Australian National University

Approaches to certifying Australia-Germany Green Hydrogen Supply Chains:

informing discussion

Produced for the German-Australian HySupply Project

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Lee White: drafted Certification 101 and description of evolving options; contributed suggestions on structure; input and comments throughout report

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Executive Summary

Certification has an important role to play in the development of green hydrogen supply chains between Australia and Germany. Appropriate certification provides off-takers with the confidence that the price premiums they are offering for green hydrogen and ammonia are buying them a product that meets customer, investor and regulatory requirements.

The need for and opportunity arising from such certification schemes has seen a proliferation of schemes in Australia, Germany, and internationally. The goal of this report is to assist market participants and other stakeholders to navigate the certification options available, make well-informed choices about their participation in it, and facilitate constructive dialogue and negotiations which can help avoid unnecessary regulatory complexity.

To this end, this report aims to provide stakeholders with a common language and conceptual framework to discuss and understand the emerging scheme options. Key institutional roles defined in this report include ’certification scheme owner’ and ’certification body’, which are not necessarily the same thing. Jargon, such as ‘third party conformity assessment’ is also explained clearly, with examples.

This report does not seek to make value judgements as to which of the emerging schemes are ‘better’ than others. Rather, this report provides a summary of key characteristics that good schemes will have. Key concepts include accuracy, trustworthiness and interoperability. In this way, the report empowers stakeholders to make their own judgements about which schemes are best for them. It further empowers stakeholders by providing factual summaries of the schemes.

There is substantial diversity in the schemes covered by this report. Key points to note include:

1. Some, such as the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) efforts, are not certification schemes but rather attempts at developing methodologies that can be referenced by different schemes.
2. Others, such as the Hydrogen Australia scheme, do not yet have methodologies but have already certified their first establishment and its hydrogen production.
3. Many schemes, including CertifHy and the Hydrogen Australia scheme, recognise the importance of alignment with emerging EU energy regulation such as the Renewable Energy Directive II.
4. Others, such as the IPHE methodology, emphasise the importance of consistent methodologies and interoperability yet include features such as providing for offsets, which are not compatible with EU regulation.
5. CertifHy, meanwhile, will need to find an acceptable way of translating EU Renewable Energy definitions to the Australian and international context, or risk accusations of discrimination and face potential to precipitate WTO disputes.

Energy security is best achieved by participation in deep and broad international energy markets. The HySupply project provides an opportunity for Australian and German stakeholders to engage with the development of emerging certification schemes to ensure they support the development of these markets.

1. Introduction

1.1 Motivation for this report

HySupply is an Australian-German Supply Chain Feasibility Study of Hydrogen produced from Renewables. This feasibility study focuses on the:[1]

1. Comparison of the current technology and research readiness levels along the whole supply chain;
2. exchange of technologies, knowledge and experiences between the partners on both sides;
3. assessment of Australian potential to produce hydrogen and hydrogen-based energy carriers from renewables for export to Germany and associated markets;
4. identification of economic, technological and regulatory requirements for the transport of and trade in hydrogen and hydrogen-based energy carriers produced from renewables;
5. determination of demand and end use for hydrogen and hydrogen-based energy carriers produced from renewables in relevant industries in Germany and associated markets;
6. identification of economic, scientific, technological, regulatory and logistical barriers of the feasibility of the supply chain; and
7. identification of business models for hydrogen and hydrogen-based energy carriers produced from renewables.

Previous outputs of the HySupply Australia project include a State of Play Working Paper assessing current technologies for the complete hydrogen and key derivatives supply chain for international trade, several open-source techno-economic modelling tools for assessing the costs of green hydrogen production, conversion and shipping, and a supply-side roadmap identifying barriers to the realisation of this supply chain and opportunities for stakeholders to assist in overcoming them.

The current report particularly relates to objectives 4, 6 & 7.

Certification is an essential component of the regulatory requirements for trade in hydrogen and hydrogen-based energy carriers produced from renewables.[2] Without the ability to verify the renewable credentials of these hydrogen products, markets will not support price premiums for these products and Australian hydrogen products may face regulatory barriers in the German market.

Regulatory competition is emerging. The importance of certification to global hydrogen markets is well understood by market participants and regulators alike. So too are the potential benefits of being the certification rule-maker, rather than a rule-taker. As a

[1] https://www.dfat.gov.au/international-relations/themes/climate-change/joint-declaration-intent-australian-german-supply-chain-feasibility-study-hydrogen-produced-renewables

[2] Throughout this report, unless otherwise specified, “hydrogen products” or simply “hydrogen” refer to hydrogen in gaseous or liquid form as well as ammonia.

consequence, both public, private and mixed entities are investing substantial resources into the development of certification schemes for hydrogen products.

Regulatory competition has drawbacks as well as benefits. A key benefit of such competition is that participants are dedicating resources to developing high-quality certification schemes at high speed, thus helping progress the increasingly urgent energy transition. There are continuing uncertainties as well regarding how best to design and implement appropriate certification, and multiple efforts may assist in answering these questions. The potential drawbacks, however, are also multiple. For example, certification schemes are characterised by network externalities (where the benefit of being part of a scheme depends on the number of other market participants that are using the same scheme). Network externalities mean that first movers with large resources may rapidly come to dominate, regardless of whether they had the 'best' scheme. Regulatory competition also means that market participants must expend extra resources to understand and navigate the certification 'regime'. This itself can generate market inefficiencies.

The purpose of this report is to assist stakeholders in maximising the benefits while minimising any drawbacks of the emergent regulatory competition in green hydrogen certification. It aims to help market participants to navigate the certification regime, make better-informed choices about their participation in it, and facilitate constructive dialogue and negotiations which can help avoid unnecessary regulatory complexities, costs and delays. It aims to achieve these goals by:

1. Providing a common 'language' for regime participants by defining and explaining technical terminology;
2. providing a clear explanation of the functional parts of a certification scheme and how they relate to one another; and
3. using this conceptual framework and clear language to summarise the major hydrogen product certification schemes existing or under development that are of relevance to Australia-Germany hydrogen product trade.

Objectives 1 & 2 of this report are particularly important because certification in general is an area of regulation that had seen substantial private involvement. As a result, language and concepts are often inconsistently defined across regulatory spheres and schemes, even within one country. These inconsistencies are a hindrance to constructive dialogue on scheme design, implementation, and adoption.

1.2 The need for certification

The fundamental motivation for certification is to correct what economists refer to as 'information failures'. Information failures lead to inefficiency in markets, including too little production/consumption and trade, or too much of the wrong trade.

Information failures arise when some market participants do not have the information that they need to make optimal decisions. Most commonly, asymmetric information means that buyers do not have sufficient information about the attributes of the product they wish to purchase. Information failures are particularly prevalent where 'process and production methods' endow the product with attributes which are difficult or impossible to verify based on the characteristics of the final product, and are important to certain market participants. Key market participants here can include private buyers with particular motivations such as minimising environmental harms, as well as governments seeking to ensure that markets deliver particular policy objectives such as emissions targets through regulatory and/or incentive schemes.

In the case of hydrogen products, the ultimate attribute of most universal interest is the extent to which the product contributes to climate change mitigation throughout its life cycle. This attribute is central because new levels of interest in hydrogen products are driven primarily by climate change concerns. As will become clear in our description of the emerging schemes, the proximate indicators of climate mitigation effect that are deemed to be most important vary among market participants. Some place more emphasis on net carbon equivalent emissions, others on the absolute emissions and hence the technology used to produce or transport the product. Where certification is designed to interact with other forms of regulation (e.g., the Renewable Energy Directive in the EU), the chosen attributes can be complex and far from self-evident for those not familiar with the related rules.

For certain markets, a broader set of attributes may also be important to certify, including additional environmental measures (such as demands on constrained freshwater supplies) and social measures (such as benefit sharing with local communities, particularly indigenous communities). Currently, however, the focus of hydrogen certification schemes is squarely on the emissions credentials of hydrogen products.

Accurate and reliable certification of the climate mitigation credentials of hydrogen products is particularly important because hydrogen production can be highly polluting. Whether derived directly from fossil fuels or by electrolysis using electricity with high embedded emissions, replacing fossil fuels with dirty hydrogen products can be as bad or worse than business as usual (Longden et al., 2022). On the other hand, genuine renewable hydrogen with clean supply chains can be a major tool in our efforts to mitigate climate change (IRENA, 2021).

2 Certification 101

There is a large and growing set of terminology and frameworks in the area of product assurance, including certification schemes and guarantees of origin, standards, regulations, rules, codes, classifications, taxonomies, branding, and labelling.

Our focus is on certification schemes and guarantees of origin. Given our interest in encouraging standardization and interoperability, the definitions below are based on definitions from the website and standards of the International Standards Organization (ISO). Consistent uptake of common language can support detailed and efficient collaboration on certification scheme development and interoperability. However, terminology and definitions thereof can vary in specifics between agencies and programs. We emphasise the importance of schemes defining their terminology to avoid confusion between schemes using the same words for different activities.

2.1 Key terms

Certification is one form of conformity assessment.[3] **Conformity assessment** involves demonstration that specified requirements are fulfilled (ISO 17000:2020).

[3] Other conformity assessments include testing, inspection, verification and accreditation.

Certification is the issue of a statement (a **certificate**) that fulfilment of specified requirements has been demonstrated (ISO 17000: 2020). Specifically, certification is the issue of a statement that the products, processes, or services for which the certification is granted have fulfilled the standards and other normative documents against which it is judged in accordance with stipulations of the applicable certification scheme (ISO 17067: 2013). The process of certification requires an audit, review, decision and provision of an attestation (ISO 17000: 2020(en)).[4]

The attestation may involve the issuance of a **mark of conformity/certificate** (ISO 17030:2021 and ISO (2022a)).

