opportunities for rights holders to lodge complaints and seek legal remedies should be established.

EIB Standard 7 concerns vulnerable or marginalised persons and groups and aims to counteract inequalities and other factors that contribute to vulnerability, marginalisation and/or discrimination in connection with a project. The affected persons and groups should be facilitated in gaining equal access to effective mitigation and/or compensation measures and to the benefits of the project. To this end, the effective participation of vulnerable, marginalised or discriminated persons and groups and gender equality as a fundamental human right should be promoted. Projects that only affect indigenous peoples must also ensure promoting full respect for their rights, identity, culture and livelihoods. In addition, project promoters must obtain the free, prior and informed consent (FPIC) of indigenous peoples affected by the project, where necessary.

Both requirements are do-no-harm requirements that must apply in both the short and long-term. The PtX Lab 2022 Study did not yet refer to EIB Standard 1 on environmental and social impacts and risks. However, as this is central to the "society" aspect of sustainability, it has been incorporated in this document. The standard refers to the assessment of the project's compatibility and risk management and aims to ensure that environmental, climate, social and human rights aspects are considered in decision-making processes.

Consequently, project promoters that are likely to have significant environmental, climate and/or social impacts, must establish an environmental and social management system. Thereby, the likely significant impacts associated with the project – both direct and indirect, positive and negative impacts – must be adequately identified, described and assessed. Furthermore, measures must be identified to prevent, avoid and reduce significant disadvantages for persons and communities affected by the project and, where necessary, to eliminate or compensate for any residual impacts. In addition, respect for human rights must be ensured. Finally, measures to maximise the positive impacts of a project must be identified and the implementation of agreed measures must be systematically monitored and, where necessary, further strengthened.

3.9.2 Comparison of criteria for society in different standards

As already mentioned, the Fairfuel Standard, like the PtX Lab 2022 Study, draws on the EIB's ESG criteria(atmosfair, 2021). In addition, reference is made to the Equator Principles, which serve as a common basis for financial institutions to identify, assess and manage environmental and social risks in project financing (Equator Principiles, 2020). These principles all fall under the sustainability aspect of "society". They stipulate that a project must first be classified based on the extent of its potential environmental and social risks and impacts (Principle 1). Furthermore, an appropriate assessment process must be carried out in line with this classification to address the risks and impacts. The assessment documentation should also include measures to reduce, mitigate and, where necessary, compensate for or eliminate risks and impacts (Principle 2).

For projects with potentially significant or limited negative risks and impacts, the development of an environmental and social management system as well as plan is required (Principle 4). For these projects, evidence of effective stakeholder engagement in the form of an ongoing, structured and culturally appropriate process is also demanded (Principle 5). The social management system, the social management plan and the involvement of stakeholders are independently audited (Principle 7). For projects with potentially significant adverse impacts on affected communities, informed consultation and participation must also be carried out – this also applies to all projects affecting indigenous peoples.

Projects with certain negative risks and impacts must establish effective grievance mechanisms that can be used by affected communities and, where appropriate, by employees (Principle 6). The grievance mechanisms must be tailored to the risks and impacts of the project and should aim to resolve the matter promptly. This requires a clear and transparent consultation process that is culturally appropriate, easily accessible, free of charge and without reprisals for the party that has invoked the mechanism. Grievance mechanisms should not impede access to judicial or administrative remedies. Moreover, the affected communities must be informed about the grievance mechanisms.

The Equator Principles set out obligations associated with compliance with the principles (Principle 8). If certain obligations are not met, remedial measures are developed to bring the project back into line with the principles. Subsequently, independent monitoring and reporting on compliance with the principles by the project is required (Principle 9). Ultimately, there are some additional reporting requirements, such as the preparation of a summary of the risks and impacts on human rights, where relevant (Principle 10).

The Green Hydrogen Standard (Green Hydrogen Organisation, 2023) also provides for the comprehensive involvement of relevant stakeholders in order to build trust and maximise opportunities for local and economic development (Requirement 2). It requires that potential issues related to the communities affected by the project to be identified through an assessment process using local knowledge (Fladvad, 2023; Müller et al., 2022). In addition, these communities must be proactively involved in the project and receive support that enables them to participate in project design. Project operators are required to commit to identifying, assessing and mitigating human rights impacts and to providing access to legal remedies through effective grievance mechanisms (Requirement 4A). Particular attention must also be paid to ensuring respect for indigenous peoples affected by the project. To this end, certification requires, among other things, their informed consultation and participation throughout the entire project process. Project operators are expected to adhere to the FPIC principle (Requirement 4 C).

Eventually, the GHS sets out requirements for governance, transparency and accountability (Requirement 7). This includes, among other things, that the project operator has sound corporate structures, policies and practices in place and establishes codes of conduct and anti-corruption standards that clearly prohibit bribery and corruption. The project operator is also expected to proactively disclose important information of public interest about its corporate structure, the terms of the contract relating to the project and financial transactions with the government. Disclosure must be made in consultation with local communities.

H2Global also requires a social impact assessment to be carried out, which covers not only the production sites but also the entire supply chain (BMWi, 2021; Hinicio, 2024). The social impact assessment is based on the guidelines of Performance Standard 1 of the International Finance Corporation, which is also dedicated to the effective involvement of communities affected by projects through the disclosure of project-related information and consultation, as well as the management of social performance throughout the entire project duration (IFC, 2012a).

The ISO 13065 standard also contains guidelines on stakeholder participation and fair operating and business practices (ISO, 2015). Concerning stakeholders, the economic operator must document how it has involved them, whereby involvement means that the stakeholders have been informed and given the opportunity to express their views. In addition, the economic operator must provide documented feedback on legitimate complaints from stakeholders. To meet these requirements, it is primarily necessary to identify the relevant stakeholders and their interests.

With regard to fair business practices, the economic operator must provide information on fraudulent, misleading or unfair business practices. Among other things, it is checked whether the economic operator has procedures in place to identify potential problems associated with such behaviour and whether it can describe measures that have been taken to deal with identified problems. The ISO guidance on social responsibility (ISO 26000:2010), which is not intended for certification purposes but is intended to provide guidance on the basic principles of social responsibility, further explains these and other points (BMAS, 2011; ISO, 2010). Accordingly, an organisation should, for example, raise awareness of corruption and the fight against it among employees, representatives, contractors and suppliers in order to prevent corruption, and encourage them to report violations of organisational policy measures. Appropriate mechanisms must be established for this purpose.

The RSB standard also includes requirements relating to an open, transparent and consultative impact assessment and management process (Principle 2) (RSB, 2023, 2020). An impact assessment including stakeholder analysis must first be carried out. If necessary, a special social impact assessment maybe required, which must be determined by means of a screening. For projects with significant social impacts, the social impact assessment must be carried out with the involvement of local experts to ensure that local customs, languages, practices and indigenous knowledge are respected and utilised. In addition, a social management plan must be drawn up and its implementation ensured by the project operator through evidence provided in the monitoring audits.

With regard to stakeholder consultations, the FPIC principle forms the basis for RSB and must be observed in all consultations. Consultations must also be gender-sensitive and should result in consensus-oriented negotiated agreements. Particular attention must be paid to ensuring that women, young people, older people, indigenous people and vulnerable people can participate meaningfully in the negotiations. Finally, the establishment of a transparent and easily accessible grievance mechanism for directly affected local communities is also required. Regarding corruption prevention, RSB requires the establishment of a system to ensure that all forms of bribery, conflicts of interest and fraudulent practices are prohibited, including a written policy from management and appropriate training for staff (Principle 1).

