TÜV NORD EnSys GmbH & Co. KG

Expert Opinion
"Certification and Guarantees of Origin for imported green hydrogen and PtX products"

H2Global Stiftung

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- “Invitation-to-tender-certification-and-guarantees-of-origin-H2G” (PDF, published on 1 March 2022)
- “Market-consultation-H2Global-products-amounts-criteria” (PDF presentation, held on 16 November 2021)
- “Schematic diagram of supply chains” (PowerPoint presentation, received via email on 24 June 2022)

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Directory of abbreviations

AEA .... Ammonia Energy Association
AIB................... Association of Issuing Bodies
BMBF .... German Federal Ministry of Education and Research
BMWK .... German Federal Ministry for Economic Affairs and Climate Action
BMZ................. German Federal Ministry for Economic Cooperation and Development
CCS................. Carbon Capture and Storage
CCU................. Carbon Capture and Utilisation
CMS .... Carbon Management Service
CoC .... Chain of Custody
CO_2.................. Carbon dioxide
COP26............. 26th Conference of the Parties
CSP .... Concentrated Solar Power
del. act............. delegated act on Art. 27 RED II
dena .... German Energy Agency
$DeNO_X$............ Removal of nitrogen oxide
draft del. act..... draft of the delegated act on Art. 27 RED II
ECN................. Energy Research Centre of the Netherlands
RE .... Renewable Energy
EECS............... European Energy Certificate System
EEG................. German Renewable Energy Sources Act
EEV .... German Renewable Energy Ordinance
EnUG............... Energy Allocation Act
ERGaR .... European Renewable Gas Registry
EU .... European Union
FPIC .... Free Prior and Informed Consent
FQD................. Fuel Quality Directive
GHG .... Greenhouse gases
GO................... Guarantee of Origin
HCV................. High Conservation Value
HCVA .... High Conservation Value Area
HkRNDV.......... Implementing Ordinance on Guarantees of Origin and Guarantees of Regional Origin
H_2..................... Hydrogen
ICAO................ International Civil Aviation Organisation
ILO................... International Labour Organisation
ILUC .... Indirect land-use change
IPHE .... International Partnership for Hydrogen and Fuel Cells in the Economy

ISCC .... International Sustainability & Carbon Certification
ITC .... International Trade Centre
KfW .... Credit Institute for Reconstruction (ger. "Kreditanstalt für Wiederaufbau")
LCA .... Life Cycle Assessment
NH_3 .... Ammonia
PCF .... Product Carbon Footprint
PPA .... Power Purchase Agreement
PV .... Photovoltaics
RED .... Renewable Energy Directive
RFNBO .... Renewable Fuels of Non-Biological Origin
RSB .... Roundtable on Sustainable Biomaterials
SAI .... Sustainable Agriculture Initiative
SCDI .... Southern Corridor Development Initiative
SCEZ .... Suez Canal Economic Zone
SDG .... Sustainable Development Goal
TSP .... Tunisian Solar Plan
UNDP .... United Nations Development Programme
WBCSD .... World Business Council for Sustainable Development
WRI .... World Resources Institute

Definitions

"Blue hydrogen" – Carbon-neutral hydrogen whose CO_2 emissions from the manufacturing process are captured by CCS and permanently stored underground. /134/

Book & Claim – The Book-and-Claim approach is a mechanism of pure certificate trading that is established in electricity trading. It decouples the physical delivery of the energy source from the issuance of the respective certificate. /3/

Chain of Custody (CoC) – The chain of custody describes the monitoring of the input and output of sustainable materials during production and the information and documentation this requires up to the final product. /138/

Carbon Capture and Storage (CCS) – CCS technology captures the CO_2 that is emitted from fossil energy generation plants, industrial plants or from biomass used for energy generation and injects it into suitable geological formations. /152/

Carbon Capture and Utilisation (CCU) – The term CCU encompasses the capture, transport and subsequent utilisation (at least one additional cycle of use) of carbon compounds. /153/

"Low-carbon hydrogen" – This Expert Opinion describes hydrogen as low-carbon when it has been produced using energy sources that are not necessarily renewable (e.g. from nuclear power generation) but do not emit CO_2 emissions. The latter can be achieved using CO_2 storage and/or using CCU/CCS converting technologies.

Compressed hydrogen (CGH_2) – For hydrogen to be stored and transported, it is compressed at 350 or 700 bar pressures. Hydrogen in this form is referred to as compressed hydrogen. This allows the volumetric energy density to be increased 445-fold. /148/

Renewable energy (RE) – Renewable energy includes geothermal, bioenergy, hydropower, wind and solar power. /30/

Renewable Fuels of Non-Biological Origin (RFNBOs) – According to Directive EU 2018/2001 Article 2 (36), RFNBOs are "liquid or gaseous fuels which are used in the transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass." /R 2/

Liquid Organic Hydrogen Carriers (LOHC) – Liquid organic hydrogen carriers are characterised by their ability to store and release hydrogen. During hydrogenation, the uncharged form of LOHC reacts with hydrogen and forms a charged hydrogen carrier. The hydrogen carrier can then be discharged again as required. /148/

Liquid hydrogen (LH_2) – At temperatures below -252°C, hydrogen condenses to a colourless liquid, referred to as LH_2 or liquid hydrogen. Its volume shrinks by a factor of 787 during liquefaction compared to ambient temperatures. The volumetric energy density increases accordingly. /148/

“Grey hydrogen” – Hydrogen produced with the aid of fossil raw materials or fuels. The resulting systemic CO_2 is released into the atmosphere as a greenhouse gas. /134/

Green characteristics – The combined features that constitute climate neutrality and fulfil sustainability requirements. /145/

“Green hydrogen” – In this Expert Opinion, hydrogen is referred to as green when the energy required for electrolysis was generated from renewable sources. It also requires the PCF emitted through transport and further processing along the supply chain to be fully offset through appropriate compensation or CCS measures.

“Climate-neutral hydrogen” – There is no generally accepted definition of this term at the time of writing. For the present Expert Opinion, the term “climate neutral” is defined as fulfilling the following condition: PCF ≤ 0.

“Sustainable hydrogen” – There is no generally accepted definition of this term at the time of writing. For the present Expert Opinion, the term sustainable is defined as fulfilling the following conditions: PCF ≤ 0, a manufacturing process based on renewable energy and compliance with the SDGs.

Physical segregation – The physical separation of a product until it reaches the consumer. /3/

Power-to-gas (PtG) – As a narrower definition of PtX, the umbrella term power-to-gas means the conversion of electricity into any kind of gaseous substance. Power-to-Gas is thus a subset of the methods summarised as PtX. /151/

Power-to-X (PtX) – This term covers various technologies that convert electricity into another form of energy. /151/

Power Purchase Agreement (PPA) – A contract between a (large-scale) energy buyer and a producerof (renewable) electricity. The electricity is purchased directly or indirectly at a prearranged price. /150/

Product Carbon Footprint (PCF) – Quantity of greenhouse gases (in the form of CO_2 equivalents) that are emitted within the life cycle or a section of the life cycle of a product. In most applications, CO_2 is the only relevant greenhouse gas for PCF calculations /134/. The following other greenhouse gases should be included in the calculation according to the Kyoto Protocol /155/, provided they occur and are emitted within the system boundaries: methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Redispatch – The term redispatch describes the short-term change in the use of a power plant at the instruction of the transmission system operator to avoid grid congestion. Since October 2021, Redispatch 2.0 also includes generators and energy storage plants with a minimum capacity of 100 kW and involves distribution system operators. /146/

Renewable Energy Directive (RED) – The Renewable Energy Directive refers to the EU Directive 2009/28/EC. The directive was amended in 2018 with the new Renewable Energy Directive (RED II, 2018/2001). The second revision (2021/0218/COD) was presented in July 2021. The directive and its revised versions regulate the requirements for the EU member states’ national action plans for renewable energy expansion. In Germany, the action plan was largely implemented in the Renewable Energy Sources Act (EEG 2017). /149/

Repowering – This term refers to the replacement of old power plants with new, more powerful plants. The available infrastructure and a large part of plant components remain in use. /147/

Traceability – Traceability is the ability to identify and trace the origin, the production process and the distribution of substances and products through the supply chain. /18/

“Turquoise hydrogen” – “Climate-neutral hydrogen” that is produced using thermal decomposition of methane (pyrolysis); this produces solid carbon which is not emitted into the atmosphere as a greenhouse gas. /134/

Hydrogen (H_2) – Under normal conditions, hydrogen is an inert gas. It has the lowest density (0.0899 kg/m^3) of all gases. Hydrogen has more energy per mass (lower heating value: 33 kWh/kg) than other energy carriers. Burning hydrogen does not directly emit greenhouse gases. Hydrogen has to be produced by splitting a source material. The kind of energy that is used generally determines the kind of hydrogen that is produced (often identified by a colour). /148/

Hydrogen derivative – The present document defines hydrogen derivatives as gaseous and liquid compounds that were largely produced from hydrogen. The document explicitly discusses ammonia, methane and methanol.

Hydrogen product – The present document uses this term to refer to pure hydrogen and its derivatives.

Hydrogen value chains – The hydrogen product value chains can be divided into the following subsections: production, storage/conversion/transport/distribution and final consumption. /145/

Well-to-Tank – The present document uses this term as a method of observation for a life cycle or supply chain up to the transfer point at the filling station (energy supply).

Well-to-Wheel – The present document uses this term as a method of observation for the total life cycle or supply chain up to consumption.

Well-to-Gate – The present document uses this term as a method of observation for a life cycle or supply chain up to the transfer point at the manufacturer’s gate.

Sustainable Development Goals (SDG) – The United Nations have set 17 goals for the global achievement of sustainable development. /144/

Executive Summary

This report gives an overview of standards and criteria with regard to the green characteristics of hydrogen products as well as their verification, certification and how a transition towards an international certification system can be quickly established. First, an overview of the existing standards and those currently being developed is given and their criteria for green characteristics are presented. Subsequently, the requirements for the verification and certification of hydrogen products along the value chains were derived. Finally, based on the analysis of the hydrogen product exporting countries (Australia, Colombia, Egypt, Namibia, Tunisia), defined by H2 Global Advisory GmbH (in the following "client"), an exemplary certification system was outlined.

- The survey of the status quo of existing standards and those currently being developed showed, that the respective standards are mostly regionally limited, have different focal points and differ in their respective configuration, with regard to their criteria. The focus of the criteria contained in the respective standards is currently on guarantees of origin for electricity from renewable sources (Article 19, RED II) and GHG reduction (Article 25, RED II).

- Sustainability criteria, such as environmental and social standards, are not yet analysed in the existing standards under consideration, or only in the context of biomass certification. In course of the elaboration of this report it becomes clear, that these criteria should be considered, especially with regard to imports from EU countries. In addition, a suitable verification system should be established for reviewing these green characteristics of hydrogen products.

- The analysed potential hydrogen exporting countries respectively differ, inter alia, in terms of their infrastructural, technical and political preconditions. In the comparison, Australia meets best the criteria taken into consideration and can serve as a benchmark. A globally uniform certification system for hydrogen products could support the development of a global hydrogen product economy.

- The challenge is to strive for the four aspects of market ramp-up, cost efficiency, energy independence and climate protection at the same time, whereby, for example, the immediate inclusion of sustainability criteria conflicts with a rapid market ramp-up. A solution can be the gradual establishment of a certification system, graduated in time from a low-threshold list of requirements to environmentally and socially sustainable requirements that are comprehensive and clearly defined from the beginning.

1 Assignment and procedure

The project of H2Global Advisory GmbH (hereinafter referred to as the Client) receives dedicated funding from the German Federal Ministry for Economic Affairs and Climate Action (ger. *Bundesministerium für Wirtschaft und Klimaschutz*, BMWK) as part of the notice of grants published on 23 December 2021. The compilation of results as a part of the research project serves neither the economic (self) interest of H2Global Foundation nor the preparation for economic activities of HINT.Co GmbH. The project exclusively serves the greater goal of environmental and climate protection.

The invitation to tender titled “Certification and Guarantees of Origin for imported green hydrogen and PtX products” formulates three questions that this Expert Opinion endeavours to answer. In addition to hydrogen, we will examine ammonia, methanol and synthetic methane as hydrogen derivatives. Hydrogen and its derivatives will hereinafter collectively be referred to as hydrogen products. This report is divided into three chapters according to the three central questions. Each question is followed by a brief summary of the approach we used to respond to it.

“Which standards and criteria are important for the assessment of the green characteristics – such as climate neutrality and other aspects of sustainability – of H_2 and PtX products?”

- We provide an overview of the status quo of common international standards and criteria that are in use or being developed. We then evaluate this status quo in terms of usability and as regards current and future (based on today’s knowledge) criteria (project duration 2024 - 2033).
- We define any criteria that may be missing from existing standards but that is indirectly or directly necessary for the assessment of the green characteristics and sustainability of the hydrogen products in question.

“How can the green characteristics of production and transport of the examined H_2 and PtX products be recorded and certified based on these parameters?”

- We compile an evidence catalogue for the verification and seamless tracking of the criteria identified in the above question while taking into consideration the availability and reliability of data coming from the target countries.
- We elaborate a checklist that is structured along the value chains of hydrogen products and divided into 1) production, 2) storage/conversion/transport/distribution and 3) final consumption. The checklist includes the relevant minimum requirements for the assessment criteria.

“How can certification systems be implemented and negotiated quickly on an international level in order to bridge the gap until the necessary systems are established within the EU and internationally?”

- We perform a brief analysis of potential exporting countries for hydrogen products with a focus on the acceptance and applicability of an “H2Global Standard”. The “H2Global Standard” is a collection of requirements and a mechanism for the certification of hydrogen products.
- We discuss the necessary prerequisites for fast market adaptation of an “H2Global Standard” both globally and in the target countries of the Global South (i.e. developing and emerging countries).
- We evaluate the role of an “H2Global Standard” in the broader European context, taking into consideration the requirements defined by RED II or RED III (Renewable Energy Directive).
- The present Expert Opinion will consider the aforementioned questions from a technical perspective alone. The overarching objective is to find a quick and low-risk way to make large amounts of low-carbon hydrogen products available for trading.

The overarching objective of the Client is to find a quick and low-risk way to make large amounts of low-carbon hydrogen products available for trading. The present Expert Opinion will consider the aforementioned questions from a technical perspective alone. The review of existing standards and standards that are being developed serves only to make a comparison. We do not intend to argue against or exclude any existing regulations.

2 Motivation and initial situation

"Climate-neutral hydrogen", both in its pure form and in the form of derivatives, will play an increasingly important role in the future energy economy. As a climate-neutral energy carrier, hydrogen can be used across sectors and has the potential to make a large contribution to the decarbonisation of the existing energy system.

The use of renewable energy sources for the production of hydrogen through electrolysis also contributes to achieving the European Union's (EU) climate goals as defined in the "Fit for 55" package. Tapping the full potential of regions that are geographically well-suited to generating electricity from renewable sources will require the creation of suitable supply chains. Areas with a great potential for solar power generation can be found in the desert regions (e.g. Arabian Peninsula, northern Sahara, Australia). The regions with the highest yield for energy generation from wind are in the oceans and in less developed regions (e.g. Patagonia, the Irish Sea, the South Pacific). The geographic distance to these locations and the lack of the right geographic and climatic conditions locally, among other things, account for the need to import hydrogen products.

It is important to ensure that the production process for hydrogen products is based on renewables and that its transport does not fully negate its green characteristics. Fuel for tankers, the operation of pipeline infrastructure, storage and transport via trucks – these aspects can limit or even eliminate hydrogen's contribution to climate change mitigation. A reliable and transparent Guarantee of Origin is indispensable for the establishment of a hydrogen economy based on renewable energy (RE) in Germany and Europe. The following countries will – at the request of the Client – serve as examples of exporting countries for hydrogen in this Expert Opinion: Egypt, Australia, Colombia, Namibia and Tunisia.

The current situation in terms of the production and export of hydrogen products varies greatly among these countries. Creating and expanding hydrogen infrastructure will therefore require significant financial resources from various actors, including those from future consumer countries. Then there are aspects such as political or economic instability, weakness of the rule of law or low environmental and social standards that must also be considered.

Consequently, a Guarantee of Origin scheme for "climate-neutral hydrogen" products must be reliable and tamper-proof. It must also adequately account for the circumstances of developing and emerging countries. A certification, which we define as a procedure with which compliance with a standard or any other normative document can be confirmed by independent third parties, also creates security for stakeholders, ensures quality and increases the reputation of the certificate holders.

This Expert Opinion compares and assesses existing standards and criteria as well as those in development with regard to the green characteristics of hydrogen products. We will then identify the necessary criteria for a potential certification system based on these findings and outline an associated evidence management along the value chains for hydrogen products. We take into account the individual starting points in the countries defined by the Client. Finally, we will discuss the minimum requirements for rapid market development with regard to the export of hydrogen products.