A **certification scheme** is a set of rules and procedures that describes the objects to be certified, identifies the specified requirements and provides the methodology for performing assessment (ISO 17067: 2013 and ISO 17000: 2020). A certification scheme sets out the following parameters, all of which should be covered by a fully realised certification scheme (ISO, 2022b):

1. The product, process or service to be certified;
2. the specified requirements (e.g., standards) that the product, process or service must fulfil;
3. the sampling criteria for the certification if required;
4. the types and combinations of conformity assessment techniques (e.g., audit, inspection or test) that will be used to evaluate the product, process or service;
5. the process to be followed for the evaluation, review and decision;
6. the mark of conformity and its control; and
7. the activities that must be undertaken during surveillance, if any.

Certification of a product is considered to also apply to certification of reliable information, with information being a 'product'. For example, a batch of hydrogen may be certified as 'renewable' if it meets the requirements of a renewable hydrogen certification scheme. Alternatively, information about embedded emissions of the product could be certified as having been gathered according to the specified requirements of the certification scheme. That is, information on embedded emissions for a batch of hydrogen may be certified as compliant with the requirements of a scheme which certifies the process used to calculate embedded emissions. Our interpretation is also consistent with others in the literature, e.g. "*The definition of GOs also refers to an obligation set in Article 3(9) of directive 2009/72/EC (the Electricity Market Directive) that forces electricity suppliers to inform their consumers on the contribution of each energy source to the overall fuel mix of the supplier over the preceding year'. This obligation is known as the 'disclosure' obligation and usually GOs are used to verify the content of disclosure*." (Hamburger, 2019).

Tradeable certificates, such as those used in the European Energy Certificate System, have all the requirements of other certificates (including need to guarantee specific attributes, methods and qualities) but also require additional actors to manage the trade aspect.

Following the ISO definitions, we consider Guarantees of Origin (GO) to qualify as certification schemes because they involve the issuance of (electronic) certificates which guarantee that the information provided about the attributes of the electricity and/or hydrogen has been

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[4] Where the terms "audit", "review", "decision" and "attestation" are as defined in the source and can be accessed at https://www.iso.org/obp/ui/#iso:std:iso-iec:17000:ed-2:v2:en

collected according to a methodology specified by the scheme owner and meets the standards of information quality set by the GO scheme.

2.2 Key actors

We next provide definitions of the types of 'actors' of relevance to this report. Definitions are based on those provided by the ISO, specifically as related to certification as a conformity assessment activity.

A **conformity assessment body (CAB)** is a person or organization that performs conformity assessment activities, excluding accreditation (ISO 17000:2020). In the case of certification, "certification bodies" are a key CAB (see below).

Third-party conformity assessment is that which is performed by a person or organisation that is independent of the object of conformity assessment and has no user interest in the object (ISO 17000:2020). This is also often referred to as 'third-party certification'.

Second-party conformity assessment is that which is performed by a person or organisation that has a user interest in the object of conformity assessment (ISO 17000:2020).

First-party conformity assessment is that which is performed by the person or organisation that provides or that is the object of conformity assessment (ISO 17000:2020).

A **certification body** is a third-party conformity assessment body operating certification schemes (ISO 17065: 2012). That is, a body that conducts certification of conformity (ISO 10144:2018(en), 3.2) and issues certificates of conformity (ISO/IEC 10641:1993(en), 3.7). See below for discussion of the difference between a certification body and a scheme owner. In most cases the certification body will provide certification based on its own audit, review and decision. When the certification body and scheme owner are the same organisation, they may, however, rely on external auditors to provide audit and review services.

A certification **scheme owner** (sometimes alternatively referred to as the Standards Development Organization) is the person or organisation responsible for developing and maintaining a specific **certification scheme** (ISO 17067: 2013). This would include designing or setting clear external references outlining the methodology that is acceptable to demonstrate compliance with the certification scheme.

The **scheme owner** can be the **certification body** itself, a governmental authority, a trade association, a group of certification bodies, or others (ISO 17067: 2013). The scheme owner can be public or private. Private scheme owners may reference government standards in setting their standards and certification requirements, but this is not essential in the setting of standards. Scheme owners may also reference other documents, such as ISO standards and associated methodologies, in setting their own standards.

Although the **certification body** can be the **scheme owner**, this only meets the criteria of third-party conformity assessment in cases where the scheme owner has no user interest in the object of conformity assessment. For example, if a scheme owner will use certificates generated by the scheme to track progress towards legislative requirements, then the scheme owner would not be able to conduct third-party conformity assessment because they have an interest in the use of the certificates.

The role of the public sector in setting standards may be as the scheme owner, but it may also be a role where the government sets minimum standards which inform development of standards by private scheme owners that may exceed government standards in some dimensions.

The **scheme owner** controls the **mark of conformity** (ISO, 2022c). The certification body is by definition the issuer of the mark of conformity. Hence the owner is only the **issuer** if they are also the certification body. When the scheme owner and certification body are not the same organisation, the scheme owner will **licence** the certification body to issue the mark of conformity on their behalf.

Accreditation bodies are responsible for ensuring that CABs have formally demonstrated competence, impartiality, and consistent operation in conformity assessment activities (ISO 17000: 2020). No new accreditation bodies specific to hydrogen are expected to emerge; there is already an international system of accreditation bodies for various conformity assessment activities.

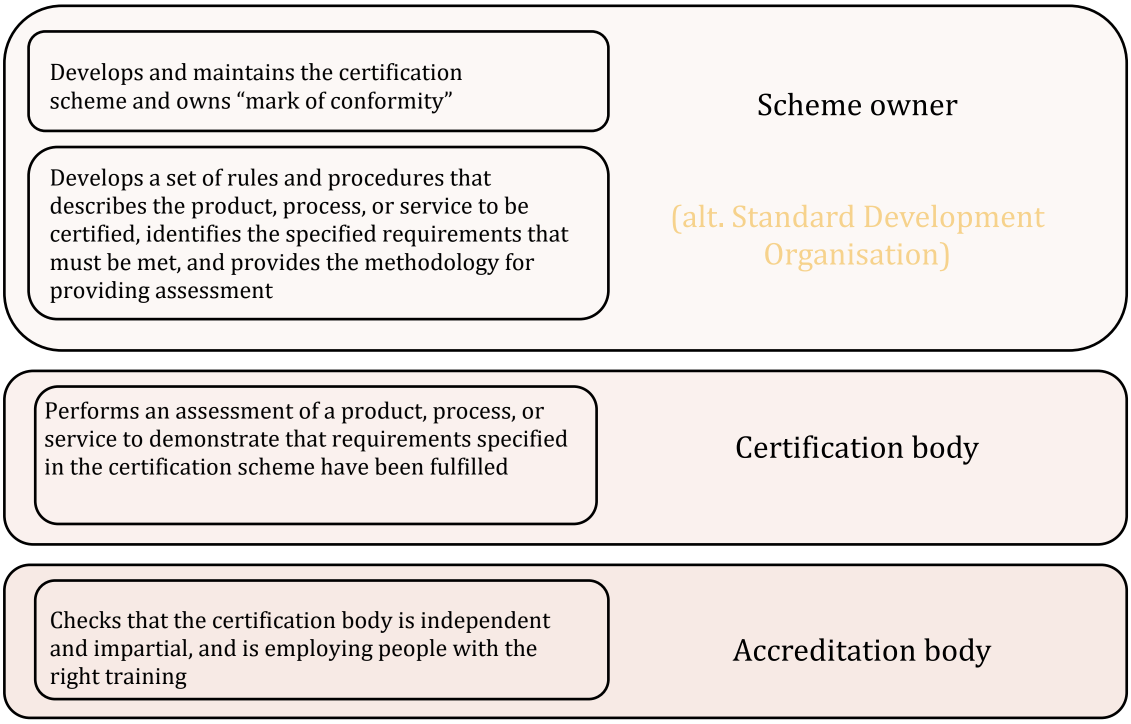

FIGURE 1: Summary of relations between key actors and their functions

2.3 Referenced ISO standards

SO/IEC 17000:2020(en): Conformity assessment — Vocabulary and general principles: https://www.iso.org/obp/ui/#iso:std:iso-iec:17000:ed-2:v2:en

ISO/IEC 17065:2012(en): Conformity assessment — Requirements for bodies certifying products, processes and services https://www.iso.org/obp/ui/#iso:std:iso-iec:17065:ed-1:v1:en

ISO/IEC 17067:2013(en): Conformity assessment — Fundamentals of product certification and guidelines for product certification schemes https://www.iso.org/obp/ui/#iso:std:iso-iec:17067:ed-1:v1:en

ISO/IEC 17030:2021(en): Conformity assessment — General requirements for third-party marks of conformity https://www.iso.org/obp/ui/#iso:std:iso-iec:17030:ed-2:v1:en

3 Desirable characteristics of certification schemes

The following discussion draws in large part from the International Social and Environmental Accreditation and Labelling Alliance (ISEAL) Credibility Principles which underpin effective practices for sustainability standards systems to achieve regulatory excellence, specifically more positive social environmental and economic impacts while minimising negative impacts (ISEAL, 2014). ISEAL proposes ten principles of credibility, with an emphasis on six of them – improvement (encourage continuous improvement toward intended outcome), relevance (standards fitting for purpose), rigor (standards setting to deliver quality outcomes), engagement (standards set after balanced and representative participation of stakeholders), transparency (free availability of information), and accessibility (minimising barrier in implementation).

We propose six desirable characteristics for certification schemes – completeness, low regulatory burden, non-discrimination, accuracy, transparency, trustworthiness, and interoperability. These tailor and expand the general ISEAL principles for the case of certification schemes for traded hydrogen, drawing on principles from trade law and emissions accounting guidelines/protocols. In particular, we discuss boundary considerations, stakeholder engagement and procedural considerations.