3.9.3 Stakeholder perspectives on society for RFNBOs

The PtX Hub(PtX Hub, 2021; Venjakob, 2024) emphasises the importance of broad participation and early involvement of local communities in the planning process, implementation and monitoring of projects. All relevant stakeholders should not only be informed, but also actively engaged and empowered. It is pointed out that appropriate involvement of the local population can help to identify and realise synergies, thereby building trust and promoting acceptance and ownership. This requires, among other things, a careful inventory of stakeholders, including an assessment of negative environmental or social impacts. Particular attention should be paid to vulnerable, marginalised or discriminated groups. On the basis of such an inventory, appropriate formats for consultation and consensus-building should be developed, ranging from hearings to interactive cooperative workshops. Positive and productive stakeholder relations could also be strengthened through regular reviews and reporting. Furthermore, complaint mechanisms for raising concerns and grievances, accessible and protected whistleblowing channels, or the appointment of ombudsmen are cited as effective measures to promote inclusive, participatory PtX projects.

In connection with responsible business conduct, the PtX Hub emphasises the importance of corporate governance, particularly about transparency, which is considered key to preventing and combating bribery and corruption. Access to information is central to this, especially in the case of large investment projects and the associated financing programmes. Project promoters should provide information on the main characteristics and structures of their companies or consortia, including the economic owners of the project developers and companies. Furthermore, integrity and accountability policies, procurement and compliance mechanisms should be explained, and codes of conduct and anti-corruption measures should be communicated.

The Öko-Institut (German Institute for Environmental Affairs) recommends conducting an environmental impact assessment, supplemented where necessary by a sustainability assessment that also takes socio-economic aspects into account (Heinemann et al., 2021). Local stakeholders should be consulted, and appropriate extrajudicial complaint mechanisms and reporting obligations should be established. Corruption should be prevented through international initiatives that set standards for economic participation and make cash flows transparent. As an example, the Öko-Institut cites the Extractive Industries Transparency Initiative (EITI), adapted accordingly with a focus on hydrogen. It should be noted that the level of corruption in a country can vary depending on the human rights situation. Against this background, the Öko-Institut also proposes conducting an analysis of a country's general human rights situation to assess sector-specific human rights risks. Following best practices in the application of due diligence in other sectors, it is proposed that an internationally recognised body (e.g. the OECD or the EU) define these risks and appropriate measures to mitigate them.

Villagrasa, writing on behalf of Brot für die Welt and the Heinrich Böll Foundation, also emphasises the importance of public consultations with local communities and civil society organisations (Villagrasa, 2022)). These consultations must make an effective contribution to the decision-making process and take place regularly during the planning, implementation and monitoring of projects. Effective participation requires investment in capacity building for local actors, the establishment of transparent complaint mechanisms and the creation of formats in which citizens can actively participate in decision-making. It should also be ensured that everyone within local communities has a say and that gender-based discrimination is avoided, for example by not allowing men to make decisions on behalf of women. Projects that directly affect indigenous communities must carry out prior consultation in accordance with the FPIC principle. Villagrasa (2022) argues that such involvement of relevant stakeholders and the participation of civil society can, among other things, ensure acceptance and is therefore in the interest of project developers.

Finally, researchers at Arepo GmbH, commissioned by the Rosa Luxemburg Foundation, also emphasise the importance of extrajudicial complaint mechanisms and consultation with stakeholders at local and regional level throughout the project planning and implementation process ((Morgen et al., 2022)). There should also be the possibility of settling legal disputes in court. Furthermore, project operators should be required to publish annual reports on, among other things, financial and other contentious issues, including information on investment flows and the benefits of the projects for local communities and the regions in general. Overall, the principles of good governance should be observed, which are characterised by, among other things, transparency and effectiveness, accountability, the involvement of all people, and consideration of minorities and the needs of vulnerable groups.

3.9.4 Proposed sustainability criteria for society at RFNBO

The proposed sustainability criteria for the social aspect are not divided into short-term and long-term criteria. As these are essential procedural aspects and practices for preventing and avoiding corruption, which are central to gaining acceptance, they must be implemented consistently from the outset. The guidelines on impact assessments and social impact assessments established by the RSB provide a good starting point for implementing the criteria for social impact assessment and social management plans, as well as stakeholder involvement, which is why it is recommended to use these as a reference (RSB, 2018, 2017).

Before the project is implemented, a social impact assessment should be carried out with the aim of identifying and evaluating the social impacts and risks of the project. The assessment should be open, transparent and consultative to ensure the involvement of all relevant stakeholders. Such participatory approaches recognise the value of the knowledge and experience of local stakeholders and seek to use this knowledge for impact assessment (EC, 2016). The social impact assessment should also be gender-sensitive and take vulnerable groups into account. Based on the assessment, a social management plan should be developed that summarises the assessed potential impacts and elaborated plans and measures for risk reduction and mitigation, and describes how social risks will be managed and monitored during the project period (RSB, 2017). The implementation of the plan must be ensured by the project operator providing evidence.

Another criterion is the involvement of all relevant stakeholders, defined by the IFC as persons or groups that are directly or indirectly affected by a project, as well as those who have an interest in a project and/or the ability to influence its outcome positively or negatively (IFC, 2007). For this purpose, a stakeholder analysis must be carried out as part of the social impact assessment. The identified stakeholders must be kept informed about the project in simple and accessible language and in a culturally appropriate manner and must be proactively consulted and effectively and independently involved from the outset. Effective participation means, among other things, that they have the right to participate in decision-making and that their contribution influences decisions. It is important – especially regarding vulnerable groups – that all stakeholders are treated as equals and have a say in the process and that no group dominates the process.

Marginalised groups must also be consulted, separately when required (RSB, 2017)). Where appropriate, stakeholders should receive support (capacity building, etc.) to enable them to participate. The principle of free, prior and informed consent (FPIC) should always be the basis for the procedure to be followed in stakeholder consultations. This principle is enshrined in the Declaration on the Rights of Indigenous Peoples (UNDRIP) and enables indigenous peoples to participate in negotiations to influence the design, implementation, monitoring and evaluation of projects. They may give or withhold or withdraw their consent to projects affecting their territories at any time (FAO, 2024). It is recommended that the FPIC principle be followed as the basis for all stakeholder consultations. The process must also be gender-sensitive, among other things. Eventually, regular monitoring and reporting, e.g. in the form of a monitoring plan, is required to ensure compliance with the criterion. This enables social impacts to be identified on an ongoing basis and at an early stage, and remedial measures to be taken, which may also necessitate a revision of the social management plan.

The third criterion recommends the establishment of a complaint mechanism that can be used by affected stakeholders and employees. Among other things, this mechanism must be easily accessible, independent, effective, transparent and understandable, as well as culturally appropriate, gender-sensitive and free of charge. Complaints must be addressed promptly and resolved in a consultative manner, and the results must be documented. It is important that the project operator provides stakeholders with easily accessible and understandable information about the mechanism. In addition, complainants must be actively protected from reprisals, i.e. there must be no retaliatory measures against individuals or groups who have used the mechanism. The existence of a complaint mechanism must not impede access to judicial or administrative remedies – the possibility of settling legal disputes in court must therefore remain available.