3 Overview of standards for the assessment of the green characteristics of hydrogen products

The following statements on the directives, registry platforms and standards provide fundamental information for the individual standards presented in section 3.1. This introduction discusses the EU's Renewable Energy Directive (RED), the DIN EN 16325:2013 standard and the German Renewable Energy Ordinance (ger. *Erneuerbare-Energien-Verordnung*, EEV) and the implications these standards have for establishing a market for certified hydrogen products. The individual standards are presented in section 3.1, based on the respective sources cited for each standard. Section 3.2 provides an assessment of the existing criteria and an outlook on constructive additions with regard to sustainability criteria.

The EU's RED could become a regulative basis of considerable importance for international systems for the certification of hydrogen products, particularly those directed at the EU market. The Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II) pursues the EU energy policy goal of reducing greenhouse gas emissions (GHG emissions) through the expansion and use of renewable energy. /R 2/

To complement this, the European Commission is currently preparing a delegated act (draft del. act) on the production of renewable fuels of non-biological origin (RFNBOs), which includes hydrogen from renewables. The draft was published in May 2022. This was followed by a four-week consultation phase. The next step will be the publication of the final draft by the European Commission. The European Council and the European Parliament will then have to agree to this draft. /29/

According to the draft delegated act, hydrogen from renewable energy should be creditable in the sense of RED II. Additional criteria may be required, but these have not yet been determined and will thus not be considered within the scope of this Expert Opinion. Detailed requirements in connection with the direct connection and grid supply from renewable energy sources are listed in the annex.

DIN EN 16325:2013 is a standard related to Guarantees of Origin. It provides a standardised framework for fuel mix disclosure. The standard also defines requirements such as quality labelling for Guarantees of Origin for electricity. It can be adapted to apply to other groups of substances, such as gases, for example. So far, it only offers specifications relating to certificates for electricity from renewable energy. The standard is currently being revised, and will then be suitable as a foundation for hydrogen certification. /3/, /R 3/

In the Federal Republic of Germany, the production of "green hydrogen" is defined in section 12i of the German Renewable Energy Ordinance (ger. *Erneuerbare-Energien-Verordnung*, EEV). It stipulates that 100% of the electricity used for the production of "green hydrogen" must come from renewable sources. The hydrogen producer must supply evidence of this through Guarantees of Origin in line with section 16 para. 3 of the Implementing Ordinance on Guarantees of Origin and Guarantees of Regional Origin (ger. *Herkunfts- und Regionalnachweis-Durchführungsverordnung*, HkRNDV). One important prerequisite for these Guarantees of Origin is that the renewable electricity must not have been subsidised by the German Renewable Energy Sources Act (ger. *Erneuerbare-Energien-Gesetz*, EEG)[1] (see section 93 of the EEG). In terms of geography, the electricity must demonstrably have been generated in the electricity price area of Germany (min. 80%) or in a price area that is electrically connected to Germany (max. 20%). The electrolyser also has to be verifiably operated in a way that serves the system. This means that the electrolyser may only operate when renewable electricity is available from the grid (in 15-minute intervals). The exemption from EEG apportionment is limited to a maximum of 5,000 full-load hours of use per year. /R 1/, /R 4/ In Germany, section 12i of the German Renewable Energy Ordinance (ger. *Erneuerbare-Energien-Verordnung*, EEV) and section 26 of the Energy Allocation Act (ger. *Energie-Umlagen Gesetz*, EnUG) will be revised to implement RED II as soon as it comes into force. /28/

3.1 Standards and assessment criteria that already exist or are in development

The following section lists the most important standards and criteria for the assessment of the green characteristics of (imported) hydrogen products from a European perspective. We reviewed freely available sources (see chapter 8) in detail at the time of writing the Expert Opinion in order to provide a summary of the most important standards and their criteria that is transparent and as thorough as possible. This included both existing standards and standards that are in development. These standards are described in regard to the Client's objective to quickly create an international certification system for market ramp-up. We discuss the following aspects for each standard:

- description and purpose,
- status and applicability,
- geographic scope,
- technical scope,
- supply chain traceability,
- target group(s) and certification criteria.

Other declaration of intent for hydrogen certification systems besides the standards considered in section 3.1 are being developed. These are still only loose concepts that are largely

[1] EEG apportionment was abolished on 1 July 2022. Chapter 3 provides an overview of the statements on directives, registry platforms and standards for the individual standards presented in section 3.1.

based on PCF methodology and are being developed outside the EU. The relevance of these standards for the EU market will become apparent in future, once they have been made more concrete. These initiatives include the "China Hydrogen Alliance Standard" /128/, the "Japan Aichi Prefecture Low-Carbon Hydrogen Standard" /129/, the "California Low-Carbon Fuel Standard" /130/ and the "GH2 – Green Hydrogen Standard" /131/ and the "Clean Energy Certification System"/143/. A detailed analysis of these standards is not part of the scope of this Expert Opinion.

3.1.1 "Low-Carbon Ammonia Certification" – Ammonia Energy Association (AEA)[2]

Description and purpose:
The Ammonia Energy Association (AEA) is developing a globally harmonised certification system for "low-carbon ammonia" to support the development of a market for low- and zero-carbon ammonia. The certification system is backed by the AEA, whose members include large industrial firms from the hydrogen, oil and gas industry. The certification system is expected to verify the origin, inputs, co-products, technological pathway and date of manufacture during registration and reporting. This data is assigned to the tradable quantity of ammonia. The carbon accounting forms the basis for transparent proof of emission reductions at the point of production ("Well-to-Gate") or, optionally, across the entire value chain. /6/

Status and applicability:
The standard has been in development since October 2021 and is expected to be published in November 2022. Prior to that, stakeholders were asked to report their requirements and needs during a consultation phase. Once the development stage has been completed, the establishment phase (December 2022 – November 2023) will see the validation of an initial portfolio of registration and certification methods and the certification of pilot projects. The standard is expected to be fully established from 2024 and is to be expanded on an ongoing basis. /6/ It is not yet applicable at the time of writing /16/.

Geographic scope:
The certification system is expected to apply in a harmonised manner worldwide /6/.

Technical scope:
The AEA's "Low-Carbon Ammonia Certification" applies to the production of ammonia, including the production of hydrogen as a raw material, and to the subsequent use of ammonia. It includes various pathways for production and use /6/. The production pathways can be either fossil (potentially including carbon capture and storage/utilisation (CCS/CCU)) or

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[2] Version: In progress; Discussion Paper (October 2021)

renewable. The pathways of use range over various industrial sectors, from energetic use to use as an industrial feedstock for processes. Certification is planned on a “Well-to-Gate” (mandatory) or a “Well-to-Wheel” or “Well-to-Tank” basis (optional).

Supply chain traceability:
The AEA plans to certify supply chain traceability through “tradable amounts” of ammonia. It uses one metric tonne of ammonia (t NH_3) as a base unit. /6/

Target group(s):
The certificate’s target groups are producers, dealers, retailers and consumers of ammonia. /6/

Certification criteria:
The certification system’s current plan is to quantify the direct and indirect GHG emissions associated with ammonia production according to the GHG Protocol. Starting points include the UNFCCC guidelines, standards such as ISO 1406X and national-level accounting and reporting guidelines. /6/

Ensuring a consistent record of carbon intensity across the entire life cycle of ammonia products requires a specific methodology that defines a consistent and transparent approach to accounting for the process of ammonia production and use. The working group is currently identifying and developing a series of initial pathways. Additional pathways can be added during the operational phase. /6/

No further specific criteria has yet been published for this standard.

3.1.2 CMS 70 “GreenHydrogen” and “GreenHydrogen +” (TÜV SÜD)[3]

Description and purpose:
The certification developed by TÜV SÜD defines requirements for the production and marketing of “green hydrogen” from renewable energy. The certification can be carried out starting from the unit of 1 MWh of hydrogen (based on the lower heating value). Remaining CO_2 emissions can be offset with CCS in line with EU Directive 2009/31/RG /R 10/. Evidence of the long-term storage must be provided for certification. /132/

Status and applicability:
The certified hydrogen may be used as a transport fuel, as an industrial feedstock for processes or as a storage medium for use in the energy market. Version 11/2021 of the standard has been in force since 1 December 2021. Version 01/2020 can still be used for initial certification until 30 November 2022. Recertification according to the current standard must be performed after a maximum of 12 months. The certified system will then be adapted to the revised standard and certified accordingly. /132/

Geographic scope:
The standard is characterised by German and European legislation, but it can generally be applied globally. It demands compliance with national regulations or the regulations of a federation of countries for the production of hydrogen from renewable energy that apply in the countries concerned. /132/

Technical scope:
The standard recognises the following technologies for hydrogen production /132/:

- Electrolysis using electricity from renewable energy
- Steam reforming of sustainable biomethane
- Pyrolysis/gasification of sustainable biomass or sustainable, biogenic residues
- Electrolysis with aqueous solutions of hydrogen chloride (hydrochloric acid) and aqueous alkali chloride solutions using renewable energy
- Hydrogen as a by-product

The “GreenHydrogen +” certification goes even further than the “GreenHydrogen” certification and requires that hydrogen production only be carried out through electrolysis using electricity from renewable energy. /132/

[3] Version: 11/2021

Supply chain traceability:
The certification defines the production facility including ancillary units as its system boundary. This includes treatment, storage, compression/liquefaction and other processing steps up to the delivery of the hydrogen at the plant gate or its injection into a hydrogen network or natural gas network. It considers a minimum achieved purity of 99.9% and a minimum achieved pressure level of 3.0 MPa.

The “GreenHydrogen +” certification, on the other hand, comprises the entire supply chain, including downstream transport to the end customer. /132/

Target group(s):
The target groups include the users and producers of certified hydrogen. /132/

Certification criteria:
The standard is based on the European regulations RED II (/R 2/) and 2009/31/EC for CCS (/R 10/).

The quantification, monitoring, reporting and validation or verification of emitted and/or extracted GHG amounts must be conducted using a quality management system /R 6/.

For certification to be granted, the electricity used for hydrogen production must demonstrably be generated on-site or be provided through a direct connection. Guarantees of Origin or comparable certificates must conform with RED II.

GHG emissions must be at least 70% lower than the reference value for biofuels. With a reference value of 94 $gCO_{2,eq}/MJ_{Hi}$, this is equivalent to GHG emissions of 28.2 $gCO_{2,eq}/MJ_{Hi}$. The standard considers a maximum balance period of 12 months. The GHG balance for hydrogen must meet the requirements of a life cycle assessment (LCA) according to ISO 14040 and ISO 14044. The LCA criterion can also be met by applying the GHG Protocol, ISO 14067 or PAS 2050. Mixed production is permitted with only the share of hydrogen produced from renewable energy receiving certification. At the end of the 12-month balancing period, the amount of hydrogen certificates sold must be covered by corresponding production. /132/

“GreenHydrogen +” requires additional criteria in line with the TÜV SÜD CMS 70 standard:

- Hydrogen for the purpose of steam/heating or cooling production must achieve a GHG emissions reduction of at least 70% compared to the reference value for biofuels according to RED II. With a reference value of 80 $gCO_{2,eq}/MJ_{Hi}$, this is equivalent to GHG emissions of 24 $gCO_{2,eq}/MJ_{Hi}$. /132/
- Subsidised electricity from renewable energy that receives higher remuneration per kWh fed into the grid is not recognised, unless it was purchased in a nationally regulated auction as defined by RED II. /132/

- Renewable energy power plants must meet the criterion of additionality: The energy generation plants must come into operation at the same time as or after the hydrogen production facility. They must not have come into operation any earlier than eleven months before the electrolyser. /132/
- They must meet temporal correlation: The hydrogen must be produced within the same 15-minute interval in which electricity is generated from RE or more electricity must be generated from RE in a 15-minute interval in the bidding zone of the electrolyser than the average annual generation of the respective country two years before the production period. /132/
- The geographical correlation must be fulfilled to avoid grid bottlenecks. Electricity generation plants must be located in the same bidding zone as the electrolyser. /132/
- Hydrogen production from glycerine and other biomass (pyro-reforming) or from biomethane (steam reforming) requires a mass balance system in line with RED II to prove its sustainability. The traceability of the delivered quantities, the origin and the sustainability of biomass must be proven. /132/

3.1.3 TÜV Rheinland standard "H2.21 Climate-neutral hydrogen"[4]

Description and purpose:
The certification developed by TÜV Rheinland is based on the principle of "Cradle-to-X". The standard aims to certify the PCF as less than or equal to zero at predefined points within the hydrogen value chains. CO_2 emissions can be compensated and stored. /134/

Status and applicability:
The "H2.21" standard can be applied since July 2021. The first "green hydrogen" and ammonia certification was announced in April of this year /10/.

Geographic scope:
The certification is available globally. In Germany, "green hydrogen" is certified according to the German statutory principles. Outside of Germany, the respective national criteria apply. Should no legal criteria exist abroad, the standard only permits electricity from a direct connection. /134/

Technical scope:
The standard is open to all technologies. This means that it recognises various manufacturing processes such as steam reforming, electrolysis and pyrolysis with the use of different energy carriers such as natural gas/oil, electricity, biomass/biogas. The standard certifies

[4] Version: 1.0 / July 2021

“climate-neutral hydrogen”. But it can also certify “green ammonia” /10/. As an option, hydrogen can be certified as “green, blue, turquoise and RED II-compliant hydrogen” by meeting additional criteria. /134/

Supply chain traceability:
Hydrogen can be certified as fully climate-neutral within a defined section of its life cycle within the supply chain. This is based on the principle of “Cradle-to-X”. Certification begins at the beginning of the life cycle and ends at a predefined point. This point can be set anywhere along the hydrogen value chains. /134/

Target group(s):
The standard is aimed at stakeholders within the defined “Cradle-to-X” life cycle section. This means that the standard is also open to parties that are involved in the supply chain for hydrogen. /134/

Certification criteria:
The standard refers to RED II (/R 2/) and Directive 2009/28/EC (/R 14/) as well as the German Renewable Energy Sources Act (EEG) (/R 4/).

Its understanding of PCF and GHG is based on the following standards: /R 11/, /R 12/, /R 13/, /R 6/ and /R 5/. The PCF calculation to be verified is carried out along the defined section of the value chains using primary data or generic data with a conservative level of certainty in accordance with ISO 14067 or ISO 14040/44.

“Climate-neutral hydrogen” must meet the following additional requirements /134/:

- All direct and indirect emissions associated with the production facilities are taken into account. Process-specific equipment and components are not taken into account.
- Potential offsetting measures: Direct offsetting measures by investing in climate intervention projects in line with DIN EN ISO 14064-2; indirect offsetting measures by purchasing and retiring registered CO_2 reduction certificates from internationally recognised climate intervention programmes and/or emission rights from established trading systems; CCS measures.

In Germany, the certification of “green hydrogen” depends on the following additional criteria (based on section 12i German Renewable Energy Ordinance – EEV) /134/:

- Demonstrable use of electricity from RE according to section 3 no. 21 of the Renewable Energy Sources Act (EEG) and without public funding through the EEG and the 2020 Combined Heat and Power Act (KWKG).
- The electrolysis plant must not exceed 5,000 hours of full-load hours of use per year.

- Electricity drawn from the grid requires Guarantees of Origin in line with section 30 of the Implementing Ordinance on Guarantees of Origin and Guarantees of Regional Origin (ger. *Herkunfts- und Regionalnachweis-Durchführungsverordnung*, HkRNDV).
- Electricity drawn from a direct connection must supply the electrolyser with renewable electricity within a 15-minute interval.

The production of "green hydrogen" outside of Germany must meet comparable criteria for renewable electricity from the grid. Should no legal criteria exist, the standard only permits electricity from a direct connection. /134/

The certification of hydrogen that conforms with RED II includes the following requirements /134/:

- The use of RE must lead to GHG emissions reductions benchmarked against the emission factor for fossil fuels.
- The electricity used must demonstrably be renewable and must not be subsidised by public funding.
- It must meet the criterion of additionality. The dates of commissioning of the electrolysis plant and the power generation plant must be no more than 12 months apart.
- An electricity supply contract must be in place between the hydrogen producer and the renewable energy producer.
- It must meet the criterion of temporal correlation. If electricity is drawn from a public grid, the electrolyser's electricity consumption must be balanced within a 15-minute interval.
- It must meet the criterion of geographic location. Electricity generation and the electrolysis plant must be located in the same electricity price area.