3.1 Completeness

Broadly speaking, 'completeness' of a certification framework refers to the extent to which relevant information has been included via the specified verification methodology. Completeness can be judged on both the extensive and intensive margins. For example, (Kennelly et al., 2019) focus on the extensive margin, referring to 'system completeness' as a measure of how encompassing the boundaries of a carbon accounting system are. The Greenhouse Gas Protocol Accounting Standard focuses on the intensive margin, defining completeness in carbon accounting as to "Account for and report on all greenhouse gas (GHG) emission sources and activities *within the chosen inventory boundary*. Disclose and justify any specific exclusions" (GHG Protocol, p.7).

In practice, we note that there are considerable variations of 'completeness' in the boundaries of certification schemes. Among all methodologies, a lifecycle analysis (LCA) of carbon emissions is widely used to set a complete boundary. However, there are also drawbacks of this approach in the context of certification schemes, especially those underpinning international trade. LCAs are complicated, the methodology is debated, and double counting can occur (Valente et al., 2017). Furthermore, supply chains which cross country and jurisdictional borders, as international hydrogen trade does, will be particularly difficult to account using a comprehensive LCA approach. As a result, full LCA requirements could place a high compliance burden on supply chain participants, be challenging to make consistent, and may create a non-tariff barrier to trade. White et al (2021) recommend a modular approach to carbon accounting in hydrogen certification, which can be used to balance environmental/completeness considerations with objectives related to free and fair trade. A modular approach to boundary definition would allow full supply chain embedded emissions to be accounted by adding together the embedded emissions in each 'module' of the supply chain. The module boundaries would be standardised and would align with boundaries of control of individual supply chain participants.

A closely related concept is comprehensiveness, which refers to a certification that covers comprehensive dimensions related to achieving sustainability of hydrogen production including water consumption, benefit sharing for traditional owners, and other social or environmental impacts besides climate change mitigation. However, there is a trade-off between completeness and other characteristics such as low regulatory burden and interoperability that we discuss below.

3.2 Low Regulatory Burden

Regulatory burden refers to the regulatory costs incurred by the regulated entities, which include substantive compliance costs, administrative costs, and delay costs (Office of Best

Practice Regulation, 2021). In the case of certification, substantive compliance costs are those which the entity seeking certification incurs in order to *meet* the requirements or standards of the certification scheme, while administrative costs are those the entity incurs *proving* that the requirements have been met. In the hydrogen certification case, substantive costs may include paying more for electricity in order to ensure it meets renewable requirements or adding carbon capture and storage to a steam methane-reforming hydrogen production line. Administrative costs include employee and contractor time in record keeping, hard- and software purchases for emissions tracking information technology, and auditor/certification body fees. Delay costs refer to the costs resulting from delays to obtaining investment, beginning marketing, or beginning sales that result from the time taken to obtain certification. Slow administration of applications for certification by the scheme owner or certifying body is a particularly wasteful form of delay cost. Schemes can lower delay costs by allowing the certification process to begin during the construction or development state – e.g., through pre-certification assessments.

Conditional on achieving the same environmental outcome, a certification scheme with lower regulatory burden is preferable. In a competitive market, regulatory compliance costs will be fully passed on to consumers, raising the costs of the energy transition. Furthermore, if a scheme has a high regulatory burden, then some producers may be excluded from the scheme. This is likely to disproportionately affect small producers and producers in countries with less existing regulatory infrastructure. If a scheme unintentionally excludes producers on the basis of regulatory burden rather than on the basis of emissions thresholds, then industry may not be able to develop efficiently, and emissions reductions may not be made in a least-cost manner.

3.3 Non-discrimination

Non-discrimination is a key principle for certification schemes for internationally traded products. Indeed, schemes that implicitly or explicitly discriminate on the basis of location can be found to contravene World Trade Organisation (WTO) commitments (WTO, 2019). Non-discrimination is a central tenet of the international trade regulatory system on the basis that if it was not the case then any and all manner of mercantilist trade policy approaches would be allowable. On the other hand, this principle is not an absolute and from the establishment of the GATT in 1947 and its incorporation as the central hub of the WTO, discrimination has been allowed. For example through preferential arrangements under customs unions or free trade areas, or where the pursuit of legitimate public policy goals are in view. However, these provisions are also subject to a range of important conditions circumscribing their application and the modification of this principle.

When examining environmental policies with trade impacts it is important to note that under the WTO (and other international trade agreements that typically defer to the WTO in this area) it is possible to discriminate against imported goods ('like products') with reference to environmental objectives and their expression through the application of standards, including in respect to the way a traded good is produced and the impact of this production process on the environment beyond the importing country.[5]

[5] United States – Measures Concerning the Importation, Marketing and Sale of Tuna and Tuna Products Recourse to Article 21.5, December 2018, WT/DS381/AB/RW/US, Section 7 (Conclusions), especially paragraphs 7.11, 7.13 and 7.14.

Relevant WTO jurisprudence has explored the relationship between the specific details of environmental policy oriented trade measures and their manner of application. This exploration covering, inter alia the role of relevant international standards and their relationship to environmental policy objectives. The relationship between trade measures, standards and related international environment agreements that parties to WTO disputes are members of has also been considered.[6]

It is well established that trade policies based on genuine environmental objectives are legitimate under the WTO rules. However, the legal tests that a trade measure based on the process and production methods of the imported good prior to importation are stringent and complex.

It should also be noted that the likely WTO consistency of trade measures based on standards that have climate change as a central raison d'etre is a difficult issue upon which to speculate. The standards themselves are a work in progress, as are many of the key policies which they will underpin. The status of such policies and standards as important implementation tools for domestic and international climate policy, including that pursuant to the UNFCCC and Paris Agreement, is also both difficult to generalise upon in the context of the relevant WTO agreements, and will be an area of evolving interpretation. Also evolving is the view of governments on the legitimacy of such standards and their application through policy as a practical issue. This latter point is of obvious importance and reflects the rapid development of relevant technologies and industries, including through international trade and investment. The interests of governments in relation to these developing industries and existing industries that can be views as competitors varies, and adds a level of contest likely to have implications for how WTO legal issues play out.

A key challenge for both the workability and WTO consistency of certification scheme requirements will be in respect to the 'equivalency' issue and what degree of flexibility will be allowed supply chain participants to meet scheme requirements. A lack of flexibility possibly creating unjustifiable or arbitrary discrimination in respect to market access for importers under key WTO Agreements (the GATT itself and the Technical Barriers to Trade Agreement). In the case of hydrogen certification, for example, a requirement that renewable electricity meet EU Renewable Energy Directive II (RED II) requirements may be challenging or even impossible to translate to non-EU jurisdictions, and hence illegitimately creating barriers to trade. Notably, flexibility is one of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) Methodology Principles (IPHE, 2022a).

The "discrimination" issue is even more complicated when technology rather than location is at issue. So-called 'technology neutrality' is a common but highly contentious policy principle, both in European renewable energy policy and Australian hydrogen policy. Similarly, the IPHE has 'inclusiveness' as a criterion for its methodology, meaning "methodologies should not exclude any potential primary energy" (IPHE, 2022a). While non-discrimination remains an important principle in this domain, there are two issues. Firstly, non-discrimination is supposed to apply to 'like products'. The definition of like products remains controversial in international trade law, especially when products are differentiated on the basis of process and production methods (PPM). On the other hand, the purpose of certification schemes is to

[6] United States – Measures Concerning the Importation, Marketing and Sale of Tuna and Tuna Products, WT/DS381R, paragraphs 4.13 and 4.14. United States – Import Prohibition of Certified Shrimp and Shrimp Products, Recourse to Article 21.5, WT/DS58/AB/RW, 22 October 2001, paragraph 133, p42, footnote 96. United States – Import Prohibition of Certified Shrimp and Shrimp Products – AB-1998-4, paragraph 168, pp67-68.

provide market participants (especially buyers and investors) the information they desire to make choices. If the technology used to make, convert, or transport the hydrogen is of interest to these market participants, then this information should be available from the certification scheme. Indeed, some schemes may choose to exclude hydrogen made using certain technologies because there is a market for such a distinction.

The second problem with technology neutrality as a design principle is that it is extremely hard to achieve. Indeed, *de jure* technology neutral approaches may end up being *de facto* discriminatory (Jerrentrup et al., 2019). Methodological transparency and inclusion of information about technologies used can help to combat this problem.

There have been calls for the 'like product' concept to be interpreted within WTO jurisprudence to more fully account for the PPM issue in respect to climate or other environmental impacts. However, this change is unlikely to see a strong level of support amongst any substantial body of WTO members in the short term. If the dispute settlement system did take this direction it would be likely to do so cautiously so that a range of strict legal tests remained in place to ensure that relevant trade policies were still applied even handedly, and not be seen as undermining broadly supported understandings on how the WTO agreements and relevant international policy and law should interact.

3.4 Accuracy

Accuracy is important for hydrogen certification because the purpose of the hydrogen certifications is to provide information so market participants can make decisions. They cannot make the optimal decision on trade-offs if the information is not accurate – for instance, the embedded emissions are miscalculated, or other information is misrepresented.

Hydrogen is increasingly understood to be a key contributor in the global transition towards net zero emissions, particularly in some hard-to-abate sectors such as high-heat industrial applications, and hence has been put forward as a way to fill the "missing link" of the decarbonisation roadmap (IRENA 2019). However, GHG emissions from different hydrogen production pathways vary greatly. Hydrogen certifications are important to provide information about climate implications of different types of hydrogen, and the most important aspect of the information is embedded carbon emissions. In this respect, accuracy specifically means, "[e]nsure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information." (Ranganathan et al., 2004).

Conformity assessment practices (discussed previously in section 2) are particularly important for ensuring accuracy. These practices include, but are not limited to:

1. Setting out aspects of required methodologies to collect and verify information from hydrogen production plants;
2. establishing processes for auditing the collection of information to ensure actual plant operation remains accurately reflected over time; and
3. formulating guidelines around which groups are most equipped to do these assessment exercises.

Accuracy is related to trustworthiness. If the information provided is not accurate, a certification will not be trusted by market participants. Consequently, it will not be widely used by producers who could not gain expected market premiums. Accuracy is also related to the regulatory burden – increased accuracy may mean enhanced regulatory cost in terms of record keeping as well as providing training to employees to understand the regulatory requirement precisely.