As it relates to the criterion of fair business practices, codes of conduct and anti-corruption standards should be established in writing that clearly prohibit corruption and bribery. Procedures for identifying possible violations must be established, along with measures for dealing with them. All employees should be familiarised with the codes of conduct and anti-corruption standards, for example through regular training. They should also be encouraged to report violations. This requires the establishment of accessible and protected whistleblowing channels and the protection of whistleblowers.

Important information of public interest about the company's structure, e.g. on financial transactions with the government, must be disclosed. Finally, independent monitoring and reporting is required, e.g. through the submission of annual reports on financial and other relevant issues.

Table 3-14: Criteria for management plan, stakeholder, complaint mechanisms and fair business practices for the long-term and short-term criteria of the PtX Lab 2025 study.

Criteria	Short-term/long-term criteria (PtX Lab 2025)
Impact assessment & management plan	• Open, transparent, consultative • Gender-sensitive and taking vulnerable groups into account • Development of a (social) management plan
Stakeholder involvement	• Stakeholder analysis • Information & consultation as an ongoing process • In principle, FPIC as the basis for the procedure to be followed in stakeholder consultations (gender-sensitive and consensus-oriented) • Special consideration for vulnerable groups • Monitoring and reporting
Establishment of a complaint mechanism	• This must be effective, transparent and understandable, culturally appropriate, gender-sensitive and free of charge • Information about the mechanism provided by the project operator to those involved • Records of all complaints, including the results • Active protection of complainants against reprisals • No obstruction of access to legal remedies
Fair business practices	• Establishment of codes of conduct and anti-corruption standards • Disclosure of important information of public interest about the company structure, e.g. financial transactions with the government • Training on anti-corruption measures, among other things • Whistleblower protection • Independent monitoring and reporting

3.10 Legality

The sustainability aspect of legality aims to ensure compliance with all relevant national and international laws, regulations and treaties. It serves to ensure legal compliance and should therefore be seen as a preliminary or overarching aspect, as the requirement to identify and comply with the relevant legal provisions applies to all listed sustainability criteria – both environmental and socio-economic.

3.10.1 PtX Lab 2022 Sustainability Criteria for Legality for PtL Kerosene

The PtX Lab 2022 Study (Altmann et al., 2022) presents the respective minimum legal requirements with regard to the individual criteria that must be used as a legal benchmark. However, there is no separate criterion for compliance with all applicable national laws and regulations (of the project country) or international laws and agreements.

3.10.2 Comparison of the legality criteria of different standards

According to ISO Standard 13065 (ISO, 2015), the economic operator must identify the legal requirements relating to the relevant sustainability aspects and document how these are addressed in relation to the indicators in the standard. Cases where the laws applicable to the economic operator impose different requirements compared to the sustainability aspects listed in the standard may also be documented.

The RSB standard (RSB, 2023, 2020) also contains a separate principle aimed at compliance with relevant laws (Principle 1). According to this principle, it must be ensured that the company's operations comply with all applicable laws and regulations of the country in which these activities take place, as well as all relevant international laws and agreements, including social and environmental aspects (such as greenhouse gas emissions and labour law). Therefore, an appropriate system must be introduced and maintained that includes a legal register or equivalent system containing all relevant international, national and regional laws and regulations. Furthermore, a training system must be established to ensure that personnel are familiar with the laws and regulations and have access to the legal register. A register must also be established containing all evidence of compliance with legal requirements (e.g. permits, licences, lease agreements) and a system to ensure that ancillary provisions are met. If there is a difference between applicable law and RSB requirements, RSB expects the stricter requirement to be complied with.

The ISCC sustainability principles for agricultural production of biomass also contain requirements regarding compliance with laws and international treaties (ISCC, 2020). It must be ensured that all applicable regional and national laws and ratified international treaties, including, regarding environmental impact assessments, water conservation and management, worker health and safety, and the rights of local communities and indigenous groups are known and complied with. Manufacturers should be able to demonstrate that they are aware of their responsibilities under applicable laws. Companies should be familiar with the relevant laws and stay up to date with any changes.

Accreditation and certification under the Green Hydrogen Standard (Green Hydrogen Organisation, 2023) requires the project operator to publish a publicly available summary of the government licences and permits associated with the project, including property rights, land use, water rights (if applicable) and environmental and health protection. If the relevant documents are publicly available, they should be linked.

Principle 3 of the Equator Principles, which the Fairfuel Standard draws on, stipulates that the assessment process regarding applicable environmental and social standards should primarily focus on compliance with the relevant laws, regulations and permits of the host country relating to environmental and social issues. However, a distinction must be made between countries that have sound environmental and social governance, legal systems and institutional capacities to protect the population and the natural environment (of designated countries) and those where technical and institutional capacities to deal with environmental and social issues are still developing (non-designated countries). With regard to the former group, compliance with the relevant laws, regulations and permits of the respective country applies. For projects in non-designated countries, the applicable

IFC Performance Standards for Environmental and Social Sustainability and the World Bank's Environmental, Health, and Safety Guidelines must be complied with (IFC, 2012b; World Bank, 2007). The review of the assessment process determines whether the project as a whole complies with the applicable standards or whether there are justified deviations from them. The applicable standards described above represent the minimum standards required. In addition, for projects in designated countries, the specific risks of the project are assessed to determine whether one or more of the IFC Performance Standards can be used as guidance for addressing these risks in addition to the laws of the host country. Additional due diligence based on additional standards that are relevant to specific risks of the project and impose additional requirements may be conducted.

3.10.3 Stakeholder perspectives on the legality of RFNBOs

The aspect of legality is not explicitly mentioned in the documents of various stakeholders considered. At most, references to legal requirements to be complied with can be found in the consideration and discussion of individual sustainability criteria.

3.10.4 Proposed sustainability criteria for legality in RFNBO

With regard to the aspect of legality, it is recommended that the proposed criterion be based on Principle 1 of the RSB standard. It is therefore proposed to ensure compliance with all relevant laws and regulations of the country in which RFNBO production takes place, as well as with relevant international laws and agreements, by implementing and maintaining a system designed for this purpose. This system must initially include a legal register (or equivalent system) that lists all relevant regional, national and international laws and regulations affecting the company. This requires the identification of the relevant legal requirements and the relevant obligations arising from them. Maintaining the register also requires that changes in the law are monitored. It is also important that employees have access to this legal register and are familiar with the relevant laws and regulations. In this respect, the system to be set up must also include an appropriate training component. Finally, a register must be set up in which all evidence of compliance with legal requirements – such as government licences or permits – is collected, as well as a system to ensure compliance with ancillary provisions. If the applicable law differs from the requirements arising from the sustainability criteria, the producer must comply with the stricter requirements. The legality criterion must be met from the outset and on an ongoing basis, so that no distinction is made between the short- and long-term criteria.

Short-term/long-term criteria (PtX Lab 2025) **Criteria: Compliance with all applicable laws and regulations of the country in which the business operates, as well as relevant international laws and agreements**
Implementation and maintenance of a system to ensure compliance with all relevant laws and regulations, including: a) Legal register or equivalent system b) Training system c) Register containing all evidence of compliance with legal requirements, as well as a system to ensure that ancillary provisions are complied with

4 Policy recommendations

Supportive policy frameworks are necessary to enable the rapid yet sustainable market ramp-up of green hydrogen derivatives. Politicians, industry and civil society must negotiate and shape these frameworks together so that sustainable green hydrogen derivatives can play their crucial role in the transition to a competitive economy within Planetary Boundaries (Demuth et al., 2025, 2023a). Sufficient but also sustainable quantities of hydrogen derivatives are required promptly, particularly for climate-neutral aviation, maritime transport and the chemical industry (Akhmetova et al., 2025; Schwuchow et al., 2024) .