3.1.4 "CertifHy"[5]

Description and purpose:
The "CertifHy" project aims to establish an EU-wide Guarantee of Origin scheme for "green and low-carbon hydrogen". The EU project is being carried out by a consortium made up of ECN, GREXEL, Ludwig Bölkow System Technik and TÜV SÜD under the direction of Hinicio and financed by Fuel Cell and Hydrogen Joint Undertaking. The establishment of a "CertifHy" Guarantee of Origin scheme aims to ensure transparency and provide information regarding the quantities of hydrogen produced by a registered production device. It also defines green characteristics for hydrogen. /2/

[5] Version: In progress; information from www.certifhy.eu (retrieved on: 1 August 2022)

Status and applicability:
The “CertifHy” project is structured into three phases. Phase 1 (2014 to 2016) saw the development of a Europe-wide definition for “green and low-carbon hydrogen” as well as a Guarantee of Origin scheme. Based on the results from this first phase, the scheme was then implemented in phase 2 (2017 to 2019). The third phase of the “CertifHy” project runs until 2023 and builds on the insights from phases 1 and 2. During this project phase, the Association of Issuing Bodies (AIB) will support the development of a certification system for renewable hydrogen. The certification system is still in development. /3/, /7/

Geographic scope:
The Guarantee of Origin scheme that has been developed can be applied across Europe. /8/

Technical scope:
“CertifHy”’s scope of consideration covers the production side of hydrogen. It encompasses the entire hydrogen production process – from the raw materials to actual production. /9/

Supply chain traceability:
In accordance with RED II, the certification of hydrogen with “CertifHy” is carried out according to the Book-and-Claim model. It uses the base unit of 1 MWh (based on the lower heating value). /9/, /18/

Target group(s):
The “CertifHy” system is directed at all actors in the hydrogen value chains. It includes the production, transport, trade and consumption of hydrogen products. /9/

Certification criteria:
The “CertifHy” project has developed a certification system that is compatible with EU legislation. The establishment of “CertifHy” has placed a particular focus on ensuring that the requirements of RED II are met. /9/

Certification through “CertifHy” distinguishes between “green hydrogen” and “low-carbon hydrogen”. Both kinds of hydrogen must achieve GHG emissions reductions of at least 60% compared to the reference value for hydrogen made from natural gas without CCS (91 $gCO_{2,eq}$/MJ) /9/. The calculation of greenhouse gas emissions is based on the GHG Protocol.

In order to receive certification as “green hydrogen”, the hydrogen must have been produced through water electrolysis using renewable energy sources. Each certificate has a value of 1 MWh, based on the lower heating value of hydrogen. Mixed production using renewable and non-renewable energy can receive a proportional amount of certificates for “green hydrogen”. /9/

The Guarantee of Origin should include information on the energy source used for production, a date of issue and erasure, greenhouse gas intensity and a unique ID number.

3.1.5 “REDcert-EU” and “REDcert²” [6]

Description and purpose:
“REDcert-EU” is recognised by the European Commission as a system for the certification of sustainable biomass. The standard covers biomass fuels for the transport sector as well as other sustainable biofuels, bioliquids and biogas. The established system is based on the requirements of RED I and RED II. The “REDcert-EU” certification ensures compliance with these EU directives as well as with additional regulations for the production of biomass. /133/

Due to the growing need for sustainability certifications, a broader certification system, “REDcert²“, was developed, which is aimed at companies in the chemical industry and producers of food products and animal feed. The certification allows these companies to gain certification of their substitution of fossil raw materials with sustainable biomass for their final products /15/. Unlike “REDcert-EU”, the requirements for GHG emissions reductions are not mandatory for “REDcert²” /133/.

Status and applicability:
The “REDcert-EU” standard was developed in 2010, based on the requirements of RED I. The revised sustainability criteria from RED II have been in force since July 2021. /133/

“REDcert²” has enabled the certification of sustainable agricultural raw materials for use in the food and animal feed sector and for biomass for material purposes since 2015. /22/

Geographic scope:
The REDcert certification systems are approved for biomass originating from the EU and are valid for locations within the EU as well as selected third countries. These third countries include the Ukraine, Norway and Canada /133/, /127/.

Technical scope:
RFNBOs can be certified under REDcert. This includes hydrogen (produced using RE), methane and synthesis gas (e.g. ammonia), among other things. This product area must meet the requirements of RED II. /135/

Supply chain traceability:
The “REDcert-EU” certification system traces the production and supply chains using a mass balance system or through physical segregation. Every biomass delivery that is used for the production of sustainable bioliquids and biofuels is clearly and unmistakably labelled

[6] Version „REDcert-EU“: EU 06; Version „REDcert²“: RC² 1.1

by these kinds of accounting systems. The specific GHG emission values must be declared for each delivery. /133/

The requirements for mass balancing also apply to RFNBOs, even if they are not explicitly mentioned in REDcert's system documentation /133/.

Target group(s):
The "REDcert-EU" certification system applies to all economic operators along the value chains of fuels from renewable raw materials. These include /133/:

- companies producing biomass,
- waste and processing residue generating facilities,
- first gathering points,
- collection points for waste and residue,
- conversion plants of all kinds and
- traders, suppliers and storage facilities.

"REDcert²" also targets the chemical industry, producers of food and animal feed and suppliers. /135/

Certification criteria:
Certification under REDcert is based on the requirements of the EU Directive RED II and of the associated criteria for electricity procurement for the production of hydrogen.

The sustainability criteria for the cultivation and creation of biomass under consideration of other applicable statutory requirements and fundamental social standards in accordance with the International Labour Organisation (ILO) Convention apply. These include the review of land use and land use change with the help of databases and satellite images, for example.

"REDcert²" certification further includes criteria defined by the Sustainable Agriculture Initiative (SAI) /22/.

All biofuels, bioliquids and biomass fuels produced must meet GHG emissions reductions in line with the applicable minimum legal requirements compared to the emissions of comparable fossil fuels. The calculation occurs in line with the description in RED II /R 2/. /133/

The difference between "REDcert²" and "REDcert-EU" is the absence of an obligation to disclose GHG emissions and to meet the prescribed requirements in terms of GHG emissions reductions for certain materials. GHG emissions can be disclosed, but they do not need to use mandatory standard values. GHG calculations are carried out on an individual and process-specific basis. The method of calculation is described in "REDcert-EU" or is carried out according to the standard ISO 14040:2006 (/R 8/) or ISO 14044:2006 (/R 9/). /133/

3.1.6 "RSB standard for Advanced Fuels"[7]

Description and purpose:
While initially covering product certification where biogenic materials are the base material, the certification body Roundtable on Sustainable Biomaterials (RSB) has expanded its portfolio to include RFNBOs. These are now considered Advanced Fuels and are part of the "RSB Standard for Advanced Fuels". RSB has established 12 principles that, in connection with additional documents, form the standards offered by the organisation. /27/

Status and applicability:
The standard in its current version (2.4) has been in place since 22 March 2022. According to Annex II of the standard, it explicitly applies to hydrogen, synthesis gas and synthetic liquid fuels. Additional raw materials can be included following approval by the RSB executive board. It can be assumed that this standard can also be used to certify ammonia, methanol and methane in addition to hydrogen. /26/

Geographic scope:
The RSB standard can be applied in the following continents/countries according to the International Trade Centre (ITC) /25/:

- Africa: Sierra Leone, South Africa , Tunisia
- Asia: China, the Philippines, the Republic of Korea, Sri Lanka, Thailand
- Australia and Oceania: Australia
- Europe: Denmark, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom
- North America: Canada, Mexico, United States of America
- South America: Brazil, Peru, Uruguay

Technical scope:
The standard focuses on the certification of fuel products of biogenic origin but also accepts non-biogenic fuels. Hydrogen, synthesis gas and synthetic fuels have been named explicitly. /26/

Supply chain traceability:
The "RSB Standard for Advanced Fuels" requires GHG emissions to be recorded across the entire supply chain up to the final point of distribution ("Well-to-Tank"). Traceability shall be ensured through a mass balance system. /26/

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[7] Version: 2.4

Target group(s):
The target group is made up of producers, the manufacturing sector and consumers. The transport sector is explicitly excluded as a target group /25/.

Certification criteria:
The certification body RSB has established 12 principles that, among other things, form the criteria for the certification of RFNBOs through the "RSB Standard for Advanced Fuels".

The 12 principles are /27/:

- Principle 1: Legality– Operations comply with all applicable laws and regulations.
- Principle 2: Planning, Monitoring and Continuous Improvement – Sustainable measures are planned, implemented and continually improved through an open, transparent and consultative impact assessment and management process and an analysis of economic viability.
- Principle 3: GHG emissions – Biofuels contribute to climate change mitigation by significantly reducing life cycle GHG emissions compared to those of fossil fuels.
- Principle 4: Human and labour Rights – The business activity does not violate any human rights or labour rights and promotes humane working conditions and the well-being of workers.
- Principle 5: Rural and Social Development – In regions of poverty, operations contribute to the social and economic development of local, rural and indigenous people and communities.
- Principle 6: Local Food Security – The measures ensure the human right to adequate food and improve food security in food-insecure regions.
- Principle 7: Conservation – Operations avoid negative impacts on biodiversity, ecosystems and conservation values.
- Principle 8: Soil – Operations implement practices that seek to reverse soil degradation and/or maintain soil health.
- Principle 9: Water – Operations maintain or enhance the quality and quantity of surface and groundwater resources, and respect prior formal or customary water rights.
- Principle 10: Air Quality – Air pollution is minimised along the supply chain.
- Principle 11: Use of Technology, Inputs and Management of Waste– The use of technologies in operations seeks to maximise production efficiency and social and environmental performance and minimise the risk of damages to the environment and people.
- Principle 12: Land Rights – Operations respect land rights and land-use rights.

The standard divides the requirements for the certification of RFNBOs into several chapters.

Chapter 2 of the standard lists the sustainability requirements. The fundamental RSB principles 3 to 12 (RSB-STD-01-001) and the connected documents must be complied with and/or presented /26/.

In addition, chapter 2 of the standard formulates requirements for the traceability of materials including RFNBOs. Section 2.2.1 demands compliance with the "RSB Chain of Custody Standard" (RSB-STD-20-001) from the start of the value chains /26/. Section 2.2.2 (a) sets the requirement of a mass balance system that covers the entire supply chain for each individual material /26/. Section 2.2.3. extends this requirement to include Guarantees of Origin for each material, which must be available for the audit. /26/. According to section 2.2.4. (3), Guarantees of Origin must include information about the type of material, its country of origin and weight or volume specifications /26/.

Additional specific requirements for RFNBOs are defined in chapter 5 of the standard. They include requirements for the designation of products (5.1.), the exclusive use of renewable electricity (5.2.), Guarantees of Origin for electricity (5.3.) and for proof of compliance with GHG accounting requirements (5.4.). According to section 5.4., GHG accounting must include the emissions from electricity generation, fuel production, gas compression and transportation of the fuel to the final point of distribution (filling station or retailer), including grid losses. /26/

3.1.7 "A Hydrogen Guarantee of Origin Scheme for Australia"[8]

Description and purpose:
Based on a consultation of stakeholders and extensive analysis, the Australian government has decided to develop a national hydrogen certification system in accordance with the IPHE (International Partnership for Hydrogen and Fuel Cells in the Economy). This will then be converted into an international scheme in a second stage. The draft scheme presented for discussion is to set the framework conditions for the Australian hydrogen economy. The main aim for creating the standard is to ensure comparability and transparency of hydrogen and hydrogen products for the end customer. A conscious decision was made not to specify emission limits in relation to the green characteristics of hydrogen. This is thought to give end customers the freedom to create their own categories according to their individual criteria, e.g. in terms of hydrogen colours. /5/

A side note: IPHE
The Australian government refers to the efforts of the IPHE in its discussion paper on a Guarantee of Origin for hydrogen. 21 countries as well as the European Commission are currently connecting under the umbrella of the IPHE. They plan to reach "10,10,10": To put

[8] Version: In progress; Discussion Paper (June 2021)

10 million mobile fuel cell systems and 10 thousand hydrogen filling stations into operation worldwide in 10 years /17/. Australia is active within the working group of the IPHE and is involved in the issues of regulations, laws, standards and safety. It aims to make its national efforts compatible internationally /5/. Other objectives include establishing international compatibility of national and multinational certification systems and coordinating a methodological basis for the calculation of the GHG intensity of hydrogen /3/.

Status and applicability:
The described Australian standard is still in development. At the time of writing (July 2022), 19 experimental projects are testing hydrogen and the certification of its origin. /5/

Geographic scope:
As the administration of the standard is to be managed by an Australian government institution, the standard’s geographic focus is on Australia. /5/

Technical scope:
The scheme permits the assessment of hydrogen production. It should be possible to expand the scope to include hydrogen derivatives and secondary products (such as ammonia) in the future. The scheme includes the following production technologies: electrolysis, coal gasification and steam reforming, always including CO_2 storage. Technologies that emit CO_2 but that do not include storage are to be explicitly excluded from certification. The system boundary along the value chains is to be defined as “Well-to-Gate” given the lower complexity for implementation. However, an expansion of the system boundary to include other parts of the value chains is not excluded. /5/

Supply chain traceability:
The reference to the production site ensures traceability to the origin of the certified material. /5/

Target group(s):
All actors along the sections of the hydrogen value chains that are covered by the standard. /5/

Certification criteria:
The following criteria are relevant for certification: Emissions record, indication of the production facility and location, indication of the production technology and the primary fuel source.

The calculation of GHG emissions will be based on the GHG Protocol (/R 5/) and the standard for the quantification of greenhouse gases (/R 6/). The information and factors required for the exact calculation of emissions shall be taken from the Australian “Intergovernmental

Panel on Climate Change” and “National Greenhouse and Energy Reporting Scheme” standards. /5/

3.1.8 “ISCC EU” & “ISCC PLUS”[9]

Description and purpose:
The International Sustainability & Carbon Certification (ISCC) has developed several certification systems. They were developed in an open multi-stakeholder process and are managed by an association with over 175 members. /11/

The ISCC certification systems that are relevant for the present Expert Opinion are “ISCC EU” and “ISCC PLUS” /12/.

“ISCC EU” is a certification system that guarantees compliance with the statutory sustainability requirements as defined in RED II and in the Fuel Quality Directive (FQD). The “ISSC EU” certification guarantees compliance with environmental, social and traceability criteria and qualifies biofuel and biomass companies for legal recognition in line with the objectives of the European fuel regulations. The legal foundations are the biofuel sustainability ordinance, the biomass electricity sustainability ordinance and the German Renewable Energy Sources Act (EEG). /19/

The certification system “ISCC PLUS” is directed at all markets and sectors that do not fall under RED II. These include, for example, the food, animal feed or energy market and various industrial applications. “ISCC PLUS” covers the certification of all kinds of raw materials originating from agriculture and forestry, waste and residues, non-biological RE and recycled carbon materials and fuels. /14/ The regulatory basis consists of the “ISCC PLUS” regulations in line with RED I/II.

Status and applicability:
With currently over 5,000 valid certificates in more than 100 countries, the ISCC is one of the largest certification systems in the world. /12/ The organisation counts 189 members, 42 recognised certification bodies and 5,744 valid ISCC certificates. There are 7 regional and technical stakeholder committees. /13/ The ISCC certification systems are established for and applicable to the above-mentioned product groups.

Geographic scope:
Both “ISCC EU” and “ISCC PLUS” can generally be applied worldwide with regard to Guarantees of Origin and traceability. The focus countries named by the client – Colombia, Tunisia, Egypt, Namibia and Australia – are mentioned explicitly, except for Namibia. /13/, /14/

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[9] Version “ISCC EU”: 4.0 / July 2021; version “ISSC PLUS”: 3.3

Technical scope:
Biofuels or electricity-based fuels, as well as synthetic methane and hydrogen (PtX) according to the 37th Federal Immission Control Ordinance (BImSchV), can be certified to "ISCC EU" /R 16/.

"ISCC PLUS", on the other hand, applies to raw materials, inputs, products (such as fertilisers), etc., which includes hydrogen, ammonia and methanol. /137/

Supply chain traceability:
The traceability of the supply chain is ensured for both "ISCC EU" and "ISCC PLUS" through a mass balance system or physical segregation. Controlled mixing is admissible under both standards. /21/

The requirements for traceability and the supply chain apply to all kinds of raw materials and their respective supply chains. The detailed requirements are listed in the ISCC system documentation 203 "Traceability and Chain of Custody". /21/

Target group(s):
The target groups of the "ISCC EU" and "ISCC PLUS" standards are producers, the manufacturing sector and consumers. The transport sector is not explicitly mentioned as a target group. /13/, /14/

Certification criteria:
The certification requirements and the corresponding processes are described in detail in the respective ISCC system documentation and are based in part on RED II. /21/

In general, "ISCC EU" & "ISCC PLUS" establish the following requirements for the substances to be certified:

- Sustainability requirements for biomass originating from agriculture and forestry, waste and residues, raw materials for the production of RFNBOs and recycled fuels containing carbon as well as raw materials with low risk of indirect land-use change (ILUC).
- Traceability requirements for the supply chain.
- GHG emission reduction and calculation requirements.

The sustainability requirements that can be certified as part of ISCC are described in the ISCC system documentation 202 "Sustainability Requirements" and the further documentation /21/. According to an ITC report, the ISCC supports in particular 11 of the 17 Sustainable Development Goals (SDGs). /11/

Chapter 3.2.2. of the ISCC system documentation 202 addresses the requirements in terms of supply chain traceability /21/. The criteria for traceability and chain of custody (CoC) ensure that two fundamental requirements are met. These are, on the one hand, the fact that sustainable products can be traced through the supply chain from their source up to the point of delivery and, on the other hand, the fact that product-specific information can be allocated to batches of sustainable materials and products.

Here, the following properties for sustainable materials (so-called sustainability characteristics) that are required as part of ISCC /21/ are recorded:

- type of raw material (e.g. hydrogen, ammonia, methanol, methane),
- origin of the raw material,
- scope of certification of the raw material (i.e. the raw material is either certified according to the sustainability criteria of Art. 29 (3) - (7) of the RED II or it conforms to the RED II definition of waste or residue),
- information on GHG emissions (mandatory for “ISCC EU”, voluntary for “ISCC PLUS”) and
- labelling as “ISCC compliant” or “EU RED compliant” (if applicable).