3.5 Transparency

Transparency of a certification scheme refers to the easy and free access to all relevant information in the certification scheme. The IPHE notes the importance of transparency both with regard to methodological approach and assumptions underpinning methodologies. In order to increase trustworthiness, transparency should apply beyond methodologies to include the development process and the content of the underlining standards, the governance structure of the system, how decisions are made and by whom, as well as the various ways that stakeholders can engage. For hydrogen certification schemes, transparency applies to what the emission numbers are, which parts of the supply chain are included and how the calculations are performed. It will be important, for example, to specify which numbers are measured on site vs. which are taken as industry or product averages (e.g., grid electricity emissions factors, emissions from leakage of methane). For modelled/estimated/projected figures, the methodology will need to disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.

Good practice of transparency may help enhance accuracy because it provides relevant references to verify the accuracy of the information and allow for feedback and improvement. While commercial confidence may limit feasibility of making all underlying details publicly available, scheme owners can still pursue transparency as a goal in both the design and availability of methodology and in the criteria for what a certificate must report. Both transparency and accuracy are the basis of a certification scheme's trustworthiness. Disclosing detailed information at micro-level may also support interoperability of different certification schemes.

User-facing transparency can also support the ISEAL recommendation of encouraging continuous improvement. In particular, certification schemes that include user-accessible statements of the embedded emissions in the hydrogen fuel allow users (e.g. off-takers) to discriminate and therefore apply more market pressure than schemes will only report a binary classification (e.g. "green" hydrogen). This type of transparency can also support communication of changes in standards (e.g. increasingly stringent definitions of "green") over time that provides certainty and prevents confusion and erosion of trust in the standard.

3.6 Trustworthiness

Trustworthiness is a quality that depends on third parties' perceptions. In this context, third parties include consumers, entities in the downstream of the supply chains, investors, and government regulators. Trustworthiness differs from accuracy as it is not the objective property of the certification itself, but the subjective perception by the third parties. It is an important characteristic for hydrogen certification schemes because perceptions of trustworthiness are directly related to whether the consumers are willing to pay for the market premiums, for the risk premium investors will demand, and for access to regulated markets.

Although subjective, trustworthiness is highly dependent on objective characteristics of a scheme. Rigorous methodology, accurate record-keeping, and transparent standards can greatly enhance the trustworthiness of a hydrogen certification. An important dimension of trustworthiness is the *impartiality* in decision-making. Once certifying standards are established, the results should be solely shaped by the data collected from applicants, and should be devoid of any certifying body bias, motivation, or other interests. Conformity assessment performed by a person or organisation that is independent of the object of conformity assessment and has no user interest in the object, as discussed in in Section 2.2, is generally considered to support these goals. Another important consideration for trustworthiness is the process of setting certifying standards – an inclusive and democratic deliberative process of the standard development can also improve trustworthiness. In addition, there should also be *consistency* of decision making, that is, a certifying process should reflect a certain level of stability of decision-making over time and under varying conditions. *Credibility* is concerned with whether a certification represents credible information of the original data, i.e., whether the third parties (in this case, consumers and others as noted above) believe what a certifying body is reporting.

3.7 Interoperability

Interoperability is a key requirement to help minimise regulatory burden and discrimination that can be caused by certification schemes for traded products. Certification systems are interoperable when at least some of the information from one scheme can be used toward meeting the requirements of another. If different markets use different and non-interoperable certification systems, supply chain participants may find themselves having to invest in multiple verification processes, thereby raising regulatory burden, often in asymmetric ways (Daugbjerg, 2012). In particular, producers located in small domestic markets will be disadvantaged by having to cater to multiple conflicting certification requirements across potential export markets.

Although related, interoperability is distinct from equivalence or mutual recognition. Where the systems are interoperable, a single verification process should be able to provide the information required for certifications for different markets. In other words, equivalence or mutual recognition of methodologies for calculating embedded emissions content and for the competencies of certification bodies is important for interoperability, but equivalence or mutual recognition of threshold embedded emissions to be considered ‘clean’, ‘green’ or ‘low carbon’ is not strictly required for interoperability.

Alignment of carbon accounting boundaries is key to supporting interoperability of methodologies. To this end, the modular approach to boundary definition recommended by White et al (2020) can go a long way towards supporting interoperability. Reeve & Aisbett (2022) show that basing modules on national carbon accounting methodologies is consistent with the modular approach and has potential to support cross-border supply chain embedded emissions calculations.

One of the most challenging aspects of achieving interoperability in our context is the treatment and definition of renewable energy inputs to hydrogen production. As with emissions thresholds, different markets will need to retain the right to define renewable energy consistently with their own regulatory frameworks and stakeholder preferences. International verification methodology processes, therefore, have a role to play in determining the minimum set of information required to enable verification of whether the renewable energy requirements of major certification schemes have been met. Meanwhile, certification schemes need to allow verification via such internationally standardised methodologies and not rely solely on certificates or guarantees of origin that are available only to producers located in certain geographic areas. For example, a European hydrogen certification scheme that relies on use of a European guarantee of origin for renewable energy will generally not be interoperable and hence not facilitate international trade in hydrogen – potentially also precipitating a WTO dispute. Europe's RED II currently prohibits recognition of guarantees of origin for electricity issued by third countries, "except where the Union has concluded an agreement with that third country on mutual recognition of guarantees of origin issued in the Union and compatible guarantees of origin systems established in that third country".

Procedurally, interoperability can be achieved through engagement and information exchange among certifying bodies and standard-setting organisations (i.e., it is supported by transparency and trustworthiness). For instance, when preparing for a new standards development process, a standard-setting organisation can inform organisations that have developed similar international standards of its intention, seek their inputs, and encourage their participation in the development process (ISEAL, 2014). When publishing the standards, the standard setting organisation can make explicit reference to other relevant carbon accounting standards. When there is a possibility that the certification is for internationally traded goods such as hydrogen, a certifying body should actively explore the possibilities for unilateral or mutual recognition for parts or all of the system requirements.

4 Evolving Options: Description and Discussion

Certification schemes for hydrogen are still evolving. Only CertifHy can currently be fully considered a certification scheme. However, other emerging schemes are rapidly defining the necessary parameters. In the following sections we summarise emergent schemes relevant to the Australia-Germany supply chain, considering their development, key actors, standards, the role of the public sector in scheme development, and methodological features.

Table 1: key features of developing certification scheme structure

	CertifHy	Australian GO	AEA	Smart Energy Council	GH2
Scheme type	Certification of low-emissions hydrogen	Certification of quality of information about hydrogen emissions and production	Certification of quality of information about ammonia emissions and production	Certification of renewable hydrogen	Certification of green hydrogen
Scheme owner type	Public-private partnership	Public	TBD	Private	Private
Certification type	Third-party conformity assessment	TBD	TBD	Third-party conformity assessment	Third-party conformity assessment
Intended scheme geographic coverage	EU-focused at present but expanding	Initially Australian, intended to be international	International	International	International
Owns a mark of conformity as of May 2022	Yes	No	No	Yes	No

Note: This table summarises only developing schemes; IPHE's developing methodology is not classified as a scheme, so it is not included.

In describing the methodology of each emerging scheme, we give particular attention to three areas of potential misalignment: treatment of electricity from grid, use of offsets, and treatment of co-products. Calculating emissions associated with grid electricity use is a rapidly evolving area with potential discrepancies between calculation methodologies; offsets are contentious as a means of emissions mitigation, particularly when they represent avoided emissions but also for some forms of stored emissions such as forestry, because there are concerns that offset quantities over-represent contributions to emissions mitigation; and treatment of co-products can have extensive implications for allocation of emissions and varies greatly between schemes (Hemming et al., 2022).

4.1 CertifHy GO scheme

CertifHy is a developing hydrogen certification scheme initiated at the request of the European Commission (CertifHy, 2022a). Development has completed two phases and is entering a third. These phases have been accompanied by shifts and evolutions in the certification scheme and its owner. All three phases were funded via public-private partnerships supporting research, technological development, and demonstration activities for fuel cells and hydrogen technologies in Europe (FCH, 2021).

CertifHy Phase II was intended to establish compliance with EU legislation and, in particular, with RED II. CertifHy Phase II is not yet fully compliant with expected updates to RED II, however, and the development of a Phase III was announced in December 2020. The goal of Phase III will be to implement a harmonised guarantee of origin for hydrogen across Europe and beyond, and to develop a certification scheme that is compliant with the updated RED II (TÜV SÜD, 2020). In CertifHy Phase III the focus remains predominantly on EU legislative compliance, with some expansion such as the planned pilot in Morocco to test the functioning of CertifHy in the Middle East and North African countries (TÜV SÜD, 2020).

4.1.1 Key actors

As of Phase III, the **scheme owner** and owner of the **mark of conformity** is a consortium made up of HINICIO, the Association of Issuing Bodies (AIB), the Commissariat à l'énergie atomique et aux énergies alternatives (CEA), Grexel, Ludwig-Bölkow-Systemtechnik (LBST) and TÜV SÜD (TÜV SÜD, 2020). It is possible that the scheme owner role will evolve further in future (Barth et al., 2019).

TÜV SÜD is the first **certification body** of the CertifHy Scheme, with more expected to be trained and become active in the near future (TÜV SÜD, 2020). The role of these bodies is to "verify the eligibility of Production Devices through a Production Device Audit and to verify the attributes of Production Batches through a Production Batch Audit." (Barth et al., 2019).

Although TÜV SÜD is both the first certification body licenced to issue CertifHy certificates and a member of the consortium owning the scheme, CertifHy can still be considered to follow a third-party conformity assessment process. This is because TÜV SÜD is not a hydrogen plant that is the object of conformity assessment, and it does not have any user interest in the object (green hydrogen and its certificates) such as by using certificates to meet legislative requirements.

