Asia-Pacific
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Low-Carbon Hydrogen International Standard – *Post-Workshop Report*

APEC Sub-Committee on Standards and Conformance

July 2022

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Glossary and Key Definitions

APS	The IEA Announced Pledges Scenario
APEC	The Asia-Pacific Economic Cooperation regional economic forum
Blue	Hydrogen produced using natural gas coupled with Carbon Capture Utilisation and Storage
BAT	Best Available Technology for merchant hydrogen production using fossil fuels. Currently, the BAT threshold used is Steam Methane Reforming.
Carbon Intensity	The number of CO_2e required to produced one unit equivalent of hydrogen i.e., $kgCO_2e/MJ$ of H_2-derived energy or CO_2e/kg of H_2 input
CCUS	Carbon capture, utilisation, and storage
CCS	Carbon capture and storage
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
gCO_2e/kg	Carbon intensity in units of grams of CO2 equivalent per kg of hydrogen input
gCO_2e/MJ	Carbon intensity in units of grams of CO2 equivalent per megajoule of hydrogen-derived energy
COP26	The 26th United Nations Climate Change Conference
EWG	Energy Working Group
Fossil fuel reference threshold	The GHG emissions reference used by RED II to define GHG emissions thresholds for hydrogen production. Compares GHG emissions reductions to current Best Available Technology (BAT) for merchant hydrogen production. Currently, the BAT used is Steam Methane Reforming (91g CO_2e/MJ)
GHG	Greenhouse gas
GO	Guarantee of Origin
Green	Commonly Hydrogen produced using renewable energy to power an electrolyser. Definition is discussed in this report
GH2	The Green Hydrogen Organisation
H_2	Hydrogen
IEA	International Energy Agency
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
i-REC	The International Renewable Energy Certificate Standard
ISO	International Organisation for Standardisation
Low carbon	Hydrogen produced using non-renewable sources and can be coupled with Carbon Capture Utilisation and Storage, generally below a specified carbon intensity
kg	Kilograms
KTPA	Kilo tonnes of hydrogen per annum
kWh	Kilowatt hours
Mt	Mega tonnes
MTPA	Million tonnes of hydrogen per annum
MJ	Megajoules
NZE	The IEA Net-Zero Emission scenario
RFNBO	A Renewable Fuel of Non-biological Origin
RED II	The EU's Renewable Energy Directive II, which came into effect on 1 January 2021
SCSC	The APEC Sub-Committee on Standards and Conformance
SDS	The IEA Sustainable Development Scenario
SMR	Steam Methane Reforming
TC	Technical Committee

Executive Summary

This report has been developed to support a discussion on the merits of low-carbon hydrogen international standard development and the role of APEC in its development. This report was commissioned in 2021 for the New Zealand-led APEC project *Low-Carbon Hydrogen International Standard.* This report is built on an issues paper that was discussed at a virtual workshop in March 2022. The objectives of the project are:

- To build consensus on the definition and criteria of low-carbon hydrogen, and how a low-carbon hydrogen international standard could look to benefit the APEC region.
- To perform an opportunity assessment of developing an APEC consensus on a low-carbon hydrogen international standard, taking into account linkages to existing domestic and international standards on renewable energy and existing international processes on low-carbon hydrogen.
- Support the development of markets and trade in low-carbon hydrogen across the APEC region, thereby achieving positive outcomes for APEC member economies, energy security and emissions reduction.

There is currently no common approach to classify hydrogen

Economies refer to hydrogen by the energy source used in its production, the production method, and/or its carbon intensity. Currently, a large range of colours are used across economies to define hydrogen.

Colours can fail to capture key information for the end user, such as the hydrogen's carbon intensity or the energy source. While this is not standardised, colours are often used to specify the method of production, such as:

- "Green hydrogen": hydrogen produced using electrolysis of water powered by renewable energy
- "Blue hydrogen": hydrogen produced using natural gas with Carbon Capture, Utilisation, and Storage (CCUS)
- "Grey hydrogen": Hydrogen produced using natural gas without CCUS.

A range of hydrogen colours and classifications exist across the APEC region, with few commonalities between economies

Low-carbon hydrogen standards are rapidly developing

A number of certification schemes already exist and have developed their own criteria, such as:

- CertifHy (Europe)
- GreenGas Certification Scheme (UK)
- Standard and Assessment for Low-carbon Hydrogen, Clean Hydrogen and Renewable Hydrogen Energy (China)
- The Climate Bonds Standard and International Renewable Energy Certificate Standards (international).

A low-carbon hydrogen standard for the APEC region should consider the criteria of existing standards and schemes.

There is yet to be a globally accepted methodology for calculating emissions intensity, but one is in development

The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) has developed a Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen[1]. The document is currently a working paper and is feeding into the development of a formal international standards development by the International Organization for Standardization. To be globally recognised, the methodology would need to be adopted by a global standards organisation such as the International Organization for Standardization. If adopted, it could be used to align low-carbon hydrogen criteria across economies and avoid discrepancies in carbon intensity calculations based on the use of different measurement approaches.

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

Standards for hydrogen beyond conversion is limited

Significant work has been done to understand the carbon emissions associated with energy production, hydrogen production, and hydrogen conversion (i.e. liquefaction or ammonia production). Developing standards for further stages in the hydrogen life cycle such as storage, distribution and use is still in progress. The scope of this report is therefore focused on energy production, hydrogen production and conversion.

A low-carbon hydrogen standard could have multiple benefits and risks

A low-carbon hydrogen standard could have multiple benefits beyond unifying definitions, such as economic and environmental benefits. Key benefits include:

- Contributing to emissions reduction by increasing uptake in low-carbon hydrogen as a fossil fuel replacement
- Increasing the value of low-carbon hydrogen
- Supporting investment in developing economies with high potential for low-carbon hydrogen
- Providing certainty to developing economies about how a hydrogen market will operate
- Providing transparency over wider environmental effects
- Support for a single standard will discourage the development of multiple standards with differing criteria
- Minimising the risk of investment in technology that is not low-carbon compliant.

Survey respondents agreed that a low-carbon hydrogen international standard can help APEC member economies to achieve greenhouse gas emissions reduction targets (30%), develop renewable energy (23%) and support cooperation between economies (27%)

A low-carbon hydrogen standard should consider the barriers it may introduce

A low-carbon hydrogen standard could negatively impact the hydrogen market. Key risks include:

- Adding an additional cost barrier
- Stifling innovation by restricting the development of new technology
- Adding another layer of complexity
- Increasing costs to end users
- Misalignment with current and future hydrogen standards
- Managing assurance and verification of the standard will be resource intensive.

A low-carbon hydrogen standard should be clearly defined and assured

Standards can perform different functions, so to be successful the objectives of a standard need to be clear. Potential objectives for a low-carbon hydrogen standard could be:

- Facilitate international trade in low-carbon products
- Provide reliable and comparable information to consumers
- Provide a science-based definition on products aligning to the ambition of the Paris Agreement and reduce green-washing risks.

A low-carbon hydrogen standard needs to be flexible and adaptable as the global hydrogen market continues to rapidly evolve

The most common criteria for low-carbon hydrogen is carbon intensity

Existing certification schemes have a carbon intensity threshold in gCO_2e/unit of hydrogen (in energy or mass). Schemes commonly label hydrogen produced using renewables as “Green”, while the “Low-carbon hydrogen” label is also used for hydrogen produced using non-renewable energy sources. “Low-carbon Hydrogen” could therefore include hydrogen produced in conjunction with a carbon capture, utilisation and storage process (CCUS), commonly referred to as “Blue hydrogen”.

49% of those who responded to the question (41% response rate) agreed that emissions intensity thresholds for production should be used determining low-carbon hydrogen, making it the preferred option amongst respondents.

Using carbon intensity and production methodology provides valuable information

Economies could adopt a standardised accounting methodology for carbon intensity of hydrogen production. Carbon intensity can then be used to classify low carbon hydrogen as "green" and "low-carbon" using carbon intensity thresholds. Any hydrogen below the defined threshold can be recognised as low-carbon hydrogen. Hydrogen under this defined threshold and produced by electrolysis from renewable energy sources can have an additional label of "green" hydrogen. Possible thresholds for two established standards are shown below.

	CertifHy (EU)	**TUV SUD Standard (Germany/EU)**
Hydrogen produced using renewable energy	• "Green Hydrogen": if the hydrogen is produced using renewable energy sources (biogas, hydro, wind, solar, etc.) • Carbon footprint of < 36.4 gCO_2e/MJ	• Carbon footprint of < 28.2 gCO_2e/MJ for hydrogen produced using renewable energy (other than electrolysis) • Carbon footprint of <24 gCO_2e/MJ for hydrogen produced using electrolysis
Hydrogen produced using other energy sources	• "Low-carbon hydrogen": if the hydrogen is produced using non-renewable energy sources (e.g., nuclear, fossil with CCUS) • Carbon footprint of < 36.4 gCO_2e/MJ	• CCS methods largely omitted from certification, however in addition to regenerative hydrogen production CCS can be applied as long as it is in accordance with the requirements of EU Directive 2009/31/EC.

Assurance is required to ensure hydrogen is compliant with the standard

Without independent assurance, there is no way for a consumer to have evidence that a unit of hydrogen is low-carbon. Assurance is required to provide consumers' confidence of emissions reductions when using low-carbon hydrogen instead of high carbon fuels, reducing the risk of fraudulent accounting.

A Low-carbon hydrogen scheme for the APEC region

The development of a low-carbon hydrogen standard within the APEC region could take multiple routes

Three Development Options for standardising low-carbon hydrogen are shown below for consideration. The way forward for APEC could incorporate more than one option. Given the work to date on developing a standard internationally, it could be more efficient to leverage an existing standard's criteria. APEC member economies would need to build consensus on the existing standard to align with, but this option would maximise interoperability while removing the need to develop APEC's own criteria.

A low-carbon hydrogen standard should seek to unify terminology and criteria across regions.

40% of respondents agreed that a wider international standard (with input from APEC member economies) would best support a low-carbon hydrogen market in the APEC region, making it the preferred option amongst respondents (45% response rate).

Development Option 1:	**Development Option 2:**	**Development Option 3:**
Individual economies to develop their own standards **2 – 3 years**	**Develop a new, APEC-wide regional standard** 5+ years	**Align the APEC member economies to an existing or emerging standard** 2 – 5 years

Development Option 1:	Development Option 2:	Development Option 3:
• **Faster – no consensus required** • **Minimal barriers to implementation** • **Higher cost per economy** • **Reduced interoperability** • **One survey respondent specified that domestic standards will also be needed, in addition to a preference for a wider international standard**	• Slower – will require consensus • High barriers to implementation • Higher cost for APEC • Highly interoperable within the APEC but potentially not outside APEC • 5% of survey respondents thought that an APEC regional standard will best support a low-carbon hydrogen energy market in the APEC region	• Could be fast or slow - as standard criteria exists but requires more consensus between APEC members • Moderate barriers to implementation • Lower cost • High interoperability internationally • Likely to provide the broadest net benefits for APEC member economies • 40% of survey respondents thought that a wider international standard with input from APEC member economies will best support a low-carbon hydrogen energy market in the APEC region

APEC has the ability to support the development of markets and trade in low-carbon hydrogen across the region

Three support options for APEC's role in developing a low-carbon hydrogen standard are shown below for consideration.

> APEC member economies should consider cooperating to promote the development of a standard

Support Option 1:	Support Option 2:	Support Option 3:
APEC promotes the development of an international low-carbon hydrogen standard	**APEC defines best practice on governance and infrastructure for a low-carbon hydrogen scheme**	**APEC creates the governance and infrastructure for a low-carbon hydrogen standard specific to the APEC region**
Adoption dependent on economies uptake	1 – 2 years	3 – 5 years
• **Moderate development time as international standard development has already begun. Timeframe adoption is largely dependent on individual member economies.** • **Minimal barriers to implementation as it involves only facilitation and promotion.** • **Low cost as this is a facilitation role rather than direct support.** • **High interoperability but no guarantee of adoption by all member economies.**	• Short timeframe as APEC's role will be limited to developing a guidance document. However, the timeframe for adoption of the standard will depend on individual member economies. • Minimal barriers to implementation as it only involves development of guidance. • Moderate cost for development of guidance and consultation with member economies. • Moderate interoperability but success dependent on member economies following best practice guidance.	• Moderate timeframe due to the need to set up governance and infrastructure organisations. However, APEC is in control of the timeframe. • Barriers to implementation as APEC need all member economies to be aligned on infrastructure and governance. • High cost for set up of infrastructure and governance but this could be made self-sustaining through user fees in the longer term. • High interoperability as APEC able to ensure interoperability.

Timeframes for Implementation

An important area for consideration will be maintaining flexibility to allow for the incorporation of new information in a dynamic landscape.

> Implementation needs to allow for new developments in hydrogen standardisation, while providing enough early guidance for producers to align with

There will be potentially be a balancing act in developing guidelines for the standard that are strict enough to encourage the up-take of low-carbon hydrogen technology, while allowing for future alignment with developing standards. Possible stages and timelines for consideration in implementing a low-carbon hydrogen standard are as follows:

	Key objectives
Stage 1 **Years 1 - 2**	• Build consensus on new low-carbon hydrogen criteria, or which existing low-carbon hydrogen criteria to align with • Investigate and leverage existing progress and identify the next phases of development • Assist with the development of the standard framework and governance infrastructure • Develop guiding principles as a starting point to allow principles to be adjusted as the market develops
Stage 2 **Years 3 - 4**	• Refine and align principles such as emissions intensity thresholds • Assist with the development of governing bodies to allow for certification • Further develop the standard depending on market preferences and developments
Stage 3 **Years 5+**	• Finalise the low-carbon hydrogen standard and certification scheme with standard bodies such as ISO • Consultation with conformity assessment or accreditation bodies in relation to scheme implementation • Implement the certification scheme

Workshop learnings

The initial issues paper and discussion points were presented at the APEC Low-Carbon Hydrogen International Standard Virtual workshop on 17 March 2022. A summary of the feedback received is detailed in Section 6. The recommendations in relation to the discussion points detailed in Section 7 are summarised below.

Hydrogen has emerged as an important energy carrier that would help us move away from fossil fuels and transition towards a low emissions future

Developing a regulatory framework for hydrogen is important for safety, sustainability and trade. Falling costs for hydrogen and the urgency of cutting emissions has given clean hydrogen momentum.

To build trust, consumers must have transparency about what they are buying

An international standard would provide producers and consumers the assurance that a unit of hydrogen is indeed low-carbon. This consistency would give consumers confidence in the emissions savings available through low-carbon hydrogen.

> "It is important that APEC economies are engaged in the development and/or adoption of an international standard for low-carbon hydrogen."
>
> - Hon Dr Megan Woods, Energy and Resources Minister and the Minister of Research, Science and Innovation, New Zealand

Placing strict and arbitrary requirements on an infant industry can stifle progress

Poorly set definitions could fail to distinguish the producers and suppliers who are extensively reducing their emissions from the ones that are doing the bare minimum and could limit low-carbon hydrogen technology progress.

Focusing on emissions intensity during production is more powerful than setting standards to define arbitrary categories of hydrogen

It is essential that a standard's role is to declare and focus on the emissions intensity of hydrogen. Dr Finkel and the panel agreed that the standard should allow economies to determine their own acceptability thresholds for low-carbon hydrogen they import and produce. This flexibility will allow for:

- Market diversity
- Supporting competition, and
- A pathway for the industry to improve operating procedures.

> "If customers have clarity on the emissions credentials of the hydrogen they're buying, this will enable willing customers to reward the producer for going the extra mile to reduce emissions."
>
> - Dr Alan Finkel, Special Adviser to the Australian Government on Low Emissions Technology

The IPHE is leading the development of an internationally aligned measurement approach for emissions across the hydrogen supply chain
The IPHE's work could be incorporated into the guidance of a standard to provide transparency over all emissions-related attributes of hydrogen. Significant support was expressed for the IPHE's work by panel members.