In a briefing published in early 2025, the PtX Lab Lausitz presented ten recommendations for action to ensure the environmental and social sustainability of hydrogen derivatives (Horndasch et al., 2025). Three overarching goals are central to ensuring environmental and social sustainability during the market ramp-up of green hydrogen derivatives (see Figure 4-1):

a) Set and certify sustainability standards
b) Resolving conflicting political goals
c) Promoting research and infrastructure

Only if sufficient measures are implemented to achieve these goals will a rapid and sustainable market ramp-up be possible. The importance of using balanced and effective sustainability criteria is demonstrated by the overarching goal a), which identifies the implementation of sustainability standards with appropriate criteria as a decisive factor. To effectively apply the sustainability criteria for RFNBO developed in Chapter 3, the ten recommendations for action provide initial impetus for prioritising measures to create the appropriate framework conditions. Suitable policy instruments and measures should deliberately help shaping a market ramp-up of RFNBO with ambitious sustainability criteria. As a major importer of green hydrogen derivatives, Germany should play a particularly active role in creating internationally harmonised, ambitious sustainability criteria, for example through targeted financial support, the establishment of hydrogen partnerships and the creation of lead markets linked to high sustainability requirements.

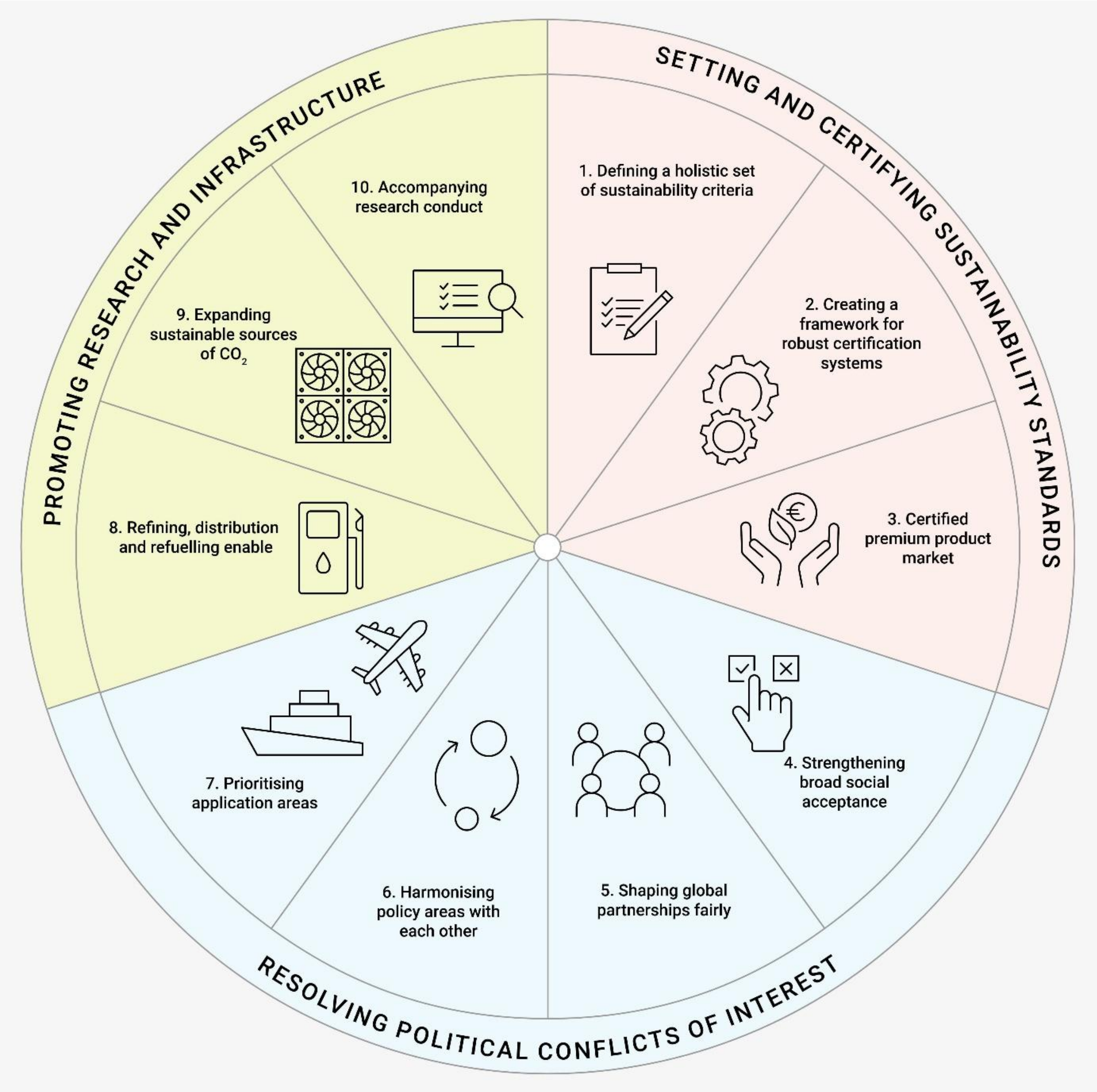

Figure 4-1: Ten recommendations for action by PtX Lab Lausitz to ensure the social and ecological sustainability of green hydrogen derivatives (Horndasch et al., 2025).

4.1 Recommendations for action for the effective implementation of sustainability criteria

The following recommendations for action highlight ways in which Germany should facilitate shaping and incentivising high sustainability criteria for RFNBOs. Building on and following up on the ten recommendations for action (1-10) in the briefing, the PtX Lab Lausitz provide **six specific additional recommendations for action (I-VI)** below, focusing on the effective implementation of sustainability criteria for RFNBO.

Additional recommendations for the effective implementation of sustainability criteria for RFNBO:

Supplementary recommendation I. Promote standardisation of sustainability criteria	
Standardisation of sustainability criteria, based on the ISO standard 13065 "Sustainability criteria for bioenergy", can provide a framework for the application of easily understandable and standardised sustainability criteria (e.g. in the form of various voluntary standards for different product groups). Standardising different methods for testing sustainability criteria increases trust in sustainability claims and can boost acceptance of voluntary standards. This could make people more willing to pay for products with better green credentials.	
Mode of action: • Regulatory certainty reduces investment risks. • Transparency creates acceptance and trust, and thus willingness to pay. • Simplifies certification and documentation through clear definitions. • Increased trust can significantly raise willingness to pay for more sustainable products.	
In support of recommendation 1:	**Define a holistic set of sustainability criteria**: *"The use of hydrogen derivatives should follow a holistic set of sustainability criteria based on the concept of Planetary Boundaries and the UN Sustainable Development Goals."*
In support of recommendation 2:	**Establish a framework for robust certification systems:** *"Governance structures should ensure the legitimacy of certification systems for hydrogen derivatives."*

Supplementary recommendation for action II.
Support and require: By linking government funding to particularly demanding sustainability standards.