Chapter 3.2.3. also specifies requirements for the method of GHG accounting. Special conditions apply for RFNBOs that are imported into the EU. The ISCC system documentation 202-6 “Renewable Fuels of Non-Biological Origin” describes the corresponding requirements and methods for GHG emissions reductions and the corresponding limits in detail. /21/ In general, fuel suppliers must prove that they have adhered to sustainable production processes and GHG emissions reductions in line with RED II. The principle of “Well-to-Wheel” applies. /21/ There are three options available for recording GHG emissions:

1. The use of standard values specific to the raw materials and processes (according to RED II)
2. The use of disaggregated default values (according to RED II). These allow the use of a combination of default and actual values.
3. The use of actual values (calculation according to RED II)

3.1.9 Standard for the certification of hydrogen products (TÜV NORD)[10]

The “Standard for the certification of hydrogen products” described below is still in development at the time of writing. Therefore, the aspects listed here reflect the current state of progress and may not necessarily be part of the final, published version.

Description and purpose:
The aim of the “Certification of hydrogen products” standard currently being developed by TÜV NORD EnSys GmbH & Co. KG (TNE) is to provide certification for hydrogen products in view of aspects such as their climate neutrality, green characteristics and sustainability.

[10] Version: In progress (as of 30 August 2022)

The standard is being developed on the basis of the established “Standard for the verification of GHG emission statements and climate neutrality” (TN-CC 020 /154/). It is meant to serve as an extension for hydrogen and hydrogen products.

Status and applicability:
The TNE’s “Certification of hydrogen products” standard is currently in the development stage. It will be based on the most up-to-date regulatory frameworks and will thus ensure long-term and reliable applicability in the near future. /141/

Geographic scope:
The standard is to be applied worldwide.

Technical scope:
The scope of this standard in development is to enable the certification along the hydrogen value chains. It shall enable all “hydrogen owners” to have their hydrogen product certified as “climate-neutral, green and/or sustainable” by TNE in a multi-stage process. This standard defines hydrogen products as both pure hydrogen and hydrogen derivatives and hydrogen carrier substances.

Supply chain traceability:
The criteria for supply chain traceability are currently being developed. The results of the PCF calculation could be disclosed through a “carbon tag”. This would simplify the tracing, assessment and tradability across all interfaces of the value chain.

Target group(s):
The target group is expected to include all actors in the hydrogen product value chains – from production to consumption (“Well-to-Wheel”).

Certification criteria[11]:
The certification of “climate-neutral hydrogen” products shall be based on the calculation and offsetting of the PCF. Detailed requirements are derived from the “TN-CC 020” standard /154/.

The certification of “green hydrogen” products is also to be based on other requirements that relate to the hydrogen production process. Hydrogen production itself, and its energy supply in particular, will be tied to certain criteria and technologies that are aligned with RED II (/R 2/) and the draft del. act. (/R 15/).

[11] The certification criteria for hydrogen products’ green characteristics (green and sustainable) that are listed here will not necessarily be part of the final, published version of the standard and are currently in development.

A potential additional certification for "sustainable hydrogen" shall also include environmental and social standards. These could be modelled on the SDGs (/144/), for example, and might incorporate criteria for environmental and social responsibility, sustainable water use, waste and hazardous substance management, working standards, the inclusion of local businesses and gender equality.

The TNE's "Certification of hydrogen products" standard is also expected to define requirements for certificate holders. These could, e.g., relate to the use of measuring equipment for reliable material flow and electricity measurement (according to ISO 14040/ 14044 – life cycle assessment) and a monitoring system. This should meet the following criteria as a minimum:

- A reliable process to continuously monitor and ensure coverage between generation, conversion, storage and delivery.
- Exclusion of multiple sales.
- Recording and documentation of the incoming and outgoing flow of energy and materials.
- Integration into the operation's monitoring system.

3.2 Overview of the identified assessment criteria for the green characteristics of hydrogen products

Table 1 summarises the criteria for assessing the green characteristics of hydrogen products that we identified in the standards discussed in section 3.1 and provides an overview[12] of their differences and similarities.

The summary presented in Table 1 reveals that the criteria included in the considered standards vary significantly in some instances. The only criteria that most of the standards discussed above share relate to the GHG emissions reduction potential and the Guarantees of Origin for renewable electricity. Those standards thus comply with RED II.

However, in particular the requirements on sustainability, such as environmental and social criteria are only partially covered by the standards, thus entailing further need for action.

Only "ISCC EU & ISCC PLUS", "REDcert-EU & REDcert²" and the "RSB standard" already cover a large part of the criteria, although in some cases the criteria still need to be adapted to hydrogen products.

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[12] The version and categorisation of the assessment criteria is in line with the "Standards Map App" /120/.

		Certification systems[13]								
Assessment criteria		Low-Carbon Ammonia Certification	TÜV SÜD CMS 70	TÜV Rheinland Standard H2.21	CertifHy	REDcert-EU & RED cert[2]	RSB Standard	Hydrogen GO scheme for Australia	ISCC EU & ISCC PLUS	TNE Standard
Environment	Land use	(-)	-	-	(-)	+	+	(-)	+	(~)
	Water use	(-)	-	-	(-)	+	+	(-)	+	(~)
	Biodiversity	(-)	-	-	(-)	+	+	(-)	+	(~)
	Forests	(-)	-	-	(-)	+	+	(-)	+	(~)
	Inputs	(-)	-	-	(-)	+	+	(-)	+	(~)
	Waste	(-)	-	-	(-)	+	+	(-)	+	(~)
	Energy consumption/renewable electricity	(~)	+	+	(+)	~	~	(+)	~	(+)
	GHG emissions reduction potential	(~)	+	+	(+)	~	+	(~)	+	(+)
Social	Human rights	(-)	-	-	(-)	+	+	(-)	+	(~)
	Labour rights	(-)	-	-	(-)	+	+	(-)	+	(~)
	Local communities	(-)	-	-	(-)	+	+	(-)	+	(~)
Management and ethics	Economic viability	(-)	-	-	(-)	+	+	(-)	+	(~)
	Responsibility in the supply chain	(-)	-	-	(-)	+	+	(-)	+	(~)
	Ethics	(-)	-	-	(-)	~	+	(-)	+	(~)
Quality	Management system for products/services	(-)	+	-	(~)	+	+	(-)	+	(+)
Compliance with RED II		(-)	+	+	(+)	+	+	(-)	+	(+)
Legend		+: Criterion described extensively		~: Criterion described in parts		-: No description of criterion		(…): In development / Not yet applicable		

Table 1: Overview of the criteria mentioned in the standards discussed in section 3.1 for the assessment of the green characteristics of hydrogen products (see /120/).

[13] The standards under consideration were the versions mentioned in section 3.1.

3.3 Desirable sustainability criteria for a hydrogen product certification system

Section 3.3 discusses the desirable sustainability criteria for a certification system for hydrogen products.
Sustainability criteria have so far only been addressed sporadically in the standards considered above. However, the sustainability criteria listed in Table 1 should become part of certification systems of the green characteristics of hydrogen products in the long term. Among other things, these include: Sustainable water use, environmental compatibility, waste and hazardous substance management, social and working standards, supporting local businesses/value creation and education and gender equality. Requirements regarding the carbon source also need to be more clearly defined. The above criteria should be explicitly directed at the production of RFNBOs.

Sustainable water use:
Criteria for sustainable water use could be included and/or expanded, particularly in regions affected by water shortage /88/. RED II only refers implicitly to water consumption as part of financing requirements by advising to refrain from high water consumption /18/. Regarding the origin of water, however, it should be distinguished between surface water, groundwater, seawater desalination plants and potential wastewater produced during use. For example, water is also used as a cooling agent or to clean Concentrated Solar Power (CSP) or Photovoltaic (PV) plants. When these types of use are incorporated in the value chains of RFNBOs, they could also be included in the sustainability criteria. This means that requirements are needed that regulate the use of surface water and groundwater reserves in these regions. Certificate holders could specify the origin, use and reclamation of water as part of the certification process. In the case of seawater desalination plants, operators could also prove energy-efficient operation and a sustainable handling of residues from the process /82/. Residues could, for example, be further processed for raw material recovery /31/. Water shortage and an increase in water prices should not be intensified. /3/

Environmental compatibility:
Aspects of environmental compatibility could also be included in certification systems in order to ensure that the operation of hydrogen product plants does not negatively impact the environment. This could include criteria for land use (LUC/ILUC), as hydrogen production has both direct space requirements for operating sites of, e.g., electrolysers and indirect space requirements for the expansion of RE plants. The land and its productive ecosystems should not be in competition with other uses such as energy generation. RED II defines criteria for minimising the ILUC risk for biofuels only. These could also be applied to RFNBOs and biogenic carbon sources. It should not be permitted to use conservation areas of cultural

or environmental importance or regions contested under international law /18/, /3/. The production of biomass must demonstrably be socially and environmentally sustainable, and it should not be permitted to restrict local food production /31/. This could also apply to the hydrogen product supply chain.

Waste and hazardous substance management:
Certification systems could be expanded to include waste and hazardous substance management by drawing on environmental standards such as ISO 14001 and European environmental management systems (Eco-Management and Audit Scheme). Existing approaches could be adapted for RFNBO plants. Chemicals should be handled in an environmentally friendly way along the entire life cycle of the plants to protect human health and the environment /31/. It would also be sensible to require insurance or other securities when working with problematic substances along the entire value chain to compensate those affected by potential damage events. These should not be government-controlled instruments so as to decouple compensation from political interference as much as possible.

Social standards and labour standards:
Some of the standards discussed have implemented social and labour standards in accordance with ILO to a certain extent, but the standards could still be adapted for companies that operate RFNBO plants, as they are currently limited to the employment of workers in the area of biomass production. For example, companies could enable access to essential services, education, and medical support. They could ensure that workers’ rights are respected and guarantee fair contract terms and adequate payment. Forced labour, child labour and discrimination must be forbidden. /140/

Supporting local businesses / local value creation:
Certification systems could also encourage support for local businesses. They could help exporting countries create value within the country and reach the SDGs. This would encompass working with and supporting local businesses and workforce. The employment of local workers could include a particular focus on gender equality. Evidence for this could also be provided. /18/, /3/, /31/

Education:
Companies could support education on the ground. Both employees and the local population, children in particular, could be given access to education/training in the region. /140/

Carbon source:
Requirements for the various production processes of hydrogen products could be developed in connection with the origin or the required electricity. They could consider methane

and carbon emissions along the individual value chains. These include natural gas production, treatment and transport, and CO_2 capture, transport and storage. In addition, the safety and security of final storage could be ensured. /3/ The carbon used for the production of hydrogen products could be obtained from direct air capture, industrial emissions or biogenic CO_2. Criteria for avoiding double counting of CO_2 emissions could be defined in the standard. /31/

The potential use and fulfilment of such criteria needs to be discussed not only but in particular with a view to countries outside Europe. Due to differences in relation to sustainability between the EU and potential exporting countries for hydrogen products, we expect the implementation of such requirements to involve a big effort. In Europe, it can be assumed that the minimum standards in terms of environmental compatibility, social standards and resource use are largely met. This may not be the case in less regulated markets.

It should be noted that the points described above may be desirable within the scope of a holistic perspective on sustainability but may be in conflict with the objective of accelerating the ramp-up of the hydrogen market. Both objectives – accelerating hydrogen market ramp-up and the ambition of “real” sustainability – cannot currently be achieved simultaneously.

4 Requirements for recording and certifying of hydrogen products along the respective value chains

The fulfilment of the aforementioned aspects and criteria that ensure the green characteristics of hydrogen products should be guaranteed by reliable and tamper-proof evidence gathered with the help of suitable reporting processes.

Building on the criteria identified in Table 1 and the insights from sections 3.2 and 3.3, this chapter presents a model evidence catalogue. In addition, we prepare a checklist that contains suggestions for evidence management along hydrogen product value chains.

4.1 Proposal for an evidence catalogue for the verification and seamless tracking of the identified assessment criteria

As noted in section 3.2, Table 1 shows that the "ISCC EU & ISCC PLUS", the "RSB standard" and, in part, the "REDcert-EU & REDcert²" standards incorporate most of the identified criteria in their system.

Based on the identified criteria from Table 1 and the conclusions presented above, the following section illustrates how the requirements for hydrogen products' green characteristics that are defined and set out in RED II and, inter alia, as part of the ISCC system may be implemented. The selected green characteristics comprise the identified criteria from Table 1, which encompass the desirable sustainability criteria from section 3.3. These are as follows:

- A management system that covers the sustainability requirements in all operational areas and, for example, requires transparent documentation processes and the consideration of risk factors must be provided.
- The GHG emissions reduction potential of the hydrogen products produced (carbon footprint) must conform with the requirements set out in RED II.
- Criteria for carbon sources need to be defined as these are not yet sufficiently specified in RED II. Questions regarding admissible sources for RFNBOs and the correct calculation method for GHG emissions from these various sources need to be answered.
- The electricity consumed for hydrogen production processes must come from renewable energy sources.
- The criteria for the creditability of "green hydrogen", as defined in RED II and in the draft del. act., (direct connection, grid supply, additionality, geographical correlation, temporal correlation) must be met.

- Traceability of sustainability criteria and information on the transactions carried out for the EU database must be ensured in line with Art. 28 (2) of RED II.
- Sustainability criteria that consider different input factors and indirect effects within a certification system, which include:
  - a commitment to the protection of areas of high biodiversity value or with high stocks of carbon as well as of HCVAs (High Conservation Value Areas);
  - a commitment to environmentally friendly production and the protection of soil, water and air;
  - safe working conditions;
  - the observation of human, labour and land rights and responsible relationships to the communities;
  - compliance with laws and international contracts.

We identify the evidence required for each of the criteria listed above and present it in the form of a model evidence catalogue. This evidence catalogue, the listed criteria and the criteria for evidence are presented by way of example and may need to be adapted during the detailed preparation of any such catalogue. The evidence catalogue can be found in the annex (see Table A-1).

The evidence catalogue is based on already standardised or established verification documents that cover the aforementioned criteria and relate to the regulatory basis of RED II and the ISCC verification processes.[14]

Some criteria in the evidence management, however, still need to be improved. These criteria are listed below:

- It is currently difficult to establish consistent evidence for carbon sources as it is unclear which kind of carbon source is being used. So far, the focus of pertinent activities and discussions has been on “green hydrogen” while hydrogen produced using non-renewable sources in combination with CCS/CCU (“blue hydrogen”) has been given lower priority. Accordingly, suitable specifications need to be prepared for the area of “grey/blue/turquoise” hydrogen in good time to avoid any potential undesirable developments /3/. The RED II delegated act should provide more clarity by a) defining suitable minimum threshold values for GHG emissions savings through recycled carbon-based fuelsand b) by defining a method for the assessment of GHG emissions reductions through renewable liquid or gaseous RFNBOs.

[14] A detailed list of evidence that covers additional aspects as part of a full certification procedure can be found in the relevant “ISCC EU” & “ISCC PLUS” documentation /21/, /137/, /138/, /139/.

- The certification system to be defined must also outline which system of traceability may be used for production-related data. Many traded goods are well-suited to physically separated tracking of individual products all the way to the consumer. This is often necessary when the criteria have a direct impact on the material quality of the final product (e.g. organic food). In the long term, “green hydrogen” will develop into a commodity, in the sense of a homogenous good, as is already the case with the input factor of renewable electricity. These goods are not traceable, or are only traceable with a very high additional effort. This underscores the need for other accounting mechanisms that work despite different goods being irreversibly mixed /18/. A Book & Claim system would provide more flexibility, particularly during ramp-up of the hydrogen economy. This method enables trading with product certificates in a way that is disconnected from the physical product. The difficulty of this approach lies in the non-existent traceability of the certified product feature due to this physical decoupling /79/. Mass balancing, unlike the Book & Claim system, requires a physical link between the point of production and the point of consumption of renewable energy. The individual consignments must be in direct contact (i.e. in a container, a processing or logistical facility, a site, etc.) to prove physical traceability /8/. In the field of gas grids, the use of mass balance systems is a prerequisite in many applications. It is meant to ensure reliable and seamless traceability from production through injection into the gas grid, transport and sale to withdrawal from the grid. Several standards already use mass balancing to ensure the traceability of hydrogen products (see chapter 3.1). In any case there is further need for discussion to define which requirements are needed to guarantee seamless traceability of hydrogen products. /3/
- There are several input factors (such as water input) and indirect effects (e.g. land use for energy generation) of hydrogen products that need to be demonstrably verifiable. RED II includes a criterion for the land use for biofuels but nothing explicitly directed at PtX fuels. Equally, there is no explicit criterion for water consumption as yet. However, close attention should be paid to the sustainability of water consumption to enable the selection of suitable locations for hydrogen production and avoid adverse environmental impacts. Out of all considered standards, only “ISCC EU & ISCC PLUS” includes water consumption in GHG emissions. The criteria and evidence regarding biodiversity, land use, water use, working and social conditions that are listed in the evidence catalogue were all formulated according to the ISCC’s “Sustainability Criteria” and were originally developed for biomass. The ISCC is expected to adapt these criteria when the certification system will be extended to include RFNBOs.