4.1.2 The standard

CertifHy is a scheme for certifying the green or low-carbon hydrogen product. The product must meet specified requirements: as of March 2022, hydrogen is only eligible for a CertifHy **mark of conformity** if it comes from a production batch or sub-batch with greenhouse gas emissions a minimum of 60% below the benchmark process of steam methane reforming, currently 36.4 gCO2eq/MJ (equivalent to around 4.400kgCO2e/kgH2) (CertifHy, 2022b). This will soon be updated to a 70% below benchmark requirement (Sailer et al., 2022). As of Phase II, 'green' labelled hydrogen must specifically come from renewable energy sources (as defined in the EU's Renewable Energy directive and verified via one of the EU's renewable energy GO certificates (Castro et al., 2016)), whereas 'low carbon hydrogen' can come from any source. A CertifHy Guarantee of Origin (GO) certificate must contain information including (CertifHy, 2022c, 2019):

1. The plant which produced the hydrogen;
2. the energy source of the hydrogen (fuel or heat) and technology;
3. whether the hydrogen production has received financial support or not;
4. the share of renewable energy; and

5. the greenhouse gas intensity of the hydrogen.

While the documents are likely to undergo refinement, as of the end of Phase II, CertifHy lays out the required sampling criteria for hydrogen batches, the conformity assessment techniques that should be used to evaluate the product, and the process to be followed for evaluation, review, and decision. Specifically, audits must be performed in accordance with ISO 14063-3 (Environmental management — Environmental communication — Guidelines and examples: section 3 on terms and definitions) and the EU Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading (CertifHy, 2019; European Commission, 2003). Following review of the auditing process by the body in charge of issuing tradable certificates, a guarantee of origin certificate can be issued. The CertifHy symbol is trademarked by HINICIO ("CERTIFHY - Trademark Details," 2021), a member of the **scheme owner** consortium.

4.1.3 Influence by public sector

CertifHy has been developed as a scheme to comply with EU directives. These have informed even the most basic elements of scheme design, such as decision to develop a guarantee of origin (GO), made because RED required that a GO be the tool used for any "communication of the attributes of energy carriers sold to households" (Barth et al., 2019). Thus, the functioning of CertifHy is defined by parameters set by EU legislation, including RED and RED II.

Phase III will develop scheme compliance with RED II's article 19 (Guarantees of Origin for Energy from Renewable Sources), with the CEN-EN 16325 Standard (Guarantees of origin related to energy - Guarantees of Origin for Electricity), and with the AIB's general requirements for GOs and other energy certificates (TÜV SÜD, 2020). CEN-EN 16325 clarifies that guarantees of origin compliant with the standard may be traded and/or used for labelling. It will "establish the relevant terminology and definitions, requirements for registration, issuing, transferring and cancellation in line with the RES, energy efficiency and IEM directives. This standard will also cover measuring methods and auditing procedures," (European Committee for Standardization, 2013).

While most documentation currently emphasises the need for CertifHy compliance with article 19 of RED II, it is expected that CertifHy will also work to develop compliance with all other RED II articles. This is due to the scheme's purpose and goals to harmonise hydrogen certification across Europe compliant with European legislation. Of note are the pending calculation methodologies for RED II's article 27, which are expected to set requirements regarding how to demonstrate that electricity used for electrolysis is 'renewable'. The 2019 CertifHy report also notes several other portions of RED II where hydrogen GOs will support demonstration of target achievement, including in renewable energy and both fuels of biological (such as bio-methane reformed via Steam Methane Reforming (SMR)) and non-biological origin (such as water reformed via electrolysis).

Phase II of CertifHy also developed and outlined the processes for issuing and trading guarantee of origin certificates. This is considered key to the scheme's functioning as part of the EU legislative environment, as the certificates are used for tracking compliance with emissions reduction requirements. The hydrogen approach is being designed to parallel that of the European Energy Certificate System.

4.1.4 Methodology development

CertifHy's carbon accounting method includes all life-cycle stages 'from well to gate', i.e., from extraction and processing of raw materials up to production of a marketable product. It does not include CAPEX, transport, use, or end of life emissions. It specifically covers the entire upstream supply chain to the production device exit gate (CertifHy, 2019).

In CertifHy Phase II, the scheme owner completed a full methodology design for conformity assessment and tested this in four plants as a pilot. The methodology developed in Phase II during pilot projects is expected to require methodological updates, particularly to support compliance with pending RED II updates.

In CertifHy Phase II, the purchase and subsequent cancellation of a renewable energy GO was sufficient to demonstrate use of 'renewable' electricity. However, the pending Delegated Act on Renewable Fuels from Non-Biological Origin (Article 27) is expected to require 1) temporal correlation (the contracted renewable generator is generating electricity at the time of hydrogen production), 2) geographic correlation (the contracted renewable generator is located on the 'hydrogen side' of any grid congestion) and 3) additionality (the fuel producer is adding to deployment or financing of renewables).

Carbon capture and storage (CCS) is permitted for technologies such as SMR. It does not appear that the CertifHy Phase II example certificate requires listing of CCS type or quantity as a separate line item (CertifHy, 2019). CertifHy documentation does not define CCS, but referring to RED II, CCS is emission savings from CO_2 capture and geological storage. The CertifHy scheme documentation does not directly mention treatment of carbon offsets. However, despite not mentioning offsets directly, the CertifHy documentation and closely related European Energy Certificate Scheme documentation detail a focus on the guarantees of origin describing the production process and its inputs, with a focus on attributes that are not subject to change (e.g., the technology used). There is nothing in the documentation to indicate that offsets would be accepted by the scheme.

Co-products are also not mentioned in current scheme documentation. However, Australia's Department of Industry, Science, Energy and Resources (DISER) notes in their hydrogen discussion paper that CertifHy appears to allocate emissions for energy-based co-products in hydrogen production, but doesn't currently allocate emissions to non-energy co-products such as oxygen (DISER, 2021)

4.2 Australian Government GO scheme

The Australian Government is developing a hydrogen guarantee of origin certification scheme, with DISER taking the lead on this development (DISER, 2021). Certification has been identified as a government priority since the 2019 release of the Council of Australian Government (COAG) hydrogen strategy (COAG Energy Council, 2019). The initial focus is on developing a domestic hydrogen guarantee of origin scheme (DISER, 2021). However, in 2019, COAG identified spearheading the development of an international certification scheme for hydrogen as an Australian priority, and Australia is engaging heavily with the IPHE in developing a methodology for internationally compatible hydrogen certification schemes (COAG Energy Council, 2019). The current focus of the Australian government scheme is on emissions accounting.

4.2.1 Key actors

So far DISER has predominantly acted as the **scheme owner** leading development of methodology. However, there is currently no **mark of conformity** associated with the scheme. Given the Australian Government's leadership of the scheme development it is expected that certificates for the eventual scheme will be licenced directly by a government agency. It is also possible that the Commonwealth agency developing and maintaining the scheme will shift over time, or that this role will be split across agencies. The Australian Government announced in 2021 that it will fund trials of a guarantee of origin Scheme via the Commonwealth's DISER and Clean Energy Regulator (CER) (DISER, 2021), bringing the CER into some aspects of the scheme owner role. It is possible that the Australian government's scheme will use third-party certification bodies to assess compliance with the standards laid out in the guarantee of origin scheme.

4.2.2 The standard

The developing Australian scheme does not define a threshold above which hydrogen is 'green' or otherwise labelled (DISER, 2021). Instead, the scheme is intended to certify the quality of information underpinning embedded emissions calculations; that is, high-quality embedded emissions information is the product to be certified. This approach is intended to "allow buyers of hydrogen to set their own definitions of 'green' or 'blue' hydrogen with reference to agreed international standards" (DISER, 2021).

Broadly, the information to be reported in certificates would include (DISER, 2021):

1. Facility details (identity, location etc);
2. the production pathway;
3. the quantity of hydrogen produced (tonnes);
4. the total emissions;
5. process information;
6. electricity (scope 2) emissions;
7. fuel feedstocks;
8. emissions calculations and factors for fuel feedstocks;
9. CCS information;
10. details of waste or co-products; and
11. the time period.

The proposed scheme will use Inter-Governmental Panel on Climate Change (IPCC) and National Greenhouse and Energy Reporting Scheme (NGERS) guidelines to support specific emissions calculations and to provide emissions factors. DISER's 2021 discussion paper details the proposed scheme as of June 2021, including scheme design, coverage and administration. The discussion paper also details carbon accounting methodology including estimation of scope 1 and 2 emissions, the tracking and verification of renewable electricity inputs and treatment of carbon capture, utilisation, and storage. The Clean Energy Regulator launched trials of the scheme in March 2021 to test the accuracy, administrative burden and verification mechanisms associated with the accounting methodologies outlined in the discussion paper (DISER, 2021). It is likely that details of certification bodies and additional processes will be advanced during these trials.

4.2.3 Influence by public sector

The developing Australian scheme is led by the public sector and being co-designed with industry, potential end-users and other significant stakeholders through the trials.

4.2.4 Methodology development

The scheme currently defines a well-to-gate boundary capturing all scope 1 and 2 emissions consistent with definitions in the 2006 IPCC Guidelines (DISER, 2021). The discussion paper also outlines the calculation or sourcing of factors for upstream emissions (scope 3) associated with the extraction, processing and delivery of coal or natural gas feedstock used for coal gasification or SMR production methods. Likewise, emissions associated with electricity as a feedstock are discussed. Like CertifHy, the Australian scheme does not currently include emissions associated with capital goods and downstream emissions, instead ending at the factory gate (DISER, 2021). The Australian discussion paper notes the importance of including emissions associated with conversion, transport, and storage and indicates potential to include these in future, but does not currently lay out methodologies to account for these emissions (DISER, 2021). These methodologies are under development through IPHE and will be included in trials once completed.