The method of traceability depends on the purpose of the standard and the maturity of the market

The method for ensuring this traceability will depend on what international standards are aligned to. There were arguments for both book-and-claim systems and mass balancing systems. The panel discussed that the European Union currently uses mass balancing. Tim Karlsson (Executive Director, IPHE) noted that the market may not have the volumes that require these mechanisms to be in place yet.

The alignment of APEC member economies to an existing standard was the preferred way forward (Development option 3)
The panel members agreed this option balanced interoperability with cost and implementation time.

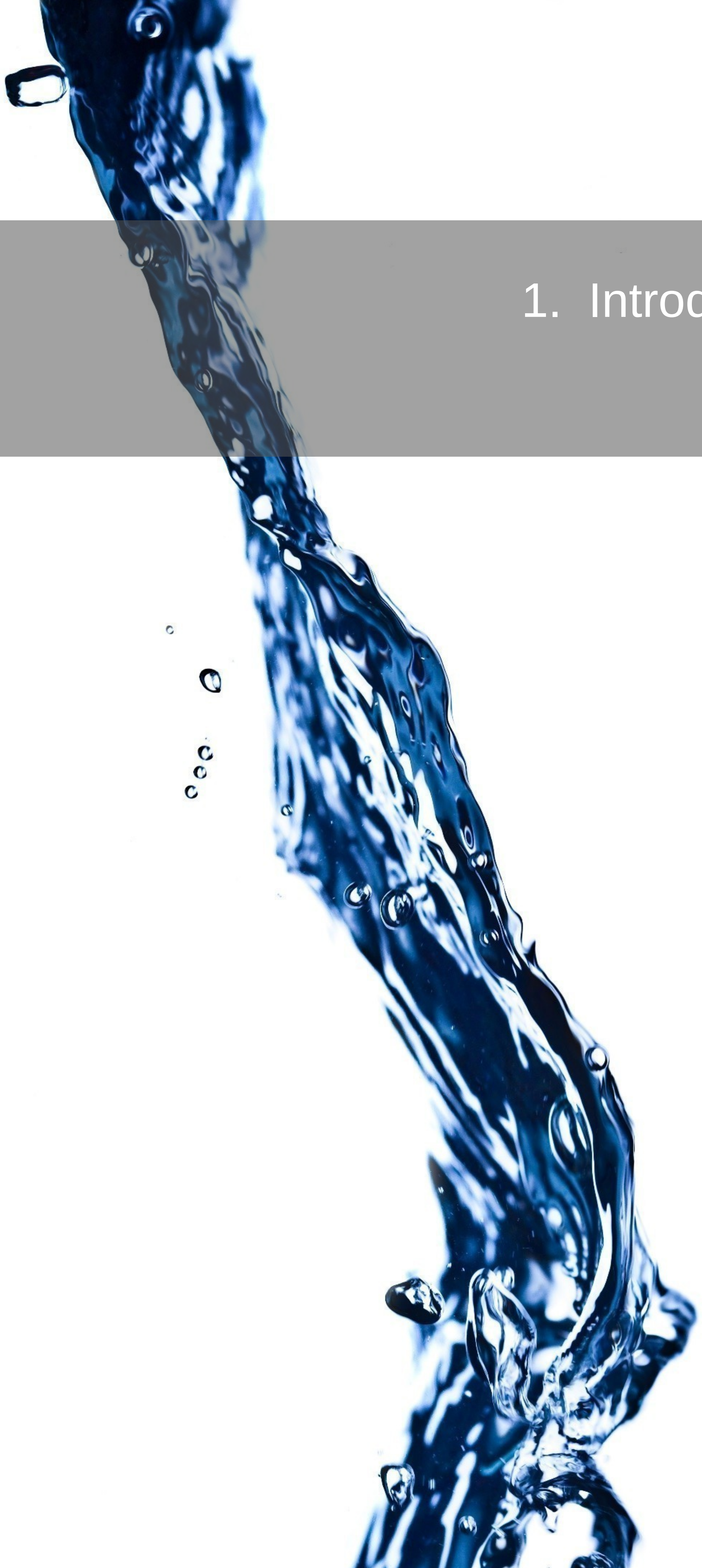
APEC could promote the development of an international low-carbon hydrogen standard (Support option 1)
The panel members discussed that the role of defining best practice, governance and infrastructure should fall upon an existing standards body such as ISO. APEC could then support the development and harmonisation of emissions thresholds for its member economies.

The development of a standard will take time. The timeline for development will depend on the progress of standards bodies such as ISO
This time would allow the market to develop naturally. The panel agreed that the speed of implementation will likely depend on the work in progress by ISO.

Recommendations

Recommendations in relation to the discussion points raised in the issues paper are summarised below.

Discussion Point 1 Should the definition and criteria for low-carbon hydrogen align with existing international standards and be defined by carbon intensity?	**Recommendation 1** Low-carbon hydrogen should be labelled with its carbon intensity using and internationally recognised methodology (such as the IPHE methodology). The focus of the standard should be on reducing the carbon intensity of hydrogen. Economies can then leverage the standard as required to meet their own low-carbon objectives.
Discussion Point 2 Is a mass balance system the most appropriate way to maximise the traceability of low-carbon hydrogen while allowing for ease of implementation?	**Recommendation 2** Mass balancing ensures the highest form of traceability. To align with standards in the EU and ensure transparency from day one, mass balancing is an appropriate method to track hydrogen. Tracking hydrogen may not be required until in-economy and cross border trade volumes increase.
Discussion Point 3 Should APEC have a role in shaping an international standard for low-carbon hydrogen?	**Recommendation 3** The alignment of APEC member economies to an existing standard is preferred rather than APEC participation in standard development. APEC can support the development of an international standard through research.
Discussion Point 4 Should APEC facilitate international discussion around aligning low-carbon hydrogen governance structures?	**Recommendation 4** APEC should support alignment with and internationally recognised methodology for calculation emissions associated with hydrogen production (such as the IPHE methodology). International standards body such as ISO are well placed to develop such standards.
Discussion Point 5 How can APEC best stage activities to allow for the standard to evolve with the emerging global hydrogen market?	**Recommendation 5** APEC should allow time in its process to allow the hydrogen market to develop. APEC can support the progress of a standard by providing guidance to ISO/TC 197 and ISO/TC 207.



1. Introduction

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1.1. Energy and hydrogen in the APEC region

The APEC region accounts for around 60% of world energy demand – by 2050, it is expected that 80% of this energy will be sourced from fossil fuels[2]. Low-carbon hydrogen has a role as a renewable energy vector that could contribute to lowering emissions from energy in the APEC region. The region's carbon dioxide (CO_2) emissions from fuel combustion are expected to rise by about 32% between 2010 and 2035[3]. All APEC member economies are committed to international agreements and climate change targets, such as the Paris Agreement, which focus on reducing greenhouse gas emissions.

Hence, developing a low-carbon hydrogen market across the APEC region could facilitate the achievement of APEC's aggregate energy intensity reduction goal of 45% by 2035, and the goal of doubling the share of renewables by 2030. Furthermore, expansion of the low-carbon hydrogen market could provide a significant economic growth opportunity and support the APEC region's economic recovery in the wake of the COVID-19 pandemic.

Establishing a low-carbon hydrogen international standard could help provide certainty to investors by clarifying the carbon emissions associated with hydrogen production, transportation, and storage technologies (which are recognised as key components of a future hydrogen supply chain). Internationally, there is currently a lack of consistency of terminology for classifying hydrogen based on its production method. Resolving these issues for the APEC region could help build confidence in the environmental integrity hydrogen sources and increase demand for low-carbon hydrogen products. This will provide the basis for producers to secure a price premium for low-carbon hydrogen in relation to conventional hydrogen and encourage investment in low-carbon hydrogen in the APEC region.

An overview of the costs and benefits of the associated with implementing a low-carbon hydrogen scheme are summarised in Table 1 below.

Table 1: Qualitative cost/benefit analysis for a low-carbon hydrogen standard in the APEC context

Benefits	Costs
• Avoids mislabelling or double-counting environmental impacts by unifying terminology and criteria across the APEC region • Provides greater transparency of carbon emissions in hydrogen production • Supports investment in hydrogen technology as it provides assurance on the decarbonisation potential of hydrogen. • Contributes to emissions reduction in the region by increasing uptake in low-carbon hydrogen • Certifies low-carbon hydrogen production to enable economies to quantify emission reductions • Provides developing economies with certainty around how a hydrogen market will operate • Allows a premium to be charged for low-carbon hydrogen • Supports investment in developing economies with high potential for low-carbon hydrogen production • Provides transparency over wider environmental effects to ensure uptake of low-carbon hydrogen does not create any additional harm • Support for a single standard will discourage the development of multiple standards with differing criteria	• Makes the hydrogen market more difficult to enter, as certification adds an additional cost barrier • May be a barrier to innovation if the standard does not adapt to new technologies • May add an additional layer to the complexity in international language on "green" or "low-carbon" hydrogen • May support higher cost low-carbon hydrogen projects by allowing a premium to be charged, thereby increasing costs to end users • Some existing domestic schemes and regulations may not be consistent with future international schemes. This creates a barrier to entry for economies with existing domestic schemes. If multiple standards are developed it will become increasingly difficult to keep criteria consistent across all standards. • May be difficult to maintain consistent assurance or verification approach across all economies included in the standard may be challenging • Substantial investment required to set up a standard and certification scheme • Irrespective of standardisation pathway, strategies to prevent barriers to market entry and innovation into hydrogen will need to be developed

[2] https://www.apec.org/groups/som-steering-committee-on-economic-and-technical-cooperation/working-groups/energy

[3] https://aperc.or.jp/publications/reports/outlook/5th/volume1/EDSO5_V1_C16_CO2.pdf

Benefits	Costs
• Minimises commercial risk by setting clear guidelines for low-carbon hydrogen and avoids early-stage investment into “low-carbon” hydrogen which is later reclassified as high-carbon	

1.2. About the Low-Carbon Hydrogen International Standard Project and this report

The Asia Pacific Economic Cooperation (APEC) is a regional economic forum of the Asia-Pacific region. APEC’s 21 member economies aim to create greater prosperity for the people of the region by promoting balanced, inclusive, sustainable, innovative and secure growth and by accelerating regional economic integration. The New Zealand-led Low-Carbon Hydrogen International Standard Project (the Project) is a legacy project of New Zealand’s APEC 2021 host year. The APEC Sub Committee on Standards and Conformance (SCSC) in collaboration with the APEC Energy Working Group (EWG) is delivering the project.[4] The objectives of the project are:

- To build consensus on the definition and criteria of low-carbon hydrogen, and how a low-carbon hydrogen international standard could look to benefit the APEC region.
- To perform an opportunity assessment of developing an APEC consensus on a low-carbon hydrogen international standard, taking into account linkages to existing domestic and international standards on renewable energy and existing international processes on low-carbon hydrogen.
- Support the development of markets and trade in low-carbon hydrogen across the APEC region, thereby achieving positive outcomes for APEC member economies, energy security and emissions reduction.

This report is the key output of the project. The report has been developed by Ernst & Young New Zealand Ltd (the project contractor) with oversight and guidance from New Zealand Ministry of Business, Innovation and Employment officials. The purpose of the report is to support an APEC member-wide consideration of the merits of low-carbon hydrogen international standard development and the role of APEC in its development. This report is informed by an issues paper that was discussed by APEC members and relevant experts at a virtual workshop in March 2022.

Significant work has been done to understand the carbon emissions associated with energy production, hydrogen production, and hydrogen conversion (i.e. liquefaction or ammonia production). Developing standards for further stages in the hydrogen life cycle such as storage, distribution and use is still in progress. The scope of this report is therefore focused on energy production, hydrogen production and conversion.

New Zealand would like to thank the following Co-Sponsoring Economies for their support of the project:

- Australia; Canada; Chile; China; Japan; Korea; Chinese Taipei; the Philippines; United States.

1.3. Stakeholder Engagement

This paper sets out the findings of desktop research, stakeholder interviews and stakeholder survey results. We would like to thank the stakeholders who participate in this research. We conducted interview with the following organisations:

- The New Zealand Gas Industry Company
- The Australian Renewable Energy Agency
- The New Zealand Energy Certificate System
- The APEC Sub-Committee on Standards and Conformance
- The Australian Department of Industry, Science, Energy and Resources
- Hinicio (CertifHy scheme developers)
- The National Climate Change Secretariat, Singapore
- The International Partnership for Hydrogen and Fuel Cells in the Economy
- The United States Department of Energy

In addition, we received 73 responses to a survey issued to all APEC member economies, from 18 different APEC economies.

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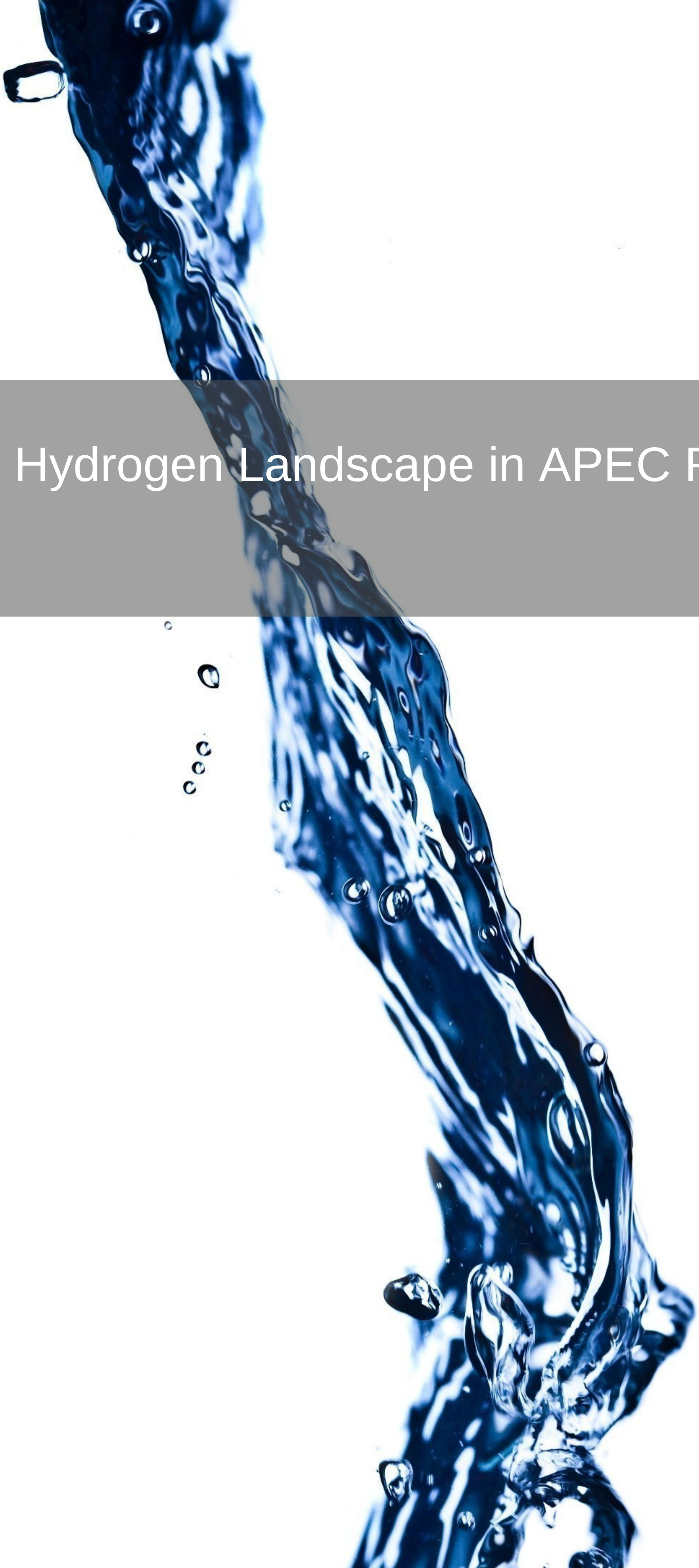
[4] https://aimp2.apec.org/sites/PDB/Lists/Proposals/DispForm.aspx?ID=2781



2. Hydrogen Landscape in APEC Region

2. Hydrogen Landscape in the APEC Region

This section reviews hydrogen strategies and classification of hydrogen in APEC member economies. We also review production, and supply scenarios globally and by APEC member economy.