4.2 Checklist for the verification of the assessment criteria

Building on the created evidence catalogue (Table A-1), we propose a model checklist for the verification of the assessment criteria in this section. This checklist is set out in the annex (see Table A-2). The checklist, the listed criteria and the respective verification process[15] are presented by way of example and may need to be specified and elaborated with sufficient nuance during the detailed preparation of any such checklist.

The assessment criteria included in the checklist along with the associated verification processes are structured along the value chains of “green hydrogenproducts. The hydrogen product value chains considered in this Expert Opinion can generally be divided into the following three subsections /145/:

1. Production
2. Storage, conversion, transport and distribution
3. Final consumption

The subsection of production contains hydrogen electrolysis. Building on this, the second and third subsections vary depending on the concerned hydrogen product value chain. For example, transport and subsequent distribution can occur through a pipeline or by sea. Another alternative that would be part of the hydrogen value chain would be conversion into LOHC, storage and transport. Pure hydrogen or hydrogen products such as methane and ammonia may finally be consumed in the mobility, industrial, building or electricity sector. Hydrogen products such as methane and ammonia need to be converted before final consumption.

The checklist underscores that a lot of criteria along the entire value chains of hydrogen products need to be taken into consideration. Only the assessment criteria for renewable electricity and the creditability of “green hydrogen” relate only to one part of the value chain – the production of hydrogen. Some of these criteria have already been established and standardised, providing a clear methodology with well-defined system boundaries for their verification.

All other criteria encompass at least two sections of the value chains. This does not hinder the establishment of a certification process. Because of this high complexity of hydrogen product value chains, any future standard should allow both the certification of the entire supply chain and the certification of subsections. Nonetheless, comparable and standardised certification also requires clearly defined accounting limits precisely because of this complexity.

[15] Detailed information on the verification process can be found in the “ISCC EU & ISCC PLUS” standards /21/, /137/, /138/, /139/.

In addition to clearly set accounting limits, it is essential that suitable data can be obtained for evidence management. The following chapter 5 analyses and evaluates, by way of example, the evidence catalogue in terms of the availability and reliability of data in the hydrogen product export countries specified by the Client.

5 Outlining an international hydrogen product certification system

Chapter 5 analyses potential hydrogen product exporting countries in view of possible EU imports, based on the cited sources. Our analysis focuses on Tunisia, Egypt, Colombia, Namibia and Australia, as requested by the Client.

We first provide a brief indicative and qualitative analysis of the political situation, the (potential) hydrogen strategy, the known hydrogen partnerships, hydrogen's prime costs, the speed at which a hydrogen economy could be ramped up and the situation in terms of RE plants, sustainability and infrastructure in the aforementioned countries.

The central question of this chapter is whether the aforementioned countries are able to achieve fast market adaptation for certified hydrogen products. Based on the brief country analysis we will then specifically investigate the countries' existing hydrogen strategy, their market design and potential available controlling bodies for hydrogen.

And in section 5.3 we will describe - based on the insights from the analysis - a gradual certification system that would allow low-threshold entry for market participants into a hydrogen economy secured through certification.

5.1 Brief analysis of potential hydrogen product exporting countries

Section 5.1 qualitatively assesses the countries specified by the Client – Tunisia, Egypt, Colombia, Namibia and Australia – in relation to the following aspects:

- Political situation[16]
- H_2 strategy
- H_2 partnerships
- RE plants
- Sustainability
- Infrastructure
- Speed of ramp-up
- Costs[17]

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[16] The analysis of the political situation takes into account, among other things, the Human Development Index (HDI), the Corruption Perceptions Index (CPI) and the Press Freedom Index. More detailed information on the named indexes can be found in the annex.

[17] The analysis discusses the prime costs for water. The prices are approximate and only offer limited comparability as they rely on different sources. All costs mentioned in this section have been taken from the cited sources. We have not carried out any independent calculation, evaluation or examination of the costs cited in the sources. The cited costs may deviate from the actual costs.

The assessment of the political situation takes into account, among other things, the Human Development Index (HDI), the Corruption Perceptions Index (CPI) and the Press Freedom Index. The aspects of hydrogen strategy and hydrogen partnerships reflect the level of advancement of a national hydrogen economy in the respective country at the time of writing this Expert Opinion. The aspect of RE plants considers the current state of renewable energy generation in the respective countries. The aspect of sustainability also summarises the environmental and social situation. The aspect of infrastructure relates to the existing exporting infrastructure. This includes ports with LNG terminals that could in future be equipped for the transport of hydrogen products and gas pipelines that could be converted. The aspect of ramp-up speed will finally compare the possible timing and implementation of future hydrogen product exports.

Our research on the potential exporting countries is based on publicly available information and exclusively reproduces the statements made therein. We have cited a minimum of one reliable source. The information given in the cited sources has not been verified.

5.1.1 Tunisia

Political situation:
Tunisia is a semi-presidential republic. The country is politically unstable and has had a democratic constitution since 2014, which was annulled, however, by a constitutional referendum in July 2022. /33/, /95/

In 2019 the country ranked 95th out of 189 countries in the HDI index with a value of 0.74. This places Tunisia in the category “high human development”. /32/

The degree of freedom of the press in Tunisia was given as 29.53 points for 2021 according to /34/. This places the country on rank 73 out of 180. The country ranked 70th out of 180 countries in terms of corruption with a CPI of 44 in 2021 /35/.

In Tunisia, democracy and rule of law were made ineffective through a one-sided constitutional process. Within a year, resident Saied annulled the constitution from 2014, dissolved parliament, restricted the independent judicial system and made changes to the once independent electoral commission. The process to legitimise the new constitution has been designed in a way that reflects the will of the president and further expands his power. There is no authority that controls the president or could unseat him. Following the change in constitution in Tunisia, NGOs fear the return of an authoritarian system. /36/, /95/, /110/

H_2 strategy:
The Tunisian economy has seen initial discussions and alliances on the subject of PtX. However, this is still in the early phase of development. An initial study on the potential of

PtX in Tunisia was conducted in 2021. Its RE potential and the availability of labour mean the country has potential to become a producer and exporter of PtX products. /39/

H_2 partnerships:
In 2021, the German Federal Ministry for Economic Affairs and Climate Action (ger. *Bundesministerium für Wirtschaft und Klimaschutz*, BMWK) instigated a German-Tunisian energy partnership on the topic of the expansion and system integration of RE for the purpose of energy efficiency and on the topic of hydrogen. Since December 2020, a German-Tunisian alliance has been working on the development of the PtX sector. A PtX pilot plant financed by the KfW with a capacity of up to 10 MW is being planned (expected start of construction 2022/2023). /37/

In addition, the German Federal Ministry for Economic Cooperation and Development (ger. *Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung*, BMZ) has guaranteed the Tunisian government a grant of 25 million € for a project to encourage knowledge transfer and to construct demonstration plants for the production and processing of "green hydrogen". /38/

RE plants:
The current share of renewable energy generation is very low in Tunisia. In 2019, it was below 3%. Energy generation is dominated by fossil fuels. However, the government adopted the "Tunisian Solar Plan" in 2010 with the aim to reach a 30% share of renewables in energy generation by 2030. The country receives over 3,000 hours of sunshine a year. It also has several areas that are suitable for wind farms, with wind speeds reaching over 7 m/s. However, this expansion is only happening very slowly. This can be traced back to various obstacles, including slow administrative and approval procedures, long delays when it comes to project execution, difficulties accessing land or the lack of government guarantees. All these challenges represent a high investment risk. A law for the use of PPAs was introduced in 2019, but investors and local banks still do not consider PPAs to be creditworthy under the authorisation scheme. This increases insecurity among project developers assessing whether to invest in major projects and delays expansion. Despite the large potential, the country has not yet completed any large solar generation projects, as set out in the "Tunisian Solar Plan". /39/, /40/

Sustainability:
Tunisia has a seawater desalination plant that is located on the southern island of Djerba. However, the production of hydrogen on a scale suitable for exports will require a substantial increase in capacity /41/. In 2015, Tunisia agreed to reduce its GHG emissions in all sectors as part of the Paris Climate Agreement. This objective was increased in October 2021: The country now aims to reduce its GHG emissions by 45% compared to the base year of 2010

by 2030. CO_2 emissions have risen by 30% since 2005. In 2018, the country emitted 26 million tCO_2; in the base year 2010, it was 25 million tCO_2. /39/, /102/

Infrastructure:
The “Trans-Mediterranean Pipeline” (TransMed for short) used for transporting natural gas could potentially be converted for exporting hydrogen products. The length of this pipeline is 155 km between Tunisia and Sicily. From Italy, hydrogen products could then be transported on to Germany and other EU member states. There are currently no plans to invest in commercial vessels for transporting hydrogen out of Tunisia. /91/, /92/

Speed of ramp-up:
There have been some initial discussions about potential PtX projects during conferences of the German-Tunisian Energy Partnership, but no specific projects have yet been launched /39/. No further information on the time schedule has been provided.

Costs:
The hydrogen prime costs in Tunisia are estimated at 4 €/kgH_2 for 2030. Technological progress is expected to reduce prime costs to 2 €/kgH_2 by 2050. /86/

5.1.2 Egypt

Political situation:
Egypt is a republic and a presidential democracy. Abdel Fattah a-Sisi has held the office of head of state since 2014, a position he attained after a military coup in 2013. Since then, the scope for action for civil society and the political opposition has been increasingly limited. Added to that, a country-wide state of emergency was announced after the terror attack in April 2017, which opened the doors to the limitation of fundamental constitutional rights. This state of emergency is currently being extended every three months. /43/

Changes to the constitution that enabled an extensive encroachment into the separation of powers, increased support for military control over civil life and extended the term of office of the president (from 4 to 6 years) came into force in April 2019. /44/

In 2019 the country ranked 116th out of 189 countries in the HDI with a value of 0.707. Egypt is assigned to the category “high human development” /45/. The degree of freedom of the press in Egypt was given as 56.17 points for 2021 according to /34/. This places the country on rank 166 out of 180. The country ranked 117th out of 180 countries in terms of corruption with a CPI of 33 in 2021 /35/.

H_2 strategy:
Egypt has agreed on a national hydrogen strategy, which has not yet been published. Initial production capacities for hydrogen production and use are planned for the near future.

"Green hydrogen" is supposed to be integrated into the national energy system. This will involve various international partnerships. A hydrogen working group was formed in December 2020. It conducted a study on the cross-sector relevance of hydrogen technology. The study analyses the production and consumption possibilities for hydrogen products. It sees ammonia and methanol as potential carrier substances for hydrogen export and plans to distribute molecular hydrogen nation-wide by pipeline. /51/

H_2 partnerships:
Agreements with international businesses for the production of "green ammonia and hydrogen" were signed in April of this year. AMEA Power (a developer from Dubai) and SFE (Sovereign Fund of Egypt) are collaborating on the construction of an ammonia plant that is projected to produce 390,000 t a year. Several international consortia have announced their interest in "green hydrogen" plants in the SCEZ (Suez Canal Economic Zone). The SCEZ is an autonomous body with executive/regulative powers. It is authorised to approve decrees and has full authorisation to oversee all questions relating to operation, staffing, budgeting, financing, the development of partnerships and the provision of services to support businesses. The United Arab Emirate's renewable energy company Masdar and the Egyptian company Hassan Allam Utilities are planning to build a plant with a production capacity of 480,000 t of hydrogen a year. The ammonia producer Fertiglobe and the corporation Orascom Construction, supported by the Norwegian energy supply company Scatec, are working on a project that is expected to come into operation in 2024. The French energy company Total Eren has signed an agreement with the authorities to construct an experimental project for the production of "green hydrogenproducts in the Suez Canal. This includes building an environmentally friendly ammonia plant in the SCEZ. The project has initially targeted a production capacity of 300,000 t ammonia a year. This should later be increased to 1.5 million t. Specific information on the time frame and costs is not publicly available. /46/

This year, another partnership was formed between Maersk and Egyptian authorities. A feasibility study for environmentally friendly fuels to examine the production of hydrogen and green marine fuel is planned before the end of 2022. As the first buyer, Maersk is set to receive green methanol from 2024. /48/

Mitsubishi Power signed an agreement with the leading Egyptian oil and gas refinery ANRPC in June 2022 to reduce emissions by converting hydrogen into fuel. /47/ Germany and Egypt also have plans for a hydrogen partnership. /114/

RE plants:
The share of RE in the energy supply in 2019 was 5% /49/. In September 2014, the government published a law for renewable energy to help reach its expansion targets with four

mechanisms: State-owned projects with tenders for engineering, procurement and construction contracts, tenders for build-own-operate contracts and a trading scheme. Since then, 30 project companies have successfully signed PPAs with the Egyptian distribution system operator. /83/

The Authority for Renewable Energy has also signed a contract for a PV plant with a capacity of 50 MW to be built in the Zafaran region. This favours the national strategy’s goal of increasing the share of renewables to 42% in 2035. The solar energy potential is very good with an annual global irradiation between 1,900 and 2,600 kWh/m^2 /42/. The country also has a high wind potential and could eventually become one of the largest producers of RE. /50/, /51/ As 95% of the country’s surface is covered by desert, RE expansion must also make use of desert areas. These are difficult to develop, have special design requirements and need power lines. /43/

Sustainability:
Egypt is one of the most arid countries in the world. It rains rarely and groundwater reserves are low. /118/ One solution for generating water for the production of hydrogen through electrolysis is the use of seawater desalination plants. These could be used to counteract additional water stress.

The national strategy for climate change “Strategy 2030” does not define a quantifiable CO_2 emissions reduction goal. In 2021, at the 26th UN climate conference (26th Conference of the Parties – COP26), Egypt announced that it had developed its national strategy for climate change “Strategy 2050”. COP26 brought together countries to accelerate action towards achieving the goals of the Paris Agreement and the UN Framework Convention on Climate Change. The strategy includes targets regarding a sustainable economy, improving climate financing and strengthening research and education. By 2030, the country aims to reduce 33% of GHG emissions in the electricity sector, 65% in the area of oil and gas and 7% in the transport sector compared to 2015. /81/, /106/, /107/, /113/

Infrastructure:
Several national projects in the areas of infrastructure, energy and transport aim to strengthen the country’s economy. RFNBOs are expected to be transported by sea as no pipelines towards Europe exist. There is one LNG export terminal in Idku near Alexandria and one LNG export terminal in Damietta near Port Said. These export harbours could be developed for hydrogen products. The well-developed national natural gas grid could also be adapted to support the transport of hydrogen. /52/

Plans for the future production of LOHC at East Port-Said in the SCEZ were announced this year. LOHC is also suitable for transport to the EU. /125/

Speed of ramp-up:
The current state of the energy supply with a low share of renewables means that “grey and blue hydrogen products” could be produced in the short term. Commissioning of the first production plants is planned for 2024. /52/

Costs:
The costs of hydrogen vary depending on the production technology and there is no precise information available on a time frame for achieving the following prices. “Grey hydrogen” is expected to cost 1.2 €/kgH_2[18] in the future, “blue hydrogen” is estimated to come in at 1.6 €/kgH_2[1] and the price of “green hydrogen” is forecast as 5.4 - 6.4 €/kgH_2[1]. Should the prices for renewable energy drop, “green hydrogen” is predicted to cost 1 - 1.8 €/kgH_2[1] in 2050. /52/, /87/

5.1.3 Colombia

Political situation:
Colombia is a presidential democratic republic. The country has been marked by a conflict with guerrilla groups that continued for 50 years. In 2016, the government at the time signed a peace agreement with the largest guerrilla group, FARC, which is still valid today. The level of violence in Colombia has dropped overall since the agreement came into effect. However, social protests persist due to social injustices within the population. Gustavo Petro, previously a guerrilla fighter himself, is the current president of Colombia. /67/, /68/

In 2019, Colombia ranked 83rd out of 189 countries in the HDI index with a value of 0.767. The country is assigned to the category “high human development” /69/. The degree of freedom of the press in Colombia was given as 130 points for 2021 according to /34/. This places the country on rank 134 out of 180. The country ranked 87th out of 180 countries in terms of corruption with a CPI of 39 in 2021 /35/.