Government financial support instruments are necessary to shape the market ramp-up of RFNBOs. Support instruments such as H2Global, CCfDs, and loans and guarantees for projects for the production and import of hydrogen should be linked to particularly demanding sustainability criteria, which should be continuously evaluated and adapted. Best practices among first movers will build practical knowledge on the certification and application of sustainability standards.

Mode of action:

- Supports the market entry of particularly sustainable products and projects
- Creates financially secure experience with demanding sustainability criteria and their certification
- Supports the development of lead markets
- Supports the targeted allocation of scarce resources to prioritised sectors
- Strengthens social acceptance by minimising negative social and environmental impacts and conflicts of interest through demanding sustainability criteria.

In support of recommendation 3:	**Certified premium products** "*Highly sustainable green hydrogen derivatives can initially be offered on the market as premium products.*"
In support of recommendation 7:	**Prioritise application sectors** "*Hydrogen derivatives should be used primarily in air and maritime transport and in selected industrial sectors.*"
In support of recommendation 4:	**Create broad social acceptance** "*Social acceptance of hydrogen derivatives should be actively strengthened through public participation and education.*"

Supplementary recommendation III. **Communicate sustainability goals: By integrating defined sustainability goals for imported RFNBOs into strategies and policy frameworks.**	
Key strategies, such as the hydrogen import strategy and the National Hydrogen Strategy, should clearly define sustainability targets for green hydrogen derivatives in order to send clear signals to the market and producers at an early stage. Germany should communicate ambitious sustainability criteria for the import of hydrogen derivatives in a coherent and transparent manner in its foreign and trade policy.	
Mode of action: • Transparency creates acceptance and thus enables willingness to pay in leading markets. • Diversified (import) partnerships create resilience.	
In support of recommendation 5:	***Shape global partnerships fairly*** *"A sustainable market ramp-up of hydrogen derivatives requires partnerships and cooperation on an equal footing."*
In support of recommendation 6:	**Coordinate policy areas** "*The market ramp-up of hydrogen derivatives should be embedded in a coherent system of policy objectives."*
In support of recommendation for action 4:	**Create broad social acceptance** "Social acceptance of hydrogen derivatives should be actively strengthened through public participation and education."

Supplementary recommendation IV.
Develop local project implementation and strategies collaboratively: Within the framework of international climate and hydrogen partnerships.

To create fair local conditions for the production and export of hydrogen derivatives, strategies and project implementation must be developed that are tailored to local contexts. Local stakeholders, especially vulnerable groups, should be inclusively involved in this process. Hydrogen and climate partnerships should therefore facilitate broad-based knowledge exchange and capacity building, enabling various stakeholders to actively participate in the development of regulations and strategies.

Mode of action:

- Creates opportunities for joint learning in practice, supplemented and supported by accompanying research
- Creates acceptance and strengthens the willingness of international partners to develop and implement necessary export projects

Supporting recommen-dation for action 5:	***Design global partnerships fairly*** *"A sustainable market ramp-up of hydrogen derivatives requires partnerships and cooperation on an equal footing."*
In support of recommendation 4:	**Create broad social acceptance** "*Social acceptance of hydrogen derivatives should be actively strengthened through public participation and education*."
In support of recommendation 10:	**Conduct accompanying research** *"Research gaps on sustainability aspects should be filled and relevant data should be collected.*"

Supplementary recommendation for action V. **Strengthen trust in green claims**	
Strengthening the legal framework for monitoring and verifying sustainability claims made about products and labels will increase consumer confidence in green claims and labels. This will help build trust in the sustainability characteristics of products. As a result, consumer confidence will grow, leading to a willingness to pay more for products that meet more stringent sustainability criteria. This can be used to refinance the green premium (increased production costs for green products). Control systems should also be established to ensure that green claims are not counted twice in different certification systems. In addition, independent and generally accessible complaint mechanisms should be established.	
Mode of action: Creates investment security through trust and acceptance of effective, fraud-proof implementation.	
In support of recommendation 2:	**Establish a framework for robust certification systems:** *"Governance structures should ensure the legitimacy of certification systems for hydrogen derivatives."*
In support of recommendation 4:	**Create broad social acceptance** "Social acceptance of hydrogen derivatives should be actively strengthened through public participation and education."

Supplementary recommendation VI. **Harmonisation of international standards: Within the framework of international forums (e.g. G7, G20, COP) and through support for international initiatives.**	
Within the framework of joint harmonisation and standardisation initiatives such as the G7 or G20, Germany should promote ambitious and transparent sustainability criteria. Consequently, Germany should seek dialogue and cooperation with countries that are likely to import large quantities of RFNBOs, such as Korea and Japan.	
Mode of action: • Creates global lead markets with harmonised conditions, thereby enabling trade and resilient, diversified markets • Trust and protection against geopolitical risks by strengthening cooperation	
In support of recommendation 5:	***Shape global partnerships fairly*** *"A sustainable market ramp-up of hydrogen derivatives requires partnerships and cooperation on an equal footing."*
In support of recommendation 6:	**Coordinate policy areas** "*The market ramp-up of hydrogen derivatives should be embedded in a coherent system of policy objectives."*
In support of recommendation 2:	**Establish a framework for robust certification systems:** *"Governance structures should ensure the legitimacy of certification systems for hydrogen derivatives."*

4.2 Analysis of the regulatory framework for sustainability criteria for RFNBO

Aiming to better understand the levels at which Germany and the EU has options for promoting sustainability criteria for RFNBO, the following section provides an overview of the regulatory framework.

4.2.1 Regulatory framework in Germany

Germany is currently establishing various support instruments for hydrogen derivatives/RFNBO (BMWK, 2024a; Bundesregierung, 2023). In accordance with the update of the National Hydrogen Strategy (NWS), the aim is to establish *"ambitious and, as far as possible, uniform sustainability standards and certification systems for hydrogen and its derivatives"* (Bundesregierung, 2023). Aspects of *the (Green Housekeeping) – "avoiding water shortages and competing uses, pollution and land competition, and protecting human rights in supply chains"* – are to be integrated into the development of certification systems (Bundesregierung, 2023). The hydrogen import strategy also announces that the German Federal Government will continue to work towards the international harmonisation of standards and certification systems. In addition, NWS monitoring will be used to check compliance with sustainability criteria in supply chains and support programmes (e.g. H2Global) (Bundesregierung, 2024). The central role of effective sustainability criteria for the successful market ramp-up of hydrogen derivatives has thus been recognised as strategically important and underpinned by initial measures. However, it remains to be seen whether the measures are sufficiently practical, tailored, concrete and secure to enable projects for the production of hydrogen derivatives to implement them easily, without significant bureaucracy, but also efficiently and effectively.

With the dual-action model for hydrogen derivatives from H2Global, which is supported by the German government with €900 million, more far-reaching sustainability criteria have already been developed that go beyond the EU criteria under RED and include aspects of land and water use as well as social aspects (BMWi, 2021; Bollerhey et al., 2023). These should be further developed after the first test auctions (Hintco, 2024). In contrast, the planned climate protection agreements (CCfD), which also cover the production of hydrogen derivatives, currently only provide for the minimum criteria under RED (BMWK, 2023a, 2023b, 2023c).