2.1. Hydrogen strategies across the APEC region

Hydrogen strategies are currently developing across APEC. Some economies are more advanced with their hydrogen strategy than others. A key factor during strategy development is the feasibility of establishing a hydrogen market. Common barriers noted into this include:

- The infancy of low-carbon technologies
- The high cost of producing low-carbon hydrogen
- The lack of infrastructure
- The lack of/gaps in safety regulations and codes.

> 85% of survey respondents have a hydrogen strategy, policy, or plan in place or under development. 17% of survey respondents do not have a hydrogen strategy, policy, or plan in place (60% response rate to this question).
>
> 70% of survey respondents indicated a growing interest in hydrogen energy within their economy, and 66% of survey respondents indicated a growing interest in low-carbon hydrogen specifically.

At the economy level, hydrogen strategy maturity typically follows the progression path shown in Figure 1 below. We have also noted the maturity level of APEC member economies in relation to hydrogen strategy development.

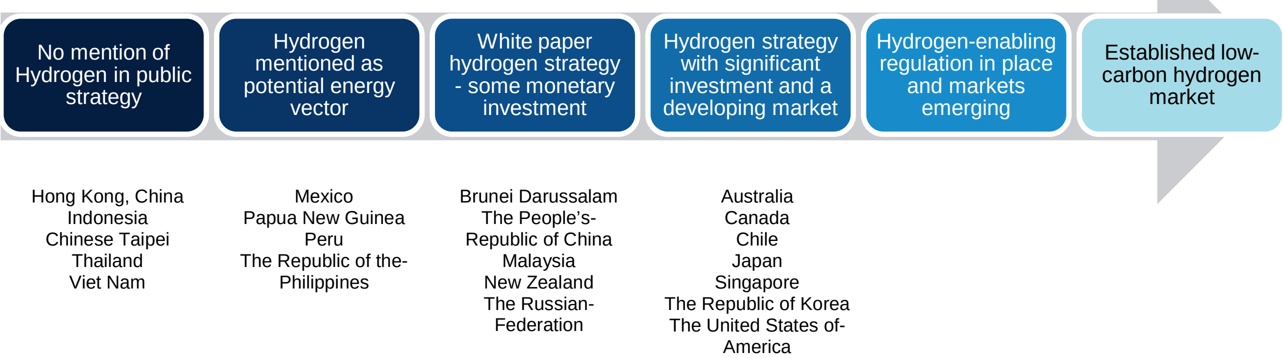


Figure 1: Hydrogen strategy maturity across APEC member economies

A summary of hydrogen trade expectations, strategies and funding across APEC member economies is shown in Table 2. Detailed information of government level hydrogen development for each APEC member economy is given in Appendix A.

Table 2: Hydrogen progress across APEC

Import/export expectations	• Fourteen APEC member economies are likely to be exporters of hydrogen, • Five member economies are likely to be importers of hydrogen, • Two member economies are likely to be both importers and exporters of hydrogen.
Strategies	• Five APEC member economies have hydrogen strategies that focus only green hydrogen, • Three member economies focus on both green and blue hydrogen, • Seven member economies focus on green, blue and grey hydrogen, and • Six member economies have not published hydrogen strategies which identify specific types of low-carbon hydrogen.

Funding	• Eight member economies have committed to funding low-carbon hydrogen development in some way, with government funding ranging from US$50 million to US$17 billion.

2.2. Bilateral agreements within APEC

The emerging global hydrogen market will include trade between economies. A number of bilateral agreements relating to hydrogen have already been signed between several APEC member economies. These cover trading, research, and co-development. The agreements provide for cooperation between economies in relation to hydrogen standards and increase the need for alignment of hydrogen standards across APEC. To date, there are nine bilateral agreements, three signed Memorandums of Understanding, and one research agreement between APEC member economies. Further information on the bilateral arrangements in place is given in Appendix A.

2.3. Hydrogen classification across APEC

There is no common approach to defining low-carbon, green, or blue hydrogen across APEC. Economies refer to hydrogen by its production method, colour, and/or its carbon intensity (in CO_2 equivalents per unit (commonly kg) of hydrogen produced - $kgCO_2e/kg\ H_2$).

Our research has shown that the definitions of hydrogen used by an economy are generally aligned to the maturity of hydrogen strategy development. Economies with more mature hydrogen strategies often specify carbon intensity thresholds. These thresholds vary between economies. Other economies simply use the production energy inputs and hydrogen production method. Using colours alone can silo economies with alternative production means, for example using high emission factor electricity for electrolysis.

65% of respondents have developed a definition for low-carbon hydrogen, however no consensus for this definition has been reached (44% response rate to this question).

A summary of commonly used hydrogen definitions by APEC member economies is provided in Table 3. Different or additional definitions are also outlined. Definitions for each economy are detailed in Appendix F.

Table 3: Low-carbon hydrogen definition across APEC

Emissions Intensity: →

	Green	Blue	Grey	Black	Brown
Commonly used definition	Electrolysis of water from renewable energy	Natural gas reforming or coal gasification with CCUS	Natural gas without CCUS	Coal without CCUS	Lignite without CCUS
Other definitions used	Electrolysis of water but no specific energy source mentioned	Carbon intensity threshold (36.4g $CO_2e/MJ\ H_2$ or 4.37-5.16 kg $CO_2e/kg\ H_2$)	• Carbon intensity threshold (~8.5kg$CO_2e/kg\ H_2$ or 9.27 kg $CO_2e/kg\ H_2$) • Gasified coal included as a feedstock	Carbon intensity threshold (~12.7-16.8kg$CO_2e/kg\ H_2$)	N/A

2.4. Hydrogen supply and demand

The IEA scenarios have varying demand forecasts, alluding to the uncertainty in hydrogen supply and demand

Currently, the annual global demand for hydrogen is estimated at 87 mega tonnes (Mt)[5] which is predominantly used for refining and industrial applications. Of the 87Mt, 9Mt comes from low-carbon hydrogen sources. The low-carbon hydrogen (according to IEA definitions) can be separated into 10% renewable electrolysis (0.45Mt) and 90% from fossil fuels with CCUS (8.55Mt)[6].

The future global demand for hydrogen is uncertain. We have used work by the International Energy Agency (IEA) to show the potential growth in hydrogen market as seen in Figure 2 these forecast vary widely. The IEA use 3 scenarios in 2021 to explore the potential hydrogen market as follows:

IEA Net-Zero Emission scenario (NZE)	• The NZE is a scenario shows an *achievable* pathway to reach net-zero emissions globally by 2050 • Under this scenario, the annual demand for hydrogen would grow to 528Mt in 2050, with 98% coming from low-carbon sources • Around half of the hydrogen is to be used in heavy industry, 30% is converted into other hydrogen-based fuels and 17% is used in gas power plants • Overall hydrogen would account for 13% of global energy final demand in 2050.
Sustainable Development Scenario (SDS)	• The SDS represents a pathway to achieve the outcomes in the Paris Agreement[7]. This does not limit warming to 1.5C. • Under SDS, hydrogen demand is expected to be around 290Mt in 2050 with 90% coming from low-carbon sources • The main sources of hydrogen demand are in the transport, industry, and power sectors • 30% of hydrogen demand is expected to be used in transport, 26% in industry and 17% used in gas power plants to balance electricity generation
Announced Pledges Scenario (APS)	• The APS models a world where only net-zero emission pledges[8] are implemented. This does not limit warming to 1.5C. • The annual demand of hydrogen expected under the APS is 250 Mt H_2 in 2050 - half the amount modelled in the Net Zero Emissions (NZE) scenario • The main sources of hydrogen demand are in the industry, transport, and power sectors • 40% of demand in 2050 is expected to be for industry applications, 17% for transport and 11% for power

NZE scenario predicts a six-fold increase in hydrogen demand by 2050.

Figure 2 shows that the NZE scenario has more than double the forecast hydrogen demand of the APS scenario. All scenarios share a common theme of growth in hydrogen demand, ranging from three to six-fold growth on 2020 annual demand by 2050.

[5] https://iea.blob.core.windows.net/assets/beceb956-0dcf-4d73-89fe-1310e3046d68/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf
[6] https://iea.blob.core.windows.net/assets/beceb956-0dcf-4d73-89fe-1310e3046d68/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf
[7] https://www.iea.org/reports/world-energy-model/sustainable-development-scenario-sds
[8] https://www.iea.org/reports/world-energy-model/policies#cross-cutting-policy-assumptions-by-scenario-for-selected-regions

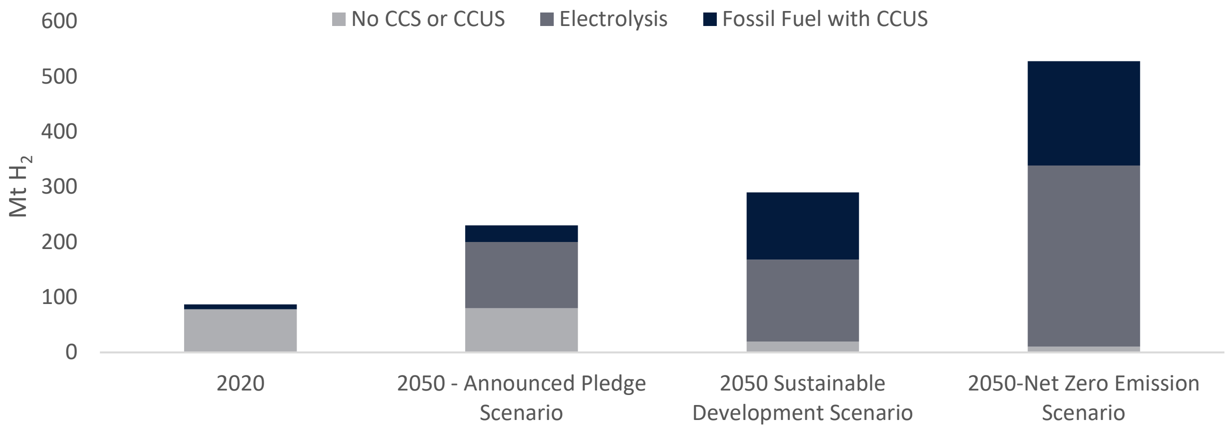


Figure 2: Hydrogen demand forecast by IEA scenarios

Current hydrogen supply in APEC member economies varies. The People's Republic of China supplies 20 million tonnes of hydrogen per annum (MTPA), followed by the United States of America producing 10 MTPA, while other hydrogen suppliers in the APEC region range from 0-3 MTPA. Hydrogen supply is expected to increase from 2030 to 2050.

Current hydrogen demand is only in the industrial sector. This is demand is expected to expand to additional sectors such as transport, export, power storage and generation, chemicals, iron and steel, and manufacturing. Forecasted hydrogen supply and demand across the APEC region is detailed in Appendix B.

2.5. Opportunities and challenges to creating a hydrogen market

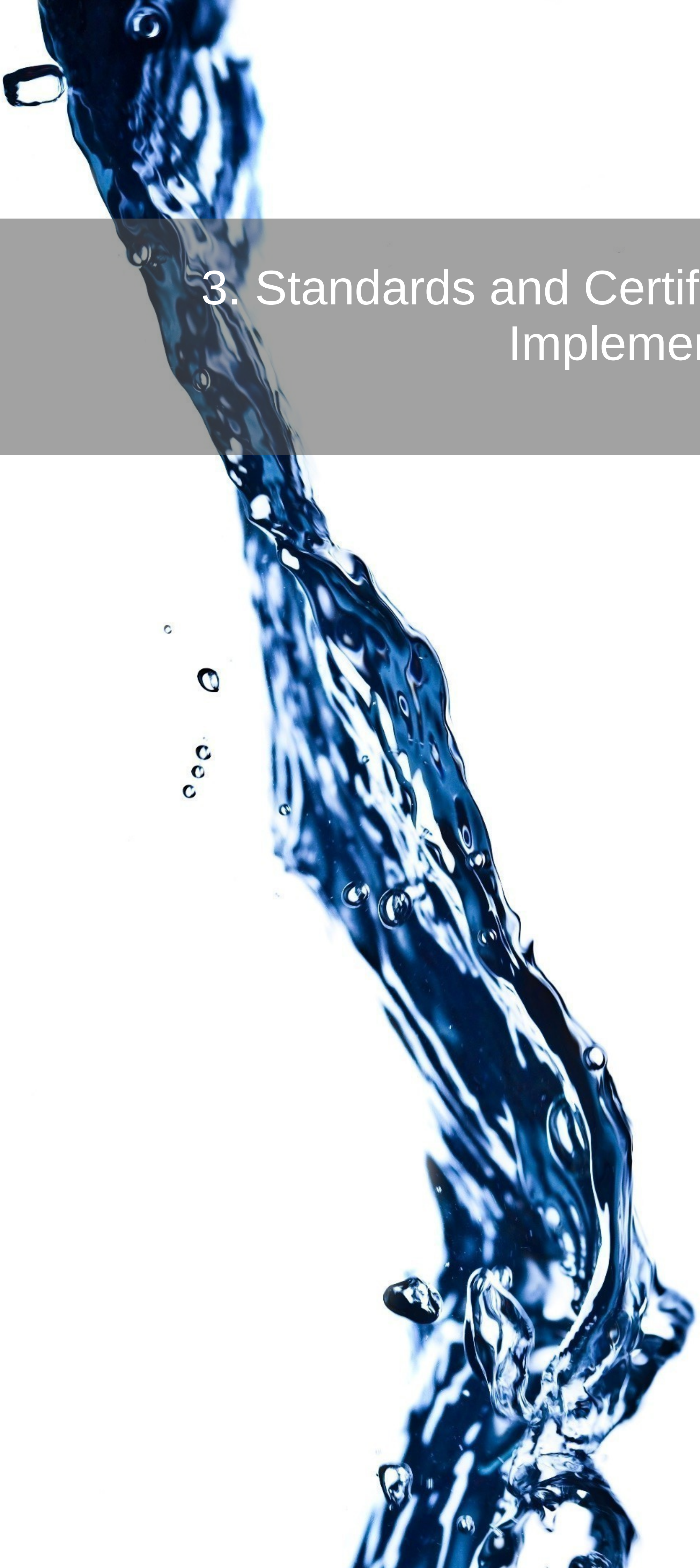
Common challenges and opportunities for the development of a low-carbon hydrogen market have been identified in a number of economy-level strategy documents. These have been summarised in Table 4, where it is noted that opportunities and challenges are often intertwined, with further detail given in Appendix B.