H_2 strategy:
Colombia has a hydrogen roadmap to 2030. It was developed to promote regulatory and legal framework conditions, market development instruments, infrastructure development and general technological and industrial development. The roadmap envisions an electrolysis capacity of 1-3 GW by 2030, which requires the commissioning of 1.5-4 GW of renewable energy. It also plans for 50,000 t of hydrogen to be produced from fossil sources with CCU/CCS (“blue hydrogen” products) by 2030. Industry is expected to consume 40% of “climate-neutral hydrogen”. The hydrogen roadmap sees “low-carbon hydrogen” becoming competitive in many areas of application in the period between 2030 and 2050, including

[18] (conversion factor 1 USD = 0.98 €; as of 5 August 2022)

export. /70/ The state-owned energy corporation Ecopetrol is planning a 50-kW electrolyser in the port of Cartagena. The hydrogen produced there is planned to be used for oil refining. /73/

H_2 partnerships:

A Bavarian hydrogen delegation is intensifying its bilateral partnership with Colombia with the aim of encouraging a hydrogen partnership. Ecopetrol is a central actor in Colombia's hydrogen initiative and has been collaborating with the delegation from the German federal state of Bavaria. /85/

RE plants:

Around 75% of the energy used in Colombia currently comes from fossil fuels. The remaining share is generated from biomass and hydropower. There is no significant energy generation from solar power or wind, for example. However, the government has passed several laws to encourage the expansion of RE. It has also decided to introduce tax relief for RE. While potential for onshore and offshore wind energy plants is very high, its level of expansion was very low until 2017 (with 1.2% of electricity coming from wind). The country also has high potential for solar power generation. The generation costs for PV and wind power are low at < 29 €/MWh[19] /71/, /72/, /75/

The long-term financial viability of RE is secured through auctions and PPAs in Colombia. /75/ The country introduced a carbon tax in 2017 (4.9 €/t$CO_{2,eq}$[1]). An Emissions Trading System (ETS) is being developed. /74/, /73/

Sustainability:

Colombia has decided to reduce the country's GHG emissions by 20% by 2030 /72/. The country has a high water supply. Colombia is one of the regions with the highest rainfall worldwide and has many rivers. /76/

Infrastructure:

The Sociedad Portuaria El Cayao LNG terminal is the only importing facility in Colombia. It has been in operation since 2016. The terminal includes a natural gas pipeline system to distribute the gas across the country. The port of Cartagena could be expanded to export hydrogen to Europe. /77/

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[19] (conversion factor 1 USD = 0.98 €; as of 5 August 2022)

Speed of ramp-up:
Colombia plans to produce competitive hydrogen from 2030. The first step is to produce “blue hydrogen”. Between 2030 and 2050, the country plans to export its hydrogen to other countries based on increasing demand and production volumes. /70/

Costs:
The prime costs for “green hydrogen” production in Colombia are forecast to reach 0,8 - 1,2 €/kgH_2[20] in 2050, depending on the scenario. /87/

5.1.4 Namibia

Political situation:
Namibia is a politically stable presidential democracy with legal certainty and good infrastructure. /53/, /54/ Human rights are largely respected in Namibia and judicial independence is ensured. In a long-term development strategy, the country set itself the goal of reaching the standard of living of an industrialised country by 2030. /55/

In 2019, Namibia ranked 130th out of 189 countries in the HDI index with a value of 0.646. The country is classed into the category “medium human development” /56/.

The degree of freedom of the press in Namibia was given as 23 points for 2021 according to /34/. This places the country on rank 24 out of 180. The country ranked 58th out of 180 countries in terms of corruption with a CPI of 49 in 2021 /35/.

H_2 strategy:
The Namibian government has a national hydrogen strategy and has created a website that serves as an information platform /112/. A report of the Namibian government provides an overview of the current developments and future plans in relation to “green hydrogen” /57/. Four potential hydrogen production regions have been identified in the country. The first development is the Southern Corridor Development Initiative (SCDI) in the Karas region. Namibia established a Green Hydrogen Council in May 2021. The government of Namibia then published an invitation to tender for the first two locations (Dolphin and Springbok) in the SCDI project in June 2021. The first project, Hyphen, is projected to produce approx. 300,000 t of “green hydrogen” for regional and global markets by the end of this decade. Production is expected to start in 2026. The project has been divided into two phases. The first phase will see up to 700,000 t of ammonia produced annually. In the second phase, production will increase to 1,700,000 t of ammonia per year. /57/

The Namibia Green Hydrogen Research Institute develops strategies and researches possibilities for end use and environmental compatibility in order to increase consumption of

[20] (conversion factor 1 USD = 0.98 €; as of 5 August 2022)

hydrogen within the country. Offshore wind turbines are also being planned near ports and electrolysers. /57/

H_2 partnerships:

In August 2021, the German Federal Ministry of Education and Research (ger. *Bundesministerium für Bildung und Forschung*, BMBF) and the Namibian government signed a declaration of intent to develop a German-Namibian hydrogen cooperation. The BMBF is supporting these plans with a financial contribution of up to 40 million €. This should finance feasibility studies, pilot projects and a grant programme for experts and students. First pilot projects are set to begin in 2022. /55/ Cooperation agreements were also signed with the port of Rotterdam and with Belgium in November 2021. /57/

RE plants:

The conditions for wind and solar power generation are very good in Namibia. The country receives over 3,500 hours of sun a year. According to the Energy Sector Management Assistance Program (ESMAP) and the World Bank, Namibia has an offshore wind potential of over 720 GW. The country plans to install renewable power plants with a total capacity of 5 GW by 2030. The first plants with a capacity of 2 GW should be commissioned by January 2027. Other RE plants, financed through PPAs, are also being planned. By 2030, Namibia plans to produce a minimum of 70% of electricity generated in the country from renewable energy sources. /57/, /93/, /108/

Sustainability:

The focus of the Namibian government's national development plan is on structural change and modernisation, which in turn is based on four pillars: economic development, social transformation, environmental sustainability and good governance. Namibia has also formulated objectives to fulfil the Paris Climate Agreement and strives to develop an economy that does not harm the climate. The updated objectives envisage an emissions reduction of 91% by 2030 compared to 2015. /55/ /103/

The hydrogen strategy aims for a proportion of 90% of Namibian employees during the phases of construction and operation of hydrogen products. This will create new jobs and increase the income level among the general public, which in turn is hoped to increase public acceptance for the project. The government expects to achieve an annual income of over 780 million € /57/

Namibia is one of the driest countries of the sub-Saharan region, which makes seawater desalination necessary for hydrogen production. The first hydrogen projects were assigned approx. 4,000 km^2 of land in the Tsau/Khaeb national park as part of a tendering procedure in which both international and regional project developers participated. /55/, /57/

Infrastructure:
Namport, the operator of the two Namibian deep-water ports, earmarked 350 hectares of land in Walvis Bay North Port for the establishment of industries related to "green hydrogen". Luderitz Port, Oranjemund Port and New Port are also included in planning. /57/

There are plans to construct a hydrogen city at the edge of the desert in southern Namibia, along the coast to the north-east of Luderitz. A LOHC storage system is supposed to provide a constant power output. An international LOHC port for ships is also being designed. /125/

Speed of ramp-up:
The first export is planned to take place in 2024. The Hyphen project will be moving into its second project phase in 2026, during which electrolysis capacity is set to increase to 1,200 MW. The share of ammonia produced in a green process will also increase. /57/

Costs:
The cost of "green hydrogen" is predicted to be 1.5 - 2 €/kgH_2 in future. The cost of "green ammonia" is expected to be below 390 €/tNH_3[21] by 2030. /55/, /57/

5.1.5 Australia

Political situation:
Australia is a constitutional monarchy with a vibrant western-style democracy and very high living standards. It has very few trade restrictions. Free-trade agreements exist with China, the USA and Asian neighbours. Australia is currently negotiating a free-trade agreement with the EU to further strengthen economic exchange. /59/, /84/

In 2019 Australia ranked 8 out of 189 countries in the HDI index with a value of 0.944. The country is classed into the category "very high human development". /60/

The degree of freedom of the press in Australia was given as 26 points for 2021 according to /34/. This places the country on rank 25 out of 180. The country ranked 18th out of 180 countries in terms of corruption with a CPI of 73 in 2021 /35/.

H_2 strategy:
Australia has a national hydrogen strategy. It aims to become a global player in the hydrogen economy by 2030. The strategy examines future hydrogen scenarios and has been designed in a way that allows Australia's hydrogen economy to expand quickly while also being able to respond to external influences flexibly. It outlines country-wide coordinated measures

[21] (conversion factor 1 USD = 0.98 €; as of 5 August 2022)

that involve government, industry and local authorities. Australia has enough resources to provide the entire country with hydrogen and to additionally export to other countries (such as Germany). The government plans to invest 1 billion €[22] in the hydrogen industry /61/

H_2 partnerships:

Last year, Australia and Germany signed a declaration of intent for a hydrogen agreement. This led to the initiative HyGATE (German-Australian Hydrogen Innovation and Technology Incubator) which consists of pilot, trial, demonstration and research projects along the hydrogen value chains. Australia and Germany have each provided up to 50 million € for this initiative /111/. The focus is on opportunities for trade with hydrogen products from RE (e.g. ammonia). /111/

The agreement, including partnerships with Singapore and Japan, covers an investment volume of 555 million €[23]. These planned expenditures of the Australian government will encourage new international technology partnerships and investments in Australian projects and create up to 2,500 jobs. /64/

RE plants:

The country generated over 24% of its electricity from RE in 2020. This high percentage can be traced back to the installation of solar plants. Solar energy currently contributes 9% of total energy generation, making it the largest renewable energy source. The country also has one of the highest potentials for power generation from wind worldwide. Several Australian solar and wind farms are already financed by PPAs. The last few years have seen more and more small consumers entering the market and a growing number of power purchase agreements being set up. /62/, /94/ Government forecasts assume that the share in renewables will grow to over 50% by 2025 and reach 69% in 2030. /63/

Sustainability:

Australia has pledged to reduce its GHG emissions by 43% compared to 2005 by 2030 according to its updated “Nationally Determined Contribution”. /104/ The hydrogen strategy also takes into consideration the environmental impact of using electricity from hydropower for the production process of hydrogen products.

Australia is developing a Guarantee of Origin scheme for “climate-neutral and “green hydrogen” (see 3.1.7). By producing “climate-neutral hydrogen”, the government hopes to create about 7,600 new jobs and to lower energy costs. This “climate-neutral and green hydrogen” should also reduce emissions. /61/

[22] (conversion factor 1 AUD = 0.69 €; as of 5 August 2022)
[23] (conversion factor 1 USD = 0.98 €; as of 5 August 2022)

The hydrogen industry requires very little water compared to the water consumption of Australian mines. However, the limited availability of the resource means that Australia has to set priorities when it comes to water distribution. Growing need can be covered through water treatment or seawater desalination plants. The additional costs are estimated at 0.03 €/kgH_2[24]. The production of hydrogen products also requires transparent proof that safety regulations to avoid environmental hazards have been complied with. /61/ /65/

Infrastructure:
Australia's most important export goods include coal and natural gas /58/. The country intends to add hydrogen to this list. By the end of 2022, hydrogen infrastructure will be assessed with respect to the electricity grid and gas network, the water supply network, filling stations, roads, rail and ports. Australia is experienced in the export of energy goods (black coal and natural gas) and feels well positioned for exporting hydrogen products. The country currently exports LNG worth 50 billion € a year and, together with Qatar, is one of the largest LNG exporters worldwide. The region of New South Wales has significant developed black coal reserves and well-established international-scale ports. Moreover, Newcastle and Port Kembla are seen as potential export ports for hydrogen. /61/

LOHC transport would be most suitable for covering the distance between Australia and the EU because cryogenic transport for the duration of several days or weeks is currently hardly feasible from a technical point of view. /126/

Speed of ramp-up:
Initial demonstration projects that produce hydrogen using RE are already underway or in planning. These include a renewable energy hub as part of the Toyota Ecopark Hydrogen, which produces renewable hydrogen for the transport sector and stationary applications /61/. Studies investigating exporting to Japan are also in progress. The plan is to produce renewable hydrogen near Gladstone (Queensland) and use a liquefaction plant at the Port of Gladstone to prepare it for transport. The facility should produce approximately 100 t of "green hydrogen" per day by 2026 and increase production to 800 t per day by 2031. Up to 3 GW of electrolysis capacity are to be installed to this end. /66/

Costs:
The prime costs for hydrogen production in Australia are forecast to reach 0.8 - 1.4 €/kgH_2[25] in 2050, depending on the scenario. /87/

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[24] (conversion factor 1 AUD = 0.69 €; as of 5 August 2022)
[25] (conversion factor 1 USD = 0.98 €; as of 5 August 2022)

5.1.6 Analysis of potential hydrogen product exporting countries in view of fast market ramp-up for certified hydrogen products

Table 2 shows a comparison of the countries discussed above and the relevant assessment criteria for potential hydrogen product exporting countries. We have qualitatively assessed the various aspects with the symbols "+", "-" and "~". "+" indicates that an aspect is considered positive, "-" indicates that it is considered negative. "~" means that the aspect can be viewed in a nuanced way and cannot be clearly assigned, for example because positive developments are already emerging but have not yet been fully achieved.

	H_2 strategy	H_2 partnerships	Infrastructure	RE plants	Speed of ramp-up	HDI	Sustainability
Australia	+	+	+	+	+	**0.944**	+
Namibia	+	+	~	+	+	**0.646**	~
Colombia	+	~	~	-	~	**0.767**	~
Egypt	-	+	~	-	~	**0.707**	~
Tunisia	-	+	+	-	-	**0.740**	~
Legend	+: Positive		~: Partly fulfilled / in development			-: Negative	

Table 2: Summary of country profiles.

Table 2 shows that Australia fulfils the most aspects of all the countries discussed. Namibia and Colombia both have a hydrogen strategy, but they do not currently meet all the infrastructure, technical and political requirements. Egypt and Tunisia are grappling with similar challenges. Both countries are only now starting to develop a national hydrogen roadmap.

Other factors in addition to the aspects considered in the country profiles also influence fast market ramp-up for certified hydrogen products. On the one hand, the composition of the energy market has a decisive impact on market adaptation in the countries defined by the Client. This includes, for example, the question of RE market design and whether this can also be adapted to hydrogen. On the other hand, suitable national regulation can help lay the groundwork for fast market ramp-up. It needs to be clarified whether funding programmes for RE and hydrogen are available or are being developed, as well as whether public institutions already exist.

These aspects and the countries' published hydrogen strategies are outlined in Table 3.

			Exporting countries				
			Australia	**Namibia**	**Colombia**	**Egypt**	**Tunisia**
Aspects	**Energy market**	Market design	Australian Energy Market Commission	Electrical Control Board	CREG - Comisión de Regulación de Energía y Gas	No data	Société Tunisienne de l´Electricité et du Gaz
		Guarantee of origin	Yes; in development	No data	Currently being investigated	No data	No data
	Regulations	Incentive systems	• Small-scale Renewable Energy Scheme (SRES) • The Large-scale Renewable Energy Target	Environmental Investment Fund of Namibia	In development	GAFI – General Authority For Investments	No data
		Funding schemes	Clean Hydrogen Industrial Hubs program	Namibian Green Hydrogen and PTX Pilot Projects Program	FENOGE - Fund for Non-Conventional Energies and Efficient Energy Management	No data	PROSOL programme
		Governance	ARENA – Australian Renewable Energy Agency	Green Hydrogen Council	UPME - Mining and Energy Planning Unit	• MOP – Ministry of Petroleum and Mineral Resources • MERE – Ministry of Electricity and Renewable Energy	MIME – Ministry of Industry, Mines and Energy
	H_2 strategy	Available	Yes	Yes	Yes	In development	Unknown
		Partnerships, funding, exporting countries, timeline, certification	**Partnerships:** • Global Green Growth Institute (GGGI) • International Association for Hydrogen Safety (HySafe) • Green Ammonia Consortium **Exporting countries:** • Japan, South Korea, Great Britain, New Zealand, Germany and the European Union **Certification:** • The European CertifHy framework is being taken into consideration for the development of a certification system	**Partnerships:** • BMBF • Port of Rotterdam • Belgium **Timeline:** • Commissioning of green H2 demonstration facility (2023) • HYPEN phase 1 (2024)	**Timeline:** • Phase 1: Existing applications (2020 → 2026) • Phase 2: Emerging applications (2027 → 2035) • Phase 3: Disruptive applications (2036 → 2050)	**No**	**No**

Table 3: Overview of additional aspects in view of fast market ramp-up for certified hydrogen products /121/, /122/, /123/, /124/, /61/, /57/.

Table 2 and Table 3 illustrate that Australia currently has the greatest potential as an exporting country for hydrogen products based on the evaluated sources and in terms of the selected criteria. The country has a stable political system and an existing hydrogen strategy. The hydrogen strategy includes aspects such as timeline, exporting countries, partnerships, certification, a volume target and the type of funding for hydrogen products. Australia already possesses an existing electricity and gas market with an established market design. The country also intends to make proof of the hydrogen production process available through a certification system. A ministry for hydrogen and existing incentive systems and funding schemes for hydrogen projects are expected to drive market ramp-up.

Namibia offers good potential as an exporting country for hydrogen products in the medium term based on the evaluated sources. The country possesses the natural, regulatory and political prerequisites for a market ramp-up for hydrogen products. The government has founded a hydrogen council tasked with advancing market ramp-up through the development of funding schemes and incentive systems. Namibia has also published a hydrogen strategy. In it, the country describes partnerships, funding for hydrogen products and volume targets. It also includes a planned timeline for hydrogen projects and project locations.

Based on the evaluated sources, Colombia has potential to establish itself as an exporting country for hydrogen products in the long term. The government of Colombia has set up a planning unit to address the question of hydrogen. Funding schemes are already available, but incentive systems are still being developed. The country has an electricity and gas market with an established market design and a hydrogen strategy with a defined timeline. The first step of market ramp-up is to produce "blue hydrogen". The country is also investigating the possible implementation of a Guarantee of Origin scheme for hydrogen products.