Similarly, the KfW PtX Platform for loans to promote projects for the production of hydrogen derivatives with a total volume of approximately €270 million has so far only defined vague, very general sustainability criteria, which address forced and child labour and exclude interventions in nature conservation areas without sufficient compensatory measures (PtX Development Fund, 2023a, 2023b). The BMWK has also presented a concept for lead markets for climate-friendly basic materials (BMWK, 2024b). Based on an accompanying study, initial proposals for the definition of climate-friendly chemical basic materials, some of which include hydrogen derivatives, were also developed. The definition is based on the product carbon footprint (PCF) approach and, apart from GHG accounting, does not yet include any other sustainability criteria (BMWK, 2024b; Sach et al., 2024). This means that the level of ambition and scope of sustainability criteria for hydrogen derivatives/RFNBO vary greatly within the frameworks of the German government's funding instruments.

A more conscious and uniform strategy for determining when, where and on what grounds specific sustainability criteria are applied and required would strengthen stakeholder confidence and secure the market introduction of green hydrogen derivatives. It may be legitimate for individual funding projects to implement particularly ambitious sustainability requirements at an early stage to test them as first movers and gain valuable experience. In contrast, broader, internationally oriented projects should pay greater attention to harmonisation, practicality and connectivity. However, this requires closer coordination in the design phase and transparent communication with the relevant stakeholders to ensure that funding approaches are understood and used.

If, on the other hand, sustainability criteria remain unclear or are perceived as impractical or difficult to calculate, this can lead to increased risk perception among investors – with the result that necessary investment decisions are not made despite the availability of funding instruments. Better coordination between funding institutions and more uniform and practical communication of requirements is therefore urgently needed.

In addition, climate and hydrogen partnerships, development cooperation and foreign climate policy in general also focus on various sustainability aspects of the hydrogen derivatives production (Auswärtiges Amt, 2023; BMWK, 2023d). The dialogue processes of the hydrogen diplomacy offices (H2-Diplo) and the International PtX Hub are used to promote knowledge building and exchange on sustainability aspects of hydrogen derivatives/RFNBO (Meller, 2022; PtX Hub, 2021). It is particularly important not only to initiate pilot and flagship projects, but also to specifically support the development of local knowledge and skills in the partner countries. This is the only way to ensure long-term security of supply and resilience through diversified supply chains. This requires continuous, trusting partnerships with as many countries as possible, which are structured on an equal footing. It necessitates a willingness to establish fair and transparent structures that also enable the participation of local civil society and thus create local acceptance. For the purpose of securing long-term and resilient partnerships, interests of not only German but also the needs and priorities of the partner countries must be taken seriously and actively incorporated into the design. If, on the other hand, sustainability criteria are perceived exclusively as an externally imposed burden without any opportunity for participation, there is a risk of rejection and loss of trust – with negative consequences for the stability of the partnerships.

Table 4-1: Overview of selected German policy instruments for promoting hydrogen and its derivatives (RFNBO) and their sustainability criteria.

Regulation/ instrument	Description	Status	Sustainability criteria/ standards for RFNBO
H2Global	Double auction mechanism	Ongoing	Own sustainability criteria(BMWi, 2021; Bollerhey et al., 2023)
Climate protection agreements	Carbon Contracts for Difference (CCfD) for the production of hydrogen & derivatives	In implementation	Criteria according to RED including blue H2 (BMWK, 2023a) , additional requirements for grid- and system-compatible operation possible (BMWK, 2023b, 2023c)
KfW PtX platform	€270 million Fund for loans	In implement-tation (First funding phase Q1 2024 to Q4 2027)	General criteria and exclusion criteria (PtX Development Fund, 2023a, 2023b)
Climate and hydrogen partnerships	Knowledge building and exchange	Ongoing	Dialogue and exchange on sustainability criteria (BMWK, 2023d; Meller, 2022)
Lead markets for climate-friendly basic materials	Stimulating demand, e.g. through public procurement	First concept paper presented	Proposal for methodology (GHG accounting) for product carbon footprint for climate-friendly basic materials (BMWK, 2024b; Sach et al., 2024)
Hydrogen import strategy	From hydrogen imports	Published	Harmonisation of standards, review of sustainability criteria through NWS monitoring (Bundesregierung, 2024)

4.2.2 Regulatory developments in the EU

The EU has begun to establish lead markets for hydrogen derivatives in prioritised sectors such as aviation and shipping with various incentives and subsidies (Quitzow and Zabanova, 2024; Thielges et al., 2022). Until now, the focus has primarily been on RFNBO. The EU has defined criteria for RFNBOs, which stipulate, in particular, a greenhouse gas reduction of at least 70% and require that the entire energy content come from renewable sources (see chapter 3.1 and chapter 3.2). Particularly strict requirements have been introduced regarding the additionality of the renewable energies used. The aim of these rules is to ensure that the high energy requirements for the production of RFNBOs do not tie up the already scarce renewable energy capacities, but that these capacities are newly created. This is to prevent the expansion of green hydrogen derivatives at the expense of the general energy transition – in short, it cannibalises it. The additionality criteria thus serve as a central instrument for maintaining the overall integrity of the energy transition(de Veries et al., 2022; European University Institute., 2021). However, there are plans to revise the electricity procurement criteria, in particular by 2028. The EU Commission is preparing a study with ICF as a basis for this. In a resolution on the Clean Industrial Deal dated 19 June 2025, the European Parliament urges that the criteria be reformed based on the results of a review study on RFNBO regulations.

The EU has begun to actively stimulate and promote the market ramp-up of RFNBOs with a broad range of instruments. As part of the EU Green Deal package and beyond, a policy mix has been established that includes quota schemes for prioritised sectors such as aviation (ReFuelEU) and shipping (FuelEU Maritime), support programmes for necessary infrastructure (Connecting Europe Facility, TEN-E), support for pilot and innovation projects (e.g. IPCEI, Horizon Europe) and market-based incentives (e.g. SAF allowances in the EU ETS, multipliers for the crediting of RFNBO in aviation and maritime transport under the RED targets) (Quitzow and Zabanova, 2024). In addition, the European Hydrogen Bank was established in 2023 as another key instrument that bridges existing cost gaps within a double auction model and creates investment security through guaranteed purchase agreements (EC, 2023e). The Net Zero Industry Act, which has been in force since 2024, enables accelerated approval procedures for the expansion of critical production capacities, including for RFNBO-relevant technologies (EU, 2024).

Despite these comprehensive measures, the market ramp-up of more complex, electricity-based synthetic fuels and basic materials – especially e-kerosene – is progressing only slowly (IEA, 2023a; Odenweller and Ueckerdt, 2025). To date, not enough projects for the production of e-kerosene have secured sufficient financing to meet the quotas set out in ReFuelEU. Many projects fail to reach the final investment decision (FID) stage because the perceived risk is still considered too high (Dietrich et al., 2023); (Hunt and Tilsted, 2024). The main reasons cited are the high, complex and uncertain regulatory requirements for RFNBOs – above all the strict and restrictive electricity procurement rules (BMWK, 2022; TSB, 2024).