Table 4: Opportunities and challenges in hydrogen market creation

	Opportunities	Challenges
Technical	• **Hydrogen hubs:** Centralising hydrogen infrastructure can make other hydrogen applications viable. For example, at airports hydrogen can be used for on-site refuelling of buses, airport heating, local industry feedstock, and potentially airplane refuelling – reducing the cost of each individual application. • **Technology advances:** Hydrogen requires new technology to become commercially viable. APEC member economies could create this technology, creating opportunities for new export markets. • **Job creation:** Hydrogen production and consumption will require high-skilled labour during the construction and operation phases. Due to the distributed nature of potential hydrogen production, this can be used for regional development or to transition regions traditionally reliant on fossil fuel industries. • **Flexible load for grid stability:** Large scale electrolysers can act as a highly flexible load and thus, be a useful tool for stability as grids move to high renewable penetration. • **Blending for faster decarbonisation:** Hydrogen can be blended at low concentrations into existing natural gas delivery infrastructure in order to achieve some decarbonisation with minimal end-user impact.	• **Transport/Distribution:** *Local*: Distribution infrastructure such as pipelines is required. The conversion of existing infrastructure requires R&D and investment. *International*: Trials are ongoing for international shipping and competing technologies exist such as liquid hydrogen, ammonia, and methyl cyclohexane as hydrogen carriers. • **Storage:** Hydrogen gas takes up a lot of space due to its low density. As a result, it needs to be compressed or liquefied to allow efficient storage in tanks. Large scale storage underground is currently de-risked for salt caverns, but this requires specific geology. De-risking of storage in other formations will be important for establishing cost-effective large-scale storage. • **End use:** End use technology such as hydrogen fuel cell vehicles, hydrogen gas turbines and hydrogen for steel, are in various stages of commercialisation. This makes it difficult to forecast supply/demand and costing for the market.
Regulatory	• **Policy:** A supportive policy environment is required to support demand creation, mitigate investment risks, harmonise standards and remove other barriers to market creation • **Low-carbon hydrogen certificates:** A robust certification scheme that consumers trust, and which can be traded or transferred on an international level will help build the international hydrogen market and help economies lower emissions • **Good safety regulation:** Good safety regulation will ensure the safety of workers and create confidence in a hydrogen economy	• **Lack of standardisation:** Currently, there is a lack of standards and certification for low-carbon hydrogen, which does not allow projects to contract low-carbon hydrogen at a premium to conventional hydrogen with assurance of carbon intensity. • **Poor hydrogen certification:** Poor certification could lead to distrust in consumers of hydrogen and could negatively impact the effectiveness of the development of a low-carbon hydrogen market. • **Current state safety regulation:** Significant work is required to make hydrogen storage and transportation regulations fit for purpose. Hydrogen has not been ubiquitous in our energy system, so regulations have been formed around niche applications and not been revised. • **Aligning current gas regulation** Gas regulation needs to be revised to allow for hydrogen and other renewable gases and blends.

Economic	• **Hydrogen market:** APEC member economies could be major exporters in the global low-carbon hydrogen market, acting as a source of income • **End use market:** APEC member economies could become leading exporters of end-use hydrogen technologies such as hydrogen vehicles • **Renewable energy generation at scale:** The significant increase in renewable energy generation capacity required to meet green hydrogen production can help APEC economies by increasing RE industry development and achieve cost reductions that will provide wider economic benefits • **Improved energy independence** Some economies will have the opportunity to decrease reliance on imported foil fuels and in turn decrease their exposure to volatile oil prices.	• **Initial investment:** Large upfront capital costs are required to build low-carbon hydrogen production facilities and to build the underlying transmission and distribution infrastructure. **Uncertainty in cost competitiveness:** Economies of scale will take time to be established as will access to cheap renewable electricity. Preliminary studies indicating the profitability of hydrogen rely on economies of scale to be cost competitive. • **Heightened electricity energy use:** The additional electricity required for renewable energy generation can add additional strain on economies electricity network and has potential to influence price if hydrogen production is at a large scale.
Environmental	• **Lower emissions:** Hydrogen offers a solution to decarbonise hard to abate sectors, helping APEC member economies achieve their emissions reduction targets • **Competing priorities:** The scale of renewable energy generation projects required to supply green hydrogen are likely to compete with other land uses and community expectation is some areas	• **Distinguishing low-carbon hydrogen from higher emissions hydrogen**: Hydrogen emissions are dependent on the energy input along the supply chain and this needs to be correctly communicated. As there is potential greenwashing. • **Social perception on safety:** Some negative perceptions around safety and appropriateness of hydrogen production, storage and transport may impact uptake if not addressed with clear balanced information

3. Standards and Certification Implementation



3. Standards and Certification Implementation

This section outlines the critical components of a standard across different subject matter.

> Standards help define and operationalise "better practice".
>
> The development and implementation of a standard need to begin with the intended purpose of the standard.

3.1. The purpose of a standard

Standards are used to define a set of practices. A standard allows for assurance that a good or service is fit for purpose. The development of a standard needs to consider the following aspects:

- **Users:** who will be using the standard and what will they use it for
- **Objective**: what issue the standard is trying to address
- **Governance structure**: how governing parties can work together to support implementation, administration, and oversight of the standard
- **Legal requirements**: whether the standard is mandatory or voluntary in particular jurisdictions
- **Assurance and certification**: how compliance with the standard is verified and, once this has occurred, communicated to the end user (e.g., in the form of a certificate).

3.2. Standards and Certifications for different users

Different users of a hydrogen standard will have different needs from a standard.

Table 5 outlines the potential benefits of a hydrogen standard and certification scheme for different users.

Table 5: Benefits of standards and certifications to different hydrogen users

	Standard	Certification
Financier	• Provides guidance for financial instruments (such as green bonds) related to hydrogen developments • Ensures funding is only secured for hydrogen that meets low-carbon criteria • Allows attraction of investors in a low-carbon financial product • Provide an important basis to analyse business case feasibility and opportunities	• Gives assurance that the project proponent will achieve revenues appropriate to a low-carbon product.
Producer	• Provides clear guidelines on how to produce low-carbon hydrogen that can be trusted by an end user • Alignment to production standard may increase product interchangeably allowing for importation/exportation of hydrogen production equipment across economies	• Enable access to a low-carbon hydrogen market • May justify a premium price for the hydrogen due to its low-carbon nature • Allows for greater confidence that product meets performance standard
Transporter	• Provides guidelines on how to transport low-carbon hydrogen to ensure safety • May provide guidance on low-carbon transport methods	• Guarantees that the hydrogen transported is low-carbon, regardless of the mode of transport (e.g., as liquid hydrogen or ammonia) • Provides assurance to off-takers that the product is low-carbon • Certification of transport emissions may enable compliance with the EU's RED II and grant access to EU low-carbon fuels market
User	• Gives assurance that the hydrogen is low-carbon	• Allows users to report on reductions in carbon emissions

This report focuses on the physical production, transport and use of hydrogen. While standards and certification will be important for financing, the financing is a secondary activity to the production and consumption of hydrogen.

> 47% of survey respondents strongly agree and 16% somewhat agree that a robust certification system can help build consumer confidence in the integrity of low-carbon hydrogen (41% response rate to this question). 52% of survey respondents strongly agree and 14% somewhat agree that a robust certification system can help build government confidence in the integrity of low-carbon hydrogen (42% response rate to this question).

3.3. Objectives of a standard

Clear objectives lead to design requirements for other elements like governance and legal requirements. A potential set of objectives and requirements for a low-carbon hydrogen standard is shown in Table 6 below.

Table 6: Potential objectives and requirements for a low-carbon hydrogen standard

Objective of low-carbon hydrogen standard	Requirements
• Facilitate international trade	• Standard is internationally recognised • Standard is open to hydrogen imports and exports • Allowable criteria of the international standard align to existing domestic standards where possible
• Provide information about hydrogen production that is consistent and comparable	• Define a methodology to account for GHG emissions associated with hydrogen production • Define a downstream system boundary • Specific certification criteria, e.g., an allowable carbon emissions threshold • Criteria for certification finds a middle ground between too strict and too broad allowing for new hydrogen production pathways
• Ensure that hydrogen produced achieves aim of lowering carbon emissions	• Define allowable hydrogen production methods • Explicitly consider the global warming production of hydrogen • In the future the standard could include requirements for non-GHG impacts of hydrogen production, such as the environment and health

3.4. Governance structure

A defined governance structure supports effective development and execution of a standard. An example of a typical governance structure, used for schemes such as i-REC, is shown in Figure 3 below.

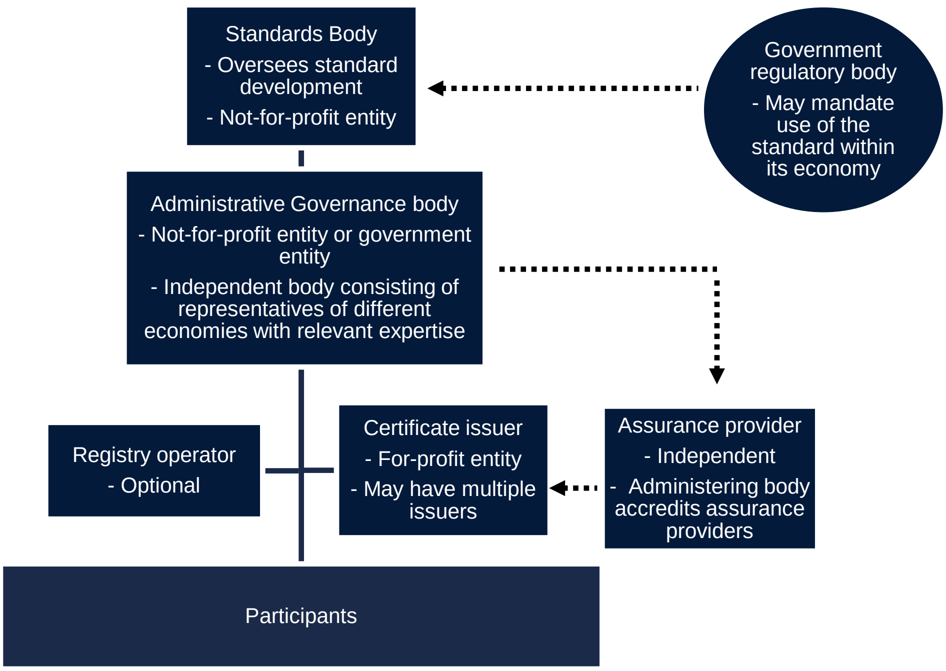


Figure 3: Governance structure of a generic standard including certification

Based on survey results, the preferred type of organisation to oversee a standard for low-carbon hydrogen is an existing internationally recognised body (56% of respondents from a 41% response rate to this question).

The type of entity suitable for each tier of the governance structure will need to align with the purpose of that tier. Some typical considerations are shown in Table 7 below.

Table 7: Entities governing different parts of a low-carbon hydrogen standard

Standards Body	• A not-for-profit entity that develops the low-carbon hydrogen standard or proposes adoption of an international standard • This is a technical expert body. The standards body will not enforce, regulate, or ensure compliance with the standard • The standard-setting body should consult with industry and align to producer and/or consumer preferences
Government regulator	• An entity separate from the standard-setting body is required to regulate the standard • The standards body will advise the government regulator which standards are appropriate to be adopted
Administrative body	• An entity separate from the government regulator may administer the standard • A not-for-profit entity may increase market trust internationally • Alternatively, a government entity could administer the standard
Certificate issuer	• The certificate issuer will maintain records about the certificate and a registry of certificates • Certification providers should be accredited by the administering body to ensure alignment to the standard
Assurance provider	• Assurance of certification providers is required to confirm the certificates have been correctly issued • Independent assurance provides confidence that the certificates have been correctly issued

3.5. Legal requirements

A standard for low-carbon hydrogen may be mandatory or voluntary. Voluntary standards can be quick to implement and lower cost for government. However, if there is continued non-compliance with a voluntary standard or potential for significant public harm due to non-compliance with the standard, a mandatory standard may be required for low-carbon hydrogen. Key characteristics associated with mandatory and voluntary standards in relation to low-carbon hydrogen are listed in Table 8 below.

Table 8: Characteristics of mandatory and voluntary standards

Mandatory standards	Voluntary standards

• Compulsory, government-regulated schemes.
• May be established through regulation to:
  o Mandate a registration and reporting framework
  o Oversee certificate creation, issuance, transfer, and cancellation.
• Legislation would also dictate a verification framework, audit, and compliance.
• Financial incentives are provided through trading or through a subsidy scheme, referred to as “compliance” markets.
• Legislation could build on existing gas or renewables legislation which could be adapted to include low-carbon hydrogen, or alternatively new legislation could be established.
• It is more difficult to implement a mandatory standard for low-carbon hydrogen internationally, as consensus is needed across multiple economies.
	• Voluntary standards provide a framework that acts in a way that adds value by providing trust for consumers.
	• There are no penalties for producers who chose not to participate in the standard, instead relying on self-regulation of the low-carbon hydrogen market.
	• The customer trust, additional demand and price differentials provided by the standard drives participation.
	• No legislation is necessary, instead certification will be guided by a framework and adherence to this will be overseen by a scheme administrator, which is usually a not-for-profit entity.
	• It is generally easier to implement a voluntary standard on an international scale.

3.6. Assurance and Certification

Assurance is required to gain certification and ensure compliance with the standard.

Assurance providers should be accredited by the administrative body of the standard. Providers should be independent.

Assurance against a standard is generally done by a third party without direct interest in the economic relationship between supplier and buyer. Assurance would help to ensure the accuracy of the declared quantities of hydrogen and their associated emissions. Third-party assurance is likely to give greater confidence than assurance by the producer.

The assurance provider follows an internationally recognised assurance standard (such as relevant ISO standards) and assesses whether the hydrogen meet the requirements of the low-carbon hydrogen standard. This assurance is then used to certify the hydrogen as low-carbon by the certification body.

10% of survey respondents do not currently provide or receive assurances about low-carbon credentials, and a further 71% of survey respondents did not answer this question. Commonly used assurance approach mentioned by the remaining 19% of survey respondents were declarations by suppliers, and certification of origins of electricity. A market-based approach where stakeholders determine acceptable credentials was mentioned as a preferred option for low-carbon hydrogen.

Based on survey results, the preferred type of organisation to issue low-carbon hydrogen certificates is an accredited certification body (23% of respondents). 10% of respondents would prefer a regulatory body to issue low-carbon hydrogen certificates.

Certification would confirm whether the hydrogen produced complies with the standard. The certificate demonstrates to the buyer the compliance of the low-carbon hydrogen standard and could have an associated label to inform the customer. Certificates can be self-issued or issued by a third party. Certificates issued by a third party are likely to provide more confidence in the integrity of the low-carbon hydrogen than those issued by a producer.

There are different options for certificate providers, governance structure, and certificate approach. A summary of the options is provided in Table 9.

Table 9: Options for hydrogen certificate features

Assurance providers		
One single assurance provider internationally • Minimises interoperability issues • May create biased issuance of certificates without competition for certification • Monopoly provider may have little incentive to provide value for money	**Multiple assurance providers** • Market sets the price of certification • Market sets certification expectations • May result in diluted value in certificate if different certifiers are interpreting standards differently	**One single assurance provider per economy** • More straight-forward for consumers to get certified • May be difficult to trade internationally due to different local interpretations of standards

Certificate provider governance	
For-profit certificate provider • Most commonly used • Fees apply • Risk of financial incentive in providing certification • Provides scope for multiple certifiers within the economy	**Not-for-profit certificate provider** • Generally linked to government, so may increase credibility • May be no fee or a small administration fee • Removes financial interest, therefore removing bias in providing certification • Likely to be the only certifier in that economy

Certificate boundary	
Certify the production of hydrogen • Guarantees that one unit of hydrogen has a particular carbon intensity • Consumers make their own decisions with the information provided within the certificate • A registry may be required to track international trade • Purpose is to certify renewable production which will create additional value for hydrogen, therefore facilitating trade • Aligns to I-REC and CertifHy	**Certify a specific asset or project** • Assesses the low-carbon value of a specific asset or project • Certification of an asset is given based on clearly defined certification criteria • No need for a registry • Purpose is to certify a specific asset to give investors confidence in the environmental credibility of their investment, therefore facilitating investment in low-carbon hydrogen projects • Aligns to Climate Bond Initiative and EU Taxonomy

4. Current state of low-carbon hydrogen standards

4. Current state of low-carbon hydrogen standards

This section outlines global developments in hydrogen standardisation and certification. This space is evolving rapidly alongside the development of the international hydrogen market.