Egypt and Tunisia are both still at the start of becoming hydrogen product exporters when directly compared to the other countries in this report. Both countries currently lack the necessary requirements in terms of infrastructure, technology and the political landscape. Governmental departments in both countries are tasked with addressing the question of hydrogen. Egypt is currently working on a hydrogen strategy and already possesses incentive systems for hydrogen products. Tunisia, on the other hand, does not have incentive systems but has introduced funding schemes.

In summary, Australia can be seen as the benchmark for fast market ramp-up. The question of whether certification of hydrogen products is feasible should not impact market ramp-up for Australia as an exporting country. Namibia and Colombia have their own hydrogen strategies and an established electricity and gas market with market design. A robust certification system could be implemented, even though there are technical, infrastructural and political challenges in both countries. Market ramp-up is currently expected to be most drawn-out in

Egypt and Tunisia. Both countries are only now starting to develop a national hydrogen roadmap. A certification system would only further slow down market ramp-up.

5.2 Minimum requirements for rapid market development with regard to the export of hydrogen products

Our analysis of the initial situation of potential exporting countries for hydrogen products shows that the preconditions for fast market adaptation for certified hydrogen products vary.

This section builds on assessment criteria identified in Table 1 and on the proposed evidence catalogue (Table A-1) to evaluate and assess the feasibility of the criteria in the target countries defined by the Client, on the basis of information gained from the sources at hand.

Our assessment is based on the country profiles and on the analysis from section 5.1. A criterion is deemed "testable" if the necessary conditions for implementation are given on a fundamental level. It is considered "partly testable" if first steps towards its fulfilment have been taken and its fulfilment will be made possible in the foreseeable future through current discussions, plans or preparations. A criterion is deemed "not testable" if the local conditions do not meet the requirements.

Assessment criterion	Australia	Namibia	Colombia	Egypt	Tunisia
Management system	+	+	+	+	+
GHG emissions reduction potential	+	+	+	+	+
Criteria for carbon source	~	~	~	~	~
Consumption of electricity from RE	+	+	+	+	+
Sustainability & the environment	+	~	-	-	-

Legend	+: Testable	~: Partly testable / in development	-: Not testable

Table 4: Status of feasibility of the identified assessment criteria in the selected target countries.

The feasibility status as shown in Table 4 should be viewed as an evaluation based on the information from the available sources. The results are described in more detail below:

- Management system based on ISCC requirements: This assessment criterion could be implemented in all countries, as an on-site check will be carried out for verification. This should be possible in all countries.
- GHG emissions reduction potential: The PCF calculations for this criterion can be done with the help of an established test. This should be possible everywhere due to internationally applicable ISO standards.

- Criteria for the carbon source: According to /52/ and /70/, both Colombia and Egypt are planning to begin with producing “blue and grey hydrogen”. Colombia’s hydrogen strategy /70/ envisions the use of CCU and CCS, which means that the criterion relating to the carbon source can potentially be met. The draft version of the “Hydrogen Guarantee of Origin Scheme for Australia” /5/ (see chapter 3.1.7) describes the option to certify “climate-neutral hydrogen”, which should make it possible to implement this criterion there. No details are known for Tunisia at the time of writing this Expert Opinion as the establishment of hydrogen production facilities is still only being discussed /39/. Namibia’s hydrogen strategy /57/ is focused on producing “green hydrogen” and ammonia. Producing green derivatives such as methanol or methane requires sustainable sources of carbon. This would normally require the creation of a production report and an on-site check. However, the large-scale use of sustainable carbon has not yet been established.
- Consumption of electricity from RE: All examined countries have objectives for renewable energy expansion, as detailed in /40/, /83/, /72/, /108/ and /63/. The analysis of the countries also shows great potential for solar and wind energy. But not all five countries have achieved the same rate of expansion over the past few years and all have varying levels of existing generation capacity from renewables.
- Creditability of “green hydrogen”:
  - Direct connection: According to /39/, Tunisia is holding initial discussions regarding PtX projects that include the expansion of renewable energy. A similar development is taking place in Egypt according to /51/. Namibia’s and Australia’s progress is thought to be further, as hydrogen hubs are being planned near renewable energy generation plants according to /57/ and /61/. Colombia has included “green hydrogen” in its hydrogen strategy /70/, which will require the expansion of renewables.
  - Temporal correlation: Starting on 1 January 2027, hydrogen production will have to occur in the same one-hour period as electricity production, for example through a PPA (according to draft del. act /R 15/) (see annex 9.2). /83/ lists project companies in Egypt that are financing renewables through PPAs. Colombia also provides the possibility of finance expansion through the sale of PPAs according to /75/. Namibia and Australia both use PPAs for financing according to /108/ and /94/. PPAs can also be provided as proof in Tunisia, but banks do not currently accept them for financing according to /39/, which means that the regulatory framework for the use of PPAs still needs to be adapted. The verification of temporal correlation also requires smart metering systems. These should be available in all countries.
  - Additionality (according to draft del. act RED II /R 15/, see annex 9.2): Additionality should be feasible in all countries. All countries have expansion goals

for RE according to /40/, /83/, /72/, /108/ and /63/, which means that new generation plants will be coming into operation.
    - Geographical correlation (see annex 9.2): Geographical correlation should be feasible in all countries as new renewable energy plants are planned. Some areas are already planning hydrogen hubs near renewable energy plants according to /40/, /83/, /72/, /108/ and /63/.
- Information for the EU database / criteria for traceability:
    - Mass balancing: Mass balancing is available for the first part of hydrogen product value chains, i.e. production, in all countries. Who is responsible for the traceability of logistics from the point of overseas transport needs to be clarified and defined as a next step.
    - Physical segregation: Physical segregation also requires that production be verifiable through evidence. It would, however, require separate transport and storage structures for “green hydrogen”products further down the respective value chains, which does not appear feasible as this would require high investment and operating costs. The responsibility for the separation from other hydrogen products for overseas transport would also have to be clarified and defined.
    - Book & Claim: A certification body checks whether the obligations from RED II /R 2/ have been fulfilled. This requires that all necessary documents be provided to the certification body. Here, too, immediate feasibility along the value chain up until transport should be given. But the system is not yet established.
- Commitment to the protection of areas of high biodiversity value or with stocks of carbon as well as of HCVAs: We did not have access to publications related to hydrogen projects in Tunisia, Egypt and Colombia. These countries can still be considered at the start of hydrogen project planning according to /39/, /70/ and /51/ . Namibia has plans to establish a hydrogen hub in a nature conservation area according to /57/. Additional investigation would be required to evaluate whether this entails any restrictions. According to /61/, western Australia has low intensive land use and a low population density and thus space to build renewable energy plants, for example. Australia also has guidelines that include, among other things, an environmental assessment for the construction of wind farms, as stated in /115/.
- Commitment to environmentally friendly hydrogen production and the protection of soil, water and air: Australia mentions water use in their hydrogen strategy /61/ and has plans for water accounting and prioritisation. The country also wants to minimise the environmental impact and has institutions that are responsible for the protection of the environment and resources according to /96/. Egypt, on the other hand, still has significant potential for improving environmental awareness

according to /97/. The country has a major water shortage /101/. According to /98/, /99/ and /100/, Tunisia, Colombia and Namibia put a greater emphasis on protecting the environment but sometimes have difficulties with implementation and face major challenges as a result. Like Egypt, Tunisia and Namibia are dry, arid countries. These countries require seawater desalination plants to avoid using fossil water or water resources that are important for food. Colombia, on the other hand, has large water reserves but does not provide information on environmentally friendly water extraction or environmentally friendly hydrogen production. Public information on such production (e.g. waste management) is not provided for Tunisia, Namibia or Egypt either. Namibia, a very dry country, has a large proportion of nature conservation areas. The same goes for Colombia with its large water reserves and substantial efforts in terms of environmental protection, according to /100/.

- Safe working conditions: Based on the cited sources and the available information at the time of writing this Expert Opinion, it can be assumed that Australia and Namibia have safe working conditions and that these can be verified on-site according to /55/ and /60/. /44/, /67/ and /110/ indicate that human rights issues have sometimes been considered a cause for concern in the past in Egypt, Tunisia and Colombia. This requires more detailed investigation.
- Observation of human, labour and land rights and of a responsible relationship to the community: The political environment and human rights issues have in the past been considered a cause for concern in Egypt, Tunisia and Colombia according to /44/, /110/ and /67/. Feasibility must therefore be evaluated more thoroughly in Tunisia and Egypt. The situation seems to have stabilised in Colombia based on /68/, which increases the likelihood of feasibility. Closer investigation is required nonetheless. In Namibia, human rights are largely respected according to /56/. However, the country’s HDI places it in the same category as the countries in Northern Africa (Tunisia and Egypt).
- Compliance with laws and international contracts: This criterion should be feasible in all countries. However, the CPI assigns a higher level of corruption to Tunisia, Egypt and Colombia than to Namibia and Australia /35/. /110/ also cites that in Tunisia the rule of law has been removed through a constitutional process. Egypt and Colombia also have shortcomings in the rule of law according to /67/ and /44/. Namibia has a high level of corruption compared to Australia according to /35/ but still fares better than Tunisia, Egypt and Colombia. Rule of law exists in Namibia according to /53/ and /54/.

To summarise, not all aspects of the criteria in question (see Table 1) currently appear feasible in the target countries defined by the Client in terms of availability and reliability of data, and implementing them would require significant effort.

The environmental and social sustainability requirements discussed in chapter 3.3 in particular would require considerable further need for action: The evaluated sources do not provide information on sustainability in relation to hydrogen for all examined countries, so the availability and reliability of data is limited. Human rights issues and the rule of law can only be verified to a certain extent.

Other criteria can generally be considered achievable and can be verified through audits using the evidence catalogue from annex 9.1. These include the requirements for management systems, the GHG emissions reduction potential, the carbon source and the use of renewable energy. Nonetheless, the effort required for implementation and feasibility has to be classified as very high in some cases.

5.3 Recommendation for the gradual introduction of a hydrogen product certification system

As noted in sections 3.3 and 5.1, the short-term implementation of the criteria identified in Table 1 into the framework of a certification system is very complex. This is why the following section proposes a gradual[26] certification system that could allow low-threshold entry for market participants into a hydrogen economy secured through certification.

This kind of phased certification system could be developed along a timeline of three phases, with gradually increasing requirements. The highest level of requirements should be disclosed from the start to inform stakeholders of necessary development and planning.

The phases could be divided as follows:

1. starting immediately, up to the entry into force of the draft del. act in line with Art. 27 RED II,
2. from the entry into force of the draft del. act in line with Art. 27 RED II up to 31 December 2026 (end of the "First Mover" phase according to the draft del. act) and
3. from 1 January 2027

The first phase will have no valid EU definition of RFNBOs for "green hydrogen" products. However, it is important to note that this first phase is expected to end at the end of 2022. Thus, while low-threshold criteria could be set until the entry into force of the draft del. act in

[26] Gradual in this context should be understood to mean a phased development from low-threshold requirements up to comprehensive environmental and socially sustainable requirements.

line with Art. 27 RED II, these would only apply for a very short timeframe. Hydrogen products could be certified using the established certification for climate neutrality that requires calculating and offsetting the PCF (see 3.1.9). A clear assessment of the product could be provided through uniform reporting of the CO_2 emissions burden. This would determine the price of the product. The lower the CO_2 burden, the higher the price / the higher the tradability of the product on the energy market. This would enable comparability and product valuation between individual products or production methods for hydrogen products. This approach would be open to all technologies and allow increased flexibility and speed for a hydrogen economy market ramp-up. The “Well-to-Wheel” approach would be most suited for this path because the “Well-to-Tank” or “Well-to-Gate” approaches do not include upstream or downstream emissions and therefore would fall short of the goal of contributing to climate change mitigation. The “Well-to-Wheel” approach quantifies all relevant emissions along the respective value chains, from treatment, transport and storage through to distribution and use. The hydrogen product’s carbon footprint can be disclosed at the point of purchase/sale. This would require the use of existing standardised methods of calculation (see 4.1). As expected, these calculation methods have been provided by the amendment to RED II. Certified offsetting measures will also allow emissions to be offset. The production of certain hydrogen derivatives requires carbon sources. The various carbon sources (fossil sources from industrial emissions, biogenic material and atmospheric CO_2) vary in terms of economic and environmental influence, which, as mentioned in 4.1, should be taken into consideration in line with framework conditions and as part of GHG emissions calculation. /89/

The second phase could include the criteria described as “First Mover” criteria in the draft del. act in line with Art. 27 RED II and, from 1 January 2027, all the criteria defined in the draft del. act /R 15/ could be applied.

It is generally advised to design the legal/regulatory aspects of the system in line with developments in the EU (RED /R 14/, RED II /R 2/ and draft del. act Art. 27 RED II /R 15/), as hydrogen industry stakeholders require security of acceptance from the EU in order to plan investments. The specific design of the system would have to consider the criteria specified by the EU.

We would further recommend establishing a certification system that includes additional sustainability criteria such as environmental protection, water consumption and land use after the third phase has ended.

The requirements of an “H2Global standard” could strive for a balanced approach to the defined targets of rapid market ramp-up, increased independence from fossil fuels, climate change mitigation and costs. However, these four objectives cannot be reached simultaneously as they are somewhat conflicting.

Requirements for the feasibility of the additionality criterion for electricity procurement (see 9.3) make the certification system more complex, as it requires that only new projects and no existing plants with potential for expansion be used. Thus, hydrogen production must co-finance the RE plants, which presupposes security of acceptance. This can be ensured by entering into international partnerships. New projects also require several years before they can be commissioned, which may delay market ramp-up. Plants need to be equipped with a smart metering system in order to source RE through a direct connection (with the exception of off-grid systems). This further increases investment costs and effort. It also requires personnel to be trained to maintain the technology.

The requirement of temporal correlation is another complex criterion. This criterion requires either evidence of electricity procurement and consumption through the smart metering system (in the case of a direct connection) or a Guarantee of Origin with a time stamp (in the case of grid supply). As long as no Guarantee of Origin scheme that includes time stamps has been established, a bilateral agreement between the generator and the consumer could be used in the interim that includes an agreement on the cancellation of the Guarantee of Origin.

Beyond that, the EU should focus on formulating a possible approach to hydrogen product traceability, most importantly by defining a suitable methodology and selecting system boundaries. This will presumably be based on the methodology that has already been established for gas infrastructure, which is mass balancing (see section 4.1). Mass balancing of hydrogen products could be achieved with the help of Guarantees of Origin that contain information on the substance, the GHG potential and other environmental and social aspects. This information is documented along the value chains and is then passed on to stakeholders involved in the value chain. This allows certified amounts to be identified in shares without being identified physically. It is likely that this method will also be used when injecting hydrogen into the natural gas grid. The proposal by the European Parliament and the Council for a directive on common rules for the internal markets in renewable and natural gases and in hydrogen (2021/0425 COD) also suggests the use of a mass balance system /R 18/.

The criteria for certification should always be adjusted to conform with the current standards and laws. We also recommend that a criteria catalogue for sustainability aspects, as described in section 3.3, be implemented following the end of the third phase. The elaboration of such a criteria catalogue could be continued and substantiated in a separate project assignment following this Expert Opinion.

A gradual certification system that includes aspects of sustainability could incorporate a selection of requirements that are least conflicting with market ramp-up. It should provide an exact definition of the criteria and a verification process with no room for interpretation. Hydrogen products, their respective production process and their appropriate colour scheme would also have to be defined. The certification of “low-carbon and “climate-neutral hydrogen” products could speed up infrastructure development and the creation of a hydrogen market as available technologies could be used. This open approach to technology, in parallel to technological transformation processes, would also highlight the additional potential for the expansion of hydrogen product value chains. This would ensure rapid energy provision for the respective application scenario. The option of including hydrogen from non-renewable energy and the use of CCS/CCU technologies means that this approach is open to all technologies and enables faster and more flexible hydrogen product market ramp-up /142/. It increases availability and allows trade partnerships to be formed to further support market ramp-up. This also gives exporters of future “green hydrogen” products security of acceptance as exporting countries can expand RE and develop a suitable legal framework in parallel.

6 Summary

The present Expert Opinion has elaborated a model system for the certification of "climate-neutral hydrogen products". The concept includes an analytical classification of the feasibility of a hydrogen product certification in the exporting countries specified by the Client.

The status quo of existing standards and those in development shows that various certification systems exist on the market, each with their own emphasis and design (see section 3.1). The main focus of these standards currently is on Guarantees of Origin for electricity from RE (Art. 19 RED II) and on GHG emissions reductions (Art. 25 RED II) in line with the requirements of RED II. Our analysis of the standards has shown that there is no uniform requirement in terms of the system boundaries for certification. We recommend that any future standard should allow both the certification of the entire supply chain and the certification of sections of the supply chain as hydrogen product value chains can be very complex.