The discussion paper laid out both market-based and location-based approaches for verifying consumption of renewable electricity in hydrogen production and proposed a market based method would be used to calculate emissions from hydrogen production. The market-based method would rely upon renewable energy certificates (large-scale generation certificates; LGCs), a mechanism currently underpinned by Australia's Renewable Energy Target (RET) which will end in 2030. DISER's discussion paper raises the possibility of developing renewable guarantees of origin for below-baseline and post-2030 renewable electricity generation,

The DISER discussion paper outlines a residual mix approach to be used alongside certificate trade to avoid double-counting, effectively attributing higher emissions intensity to the locale that the LGC is purchased from. The second proposed approach is location-based. This would apply an emissions factor reflective of renewable electricity in the grid and not adjust this factor based on purchase/claim/export of LGCs; LGCs would continue to be used to meet any other targets if they remain in place after 2030. In the proposed Australian scheme, there is no explicit requirement for temporal matching, geographic matching, or meeting additionality criteria in determining renewable electricity supply. It is unclear how the use of LGCs would be viewed in the pending accounting for RED II's Article 27 methodology, but it unlikely they would address all criteria.

The discussion paper also lays out two alternative approaches for dealing with offsets. The first option is to only permit CCS defined as occurring onsite or relating to permanent storage of CO_2. The second option is to include these CCS options and also to allow the use of Australian Carbon Credit Units as emissions offsets incorporated into calculations of embedded emissions; DISER notes that "consultation revealed a clear preference that if this option is pursued, emissions both gross and net of offsets should be recorded on the GO certificate to provide full transparency to the consumer. Noting scepticism about the permanence of non-geological carbon storage, this would need to include tracking of the source of the offset to allow buyers to differentiate in their purchases on this point" (DISER, 2021).

DISER's discussion paper includes a thorough discussion of co-products, with reference to alternative calculation methods and relevant ISO standards. DISER would intend to cover both energy and non-energy co-products, in line with the IPHE approach (DISER, 2021). That is, co-products such as oxygen from electrolysis would be included in the scheme's methodologies for emissions accounting.

4.3 Ammonia Energy Association (AEA) discussion paper

The Ammonia Energy Association (AEA) is a global non-profit industry association aiming to support development of an internationally harmonised certification scheme for low-carbon ammonia. As one of the most feasible early pathways for converting hydrogen into a form suitable for transport, ammonia is considered sufficiently relevant to include in this report.

4.3.1 Key actors

The scheme is still developing. Although AEA is currently leading development, they will not necessarily be the eventual **scheme owner** responsible for developing and maintaining the certification scheme. Scheme development will be guided by a steering group of industry members reporting directly to AEA, and an Advisory Group consisting of non-member organisations and stakeholders (AEA, 2021). Three working groups consisting of AEA member and partner organisations will inform development of methodology and other scheme aspects. The scheme currently does not have a **mark of conformity**.

4.3.2 The standard

The scheme is intended to certify information on embedded emissions. Specifically, it will certify the calculation of the absolute GHG emissions associated with ammonia production.

Certificates from the scheme would report metrics including (AEA, 2021):

1. Carbon intensity;
2. origin;
3. inputs;
4. co-products;
5. technology pathways; and
6. date of manufacture.

The proposed scheme focuses on embedded emissions quantities rather than on thresholds. The discussion paper asks whether categories such as blue and green should be considered, and there may be future development of threshold labels for convenience. However, the core intent of the scheme is to certify high-quality information on embedded emissions content.

In setting quantification methods, the scheme will draw on existing ISO standards for quantification and reporting of GHG emissions (including ISO 14064-1: 2018 and ISO 14064-2:2019 and ISO 14064-3:2019 and ISO 14067: 2018 and ISO/CD 14083 and ISO 19694-1: 2021). Specification of types and combinations of conformity assessment techniques is still emerging, but initial documents draw on quantification and verification in ISO standards including 14066:2011 and 14064-3:2019 (AEA, 2021).

4.3.3 Influence by public sector

The discussion paper identifies that a Working Group focused on Regulations will conduct a global review of existing and under-development regulatory measures and standards or certifications for relevant products and processes (AEA, 2021). This is intended to determine how the draft AEA scheme aligns with other existing and developing standards.

4.3.4 Methodology development

Methodology is still under development. In October 2021 the AEA released a discussion paper seeking feedback on proposed methodology for the certification scheme (AEA, 2021). They have established three working groups focused on 'principles and methods', 'pathways', and 'regulations'. These groups will have input to the development of the scheme.

The scheme aims to certify at minimum the 'well-to-gate' emissions including Scope 1, Scope 2, and selected Scope 3 emissions – specifically the upstream Scope 3. That is, at minimum the scheme would include feedstock emissions (upstream scope 3) but not emissions associated with moving ammonia from point of production to point of use. The AEA additionally identifies optional certification levels that would include downstream scope 3 emissions, for well-to-tank (including some downstream Scope 3) or well-to-wheel/wake certification (including end-use emissions).

The AEA scheme does not yet include a detailed discussion of treatment of grid electricity but does indicate that electrolysis from grid electricity with 'no PPA' or 'with PPA' will both be production pathways in the non-exhaustive list, alongside electrolysis from dedicated renewables and electrolysis from nuclear power. It is unclear how this would map to criteria such as additionality, geographic correlation, and temporal correlation.

The AEA discussion paper does not mention the use of offsets. However, given its focus on facilitating international interoperability, it is likely that offsets would at minimum need to be clearly identified in any calculation methodologies, if they are not outright prohibited. However, carbon capture and sequestration and carbon capture and utilisation are listed as part of potential production pathways. AEA references ISO/TR 27912:2016 (Carbon dioxide capture — Carbon dioxide capture systems, technologies and processes); this ISO technical report does not limit definition of CCS to geological formations, instead setting out guides on which information is needed for various technologies to demonstrate capture. Co-products are also flagged as an area for discussion in scheme design and identified as a metric that should be reported.

4.4 IPHE methodology

The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) has a mission to "facilitate and accelerate the transition to clean and efficient energy and mobility systems using hydrogen and fuel cell technologies across applications and sectors" (IPHE, 2022b). The organisation is an international partnership comprising 22 members, including Australia, the European Commission (and several European countries including Germany), Japan, and the US. The IPHE methodology is intended to support international harmonisation of standards, but this is dependent on choices by countries to adopt this methodology (IPHE, 2022a).

4.4.1 Key actors

The IPHE is not developing a full certification scheme. Instead, they are developing methods expected to be referenced by certification scheme owners internationally to support harmonisation (IPHE, 2022a). There is therefore no **scheme owner** or **mark of conformity** associated with the IPHE processes. It is intended that the work of the IPHE will be put forward to the ISO for the development of a standard for emissions accounting across the hydrogen supply chain.

4.4.2 The 'standard'

The IPHE is developing methodology intended to be used by certification scheme owners internationally. The IPHE does not define a specific emission threshold for low-emissions hydrogen, nor does the document include labelling for green, blue, or other colours of hydrogen; it is solely a methodology for accounting to underpin labels assigned through country choices.

The IPHE document references several ISO standards (14040, 14044 and 14067) and GHG Protocol (Corporate Accounting and Reporting Standard) as basis for definitions and calculations, with the goal of creating a "universally recognised methodology to study the carbon footprint (and other impacts) of fuel production," (IPHE, 2022a). RED II is also referenced in defining renewable energy, but not regarding methods, other definitions, or thresholds (the IPHE does not set thresholds).

4.4.3 Methodology development

The IPHE produced a report on "Methodology for Determining the Greenhouse Gas Emissions Associated With the Production of Hydrogen" in October 2021, noting that it is one of several international organisations working towards harmonisation of hydrogen emissions certification (IPHE, 2022a). This draft methodology also noted that the document itself was only a first version available for revision, may not include all relevant emissions for some determinations, and should not be considered a statement by IPHE or its members on the appropriateness of scope boundaries for hydrogen certification. The first version of the methodology is 'well-to-gate', excluding emissions from the building of capital goods. The 'gate' is the gate of the production factory, not the 'usage gate'; that is, conversion and transport necessary to get the hydrogen to the point of use are excluded. For those processes included within the IPHE's well-to-gate boundary, all Scope 1, all Scope 2, and partial Scope 3 emissions are included. Partial Scope 3 emissions considered include associated impacts from the raw material acquisition phase, raw material transportation phase, hydrogen production and manufacture – that is, feedstock emissions are considered. However, downstream Scope 3 emissions are excluded (those associated with distribution and storage, use and end-of-life for the plant).

$$E_{emissions\ inventory} = E_{combustion\ emissions} + E_{fugitive\ emissions} + E_{industrial\ process\ emissions} + E_{energy\ supply\ emissions} + E_{embodied\ emissions}$$

The grid-connected emissions discussion references the GHG Protocol methods. Like the DISER scheme, it includes both location-based and market-based options for renewable energy. Market-based methods could rely on power-purchase agreements or other contractual arrangements. Renewable electricity certificates are noted as one plausible market mechanism; as with the DISER scheme, this would come with the requirement that the regional grid's residual mix be adjusted to reflect exit of certificates. The location-based method would reference emissions from the relevant regional grid, at the time of the production (in hours). In both methods, there is not an explicit additionality requirement, nor is there a requirement for geographic correlation of generated electricity and generated hydrogen.

IPHE defines CCS as “capture and storage of waste carbon dioxide in a geologic reservoir, for the purposes of reducing emissions of CO_2 to the atmosphere” (IPHE, 2022a); offsets are not explicitly defined in the IPHE document, but can be assumed to cover any form of stated emissions capture or avoidance that is not direct storage of waste products from the hydrogen production process. CCS is expected to be used alongside technologies such as SMR and coal gasification, and IPHE also identifies that the CO_2 capture rate, type of CO_2 storage and amount stored, and any associated fugitive emissions should be among the details reported. Offsets are mentioned in the context of several hydrogen production technologies (such as SMR and coal gasification). IPHE notes that “at this stage permitting the use of offsets is contentious and not recommended” and recommends that where offsets are used the type and quantity of offsets used should be identified in reported information.