Although H2Global, for example, imposes additional sustainability requirements beyond the EU criteria – for example on water, land use and social standards– feedback on these requirements showed that criticism focused primarily on the electricity criteria set by the EU(BMWK, 2022). This is particularly evident when comparing two H2Global bidding procedures: while the procedure for Sustainable Aviation Fuels (SAF) failed, the procedure for ammonia was successfully completed – despite identical additional sustainability criteria. Specific reasons for the failure of the SAF lot include product-specific challenges with the EU RFNBO requirements, particularly with regard to the definition of permissible carbon sources, GHG accounting and the lack of freedom to allocate in co-processing processes with multiple by-products (Hintco, 2024). However, there is no indication that the extended sustainability requirements relating to water, land, social aspects or biodiversity were perceived as a major hurdle by bidders. These experiences show that it is not the comprehensive sustainability criteria per se that are hampering the market ramp-up. Rather, the main barriers to investment are the current impractical design of the additionality rules for electricity procurement, inflexible GHG accounting requirements and a lack of allocation options for complex production routes, such as E-SAF.

Fossil-free low-carbon fuels as a bridge to RFNBO

Numerous stakeholders from politics and industry are calling for a reform of the electricity procurement criteria, particularly regarding the additionality requirements (see Section 3.1.4). In response to the slow market ramp-up of RFNBO to date, there is also increasing discussion of establishing low-carbon fuels (LCF) as a bridge technology to enable a pragmatic entry into the hydrogen economy (COP28, 2023; Holl et al., 2024). The underlying narrative is that instead of waiting for a complete market ramp-up of green hydrogen derivatives (RFNBO), the necessary infrastructure expansion should initially also be based on low-carbon alternatives.

In this context, the EU has begun to develop definitions for LCF and integrate them into regulatory frameworks (EC, 2024d; Fuentes et al., 2025). However, criticism has been levelled by stakeholders who complain that the umbrella term LCF lumps together very different production pathways – including blue hydrogen, hydrogen from plastic waste and electricity-based low-carbon hydrogen – without distinction (Climate Action Network (CAN) Europe, 2024; Holl et al., 2024). In particular, there are concerns that this could lead to excessive dependence on blue hydrogen. Blue hydrogen has been criticised for cementing fossil fuel structures and promoting so-called "fossil lock-ins", which could potentially block the market ramp-up of RFNBO.

Initial political responses to this issue are already visible: for example, the ReFuelEU Aviation Regulation allows the use of low-carbon fuels to meet quotas on a transitional basis, but explicitly excludes derivatives based on blue hydrogen. Only fossil-free LCFs that achieve at least a 70% GHG reduction are permitted (EU, 2023b). However, unlike RFNBOs, these fuels do not necessarily have to be produced with electricity from 100% renewable sources.

The EU regulation thus effectively establishes an intermediate category: hydrogen derivatives that meet the GHG reduction criteria but do not have to meet all the strict requirements for the origin of electricity (such as additionality, simultaneity and regionality). This intermediate category can serve as a useful bridge, especially if production facilities are built at sites with a high share of renewable energies, so that GHG reductions of over 70% can already be achieved today and, in the future, with further grid expansion, the criteria for RFNBO can also be met.

This bridge category also allows the temporary use of hydrogen derivatives that have been supported by financial incentives from programmes such as the US Inflation Reduction Act (IRA) tax credits. Such incentives contradict the strict requirements for "financial additionality" under RFNBO but are permissible under LCF.

Within the framework of the Clean Industrial Deal, there are indications that LCF will increasingly be used strategically as a transition technology to the hydrogen economy. However, to ensure that this bridge does not become a dead end but leads to a fully green hydrogen economy in the long-term, policy measures should primarily address fossil-free LCF and promote its use for a clearly limited period of time. A transparent and binding timeline for the transition phase is essential to create investment certainty. This is also in line with the S-curve model presented in Chapter 2.2.1, which provides for a gradual increase in sustainability requirements to enable a rapid but also ecologically robust market ramp-up.

Fossil-free LCF+ approach for support programmes

Support programmes such as H2Global, IPCEI or the European Hydrogen Bank could follow this logic and integrate support for low-carbon fuels and basic materials on a transitional basis. In doing so, the complex electricity procurement requirements could be temporarily waived as a prerequisite for support. Instead, a so-called "fossil-free LCF+" approach would be conceivable, in which not all RFNBO electricity criteria would (yet) have to be met, but easily implementable and verifiable sustainability requirements would be taken into account – particularly concerning greenhouse gas avoidance, water and land use, and social standards. Such an approach builds on existing experience: both RFNBO funding programmes and voluntary standards such as the RSB already integrate extended sustainability criteria that go beyond EU requirements. While binding minimum standards would apply in the areas mentioned, more ambitious requirements – particularly for electricity procurement – could be introduced gradually. LCF+ could thus help to increase investment certainty, smooth regulatory transitions and scale up the necessary infrastructure and market mechanisms more quickly. However, to ensure credibility and steering effect, the concept must be clearly defined, communicated transparently and embedded in a binding roadmap for the gradual increase of sustainability requirements.

4.2.3 Regulatory framework in an international context

The minimum quantities (quotas) for renewable fuels in the EU (ReFuelEU Aviation and RED III) and the UK (RTFO) as well as tax credits (V45) in the US are decisive policy instruments for promoting the production of hydrogen and its derivatives (Department for Transport UK, 2024; Haley and Hargreaves, 2023; NOW GmbH, 2024, 2023). They define global requirements and sustainability criteria for RFNBO by stipulating criteria similar to those for GHG accounting and the renewability of electricity, including additionality criteria (Department for Transport UK, 2024; EC, 2023a; IRS Treasury, 2023; Sailer et al., 2022). In addition, some countries or multinational initiatives (e.g. Global Hydrogen Standard) are developing their own standards for hydrogen and its derivatives (Green Hydrogen Organisation, 2023). Examples include the Australian Zero Carbon Certification Scheme and the US-Canadian Low Carbon Fuels Standard (LCFS) (Sailer et al., 2022; Seebach et al., 2023).

The various incentive systems and standards differ in their measurement methodologies and the scope of sustainability criteria. A uniform, globally harmonised sustainability standard for hydrogen derivatives seems unlikely, as different actors (importing companies, producing companies, importing and exporting countries) pursue different priorities and scopes of sustainability goals (Sailer et al., 2023, 2022). It is more likely that harmonisation of the methodology for selected sustainability criteria such as GHG and electricity criteria can be achieved, but not for a comprehensive set of sustainability criteria. For example, the International Partnership for Hydrogen and Fuels in the Economy (IPHE) and ISO are currently only seeking to harmonise the methodology for determining GHG emissions from hydrogen derivatives (ISO/WD 19870) and not a standard with a comprehensive set of sustainability criteria (Heinemann et al., 2023; Kuhn and Koop, 2023; Piria et al., 2021; Sailer et al., 2023)

The EU is working within the IPHE and the Clean Energy Ministerial Hydrogen Initiative (CEM H2I) to promote international sustainability criteria for hydrogen and its derivatives. In addition, the EU is working in multilateral forums such as the G20, IEA and IRENA to further develop harmonised standards (EC, 2020). These mostly focus on GHG emissions, criteria for renewable electricity and permissible carbon sources (Sailer et al., 2022).

Comprehensive sustainability criteria should first be tested and agreed upon jointly within a coalition of the willing so as to create a viable basis for their future harmonisation. Instead of claiming from the outset to enforce global standards that fully cover all aspects of sustainability, a two-pronged strategy is advisable:

1. Broad harmonisation of basic criteria, particularly regarding greenhouse gas reduction and electricity origin, in order to facilitate international comparability and market access.
2. Testing of more extensive sustainability criteria – for example on water, land use or social aspects – in dialogue with a group of countries and stakeholders that are prepared to commit to more ambitious standards.