4.1. The hydrogen life cycle

Hydrogen is a versatile energy carrier. It can be produced, transported, and used in many ways - each of which has an impact on embodied emissions. The components of the hydrogen production life cycle are shown in Figure 4 below.

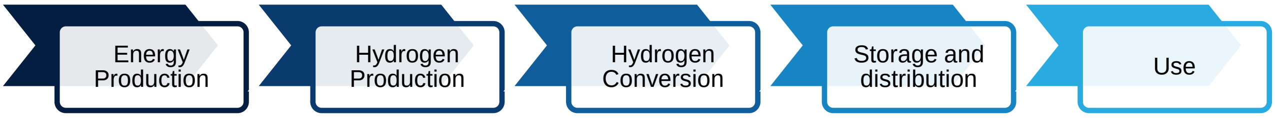


Figure 4: Components of the hydrogen lifecycle

A description of each component is shown in Table 10.

Table 10: Hydrogen life cycle component descriptions

Component	Description
Energy production	The energy used to produce hydrogen can be renewable or non-renewable. Renewable energy could be solar or hydro, while non-renewable includes fossil fuels such as natural gas and coal. The source of energy will impact emissions intensity.
Hydrogen production	There are multiple ways to produce hydrogen. Fossil fuels can be used directly through methods such as natural gas reforming and coal gasification. Fossil fuels can also be used indirectly to produce electricity for the electrolysis of water; the same way renewable electricity can be used to produce hydrogen. The production method and source of energy will impact emission intensity.
Hydrogen conversion	Hydrogen can be converted for different transportation methods and end uses, such as liquid hydrogen or ammonia. These steps and the energy used in these conversion steps will impact emission intensity.
Storage and distribution	Hydrogen can be used at site and can be stored for future use. It may be stored as a gas or stored as ammonia or liquid hydrogen. The choice of storage medium and transportation mechanism will impact emissions intensity.
Use	Hydrogen combustion produces zero greenhouse gas emissions. However, if used in conjunction with other gases there can be emissions produced at end use.

4.2. Existing low-carbon standard scope

The components of the hydrogen lifecycle present options for the scope of a hydrogen standard (i.e. coverage of energy production to end of life, or a limited scope covering certain components only). The storage and distribution and use stages of the lifecycle are difficult to assess due to:

- The distance between a producer and an end user
- The distribution method used.

Existing low-carbon hydrogen standards cover energy production, hydrogen production, and hydrogen conversion.

As a result of these challenges, low-carbon standards for hydrogen beyond the hydrogen conversion component are yet to be developed. Significant work has been done to understand the emissions associated with energy production, hydrogen production, and hydrogen conversion.

Existing certification schemes such as CertifHy issue certificates that focus on the first three life cycle components. To reflect the current state of low-carbon hydrogen standards, this study focuses on energy production, hydrogen production and hydrogen conversion.

4.3. Current low-carbon hydrogen standards and certification schemes

There are several standards and schemes which relate to low-carbon hydrogen. Two types of schemes have been investigated in this report:

- Guarantee of Origin (GO) certification schemes such as CertifHy, which provide evidence to customers that a unit of energy was produced to a scheme's criteria. The process is as follows:
  - Evidence is usually provided as a certificate associated with a unit of hydrogen
  - A producer can receive a certificate from a scheme provider to pass on to a consumer
  - The consumer pays a premium for the certificate, which can be used for greenhouse gas accounting
  - Once redeemed by a consumer, a GO certificate is cancelled.
- Low-carbon investment standards such as the Climate Bonds Standard and Certification Scheme, which provide guidance on low-carbon hydrogen related to financial instruments such as green bonds.

11% of survey respondents indicated that their economy has a standard under development or in place related to low-carbon hydrogen. Specific standards mentioned in the survey were:

- CertifHy (European scheme) potentially to be used in Chile (see details in Table 11 below)
- IPHE has developed guidelines with input from various governments (see details in Table 11 below)
- California Air Resources Board Low Carbon Fuel Standard
- Standards Australia, ME-093 committee
- ISO/TC 197
- IEC TC 105

Note that the Low Carbon Fuel Standard, ME-093, ISO/TC 197 and IEC TC 105 are not directly relevant to the scope of this project. These schemes have therefore not been summarised in this report.

An outline of the existing schemes is given in Table 11.

Table 11: Existing standards and certification schemes relating to low-carbon hydrogen

Standard/scheme	Geographical scope	Description	Boundary	Low-carbon Hydrogen Criteria
IPHE's Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen	International	This working paper aims to develop a mutually agreed upon methodology for determining GHG emissions associated with the production of hydrogen.	Hydrogen Production	Not applicable – a methodology rather than strict criteria
International Renewable Energy Certificate Standard (i-REC Standard)	International	The I-REC standard is a list of rules, regulations and best practises to be used by attribute tracking systems such as a hydrogen certification scheme	Governance structure of standards and certifications	As outlined in the International Attribute Tracking Standard (Appendix F)
Climate Bonds Standard and Certification Scheme	International	The Climate Bonds Standard and Certification Scheme is a labelling scheme for bonds and loans. The Scheme is used by bond issuers, government, investors and financial markets to prioritise investment that are consistent with 2-degree Celsius warming limit in the Paris Agreement.	Entire hydrogen life cycle	To be eligible hydrogen has to be generated from renewable sources with provided environmental and social impact assessments Lifecycle emissions of less than 100g CO_2e/kWh, declining to 0g by 2050.

Standard/scheme	Geographical scope	Description	Boundary	Low-carbon Hydrogen Criteria
CertifHy	Europe	A voluntary certification scheme that provides evidence that a unit of hydrogen meets its criteria for low-carbon hydrogen	Hydrogen production	If the hydrogen is produced using renewable energy sources (biogas, hydro, wind, solar, etc.) and the emissions of this fraction is < 36.4 gCO_2e/MJ then it is eligible for the "Green Hydrogen" certificate CertifHy low-carbon hydrogen – covering hydrogen from non-renewable low-carbon energy sources (e.g., nuclear, fossil with CCUS) with an emissions benchmark of 36.4 gCO_2e/MJ (-60% compared to Steam Methane Reformation) No production technology is excluded
Vertogas	Netherlands	Vertogas is a guarantee of origin scheme for biomethane proving that the purchased gas was produced using sustainable biomass. The standard will be expanded to include hydrogen.	Energy production	The transformation process must not involve fossil materials The certification of the sustainable raw material is based on the technical criteria of the standard NTA8080: Sustainably produced biomass for bioenergy and bio-based products
TUV SUD GreenHydrogen	Germany	A voluntary certification scheme that provides evidence that a unit of produced hydrogen has lower emissions than fossil fuel- produced hydrogen or fossil fuels	Energy production Hydrogen production Use (transport only)	A variety of criteria dependent on energy production, hydrogen production and use The standard certifies "green" hydrogen, defined as hydrogen produced using renewable energy and/or waste as well as residues/by-products. Green hydrogen used in the transport sector must have a greenhouse gas emission reduction potential of at least 70% compared to a fossil fuel reference value in RED II. Green hydrogen not intended for mobility must have an emission reduction potential of at least 70% compared to reference value for biofuels.
Green Gas Certification Scheme	United Kingdom	A scheme that tracks biomethane, or 'green gas', through the supply chain. It provides consumers who buy the gas, confidence in the green gas sector and an incentive for gas producers to inject green gas into the grid instead of using it to generate electricity	Energy production	Biomethane: 34.8 gCO_2e per MJ of injected biomethane over the entire life cycle
Green Power Renewable Gas Certification Scheme	Australia	GreenPower is a domestic renewable energy accreditation program. They recently released a consultation document for a renewable gas certification pilot expected to start in mid-2022. This aims to be a voluntary renewable gas certification scheme to enable selling, purchasing and tracking	Energy production	Green hydrogen defined a hydrogen that is produced using renewable energy source and feedstocks with minimal or zero waste. This can be done through electrolysis using renewable electricity or by using biomethane SMR.

Standard/scheme	Geographical scope	Description	Boundary	Low-carbon Hydrogen Criteria
		of renewable gases such as hydrogen in Australia.		
Zero Carbon Certification Scheme (Smart Energy Council)	Australia	Guarantee of origin scheme which promotes uptake and distribution of renewable hydrogen products. There are three parallel certificate 'badges' for renewable hydrogen, green ammonia and green metals. All products must be made from renewable sources.	Production	Blue hydrogen made from fossil fuels with CCS will **not** be covered by this scheme Renewable Certification Scheme. Based on industry led CertifHy for accounting methodology. Allow for electricity to be sourced directly from renewable generation plant, via third party power purchase agreements, or via the grid (provided zero emissions can be demonstrated).

4.4. Low-carbon criteria for existing hydrogen standards

29% of survey respondents indicated a preference for emissions intensity thresholds for production as a low-carbon hydrogen criteria, while 10% of survey respondents would prefer criteria based on specific production methods. 3% of respondents would prefer other criteria. 59% of survey respondents did not provide an answer to this question.

There is currently no universal standard that defines low-carbon hydrogen globally. However, a number of certification schemes have developed their own criteria that can be applied to hydrogen, as follows:

- **CertifHy**: Standards such as CertifHy in Europe apply to hydrogen specifically.
- **Green Gas Certification Scheme**: Includes hydrogen as well as other fuel types.

Common criteria from existing standards are shown in Table 12.

Table 12: Existing criteria for low-carbon hydrogen standards and certification schemes

	Examples of criteria associated with focus area	Example standards
Greenhouse gas intensity	• A quantitative threshold for the greenhouse gas emissions associated with a unit of hydrogen, where: o Emissions are $kgCO_2e$, which account for other greenhouse gases other than CO_2, such as methane o Units are usually expressed per megajoules MJ (10^6 joules) of energy derived from hydrogen o Type of hydrogen and energy production method (e.g. TUV SUD) o Value independent of production methods (e.g. CertifHy, Climate Bonds Standard) o Multiple classifications (e.g. CertifHy has thresholds for "green" and "low-carbon" hydrogen) o Percentage reduction when comparing hydrogen production methods (e.g. TUV SUD, which requires % reductions from referenced fossil fuel greenhouse gas intensities) o Thresholds for European schemes such as CertifHy and TUV SUD are based on the minimum emissions reduction percentage outline in the Renewable Energy Directive (RED). The reduction is a percentage from the best available technology at the time, which is currently steam methane reforming with a reference value of 91 gCO_2e/MJ	• CertifHy o "Green Hydrogen": if the hydrogen is produced using renewable energy sources (biogas, hydro, wind, solar, etc.) and the carbon footprint is < 36.4 gCO_2e/MJ (60% reduction from a RED II reference value of 91gCO_2e/MJ) o "Low-carbon hydrogen": if the hydrogen is produced using non-renewable energy sources (e.g. nuclear, fossil with CCUS) and the carbon footprint is < 36.4 gCO_2e/MJ (the same threshold for Green Hydrogen) • TUV SUD GreenHydrogen Standard o "Green Hydrogen" < 28.2gCO_2e/MJ (70% reduction from a RED II reference value of 94gCO_2e/MJ) production well to gate o "Green Hydrogen+" < 28.2gCO_2e/MJ (70% reduction from a RED II reference value of 94gCO_2e/MJ) production well to wheel (includes delivery of hydrogen to consumers) • Green Gas Certification Scheme o < 32.8 gCO_2e/MJ (65% reduction from a fossil fuel equivalent reference value of 94gCO_2e/MJ) for renewable fuels of non-biological origin • Climate Bonds Standard and Certification Scheme o Must be generated from renewable sources with provided environmental and social impact assessments being undertaken with no significant controversies identified, along with lifecycle emissions of < 27.7 gCO_2e/MJ
Hydrogen production method	• The method for producing hydrogen, such as: o Electrolysis of water o Steam methane reforming o Coal and biomass gasification o May include Carbon Capture, Utilisation and Storage (CCUS) if produced with fossil fuels o Hydrogen produced as an industrial by-product. Note that the greenhouse gas intensity for hydrogen produced as an industrial by-product should include consideration of the carbon footprint of the main product as well as the hydrogen by-product. o Often impacts greenhouse gas intensity thresholds, such as for TUV SUD where the threshold for certification is more demanding if the hydrogen is produced with hydrolysis of water	• TUV SUD GreenHydrogen Standard o The carbon intensity threshold for hydrolysis of water is lower than that of other production methods • Green Gas Certification Scheme o Only hydrogen produced by electrolysis powered by renewable electricity is eligible for the certificate

	Examples of criteria associated with focus area	Example standards
Energy production method	• The type of energy used for hydrogen production, such as: o Renewables (e.g. solar, hydro, wind) for electrolysis o Natural gas for steam methane reforming o Coal for coal gasification o Biomass for biomass gasification o Often impacts greenhouse gas intensity thresholds, such as for CertifHy, TUV SUD and the Green Gas Certification scheme	• CertifHy o The hydrogen is classified as “Green” if produced by renewable energy sources and “Low-carbon” if produced using other energy sources • TUV SUD GreenHydrogen Standard o Green hydrogen is defined as hydrogen produced using renewable energy or waste • Green Gas Certification Scheme o Only hydrogen produced by electrolysis powered by renewable electricity is eligible for the device.

4.5. Traceability of low-carbon hydrogen

Low-carbon hydrogen needs to be tracked by the certification scheme provider to prevent double counting of low-carbon production. Different options for tracing low-carbon hydrogen as shown in Table 13.

Conflicts could arise due to economies having different preferences on the system used to trace hydrogen. Importing economies or economies without the means to produce low-carbon hydrogen may want a book-and-claim system. A book-and-claim system would enable these economies to purchase certificates to offset their local high-carbon hydrogen production. Exporting economies and end users may want a traceable system such as mass balancing to encourage physical purchasing of the economy’s low-carbon hydrogen.

Physical connection of supply and demand can affect traceability. For example, if all users are physically connected to the same gas grid, then carbon accounting and offsets are more straightforward. However, if the scheme is needed to operate across networks, across different gas blends or across different borders/economies, then there are additional requirements and challenges.

Table 13: Traceability of hydrogen in the supply chain

Traceability of Supply Chain		
Book-and-Claim	**Mass balance**	**Segregated**
• Certificates are earned by suppliers at the point of production, and sold to users alongside the physical commodity • Certification is based on the transfer of environmental impact characteristics • Useful for complex supply chains where physical tracking of a unit of production is difficult to maintain along all points of the supply chain • Affordable method of traceability • More potential for errors or fraud as there is no physical link between production and use, which reduces transparency • Purpose is to increase market uptake of certified low-carbon hydrogen • Aligns to I-REC, CertifHy and TUV SUD’s guarantee of origin processes	• Measures the percentage of certified and uncertified materials – e.g., “this product contains 50% low-carbon hydrogen” • Reconciles the inputs and outputs of a product throughout the supply chain • Certification is based on physical tracking to the point of blending with other products • Useful for complex supply chains • Can have mixed use of both low-carbon and higher-carbon intensive hydrogen. Useful when different technologies are being used to produce hydrogen or hydrogen is blended with other gases • A reconciliation period must be a defined to track the mass balance	• All certified materials are physically separated from materials that are not certified and cannot be physically mixed • Blending of certified low-carbon hydrogen with non-certified or high-carbon hydrogen would not be allowed (such as in a pipeline or gas grid) • Certification is based on physical tracking throughout the supply chain, therefore a very transparent method of tracing • Useful for simpler supply chains • Used when certifications must be strictly enforced, such as in the food and beverage industry • Stringent monitoring required

4.6. Emerging hydrogen standards and certification schemes outside of APEC/internationally

The European Union

The European Union is well advanced in the implementation of hydrogen standards and has enacted the Renewable Energy Directive II (RED II). The RED II requires:

- 50% of the hydrogen used by industry to be “green” hydrogen (more specifically, a renewable fuel of non-biological origin (RFNBO)) by 2030
- A minimum of 2.6% of transport fuel needs to be an RFNBO by 2030.

the European Union will need to unify certification schemes to enable the trade of hydrogen between economies

The RED II mandate presents several opportunities and challenges, including:

- There is currently no universal standard to align to
- Economies may develop schemes with different criteria
- The mandate requires renewable transport fuels of non-biological origin (which includes hydrogen) to reduce emissions by 70% compared to fossil fuels.