The IPHE scheme also contains a detailed discussion of co-products, based on relevant ISO standards. Regarding treatment of emissions, it is recommended in this scheme that emissions associated with co-products be removed from the inventory if the co-product is sold to market. The inventory would also list the amount of co-product sold. Both energy and non-energy co-products would be considered. Hydrogen itself may also be a co-product of other processes, and the IPHE methodology also discusses these cases.

4.5 Smart Energy Council (Australia) Scheme[7]

In December 2020, Hydrogen Australia launched its "Zero Carbon Certification Scheme".

4.5.1 Key actors

Hydrogen Australia is a division of the Smart Energy Council, a major renewable energy industry association in Australia. Although the **mark of conformity** will belong to Hydrogen Australia (**the scheme owner and standard development organisation**), the scheme's founding partners include several Australian State Governments (Australian Capital Territory, Western Australia, Victoria, and Queensland), energy distributors (EvoEnergy), technology collaborators (e.g., Powerledger), and current and prospective hydrogen and ammonia producers (e.g., CWP Global, Yara Pilbra) (Hewitt, 2021).

Auditing and verification for the scheme is undertaken by accredited certification bodies. The scheme hence uses third-party conformity assessment to certify the 100% renewable energy claim.

4.5.2 The standard

The scheme is designed to certify hydrogen and ammonia (and prospectively metals) produced from renewable energy only. It will certify the 100% renewable energy claim and verify claims about the amount of hydrogen per year that can be produced on site from 100% renewable energy. It will also provide a verified estimate of the embedded emissions per kilogram of hydrogen.

[7] Information on this scheme throughout this report is derived from the Hydrogen Australia website (https://smartenergy.org.au/zero-carbon-certification-scheme/), from Hewitt (2021) and personal communications. The information has also been checked by Max Hewitt and confirmed correct.

4.5.3 Influence by the public sector

While the SEC scheme includes several state governments among its founding partners, it is currently pursuing development independent of the scheme being developed by the Commonwealth government. It is unclear if these exercises will later be brought into alignment. In light of the importance of the European market, efforts are also being made to align the scheme with evolving EU requirements such as accounting for downstream emissions from transport to offtake point.

4.5.4 Methodology development

The current boundary is cradle/well-to-(production) gate, however, it is likely to expand downstream in the future.

At this stage the scheme is using the Australian Government definition of renewable energy. The scheme does not currently have a defined methodology for calculation of embedded emissions. The accredited verifiers/certifiers are therefore free to use their professional opinion, including reference to ISO standards to determine appropriate methodology. There is, however, a strong preference for auditors/certifiers to be recognised on the register of Greenhouse and Energy Auditors under the Clean Energy Regulator (CER).

The scheme is taking a practical, learning by doing, approach to certification, having already certified the hydrogen refuelling station in the Australian Capital Territory. Australian company Point Advisory acted as the certification body. The ACT case was relatively simple given the ACT has power purchase agreements in place sufficient to claim that the state has 100% renewable electricity (underpinned also by voluntary surrender of renewable electricity certificates to support this claim), although it is notable that this approach does not align with RED II's pending requirements for geographic correlation, temporal correlation, and additionality. Additional considerations were also made regarding the source of the water and the power requirement for pumping. The scheme does not currently provide documentation discussing the role of offsets or co-products. However, offsets are under consideration in order to enable 'zero carbon' certification. Treatment of co-products is unclear based on public information, but it is expected that these would be detailed in audit reports where relevant (at the auditor's discretion of methodology type).

The scheme is currently undertaking a far more ambitious certification project to certify ammonia produced by Yara Pilbra. Yara is in Western Australia, and their site produces ammonia using the Haber-Bosch process, using hydrogen produced on site from a mixture of electrolysis and steam methane reforming. Initially the scheme will provide a pre-certification assessment of the renewable ammonia production. Bureau Veritas is currently undertaking the pre-certification assessment.

4.6 GH2 Scheme

The Green Hydrogen Organisation (GH2) was established in 2021 (GH2, 2022). Formally it is a not-for-profit foundation under Swiss Law. Its mission is to accelerate the production and use of green hydrogen across a range of sectors globally. It will particularly seek to facilitate decarbonisation of 'hard to abate' industries like steel, cement, fertilisers, shipping, and aviation. The GH2 Green Hydrogen Standard is one of its four key initiatives which also include the Global Green Hydrogen Charter, Development Plan and CEO Roundtable. Membership is open to industries, government and other stakeholders, although there doesn't currently appear to be a publicly available membership list. It has offices in the UK, Switzerland, and Australia.

GH2's draft Green Hydrogen Standard was released for public comment in March 2022. The Standard was published in May 2022 (Green Hydrogen Organisation, 2022)

In the published Standard, GH2 note that by 30 June 2022 the GH2 Board will issue Policy Notes addressing Terms of Reference for the GH2 Accreditation and Certification Body, the Procedure for the appointment of Independent Assurance Providers (IAPs) and Standard terms of Reference for the engagement of Independent Assurance Providers (IAPs). By 31 December 2022, GH2 will issue Policy Notes addressing the procedures and the Terms of Reference for the establishment of the GH2 Registry. GH2 has also released Guidance and principles for good green hydrogen contracting with 8 briefs covering Policy and regulatory developments, Financing of green hydrogen projects. Fiscal terms and incentives, Community engagement and transparency practices, Land acquisition and use, Infrastructure access and common use and Sustainable development contribution.

As such, the Standard is still under development and some key design questions are still to be finalised.

4.6.1 Key actors

GH2 has a board currently comprising key industry leaders (CEO, Chairman, VP level) from companies across Australia (Fortescue Future Industries FFI), Germany (ThyssenKrupp), Italy, (Snam), Korea (Hyundai and Korea Zinc), Finance (Southbridge), non-profit industry-oriented associations (H2 Chile, SDG House, Energy Transitions Commission) and Government-industry initiatives (Daxing International Hydrogen Energy Demonstration Zone). The Inaugural Chair is the former Australian Prime Minister, the Hon. Malcolm Turnbull. GH2 notes the generous support of FFI in funding its operation.[8] The emerging scheme owner appears to be GH2 as a group, who will also presumably own the mark of conformity.

GH2 will accredit auditors (which they refer to as "independent assurance providers"). These bodies will be engaged by project developers seeking certification. GH2's Accreditation and Certification Body base their decision on final audit and review reports prepared by these assurance providers, and license projects meeting the Standard to use the label "GH2 Green Hydrogen" and be eligible to obtain and trade GH2 certificates of origin. Since GH2's Accreditation Body will have the final say on whether a producer receives certification following assessment by the auditor, if GH2 is considered to have a user interest in the certificates produced, then this scheme would not meet the criteria for third-party conformity assessment.

GH2 is currently establishing a Technical Committee whose role will be to advise the GH2 board on developing, testing and implementing a greenhouse gas accounting framework for green hydrogen reduction, associated environmental, social and governance (ESG) performance assessment and a framework for addressing the development impact and Sustainable Development Goals (SDG) performance of green hydrogen production.

4.6.2 The standard

GH2 requires projects to demonstrate that hydrogen is produced through the electrolysis of water utilising 100% or near 100% renewable energy. It includes storage, conversion and delivery of H2 and its derivatives, with green ammonia being prioritised as a leading candidate for green hydrogen transportation and use for both energy and industrial feedstock applications.

It is notable that the emerging GH2 scheme sets different levels of methodological requirements (mandatory, expected, and recommended). As marks of conformity for the scheme emerge in future, there will be a need to consider how to consistently represent these various levels of what the scheme requires for a certification to be granted.

The Green Hydrogen Standard seeks to ensure no or close to zero greenhouse gas emissions from green hydrogen production, setting a maximum threshold of less than 1kg CO_2e per kg H_2 for the well-to-gate boundary, which they argue is significantly lower than the thresholds proposed by some other organisations. GH2 references the IPHE methodology document in detailing emissions calculations.

Of note, project operators must also provide publicly accessible evaluation of the project's impacts on the energy market, with the expectation that green hydrogen projects contribute to the build-out of new renewable energy capacity and avoid greater use of fossil-fuel derived electricity elsewhere.

GH2 argues that while emissions associated with hydrogen production are a key factor, broader social, environmental and governance performance will also be key to truly green hydrogen production. The standard requires that project developers address their impacts on affected communities, labour and working conditions, as well as best practice health and safety standards.

Finally, the Standard requires that projects are assessed in terms of their impact on contribution towards achieving the Sustainable Development Goals with a view to maximising the project's contribution to development goals.[9]

The process for certification is as follows:

1. The project developer ensures compliance with the standard;
2. the Project developer engages an independent assurance provider (IAP) accredited by GH2;

[9] The GH2 has six general principles:

1. Sovereignty and subsidiarity; acknowledging the role of sovereign governments in the development of resources and energy markets, and noting that demonstrated adherence to credible and comprehensive national requirements shall be deemed sufficient to meet GH2's accreditation and certification requirements,
2. Proportionality (materiality); allowing for minor gaps and deviations in meeting requirements where the broader objective of the requirement is met,
3. Harmonization; with GH2 encouraging alignment with international best practice and seeking interoperability,
4. Consultation; with accreditation and certification requiring broad stakeholder consultation,
5. Transparency; with expectations of timely comprehensive and publicly accessible disclosures
6. Concerns and appeals; noting that GH2 is not an investigative body but will establish mechanisms for appeals and raising concerns.

3. the IAP consults stakeholders and prepares a draft report made available for public comment;
4. the final report is submitted to GH2's Accreditation Body. Projects that meet the standard are licensed to use the label 'GH2 Green Hydrogen'' and are eligible to obtain and trade HG2 GO certificates;
5. the GH2 Registry issues, tracks and cancels GH2 Green Hydrogen GO certificates.

4.6.3 Influence by the public sector

There are no governments currently formally represented on the GH2 board although they are welcome to apply for membership. Note, however, that the GH2 certification process is intended to rely significantly on the IPHE *Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen*, and that organisation has significant government involvement and direction as noted above.