Sustainability criteria such as environmental and social standards are currently missing from most of the standards or have only been included in the context of biomass certification. Based on the present analysis of the assessed standards, we recommend that the standards be supplemented with these criteria, particularly in view of imports from non-EU countries. The model evidence catalogue in section 4.1 outlines a possible approach to international evidence management for the verification of the green characteristics of hydrogen products. Much of this evidence has already been standardised and established. In some areas, however, evidence management still needs to be implemented. This includes evidence of the carbon source, of traceability through mass balancing, of physical segregation or Book & Claim and evidence for sustainability criteria such as water consumption and land use. Evidence for sustainability criteria has so far been described for biofuels in various standards and this Expert Opinion recommends adapting these for hydrogen products. While an immediate inclusion of sustainability criteria would be desirable, this would run counter to fast ramp-up of a hydrogen economy in the current phase of hydrogen development. Introducing far-reaching criteria for evidence at the beginning of market ramp-up would impede rather than accelerate it. We encourage a gradual implementation of sustainability criteria.

Our analysis of the testability of the identified criteria and corresponding evidence in the hydrogen product exporting countries in focus shows that Australia has the greatest potential to become an exporter of hydrogen. While the natural preconditions are equally met in the other countries, these countries cannot meet all requirements in terms of infrastructure, technology and the political landscape. A globally recognised certification system for hydrogen products could, from the perspective of this Expert Opinion, provide the unique opportunity to create the economic and climate policy support that is needed for achieving climate neutrality and sustainability in the hydrogen product exporting countries.

Based on the findings in this document, a rapid implementation of certification systems for hydrogen products that are coordinated and accepted at an international level appears distinctly challenging. But harmonising existing certification systems could be a promising and desirable approach in the long term. A gradual, phased implementation starting with low-threshold requirements and increasing to comprehensive environmentally and socially sustainable requirements that have been clearly defined from the beginning could be a solution. According to the World Energy Council, this approach should be designed to be open to all technologies, thus including the option of crediting “low-carbon hydrogen” products and to use renewable energy from existing plants that are not subsidised at the time of electricity generation (see section 5.3). In the present Expert Opinion, we define two transitional phases for the period until 2027 that are followed by a third phase in which all criteria must be fulfilled. We recommend that a criteria catalogue for aspects of sustainability be developed for the last phase following this Expert Opinion.

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9 Annex

9.1 Evidence catalogue and checklist for the verification of the identified assessment criteria

Assessment criterion	Short description	Required evidence
Management system	Certification requires an appropriate management system that enables the management of risk factors, the sharing of relevant information, the designation of employees for certain activities, training, audits, preventive measures, internal audits, process documentation, procedure descriptions, technical equipment and infrastructure, data and their storage according to ISCC document 203 "Traceability and Chain of Custody" as well as risk assessment and the collection of relevant information about other certification systems.	Providing evidence will require the provision of interviews, internal documents, internal systems, system documents, process and procedure instructions, internet information, training materials, lists, plans, contracts, diagrams, reports, protocols, written communication, mailing lists, the operating licence, mass balances, certificates, attestations, databases, registers, the report and action plan of the last external audit (not applicable for initial certification), declarations of commitment, ISCC registration, the ISCC confirmation email, a summary of the amounts reported to the ISCC (communicated by the ISCC in the confirmation email), the latest signed ISCC terms of use, the signed statement, among other things.
GHG emissions reduction potential	The quantification of all emissions related to the production of the hydrogen product in question as well as all relevant emissions from treatment, transport, storage, distribution and consumption. According to annex V of Art. 19 RED II, from 2021, new RFNBO plants must ensure a minimum GHG emissions reduction of 70% compared to the reference value for liquid biofuels, which is 94 $gCO_{2,eq}$/MJ. The reference values for gaseous biofuels (such as methane) are 80, 124, 183 or 212 $gCO_{2,eq}$/MJ. As yet, there are no reference values available for RFNBOs.	• Documentation of GHG emissions • PCF calculation according to ISO14064-1, ISO14040/44, ISO 14067, GHG Protocol or RED II (the RED II formula is binding for ISCC EU) • Delivery notes, sustainability declarations, internal reporting, mass balances • List and description of the measures taken to avoid and reduce GHG emissions (mandatory when preparing the initial balance sheet) • Description and type of CO_2 offsetting (if applicable)
Criteria for carbon source	CO_2 must be effectively captured and safely stored (following the Directive 2009/31/EC). Methane emissions require seamless recording, which includes the upstream natural gas chain, transport, CO_2 capture, CO_2 transport and CO_2 storage. Final storage only requires a record of CO_2 emissions.	• Production reports (e.g. captured CO_2 ($kgCO_2$/year)) • On-site inspection of carbon capture plant • Contracts with the buyers of CO_2 • Transparent documentation of calculations, formulas, all input data and results • Control of the further use of the product
Consumption of electricity from RE	The consumption of electricity for hydrogen production processes comes from renewable sources and the RE plant must not have received funding in the form of operating or investment subsidies other than through national auctions in line with RED II.	• Evidence of certified green electricity through recognised body or through PPAs • The proof of the GO cancellation (EECS) provided must be equivalent to the amount of electricity consumed • Declaration that the energy was generated from renewable resources, not from biomass • Contracts regarding the purchase of electricity from renewable energy sources • Process descriptions and monitoring data

Assessment criterion		Short description	Required evidence
Creditability of “green H_2”	**Direct connection**	Electricity is supplied through a direct connection between the electrolyser and the RE plant. This may also be an off-grid system.	• Process descriptions and monitoring data • Proof that no mains electricity was used for the production of hydrogen through a smart metering system, if the system is not off-grid
	Grid supply: Temporal correlation	The hydrogen must be generated in the same hour as the electricity was generated under the PPA. The electricity may also be drawn from a storage facility if this is located behind the same network connection point as the electrolyser.	• Guarantees of origin according to section 16, para. 3 of the HkRNDV (public grid) • Evidence of electricity procurement through PPAs
	Grid supply: Additionality	The RE plant must have been commissioned no earlier than 36 months prior to the electrolyser; the electrolyser may be expanded within 36 months after commissioning.	• Proof of building permit and commissioning of the plants from public authority
	Grid supply: Geographical correlation	The RE plant and the electrolyser must be located in the same bidding zone. Alternatively, the RE plant may be located in a neighbouring bidding zone with the same or a higher electricity price or in an off-shore bidding zone that is adjacent to the location of the electrolyser.	• Guarantees of Origin according to section 16, para. 3 of the HkRNDV
Information for EU database /criteria for traceability	**Mass balance system**	The tracing and linking of generation-related data (such as the location and time of hydrogen electrolysis) to a certain consumer. This approach links the certificate to the respective physical delivery of the energy carrier. Sustainability certificates are traded through mass balancing so that the physical delivery of the energy carrier goes hand in hand with the certificate.	• The start and end date of mass balance periods, inbound and outbound sustainability declarations, bills from platform scales, conversion factor, list and amounts of stocks, list of external locations, contracts for the delivery of sustainable materials, etc. • The supply contract for renewable hydrogen and meter data must be provided along the entire supply chain • The delivery must be documented in a mass balance system (see European Renewable Gas Registry /dena biogas register) • In the case of gaseous RFNBOs: Documentation of handover point (input and output meter) • In the case of liquid RFNBOs: Delivery notes from forwarding company
	Physical segregation	The tracking of the product in a physically separated manner (“segregation”) up to the consumer. Guarantees that only material that has been received as sustainable is declared sustainable and that the sustainability criteria of the outgoing material match the sustainability criteria of the incoming material.	Accounting, process descriptions, delivery documents, incoming and outgoing sustainability declarations.
	Book & Claim	The physical treatment of the commodity (injection, trade and transport, consumption of electricity) within defined system boundaries (e.g. the EU or the European electricity grid, if applicable including Iceland) is de-coupled from the balancing of the respective property (e.g. production method and “allocation” of this property to an analogous amount of electricity consumption)	Proofs of sustainability via GO schemes (e.g. voluntary schemes) in accordance with Art. 19 RED II

Assessment criterion	Short description	Required evidence
Commitment to the protection of areas of high biodiversity value or with high stocks of carbon as well as of HCVAs	No use of areas of high biodiversity value, high carbon stock or peat soils	Evidence in accordance with RED II, Directive 2015/1513/EC amending 2009/28/EC and 2009/30/EC
Commitment to environmentally friendly production and the protection of soil, water and air	Natural resources and biodiversity must be preserved by adhering to proven processes for storing operating resources, preserving and improving water quality and quantity and regarding waste and energy management.	Evidence in accordance with the cross-compliance system according to Regulation (EU) No. 1306/2013
Safe working conditions	The national and local regulations concerning working conditions must be adhered to. The company should be familiar with the pertinent legal regulations and remain informed about changes in the law.	• Information from the employer's liability insurance • Proof of education and competency in the form of records of training activities and by keeping certificates of competence • Written record of policies and procedures for health, safety and hygiene, including risk assessment • Protective clothing and equipment for accidents and facilities for dealing with accident-related contamination • Potential dangers are clearly identified
Observation of human, labour and land rights and of a responsible relationship to the community	The ILO's (International Labour Organisation's) internationally recognised requirements for social aspects are seen as the foundation. Companies are required to conform with pertinent national and local laws. Rural and social development shall be supported and access to education and fundamental services be ensured. This presupposes the self-imposed obligation to observe human rights and fundamental working conditions.	Proof of compliance with • ILO 29 • ILO 105 • ILO 138 • ILO 182 • ILO 87 • ILO 98 • ILO 100 • ILO 111
Compliance with laws and international contracts	The operator should prove the lawful use of land and the protection of traditional land rights. Documentation must prove the lease, the history of land ownership or the actual lawfulness of the use of the land. The operator must identify and respect existing land rights. The rights of indigenous people must be respected. The FPIC process (Free, Prior and Informed Consent) is applied when acquiring new land.	Evidence of rightful land use according to regional and national laws and international contracts

Table A-1: Example of an evidence catalogue for verifying the identified assessment criteria, developed in section 4.1 (on the basis of: RED II, ISCC EU & ISCC PLUS)

Production	Storage / Conversion / Transport	Final consumers	Assessment criterion		Verification process
x	x	x	Management system		The certification body checks whether a management system is available and whether the system covers the sustainability requirements in all relevant areas. It also verifies that the risk factors such as expert knowledge, education and training of employees, service providers and subcontractors are provided for.
x	x	x	GHG emissions reduction potential		The certification body first checks whether the selected system boundary of the reference value matches the considered section of the value chain. It then evaluates whether the necessary GHG emissions reductions have been achieved.
	x	x	Criteria for carbon source		The audit assesses whether CO_2 is being effectively captured and then safely stored (CCS in line with the Directive 2009/31/EC).
x			Consumption of electricity from RE		The certification body verifies that the requirements for RE have been met. The prerequisite for this inspection item is that the submitted documents have been issued on the basis of the EECS. This is carried out by the relevant national/regional authorities who must be members of the AIB.
x			Creditability of "green H_2"	Direct connection	The certification body verifies whether the obligations for the procurement of renewable electricity that result from RED II and the delegated act have been fulfilled.
				Grid supply: Temporal correlation	
				Grid supply: Additionality	
				Grid supply: Geographical correlation	
x	x	x	Information for EU database /criteria for traceability	Mass balance system	The certification body performs a control calculation of the mass balancing based on the submitted evidence. This requires that all necessary documents be provided for the audit. The document review verifies that accounting has been seamless and that no mass balance period exceeds three months.
				Physical segregation	All documentation of incoming and outgoing deliveries are checked as part of the audit. This includes verifying whether the segregated sustainability characteristics are clearly and correctly specified on the entry or exit declarations.
				Book & Claim	The certification body checks whether the obligations from RED II have been fulfilled. This requires that all necessary documents be provided for the audit.
x	x		Commitment to the protection of areas of high biodiversity value or with high stocks of carbon as well as of HCVAs		The certification body checks that the requirements of ISCC principle 1 have been fulfilled. This requires that all necessary documents be provided for the audit.

Production	Storage / Conversion / Transport	Final consumers	Assessment criterion	Verification process
x	x		Commitment to environmentally friendly production and the protection of soil, water and air	The certification body checks that the requirements of ISCC principle 2 have been fulfilled. This requires that all necessary documents be provided for the audit.
x	x	x	Safe working conditions	The certification body checks that the requirements of ISCC principle 3 have been fulfilled. This requires that all necessary documents be provided for the audit.
x	x	x	Observation of human, labour and land rights and of a responsible relationship to the community	The certification body checks that the requirements of ISCC principle 4 have been fulfilled. This requires that all necessary documents be provided for the audit.
x	x	x	Compliance with laws and international contracts	The certification body checks that the requirements of ISCC principle 5 have been fulfilled. This requires that all necessary documents be provided for the audit.

Table A-2: Example of a checklist of the evidence to be provided for the confirmation of the assessment criteria along the value chains. Building on the evidence catalogue (see A-1) developed in section 4.2. (Basis: RED II, ISCC EU & ISCC PLUS standards)

9.2 Detailed requirements for direct connection and grid supply from the draft del. act

According to the draft, hydrogen from RE can be fully credited in line with RED II. The detailed requirements for crediting electricity obtained through the direct connection and grid supply as fully renewable are as follows:

Direct connection
The following rules apply for the creditability of electricity per direct connection according to Art. 27 (5) RED II in conjunction with Art. 3 draft del. act:

1. There must be a direct connection between the electrolyser and the RE plant. /R 15/
2. The RE plant must have been commissioned no earlier than 36 months prior to commissioning of the electrolyser. /R 15/
3. It must be an off-grid system. Should the plant not be off-grid, proof that no mains electricity was used for the production of hydrogen must be provided through a smart metering system. /R 15/

Grid supply
There are three options for the full creditability of electricity from a grid supply:

1. According to Art. 27 (6) RED II in conjunction with Art. 4 (1) draft del. act, the electrolyser must be located in a bidding zone where the average share of RE exceeds 90%. Hydrogen production must not exceed a maximum number of hours equivalent to the total number of hours in each calendar year multiplied by the share of renewable electricity in the grid. /R 15/ For hydrogen to be credited as fully renewable, hydrogen production must not cause any grid congestion according to Art. 4 (4) draft del. act. (This option currently has no practical relevance in the Federal Republic of Germany as the share of RE in the grid has not yet reached 90%. /30/)
2. Art. 27 (6) RED II in conjunction with Art. 4 (4) draft del. act sets out that hydrogen production must occur during grid congestion /R 15/. This would reduce the need for redispatching measures, although the feasibility of this option is still unclear /28/.
3. According to Art. 27 (6) RED II in conjunction with Art. 4 (2) draft del. act, the electricity for hydrogen production must be generated under a Power Purchase Agreement (PPA) by an operator of RE plants /R 15/. The following additional criteria must be met:
    a. Additionality: The RE plant must have been commissioned no earlier than 36 months prior to the electrolyser; the electrolyser may be expanded within 36 months after commissioning. Once a plant has been declared “additional” it shall always fulfill the criterion of additionality. However, the criterion of additionality shall not apply for electrolysers that come into operation before 1 January 2027. /R 15/

b. No funding: The RE plant must not have received funding in the form of operating or investment subsidies. Funding for repowering RE plants and subsidies that do not constitute net funding (e.g. that must be fully repaid) are exceptions to this rule /28/. This criterion is also suspended for electrolysers commissioned before 1 January 2027. /R 15/
c. Temporal correlation: The hydrogen must be generated in the same hour as the electricity was generated under the PPA. The electricity may also be drawn from a storage facility if this is located behind the same network connection point as the electrolyser. However, this electricity must have been stored within the same hour in which the renewable electricity was generated. The balancing period is expanded from one hour to one month until 31 December 2026. Within the criterion of temporal correlation, hydrogen production must be possible at the day-ahead market electricity price of up to 20 €/MWh or up to 0.36 times the price of a GHG emissions allowance. /R 15/, /28/
d. Geographical correlation: The RE plant and the electrolyser must be located in the same bidding zone. Alternatively, the RE plant may be located in a neighbouring bidding zone with the same or a higher electricity price or in an off-shore bidding zone that is adjacent to the location of the electrolyser. /R 15/

9.3 Detailed information on the indexes used in the brief analysis

The assessment of the political situation takes into account, among other things, the respective countries’ Human Development Index (HDI), Corruption Perceptions Index (CPI) and Press Freedom Index.

<u>HDI</u>
The HDI is published annually by the United Nations Development Programme – UNDP. This well-established index records the countries’ average achievement in key dimensions of human development. This includes life expectancy at birth, the level of education, and income per capita. These individual scores are then ranked and indicate the status of average development. There is a total of four categories:

- Low: HDI < 0.550
- Medium: 0.550 - 0.699
- High: 0.700 - 0.799
- Very high: HDI ≥ 0.80

Unlike countries with a low HDI, industrial countries such as Germany, Australia and France are characterised by stable governments, a widespread and affordable education and healthcare system, high life expectancy and a strong, growing economy (HDI ≥ 0.8). Political instability has a negative influence on the HDI, which is taken into account in the following assessment. /109/

CPI
The Corruption Perceptions Index (CPI) draws data on the perception of the corruption level in the public sector from 13 individual indexes from 12 independent institutions. /116/

Press Freedom Index
The level of freedom of the press has also been taken into account for the analysed countries. The index is published by the NGO “Reporters Sans Frontières” (RSF) as a ranking list and is based on a quantitative record of attacks on media professionals and a qualitative analysis of local conditions. The evaluation is carried out via questionnaires and is based on a definition of press freedom published by RSF and a committee of experts. /117/, /119/