Energy is already freely traded as a commodity across Europe and hydrogen use will increase significantly as part of the RED II’s requirements. Therefore, the European Union will need to unify certification schemes to enable the trade of hydrogen between economies. The RED II may accelerate the development of a standard.

International Organization for Standardization

The International Organization for Standardization (ISO) has a technical committee dedicated standardization in the field of environmental management to address environmental and climate impacts (ISO/TC 207). The focus of TC 207 includes environmental management systems, verification/validation and related investigations, environmental labelling, environmental performance evaluation, and life cycle assessments.

ISO also has a technical committee dedicated to hydrogen technologies (ISO/TC 197). The scope of ISO/TC 197’s work is standardization in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen. The technical committee has an active standards development work programme covering a range of topics in this field such as hydrogen fuel quality, safety systems, sampling, storage and fuelling. ISO provides for its members to submit proposals for new standards the relevant technical committee for consideration.

4.7. COP26 and the Green Hydrogen Organisation

At the 26th United Nations Climate Change Conference (COP26), the Glasgow Breakthrough Agenda was signed by 42 economies, of which eight APEC member economies signed[9]. The Breakthrough Agenda identifies five key sectors, one of which was hydrogen, with the aim to make affordable renewable and low-carbon hydrogen globally available by 2030. The Glasgow Breakthrough on Hydrogen aims for public and private stakeholders to collaborate to deploy 25GW of green hydrogen capacity by 2026.[10]

At COP26, the Green Hydrogen Organisation (GH2) launched the development of the “Green Hydrogen Standard”. GH2 was formed September 2021 with the goal of accelerating the uptake of green hydrogen. The Green Hydrogen Standard will be presented at the Green Hydrogen Global Summit and Assembly between 17 – 18 May 2022 and will focus on three key pillars:

- **Greenhouse gas emissions accounting**: The GH2 standard will guarantee that green hydrogen is based on renewable sources with close to zero emissions. The standard will include carbon accounting procedures and thresholds that will apply to grid and off grid production.
- **Environmental, social and governance**: The GH2 Standard will track the overall social, environmental and governance impact of GH2 certified hydrogen.

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[9] Australia, Canada, Chile, China, Japan, New Zealand, Korea and the U.S.A. were signatories
[10] https://racetozero.unfccc.int/system/glasgow-breakthroughs/

- **Development impact:** The GH2 Standard will assess the development impact of any GH2 Standard certified green hydrogen, based on the United Nations Sustainable Development Goals.

4.8. Emerging hydrogen standards and certification schemes across APEC

A significant amount of research is being completed in the APEC region to understand how a low-carbon hydrogen standard can be developed. Notable advances in the development of a standard include:

- The Australian government are trialling a guarantee of origin certificate system
- Chile have engaged Hinicio, the consultancy that developed CertifHy, to investigate a low-carbon hydrogen certification scheme for the economy
- The People's Republic of China has developed a low-carbon hydrogen standard.

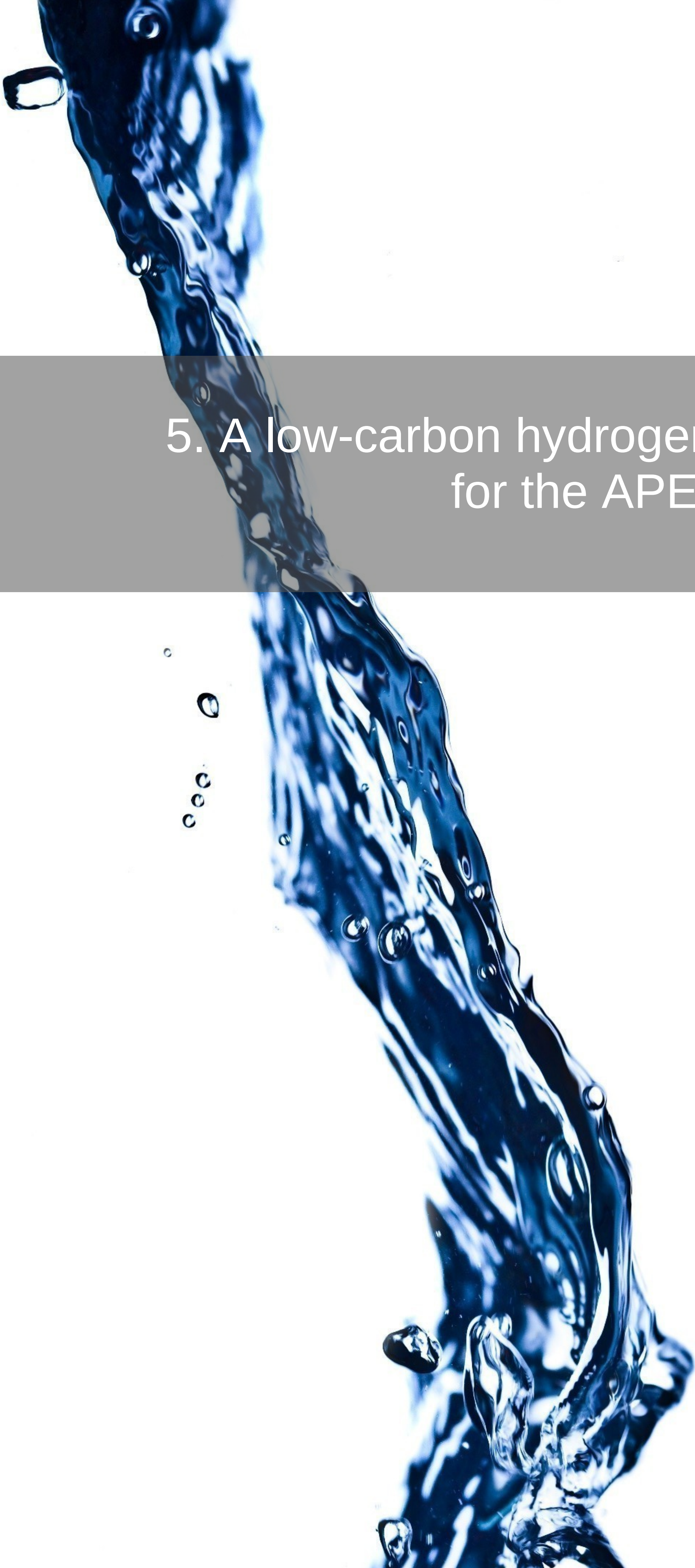
An outline of these developments is given in Table 14, based on both desktop research and survey responses.

Table 14: Emerging hydrogen standards and schemes in the APEC region

Economy	Established standard/ scheme	Emerging standard/ scheme	No action
Australia		✓	
Brunei Darussalam			✓
Canada		✓	
Chile		✓	
The People's Republic of China	✓		
Hong Kong, China			✓
Indonesia			✓
Japan			✓
The Republic of Korea			✓
Malaysia			✓
Mexico			✓
New Zealand		✓	
Papua New Guinea			✓
Peru			✓
The Republic of the Philippines			✓
The Russian Federation			✓
Singapore			✓
Chinese Taipei			✓
Thailand			✓
The United States of America	✓ *	✓ *	
Viet Nam			✓

*Note the United States of America has an economy-wide standard under development. The state of California has an established standard, California Air Resources Board Low Carbon Fuel Standard, which includes hydrogen.

5. A low-carbon hydrogen scheme for the APEC Region



5. A low-carbon hydrogen scheme for the APEC Region

This section outlines the options for development of a low-carbon hydrogen standard and the potential role for APEC in development of the standard.

5.1. Options for a low-carbon hydrogen standard

We have identified three options for discussion for the development of a low-carbon hydrogen standard within the APEC region. We have considered the speed of standard implementation, barriers to implementation, costs of standard development and interoperability with international standards. A summary of this analysis is shown in Table 15 below.

Given the work to date on developing a standard internationally, it would seem more efficient to leverage an existing standard's criteria. APEC member economies would need to build consensus on the existing standard to align with, which will have a significant impact on the speed and ease of implementation.

Table 15: Options for development of a low-carbon hydrogen standard for the APEC region

	Development Option 1: **Individual economies to develop their own standards** **2 – 3 years**	**Development Option 2:** **Develop a new, APEC-wide standard** 5+ years	**Development Option 3:** **Align APEC member economies to an existing standard** 3 – 5 years
Speed of Implementation	May be faster, as no consensus is needed to be reached. Speed is dependent on member economies individual processes and who is regulating the standard i.e. (public or private). Speed will also depend on whether the standard is an amendment to an existing standard within the economy or a stand-alone standard.	Slower, as the standard will be developed from scratch and a consensus will need to be reached. It will likely take longer as the standard will need consensus across APEC regions and will need a governing body to be created.	Faster, as standard criteria already exist. An ISO standard takes around 3 years from the first proposal to final publication.[11]
Barriers to implementation	Minimal. Each economy can decide on criteria that suit their market. Barriers are dependent on member economies' individual processes. With opposition from key stakeholders, inadequate human or financial resources, lack of clarity on operational guidelines or roles and responsibilities acting as barriers to implementation.	High Consensus is needed across all APEC member economies. Individual economies will have different interests - for example, a hydrogen import market will have different priorities for standard criteria than an export market.	Moderate There may be criteria in existing schemes that do not align with current APEC market preferences. There may be unforeseen updates to existing schemes. However, most participants within APEC would already be familiar with the existing schemes.
Costs	Costs lie entirely within the individual economy. This is likely to duplicate effort so the total costs will be higher across APEC.	Higher cost, as developing a standard from scratch is a resource-intensive process. Costs can be spread across APEC member economies.	Lower cost, as this is a less resource-intensive option. Costs largely lie with the economies which developed the existing standards, and any remaining costs can be spread across participating economies
Interoperability with international schemes	Potential for reduced interoperability, as individual economies may develop standards with conflicting criteria, making importing and exporting hydrogen difficult.	Highly interoperable within the APEC region. Interoperability may be reduced with other regions, as some criteria may differ from existing international standards	High interoperability, as criteria have been specifically designed to align with existing standards. This option has the greatest potential for interoperability both across APEC and outside the region.

[11] https://www.iso.org/developing-standards.html

5.2. The potential role for APEC in facilitating low-carbon hydrogen schemes

We have developed three options for consideration regarding the role of APEC in developing a low-carbon hydrogen standard. We have again considered the speed of standard implementation, barriers to implementation, costs of standard development and interoperability with international standards.

Table 16: Support options for APEC's involvement in a low-carbon hydrogen standard

	Support Option 1: **APEC promotes the development of an international low-carbon hydrogen standard**	**Support Option 2:** **APEC defines best practice on governance and infrastructure for a low-carbon hydrogen scheme**	**Support Option 3:** **APEC creates the governance and infrastructure for a low-carbon hydrogen standard specific to the APEC region**
Speed of Implementation	**Dependent on economies adoption rate** Moderate development time as international standard development has already begun. Timeframe adoption is largely dependent on individual member economies	**1 – 2 years** Short timeframe as APEC's role will be limited to developing a guidance document. However, the timeframe for adoption of the standard will depend on individual member economies.	**3 – 5 years** Moderate timeframe due to the need to align government and infrastructure organisations. However, APEC is in control of the timeframe.
Barriers to implementation	Minimal Facilitation and promotion role only.	Minimal Development of guidance role only.	Higher Need to get all member economies aligned on infrastructure and governance.
Costs	Low cost as this is a facilitation role rather than direct support.	Moderate cost for development of guidance and consultation with member economies.	High cost for set up of infrastructure and governance but this could be made self-sustaining through user fees in the longer term.
Interoperability with international schemes	High But no guarantee of adoption by all member economies.	Moderate Success dependent on member economies following best practice guidance.	High. APEC able to ensure interoperability. Allows APEC to participate in the process of standard development and ensure alignment to the best interest of APEC member economies.

5.3. Timeframe for implementation

Hydrogen technology and low-carbon hydrogen standards are rapidly emerging across APEC and the world. When developing a standard, the timeframe for implementation needs to be considered. Table 17 details the impacts of implementing a standard quickly, compared to a slower approach.

Table 17: Benefits and risks of different implementation timeframes

	Implementation Option 1: Slow implementation **APEC allows the hydrogen market to develop and implements a standard based on more mature information**	**Implementation Option 2: Fast implementation** **APEC use the information available and prioritises rapid uptake of a standard**
Benefits	• New information may become available that will improve the standard, such as the IPHE methodology • APEC can leverage new information, reducing the resources required of it to develop a standard • More time to allow for consultations, quality control and improvements • Allows new technology to develop	• Provides the best chance of aligning low-carbon criteria across APEC • Restricts the development of hydrogen technology that won't be considered low-carbon in future standards
Risks	• May allow hydrogen technology to develop that isn't compliant with future standards • APEC member economies may develop standards that do not align and restrict trade	• Emerging information and standards may supersede the standard • May restrict the development of new technology • May restrict economies that are yet to develop hydrogen infrastructure from entering the market

A staged approach could be used to ensure that the benefits of both a fast and slow implementation are captured. Throughout the implementation, a standard could be sufficiently flexible to allow for new information to be incorporated. The guidelines of the standard could still be strict enough to encourage the up-take of technology compatible with international low-carbon schemes. Possible stages and timelines for implementing a low-carbon hydrogen standard are shown in Table 18.

Table 18: Timeline of implementation for a low-carbon hydrogen standard

	Key objectives
Stage 1 **Years 1 - 2**	• Build consensus throughout APEC on new low-carbon hydrogen criteria, or select existing low-carbon hydrogen criteria to align with • Work with organisations in the hydrogen standard development industry (such as CertifHy, ISO and The Green Hydrogen Standard) to leverage existing progress and identify the next phases of development. The next phases are likely to include feasibility studies, strategy development and implementation plans • Coordinate with standards bodies such as ISO to facilitate the development of the low-carbon hydrogen standard framework, including classification and criteria • Develop guiding principles as a starting point • Allow principles to be adjusted as the market develops • Coordinate with certification bodies such as CertifHy and TUV SUD to facilitate the development of the governance infrastructure required for future certification • Identify key gaps and current developments that may influence the standard
Stage 2 **Years 3 - 4**	• Refine and align principles such as emissions intensity thresholds to enable the trade of low-carbon hydrogen between APEC regions as well as international markets • Coordinate with APEC member economies and international standards bodies to facilitate the development of governing bodies to allow for certification • Further develop the standard depending on market preferences and developments, such as including life cycle emissions and incorporating new standards such as the IPHE methodology • Continue to identify key gaps, sources of misalignment and current developments that may influence the standard

Stage 3 **Years 5+**	• Finalise the low-carbon hydrogen standard and certification scheme with standard bodies such as ISO • Consultation with conformity assessment or accreditation bodies in relation to scheme implementation • Implement the certification scheme

6. Workshop learnings

6. Workshop learnings

The issues paper and discussion points were presented at the APEC Low-Carbon Hydrogen International Standard Virtual Workshop on 17 March 2022. The workshop included:

- An address from Hon Dr Megan Woods, New Zealand's Energy and Resources Minister and the Minister of Research, Science and Innovation
- An address from Dr Alan Finkel, Special Adviser to the Australian Government on Low Emissions Technology
- A panel discussion with hydrogen experts from Ernst & Young Limited, the IPHE, the Thailand Energy Innovation Research Group, the German energy Agency GmbH and the China National Institute of Standardization.