4.6.4 Methodology development

The Standard draws significantly upon the IPHE methodology in terms of scope, as detailed below. More generally, it includes a range of assessments on environmental and social impacts of the projects.[10]

Note that the Standard includes mandatory (will be taken into account in certification), expected (should be addressed) and recommended (certification will consider any work but progress will not impact certification) criteria, leading to some criteria being fairly open in terms of application to certification. GH2 notes that its draft standard draws on the IFC's Environmental Social Performance Standards, the Hydropower Sustainability Council's Hydropower Sustainability Standard and the UN's Sustainable Development Goals.

Of particular importance to this report GH2 accreditation and certification **requires** that project operator to demonstrate that hydrogen is produced through electrolysis powered by 100% or near 100% renewable energy, as demonstrated by means such as PPAs or GO

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[10] The Draft Standard **requires** project operators to:

7. Publish a publicly accessible and transparent overview of the project addressing expected outcomes and impact
8. Publish a publicly accessible summary of government licenses and approvals which should address property rights, land use, water right, environmental, public health and foreign investment approvals as appropriate
9. Provide a publicly accessible evaluation of project siting and design options
10. Identify issues related to affected communities, public health and human rights impacts and associated management measures being undertaken
11. Avoid compulsory resettlement wherever possible
12. Minimise negative impacts on indigenous communities
13. Undertake human resource and labour management assessments
14. Not employ children in any manner that is economically exploitative or likely to impact their health, education or development.

The Draft Standard **expects** that projects will have been subject to social and environmental impact assessments in accordance with applicable regulatory requirements certificates. Hydropower, wind, geothermal energy, tide, wave and other ocean energy sources are acceptable while GH2 will consider proposals utilising other renewable non-fossil sources on a case-by-case basis.

Projects are **required** to undertake an evaluation of the project's impact on the energy market including where applicable its impact on greenhouse gas emissions from the electricity grid. If the project may lead to significant utilisation of renewable energy from the grid and/or increased emissions, there is an **expectation** the project implements technically feasible and cost-effective measures to support the deployment of additional renewable energy capacity. That is, additionality is encouraged but not required, and would not necessarily align with future RED II requirements.

Emission accounting procedures and thresholds are intended to be able to be applied consistently to grid and off-grid production. Electricity taken from the grid can be counted as fully renewable if they have power purchase agreements with renewable projects for an amount that is at least equivalent to the amount of electricity claimed as renewables. PPAs **should** make use of credible GO certification schemes where available. There is an **expectation** that the project operator has addressed temporal (on at least an intraday basis) as well as geographical correlation (within the same power market) with these PPAs.

GH2's draft standard applies the methodology for the electrolysis production pathway developed by IPHE Working Paper Methodology for the Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen. Up to 5% grey electricity may be consumed by electrolysers in a given year if there have been technical or market constraints requiring such use. Emissions from this consumption need to be calculated according to the rules applied by the United Nations Framework Convention on Climate Change (UNFCCC). The overall threshold for the GHG intensity of produced hydrogen must not be exceeded on a yearly basis.

GH2 accreditation and certification **requires** that projects operate at less than 1kg CO_2e per kg H_2) assessed as per the IPHE methodology. There is also an **expectation** that projects calculate and report on indirect greenhouse gas emissions associated with production processes (e.g. water use and waste disposal) and the emission associated with the storage, conversion and delivery of H_2 and its derivatives. GH2 also **encourages** reporting on embedded emissions including those associated with purchased energy and construction of the production facilities and associated infrastructure.

There are some minor refinements to the IPHE Working Paper Methodology. In particular, GH2's Draft Standard does not take the IPHE methodology assumption that the GHG impact of electricity generation from wind, solar PV, hydropower and geothermal will be assumed to be zero, but will instead require that these emissions are quantified.

There is currently no mention of offsets, CCS, or co-products in the standard.

4.7 Summary

In sum, most emerging schemes appear to be aligned on several key methodology features. Most are currently focused on well-to-gate (factory gate) emissions and expected information to be reported on certificates shares many common features. However, emerging areas of divergence are appearing in treatment of emissions from grid electricity, treatment of carbon offsets, and treatment of co-products. Table 2 summarises several key aspects of emerging schemes.

Table 2: Key features of scheme methodologies

Agency	Status	Scheme boundaries	Emissions scope	Grid electricity eligibility	Offset treatment (not CCS)	Treatment of co-products
CertifHy Phase II	Completed pilot program	Well-to-gate (factory)	Scope 1, 2, upstream 3 (feedstock)	With surrender of renewable energy certificate	Not mentioned directly, but description of certificate requirements suggests offsets not acceptable	Not mentioned; is not recommended for report on certificates
CertifHy Phase III	Press release	Assumed same as Phase 2	Assumed same as Phase 2	Expected to align with RED II requirements (if including pending Article 27 this would mean additionality, geographic match, temporal match)	Assumed same as Phase 2	Assumed same as Phase 2
Australian Government GOO	Trials proceeding	Initially Well-to-gate (factory) with intention to extend to cover conversion, storage and transport	Scope 1, 2, upstream 3 (feedstock)	Via market-based mechanisms	Undecided. If permitted recommendation is to include tracking of source of offset	Discussed in detail; recommended for report on certificates
AEA	Discussion paper	Well-to-gate (factory)	Scope 1, 2, upstream 3 (feedstock)	With or without PPA (non-exhaustive)	Not mentioned directly, but likely to receive similar	Mentioned as a reporting metric

					treatment to IPHE recommendation	
IPHE	Methodology draft	Well-to-gate (factory) with intention to extend to cover conversion, storage and transport	Scope 1, 2, upstream 3 (feedstock & capital)	Via location-based and/or market-based mechanisms	Recommendation against using offsets; where used, report type and quantity	Discussed in detail; recommended for report on certificates
Smart Energy Council	First pilot facility has been certified	Well-to-gate (factory)	Scope 1, 2, upstream 3 (feedstock), planned expansion for downstream (well-to-wheel)	Australian Government renewable energy definition	Offsets under consideration in order to enable 'zero carbon' certification	Treatment of these unclear based on public information. Anticipate these will be detailed in audit report
GH2 Scheme	Standard draft (March 2022)	As per IPHE although proposed extensions to storage, transport and use	As per IPHE with some modification	Via location-based and/or market-based mechanisms	Offsets not discussed in Draft Standard but note application of IPHE draft method	No specific mention of co-products

5 Conclusion

Certification has an important role to play in the development of robust markets for green hydrogen that can help to improve energy security and decarbonise economies all along the supply chain. Many different certification schemes are currently under development. While there are advantages to this emerging 'regulatory competition', there are also dangers that the associated complexity will lead to less fair and efficient outcomes, and ultimately hinder the development of the global green hydrogen market. It is important for stakeholders to participate in the private and public regulatory developments and to push for fair and efficient outcomes.

In order for stakeholders to participate meaningfully in certification landscaping, they need to be conversant at least in a basic common language, understand what makes a 'good' certification scheme, and be aware of the features of emerging schemes. The objectives of this report have been to provide these essential knowledge pillars for stakeholders in Australia-Germany green hydrogen supply chains.

Going forward, consistent methodologies are important. The IPHE is to be applauded for its efforts in this regard. However, given the diversity of market and regulatory requirements around the world, the emissions accounting boundaries for these methodologies will need to comprise clearly defined ‘modules’ so that different certification schemes can pick and choose which modules they wish to include. A case in point is emissions offsets which may be acceptable in some schemes but unlikely to be appropriate for certification schemes seeking to align with European regulation.

Other important and technically complex issues that will need to be addressed by schemes as they evolve are the treatment of co-products, and the definition of renewable energy. Requirements for additionality, geographic and temporal alignment are features of some schemes intended to ensure green hydrogen does not end up causing increasing greenhouse emissions. On the other hand, differences in electricity systems and markets across countries pose challenges for designing fair and equivalent rules for international certification systems. Likewise, some actors may value the flexibility afforded by offsets, while others have ongoing concerns that offsets risk undermining emissions mitigation goals. Emerging approaches largely highlighting transparency of offset use in emissions calculation appear to be reaching for a middle ground in this space.

Finally, registers and systems of tradable certificates are obviously closely related to certification schemes. They are beyond the scope of this report, but should be a priority for future work. Trading systems have important implications for market access, global emissions outcomes (particularly where offsets are allowed) and for the distribution along the supply chain of the claimed emissions reduction benefits.

Glossary of acronyms

AEA (Ammonia Energy Association)

AIB (Association of Issuing Bodies)

CAB (Conformity assessment body)

CAPEX (Capital Expenditure)

CCS (Carbon capture and storage)

CEA (Commissariat à l'énergie atomique et aux énergies alternatives)

CER (Clean Energy Regulator)

COAG (Council of Australian Government)

DISER (Department of Industry, Science, Energy and Resources)

ESG (Environmental, social and governance)

EU (European Union)

FFI (Fortescue Future Industries)

GHG (Greenhouse gas)

GH2 (Green Hydrogen Organization)

GO (Guarantee of origin)

IAP (Independent assurance provider)

IEM (Internal electricity market)

IPHE (International Partnership for Hydrogen and Fuel Cells in the Economy)

IRENA (International Renewable Energy Agency)

ISEAL (International Social and Environmental Accreditation and Labelling Alliance)

ISO (International Standards Organization)

LBST (Grexel, Ludwig-Bölkow-Systemtechnik)

LCA (Lifecycle analysis)

LGC (Large-scale generation certificate)

NGER (National Greenhouse and Energy Reporting Act)

PPA (Power purchase agreement)

RED II (Renewable Energy Directive II)

RES (Renewable Energy Systems)

RET (Renewable energy target)

SDG (Sustainable Development Goal)

SEC (Smart Energy Council)

SMR (Steam methane reforming)

UNFCCC (United Nations Framework Convention on Climate Change)

WTO (World Trade Organization)

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