This will enable the gradual achievement of a deeper and more realistic integration of comprehensive sustainability requirements without blocking the market ramp-up through excessive requirements.

German contribution to the international discourse

Germany has not yet been directly involved in the IPHE process to develop a harmonised measurement methodology. Its involvement in multilateral dialogue formats and exchange processes has also been relatively limited to date (Quitzow et al., 2024). Instead, Germany has mainly contributed to the international discourse on sustainability criteria for hydrogen derivatives through its bilateral energy and climate partnerships and at EU level. However, as the National Hydrogen Strategy is updated, Germany is expected to play a more active role in international, and in particular multilateral, exchanges on sustainability standards in future (Bundesregierung, 2023; Quitzow et al., 2024). First steps in this direction can be seen in Germany's participation in relevant initiatives within the G7, G20 and COP28, which are working towards harmonised and mutually recognised minimum standards for renewable and low-carbon hydrogen (G20 2023b; G20 2023a; G7 2023; COP28 2023; ISO 2023; International PtX Hub 2023). At a later stage, Germany should proactively participate in the international harmonisation and establishment of credible sustainability criteria.

Table 4-2: Overview of selected European and international policy instruments for promoting hydrogen and its derivatives (RFNBO) (based on (Sailer et al., 2022)).

Scope	Regulation/ instrument	Description	Status	Sustainability criteria/ standards for RFNBO
United States	IRA 45V Tax Credit	**Tax credits** of up to 3.0$ /kg hydrogen	Implemen-ted/active[39]	Sustainability criteria for 45V Tax (IRS Treasury, 2023) : o Less than 0.45 kg CO2e/kg H_2 o Additionality of electricity
EU	RED(NOW GmbH, 2024)	**Quotas** for EU countries: 1% RFNBO by 2030	Implemen-ted/active	Sustainability criteria for GHG and electricity procurement according to DA of the RED (EC, 2023a, 2022b)
EU	ReFuelEU Aviation (EC, 2021)	**RFNBO quotas for kerosene:** 1.2% RFNBO by 2030, 35% RFNBO by 2050	Implemen-ted/active	Sustainability criteria for GHG and electricity procurement according to DA of the RED (EC, 2023a, 2022b)
UK	Renewable Transport Fuel Obligation (RTFO)	**Quotas** for renewable fuels (13.6% in 2024, rising to 17.7% in 2032) and sub-quota for advanced fuels (1.4% in 2024)	Implemen-ted/active	Criteria for RFNBO: GHG and electricity criteria (Department for Transport UK, 2024)
Aus-tralia	National Hydrogen Strategy	Development of the Zero Carbon Certification Scheme as part of the Hydrogen Strategy	In develop-ment	Zero Carbon Certification Scheme (proof of origin for renewable electricity and GHG accounting) (Australian Government, 2021)

[39] The Trump administration has announced that it will remove this from the "One Big Beautiful Bill".

4.3 Conclusion

In this study, PtX Lab Lausitz developed a comprehensive set of sustainability criteria for RFNBO (hydrogen derivatives). Comprehensive sustainability criteria for RFNBO are necessary to ensure a sustainable and rapid market ramp-up of RFNBO and to obtain the necessary acceptance and security. The proposed set of sustainability criteria provides for a predictable, gradual tightening of the criteria (see chapter 2.2) in order to maintain the necessary pace of transformation without jeopardising Planetary Boundaries and sustainable development goals (SDGs) (see chapter 2.1). Appropriate sustainability criteria were formulated for **10 relevant sustainability aspects,** derived from the Planetary Boundaries and SDGs (see chapter 3.2 and Table 4-3).

The study was based on the set of sustainability criteria for PtL kerosene developed in 2022 by LBST and ifeu for the PtX Lab Lausitz (see chapter 3.1) (Altmann et al., 2022). The revised set of criteria was developed by analysing existing standards and criteria sets for RFNBO and evaluating various stakeholder positions (see chapter 3.2). Three **guiding principles** were used as a basis, which set a framework for balanced and appropriate sustainability criteria (see chapter 2.1):

1. **Minimisation of social and environmental risks** (do-no-harm)
2. **Generation of added value** (benefit-sharing)
3. **Acceleration of transformation/market ramp-up**

Comprehensive sustainability criteria for RFNBO should be supported by appropriate policy measures and instruments. The policy landscape was therefore analysed and **six extended recommendations for action** were formulated **for German policymakers** on how necessary and appropriate sustainability criteria should be strengthened and promoted within a market ramp-up of RFNBO (see Table 4-4). Furthermore, the proposed set of sustainability criteria is intended to support the further development of appropriate voluntary sustainability standards, certifications and labels for hydrogen derivatives and products based on them.

Table 4-3: Overview of the further developed PtX Lab 2025 sustainability criteria set for RFNBO.

Sustainability aspect	Sustainability criteria (PtX Lab 2025)
Requirements for electricity	• Renewability • Additionality • Development of additional renewable energies • Resource consumption • Grid compatibility • Energy efficiency • Permitted energy sources
Greenhouse gas reduction	• GHG accounting method • GHG reduction • Monitoring and reporting of GHG leaks during transport and storage

Sustainability aspect	Sustainability criteria (PtX Lab 2025)
Carbon and nitrogen sources	• Renewability of electricity for nitrogen and CO_2 production • Permitted CO_2 sources • Restrictions on biomass and non-recyclable plastic sources for biogenic and waste-based CO_2
Resources	• Environmental impact of resource requirements • Availability of metallic and non-metallic minerals
Water	• Excluding use of non-sustainable water sources in areas with water stress • Requirements for wastewater treatment of brine in seawater desalination • Impact assessment and water management plan to ensure consistent water quality, quantity and prices
Land use and land use change	• No-go areas (protected areas) • No-conversion areas (areas with high conservation value) • Buffer zones and ecological corridors • Environment and waste management
Labour	• Overtime pay, payroll accounting • Information and disclosure requirements • Collective agreements and freedom of association • Promotion and development opportunities • Regulated rest and working hours • Protection against dismissal and notice periods • Non-discrimination measures and protective measures • Complaints mechanism • Occupational safety measures • Exclusion of children and forced labour or modern slavery
Standard of living	• Respect for land rights (FPIC) • Respect for water rights (FPIC) • Promotion of energy availability • Co-benefit sharing: investment in the common good
Society	• Social impact assessment (gender-sensitive, transparent and consultative) • Stakeholder participation • Complaints mechanism • Fair business practices (transparency, anti-corruption)
Legality	• Legal register • Training system

Table 4-4: Overview of recommendations for action for German policymakers.

Recommendation	Description
I. Support and require	Link state financial support to particularly high sustainability criteria
II. Promote standardisation of sustainability criteria	Support national and international standardisation of sustainability criteria.
III. Communicate sustainability goals	By integrating clear sustainability targets for imported hydrogen derivatives into strategies and foreign policy
IV. Develop local regulations and strategies collaboratively	Support the development of local regulations and strategies within the framework of bilateral and multilateral climate and hydrogen partnerships.
V. Strengthen trust in green claims	Strengthen regulation and control of green claims.
VI. Harmonise international standards	Support international initiatives to establish uniform, higher sustainability criteria for hydrogen derivatives.

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