Learnings from the workshop in relation to discussion points previously raised in the issues paper are summarised below.

Hydrogen has emerged as an important energy carrier that would help us move away from fossil fuels and transition towards a low emissions future

Developing a regulatory framework for hydrogen is important for safety, sustainability and trade. Hon. Megan Woods, noted that clean hydrogen provides many opportunities, including:

- New jobs
- Diverting heavy transport away from fossil fuels and,
- Improving energy security.

> "It is important that APEC economies are engaged in the development and/or adoption of an international standard for low-carbon hydrogen."
>
> - Hon Dr Megan Woods

Falling costs for hydrogen and the urgency of cutting emissions has given clean hydrogen momentum. Economies are pursuing low emission hydrogen technologies, including with carbon capture and storage.

To build trust, consumers must have transparency about what they are buying

An international standard would provide producers and consumers the assurance that a unit of hydrogen is indeed low-carbon. Dr Alan Finkel, noted that for this trust to be established, hydrogen-related emissions need to be tracked and reported in a consistent way across the globe.

This consistency would give consumers confidence in the emissions savings available through low-carbon hydrogen. Consumers could then opt to pay a premium for low-carbon hydrogen based on emissions savings. This premium will help build the market for low-carbon hydrogen products.

> "If customers have clarity on the emissions credentials of the hydrogen they're buying, this will enable willing customers to reward the producer for going the extra mile to reduce emissions."
>
> - Dr Alan Finkel

Placing strict and arbitrary requirements on an infant industry can stifle progress

It was noted that hydrogen might be blended into a single pipeline with natural gas, injected into a dedicated pipeline, loaded into a ship or used at a refuelling station. Hydrogen at these distribution points could come from a variety of sources with differing emissions intensities. Dr Finkel noted that definitions of hydrogen should facilitate a diversity of supply options to allow for robust market development.

It is also important that international standards allow for new hydrogen technology. Poorly set definitions could fail to distinguish the producers and suppliers who are extensively reducing their emissions from the ones that are doing the bare minimum and could limit low-carbon hydrogen technology progress.

Focusing on emissions intensity during production is more powerful than setting standards to define arbitrary categories of hydrogen

It is essential that a standard's role is to declare and focus on the emissions intensity of hydrogen. The panel noted that the standard needs to consider the different stages of hydrogen market development in each economy. Dr Finkel and the panel agreed that the standard should allow economies to determine their own acceptability thresholds for low-carbon hydrogen they import and produce. This flexibility will allow for:

- Market diversity
- Supporting competition, and
- A pathway for the industry to improve operating procedures.

The standard should focus on the outcome

The panel agreed with Dr Finkel's discussion points that the outcome of carbon reduction should be the focus of the standard as opposed to production methodology. Angela Ogier (Associate Director, Ernst & Young Limited) agreed that the standard needed to create an environment with focus on carbon intensity and outputs, rather than the inputs themselves.

In addition, it was agreed that aligning to certain technologies should be avoided to prevent the stifling of new production technologies. It was noted by the panel that the purity of the gas stream should be taken into consideration and set in the definition of the boundary conditions for a standard.

The IPHE is leading the development of an internationally aligned measurement approach for emissions across the hydrogen supply chain

The IPHE's work could be incorporated into the guidance of a standard to provide transparency over all emissions-related attributes of hydrogen. Significant support was expressed for the IPHE's work by panel members.

The method of traceability depends on the purpose of the standard and the maturity of the market

The panel agreed that transparency and traceability is essential to building consumer trust. The method for ensuring this traceability will depend on what international standards are aligned to. There were arguments for both book-and-claim systems and mass balancing systems.

The panel discussed that the European Union currently uses mass balancing. A low-carbon hydrogen standard would therefore need to use mass balancing to align with these existing standards. Using mass balancing as a starting point would ensure the highest level of transparency from the beginning. However, Tim Karlsson (Executive Director, IPHE) noted that the market may not have the volumes that require these mechanisms to be in place yet.

APEC is a key international forum for influencing the approach to developing or adopting international standards

All parties agreed that APEC economies should be engaged in the development and/or adoption of an international standard for low-carbon hydrogen. It was agreed by the panel members that multiple existing standards may need to be considered. The consistencies between standards could be used to define the criteria for a recommended APEC standard. It was agreed that developing consensus on the criteria will be an iterative process.

APEC could conduct research required to support standards bodies such as ISO

It was recommended that an APEC recommendation on a standard should incorporate the work done by IPHE, ISO 14067 [12](Greenhouse gases — Carbon footprint of products) and ISO/TC 197[13] (Hydrogen technologies).

The alignment of APEC member economies to an existing standard was the preferred way forward (Development option 3)

The panel members agreed this option balanced interoperability with cost and implementation time. Other options were not considered due to the risks of low interoperability, time requirements and high implementation costs.

APEC could promote the development of an international low-carbon hydrogen standard (Support option 1)

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[12] ISO - ISO 14067:2018 - Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification

[13] ISO - ISO/TC 197 - Hydrogen technologies

The panel members discussed that the role of defining best practice, governance and infrastructure should fall upon an existing standards body such as ISO. As such, alternative support options that involved APEC defining these elements were not considered. Workshop participants generally agreed that APEC could focus on encouraging member economies to align with the IPHE's methodology for calculating emissions. APEC could then support the development and harmonisation of emissions thresholds for its member economies.

The development of a standard will take time. The timeline for development will depend on the progress of standards bodies such as ISO

This time would allow the market to develop naturally. Angela Ogier noted that the challenge will be to develop an agile standard at the pace the industry needs to meet its climate ambitions. The panel agreed that the speed of implementation will likely depend on the work in progress by ISO/TC 197 and ISO/TC 207[14] (Environmental management). It was suggested that APEC can assist ISO with progressing the standard by providing guidance. It was also agreed that any outcomes such as preferred carbon intensity should align with regulatory frameworks as they develop.

[14] ISO - ISO/TC 207 - Environmental management

7. Recommendations

7. Recommendations

The feedback received from the issues paper and virtual workshop provided valuable guidance on the way forward for an APEC low-carbon hydrogen standard. Recommendations in relation to the discussion points raised in the issues paper are summarised below.

Discussion Point 1: Should the definition and criteria for low-carbon hydrogen align with existing international standards and be defined by carbon intensity?

The standard should focus on emissions intensity rather than on production technology
The IPHE is leading the development of an internationally aligned measurement approach for emissions across the hydrogen supply chain. The IPHE's work could be incorporated into the guidance of a standard to provide transparency over all emissions-related attributes of hydrogen.

Recommendation 1

Low-carbon hydrogen should be labelled with its carbon intensity using and internationally recognised methodology (such as the IPHE methodology). The focus of the standard should be on reducing the carbon intensity of hydrogen. Economies can then leverage the standard as required to meet their own low-carbon objectives.

Discussion Point 2: Is a mass balance system the most appropriate way to maximise the traceability of low-carbon hydrogen while allowing for ease of implementation?

Mass balancing ensures the highest form of traceability, but tracking hydrogen may not be required until the market develops
A low-carbon hydrogen standard would need to use mass balancing to align with existing European Union hydrogen standards. Using mass balancing as a starting point would ensure the highest level of transparency from the beginning. However, the market may not have the volumes that require these mechanisms to be in place yet.

Recommendation 2

Mass balancing ensures the highest form of traceability. To align with standards in the EU and ensure transparency from day one, mass balancing is an appropriate method to track hydrogen. Tracking hydrogen may not be required until in-economy and cross border trade volumes increase

Discussion Point 3: Should APEC have a role in shaping an international standard for low-carbon hydrogen?

APEC member economies could align to an existing standard (Development option 3)

This option balances interoperability with cost and implementation time. Other options included an APEC-specific standard and allowing economies to develop domestic standards. These alternatives are at risk of low interoperability, high time requirements and high implementation costs. APEC could conduct research required to support standards bodies such as ISO, leveraging the work done by the IPHE, ISO and existing standards.

Recommendation 3

The alignment of APEC member economies to an existing standard is preferred rather than APEC participation in standard development. APEC can support the development of an international standard through research.

Discussion Point 4: Should APEC facilitate international discussion around aligning low-carbon hydrogen governance structures?

APEC could support an existing standards body with developing an international low-carbon hydrogen standard (Support option 1)

The roles of defining best practice, governance and infrastructure should fall upon an existing standards body such as ISO as opposed to APEC. APEC could focus on supporting these standards bodies by providing research and encouraging alignment with the IPHE's methodology for calculating emissions.

Recommendation 4

APEC should support alignment with and internationally recognised methodology for calculation emissions associated with hydrogen production (such as the IPHE methodology). International standards body such as ISO are well placed to develop such standards.

Discussion Point 5: How can APEC best stage activities to allow for the standard to evolve with the emerging global hydrogen market?

APEC should allow time in its process to allow the hydrogen market to develop

The speed of implementation will likely depend on the work in progress by ISO/TC 197[15] and ISO/TC 207[16] (Environmental management). APEC could assist ISO with progressing the standard by providing guidance.

Recommendation 5

APEC should allow time in its process to allow the hydrogen market to develop. APEC can support the progress of a standard by providing guidance to ISO/TC 197 and ISO/TC 207.

[15] ISO - ISO/TC 197 - Hydrogen technologies
[16] ISO - ISO/TC 207 - Environmental management

Appendices

Appendix A:
Hydrogen policy and strategy across the APEC region

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
Australia	• Paris Agreement signatory • Every state has net zero by 2050 target • Renewable energy target of 20% in 2020 (met) • Signed the COP26 Breakthrough Agenda • Bilateral partnerships with Germany, Singapore, The Republic of Korea, and Japan.	• Economy level hydrogen strategy: National Hydrogen Roadmap17 • Development of supporting associations and strategy • Pilot green hydrogen project (Port Lincoln Hydrogen and Ammonia Supply Chain Demonstrator).18 • 2022 - Hydrogen infrastructure assessment to be undertaken • 2019 – Australia's economy hydrogen strategy published with the desire to export clean hydrogen.	• ARENA Renewable Hydrogen Deployment Funding – conditional funding of AUD$103.3m (USD$76.6m) awarded in May 2021 to three commercial-scale renewable hydrogen projects • Australian government is investing AUD$1.2b (USD$888m) into building a hydrogen industry.	• Exporter	Green Blue
Brunei Darussalam	• Paris Agreement signatory • Brunei Darussalam National Climate Change Policy (BNCCP) committed to a 20% reduction in GHG by 2030 relative to 2015 • Entered partnership with Japan in 2020, through Advanced Hydrogen Energy Association for Technology Development (AHEAD).	• Report released in 2020, "Brunei Darussalam: Shifting to a hydrogen society19". Deep dive report into strategy and feasibility of using hydrogen to support renewable electricity generation.	• N/A	• Exporter	Green Blue Grey
Canada	• Paris Agreement signatory • 80% net emission reductions below 2005 levels by 2050 • Total use 4Mt H2/y 6.2% total final energy consumption by 2030 • Signed the COP26 Breakthrough Agenda • Bilateral partnerships with Germany, Chile and Japan.	• Hydrogen strategy for Canada 2020 shows commitment to invest in hydrogen energy and wants to be a lead user • Province-level strategies and roadmaps include: • Ontario has developed a Low-Carbon Hydrogen Strategy[20]: a plan to accelerate and sustain a low-carbon hydrogen economy.	• British Columbia released its hydrogen strategy in July 2021 – US$10m investment over 3 years • Natural resources Canada launched a CAD$1.5b (USD$1.21b) clean fuel fund during the World Hydrogen Technologies convention • Invest CAD 25 million by 2026 into Hydrogen (~USD 19million).	• Exporter	Green Blue

[17] https://www.csiro.au/en/Do-business/Futures/Reports/Hydrogen-Roadmap
[18] http://www.renewablessa.sa.gov.au/content/uploads/2019/09/south-australias-hydrogen-action-plan-online.pdf
[19] https://www.eria.org/uploads/media/Research-Project-Report/RPR-2020-04-Brunei-Shifting-Hydrogen-Society/Brunei-Darussalam-Shifting-to-Hydrogen-Society-new.pdf
[20] Ontario's Low-Carbon Hydrogen Strategy | ontario.ca

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
		• The Québec Green Hydrogen and Bioenergy Strategy has been developed with the purpose of creating[21] a coherent framework and a favourable environment to accelerate the production, distribution and use of green hydrogen and bioenergy. • Alberta is building a lower emission energy future with hydrogen and have developed The Hydrogen Roadmap[22] as a key part of that future. • Alberta Natural Gas Vision and Strategy which identifies blue hydrogen as a key growth area released in October 2020. • The Government is collaborating with Transition Accelerator, the Canadian Hydrogen and Fuel Cell Association (CHFCA and the Canadian Gas Association.			
Chile	• Paris Agreement signatory • Carbon neutral by 2050 (being legislated) • Hydrogen generation goal of 25GW electrolysis by 2030 • Signed the COP26 Breakthrough Agenda • Bilateral Partnerships with Germany, Costa Rica, Colombia, Canada and Singapore.	• Economy-level hydrogen strategy: Hydrogen Technologies and Perspectives for Chile[23] • Commitments to decarbonise and transition to clean energy transport system and increase demand for clean hydrogen. • New legislation is currently being formulated to drive increased resources/R&D to green hydrogen infrastructure development. • Strong focus on energy transition to low emissions, with funding to progress hydrogen supply chain R&D	• Green Hydrogen Funding offered by Government of Chile in 2021, with pool of USD$50m in max USD$30m per fund to give out.	• Exporter	Green

[21] Québec Green Hydrogen and Bioenergy Strategy | Gouvernement du Québec (quebec.ca)
[22] Hydrogen Roadmap | Alberta.ca
[23] http://4echile.cl/4echile/wp-content/uploads/2019/06/Tecnolog%C3%ADas-del-hidr%C3%B3geno-y-perspectivas-para-Chile_2019.pdf

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
		being prioritised. This is exemplified through plans to develop the economy's largest technological institute in the context of the energy transition.[24]			
The People's Republic of China	• Paris Agreement signatory • Reach carbon neutral by 2060 • Signed the COP26 Breakthrough Agenda.	• National Green Hydrogen Strategy released December 2020 • Economy-level hydrogen strategy: Energy Technology Revolution & Innovation Initiative (2016-2030) • Strong government support for hydrogen infrastructure development through subsidy schemes to boost hydrogen fuel in the transport sector. The Government announced the decision to support hydrogen over electric vehicles in their 'Made in China 2025' strategy.[25] • the People's Republic of China has undertaken extensive pilot studies on hydrogen FCV's. One million FCVs are set to be put to market in 2020, with plans to continue to scale up in the long-term. • Bloomberg NEF has tracked approximately USD 17 billion worth of investments in the hydrogen transport industry through to 2023.[26]	• Government subsidies on electric vehicles influenced USD$17b hydrogen projects to be signed in the People's Republic of China in 2021.	• Exporter/ Importer	Green Blue Grey Black/Brown (short-term)
Hong Kong, China	• Paris Agreement signatory	• Hong Kong Roadmap on Popularisation of Electric vehicles includes incentive to conduct trials of hydrogen fuel cell buses[27]	• N/A	• Importer	N/A
Indonesia	• Paris Agreement signatory	• Hydrogen not publicly mentioned in energy strategy	• N/A	• Exporter	N/A

[24] https://fuelcellsworks.com/news/government-of-chile-supports-green-hydrogen/
[25] https://www.rvo.nl/sites/default/files/2019/03/Hydrogen-economy-pfp
[26] https://www.bloomberg.com/news/articles/2019-06-27/china-s-hydrogen-vehicle-dream-chased-by-17-billion-of-funding
27 https://www.policyaddress.gov.hk/2021/eng/p99.html

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
Japan	• Paris Agreement signatory • 46% reduction GHG emissions by 2030 compare with 2013 levels • Signed the COP26 Breakthrough Agenda • Bilateral partnerships with Australia, Argentina, Canada, EU, Malaysia, Netherland, New Zealand, Indonesia, Singapore, Thailand, and the Russian Federation, the United Arab Emirates with Memorandum of Cooperation and/or other cooperation framework.	• Strategic Energy Plan (revised 2021) • National Hydrogen Strategy 2017 • Green growth strategy 2020 • Green Innovation fund • Japanese govt budget: R&D for fuel-cell technology, developing international hydrogen supply chain and domestic hydrogen production, feasibility study and demonstration of hydrogen utilization in region, subsidy for purchasing FCV, subsidiary for construction of hydrogen refuelling station, etc.	• Japanese govt allocated approx. USD$3.26b from green innovation fund towards R&D/Demonstration in hydrogen.	• Importer	N/A
The Republic of Korea	• Paris Agreement signatory • The Republic of Korea has committed to 37% below BAU by 2030. No long-term goals have been made. • Total use 1.94Mt H2/y by 2030 • Signed the COP26 Breakthrough Agenda • Letter of intent to progress partnership between The Republic of Korea and New Zealand.	• Economy-level hydrogen strategy: Hydrogen Economy Plan in Korea[28] • Legislation on hydrogen has been established to support hydrogen supply chain development, particularly hydrogen-specialised companies and education programs. • The Republic of Korea Government has decided to support hydrogen over electric vehicles.29 • Hydrogen Fuel Cell Vehicles (FCVs) have already been commercialised and is expected to continue to increase with over USD 2 billion invested in the production of FCVs by 2022. • Member economy government assembly passed the Hydrogen Economy Promotion and Hydrogen Safety Management Law in 2020, which provides an overarching legal framework for hydrogen development.	• In July 2020 announced Green New Deal, committing USD$17.7b fiscal investment by 2025 in green mobility.	• Importer	Green Blue Grey
Malaysia	• Paris Agreement signatory	• Roadmap to transition from fossil fuel to renewable energy sources strategy	• N/A	• Exporter	Green

[28]https://static1.squarespace.com/static/5c350d6bcc8fedc9b21ec4c5/t/5e1d1b23c551b3461b49de7d/1578965797343/Hydrogen-economy-plan-in-Korea.pdf
[29] https://www.rvo.nl/sites/default/files/2019/03/Hydrogen-economy-plan-in-Korea.pdf

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
	• Bilateral partnership with Japan for the feasibility of exporting hydrogen.	published. A hydrogen energy road map 2005-2030 was published • Despite great enthusiasm from the government, lack in hydrogen technology development means Malaysia were unable to complete their hydrogen goals • In March 2021, published Hydrogen energy vision 2060: Hydrogen as energy Carrier in Malaysian primary energy mix – Developing Power to Gas case.			
Mexico	• Paris Agreement signatory • 50% reduction in GHG emission by 2050.	• The Sectoral Program derived from the National Development Plan 2019-2024 was published. Within mentions wants to explore use of Hydrogen. • In 2016, the SMH published the National Hydrogen Plan (the "Plan"). The main aim of the Plan was to identify key technologies, products, and markets for the development of hydrogen as a fuel and sustainable energy source in Mexico. • Also in 2016, the Mexican Energy Ministry (Secretaría de Energía) and the CONACYT granted funds to develop a prototype for a zero-emission electric vehicle powered by hydrogen fuel cells.	• N/A	• Exporter	Green Blue Grey
New Zealand	• Paris Agreement signatory • Zero Carbon Act (CO2e neutral by 2050) • 100% Renewable energy target • Signed the COP26 Breakthrough Agenda • Strategic partnerships with the Republic of Korea, Japan, Singapore and Germany.	• Domestic white paper level hydrogen strategy: A Vision for Hydrogen in New Zealand Green Paper[30] • Development of supporting associations and strategy. • R&D and pilot green hydrogen projects (Taranaki H_2). • Roadmap for hydrogen in New Zealand signed in September 2020	• N/A	• Exporter	Green

[30]https://static1.squarespace.com/static/5c350d6bcc8fedc9b21ec4c5/t/5d6f11fa2b5adf00018e36b8/1567560240444/a-vision-for-hydrogen-in-new-zealand-green-paper.pdf

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
		• As of September 2021, Meridian and Contact Energy's Southern Green Hydrogen project has attracted more than 80 responses to its registration of interest process. Plan to use closure of Tiwai Points energy to power Hydrogen plant in Southland.			
Papua New Guinea	• Paris Agreement signatory • Aims to reduce its emissions to 50 percent by 2030 - and to be carbon neutral by 2050.	• Papua New Guinea National Energy Policy 2016-2020 published. Mentions acceptance to hydrogen-powered vehicles A deed of agreement between PNG and Fortescue Future Industries to develop renewable energy project was established in August 2021.	• N/A	• Exporter	Green
Peru	• Paris Agreement signatory • 30% reduction in emissions compared to established BAU scenario in 2030.	• Pampilla refinery starting operation of a hydrogen plant in 2016 • Peru's National Energy Plan 2014 – 2025 published with a governmental commitment to promoting clean energy strategies. No specific hydrogen strategy mentioned • ***2010*** - The National Energy Policy 2010-2040 published with the desire to have a "diversified energy mix, with an emphasis on renewable sources and energy efficiency" by 2040. No specific hydrogen strategy mentioned.	• N/A	• Exporter	Green Blue
The Republic of the Philippines	• Paris Agreement signatory • The Republic of the Philippines aims to reduce greenhouse gas emissions by about 70% by 2030 relative to its baseline scenario of 2000–2030.	• The Department of Energy (DOE), on April 2021 signed a Memorandum of Understanding (MOU) with Tokyo-based Hydrogen Technology Inc. (HTI) to explore the use of hydrogen as a fuel for power generation. • Under the MOU, the DOE and HTI plan to "investigate hydrogen production in the Republic of the Philippines to make the economy energy independent and significantly	• N/A	• Exporter	Green Blue

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
		reduce the economy's CO_2 emissions."[31]			
The Russian Federation	• Paris Agreement signatory • Target is to reduce emissions by 25% to 30% below 1990 levels by 2030 • Export 2Mt H_2/y by 2030 • Bilateral partnerships with Japan and The Republic of Korea.	• Hydrogen Roadmap 2020-2024 created. Assigns a special role to Gazprom and Rosatom in meeting goals set in the Energy strategy • Goal to develop technology and provide legislative support for hydrogen production • Partnerships with industry companies (Rosatom State Corporation, Gazprom PJSC), and St. Petersburg Mining University to develop hydrogen technology.	• N/A	• Exporter	Green Blue Grey
Singapore	• Paris Agreement signatory • Peak absolute emissions at 65MtCO2e around 2030. • Halve emissions to 33MtCO2e by 2050 • Bilateral partnerships – New Zealand, Chile and Australia.	• Published a decarbonation roadmap32 • Collaborate in the development of Hydrogen standards and regulations • Conducted feasibility analysis for storage and use of Hydrogen across industries • Singapore Green Plan 2030 published in February 2021, with investment into a "Green economy" Pillar. No direct mention of hydrogen • Scoping study of Hydrogen in Singapore released in 2020: Study of Hydrogen Imports and Downstream Applications for Singapore[33].	• Singapore government released a USD$36.6m Low-Carbon energy research funding initiative.	• Importer	Green
Chinese Taipei	• Reduction in energy intensity from 2005 levels by 20% by 2015 and 50% by 2025.	• No economy hydrogen strategy found • Energy policy published in 2009 with the desire to increase renewable	• N/A	• Importer	N/A

[31] https://www.doe.gov.ph/press-releases/cusi-pushes-rd-hydrogen-energy
[32] https://www.nccs.gov.sg/docs/default-source/default-document-library/hydrogen-study-report.pdf
[33] https://www.nccs.gov.sg/docs/default-source/default-document-library/hydrogen-study-report.pdf

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
		energy and reduce emissions. No mention of hydrogen.			
Thailand	• Paris Agreement signatory • The current water development plan (PDP 2018–2037) shows the economy's ambition to embrace renewable energy, by 2037, power production is expected to come from natural gas (53%), non-fossil fuels (35%), and coal (12%).	• Hydrogen not publicly mentioned in energy strategy • Thailand created a megawatt-scale renewable hydrogen-based energy storage project. Using surplus electricity from wind generation to generate hydrogen during off-peak hours.	• N/A	• Exporter	N/A
The United States of America	• 24 states upheld Paris Commitment reducing emissions 26 - 28% below 2005 levels by 2025. • President Biden announced in April 2021 that America would cut its GHG emissions 50-52% below 2005 levels by 2030 • Signed the COP26 Breakthrough Agenda.	• Bipartisan Infrastructure deal announced in President Biden's Build Back Better agenda in 2021 includes over $62b for the U.S. Department of Energy (DOE) to have a more equitable clean energy future. Includes specific investment into hydrogen to achieve this goal. • Department of Energy Hydrogen Program Plan[34] sees a two-to-four-fold increase in hydrogen demand across the economy. This will be done through fossil resource, biomass and electrolysis. • Hydrogen roadmap developed by industry leaders[35] and the Californian Hydrogen Business Council[36] • Strategic partnerships in place to increase investment in supply chain development and commercialisation of clean hydrogen. • Significant infrastructure already in place for transport (pipeline) and storage of hydrogen fuel.	• The Bipartisan Infrastructure deal includes an additional $8 billion for clean hydrogen, specifying that $1.5 billion will be for clean hydrogen manufacturing and advancing recycling RD&D[37] • The United States of America Department of Energy announces USD$52.5m to fund 31 projects to advance clean hydrogen technologies.	• Exporter/ Importer	Green Blue Grey

[34] https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf
[35] http://www.fchea.org/us-hydrogen-study
[36]https://static1.squarespace.com/static/58e8f58d20099ea6eb9ab918/t/5afd25a9f950b7543abe21ba/1526539702668/EIN_RH2_Paper_Lowres.pdf
[37] https://www.energy.gov/articles/doe-fact-sheet-bipartisan-infrastructure-deal-will-deliver-american-workers-families-and-0

Economy	Climate commitments / Partnerships	Focus of hydrogen strategy/ investment	Funding	Likely future position in the supply chain	Types of hydrogen of strategic focus
		• California on par with the People's Republic of China to meet targets of one million FCVs on the road by 2030.			
Viet Nam	• Paris Agreement signatory • Reduce GHG emissions in energy activities by 20 to 30% compared to business as usual by 2030 against a 2010 baseline.	• Published power development plan 2021-2030 in February 2021. Hydrogen not mentioned. However, focus placed on renewable energy (reduction in coal and investment in Wind and Solar)[38].	• N/A	• Exporter	N/A

[38] https://britchamvn.com/wp-content/uploads/2021/02/BritCham-Vietnam_Renewable-Energy-Sector-Briefing-2021.pdf

Appendix B: APEC hydrogen supply and demand

Economy	Current hydrogen Supply[39]	Current Demand Sectors	Predicted future hydrogen demand/supply	2030	2040	2050	Future Demand Sectors
Australia[40]	~650ktpa – virtually all of this us made by Natural Gas SMR and is immediately consumed by the associated ammonia synthesis (65%) and crude oil refining in plant[41] ~0.4ktpa capacity from low-carbon sources	Industrial - Feed stock to ammonia plants, feedstock to crude oil refineries processes	Scenario: Energy of the future[42]	1MTPA	4 MTPA	20 MTPA	Industrial Chemicals Manufacturing Transport
			Scenario: Targeted Deployment	<1MTPA	2 MTPA	8 MTPA	
			Scenario: BAU	<1MTPA	<1 MTPA	2 MTPA	
			Scenario: Electric Breakthrough	<1MTPA	<1 MTPA	1 MTPA	
Brunei Darussalam[43]	N/A	N/A	Scenario: BAU	N/A	0.039 MTPA (demand)	N/A	Transport Export Power Storage
			Scenario: Targeted hydrogen	N/A	0.223 MTPA (demand) 0.781 MTPA(Supply)	N/A	
Canada[44]	3 MTPA 0.303MTPA from low-carbon sources	Industrial Used as feedstock for: Petroleum refining, bitumen upgrading, Ammonia, Methanol, and steel production		4MTPA	N/A	20 MTPA	Transport Industrial chemicals Iron and steel Power storage Export
Chile[45]	N/A 0.0094ktpa from low - carbon sources	N/A		25GW Electrolysis capacity	N/A	160 MTPA	Export

[39] All low-carbon sources quoted from : IEA (2021), Hydrogen Projects Database
[40] https://arena.gov.au/renewable-energy/hydrogen/
[41] https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf
[42] Scenarios detailed in Australian and Global Hydrogen Demand Growth Scenario Analysis, Nov 2019
[43] Brunei Darussalam: Shifting to a Hydrogen Society, 2020
[44] Canada's hydrogen future – risk and rewards, EY, 2021
[45] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/rich-in-renewable-energy-chile-seeks-to-become-global-hydrogen-powerhouse-66012212

Economy	Current hydrogen Supply[39]	Current Demand Sectors	Predicted future hydrogen demand/supply 2030	2040	2050	Future Demand Sectors
The People's Republic of China[46]	20 MTPA 2.3ktpa from low-carbon sources	Industry Transport	10000 Filling stations by 2030 15% of hydrogen consumed labelled Green hydrogen	45% of hydrogen consumed labelled Green hydrogen	70% of hydrogen consumed labelled Green hydrogen	Transport Chemicals
Hong Kong, China	N/A	N/A	N/A	N/A	N/A	N/A
Indonesia	N/A	N/A	N/A	N/A	N/A	N/A
Japan[47]	1 MTPA, 94% of primary energy supply is imported 1.8ktpa low-carbon sources 2Mt H2/year mainly from by-product	Industrial Feedstock in chemical processing FCEV Stationary fuel cell	3Mt H2/year (JPY30/Nm3) 800,000 FCEV 1,200 hydrogen buses 1000 Hydrogen refuelling stations	N/A	20Mt H2/year (JPY20/Nm 3)	Transport Electricity Industrial Chemicals Residential
The Republic of Korea[48]	1.64 MPTA	Industrial Feedstock in chemical processing	1.94MTPA 2.9mil FC cars 1,200 HRSs 80,000 FC taxis 40,000 FC buses 30,000 FC trucks 8 GW stationary FC (plus 7 GW exported) 2.1 GW of micro-cogeneration FCs[49]	5.3 MTPA	N/A	Transport Importation Chemicals Manufacturing
Malaysia[50]	N/A	N/A	Blend 5-15% hydrogen with domestic gas network	N/A	Blending produced by renewable energy increased by 50%	Transport Industrial Power storage
Mexico[51]	N/A	Industrial	N/A	N/A	N/A	Transport Industrial Power generation Chemical

46 The Hydrogen Revolution in APAC, DLA PIPER

47 Fuji Keizai, Ifri Center for Energy, Basic Hydrogen Strategy, IEA

48 https://iea.blob.core.windows.net/assets/e57fd1ee-aac7-494d-a351-f2a4024909b4/GlobalHydrogenReview2021.pdf

49 https://iea.blob.core.windows.net/assets/e57fd1ee-aac7-494d-a351-f2a4024909b4/GlobalHydrogenReview2021.pdf

50 Hydrogen energy vision 2060: Hydrogen as energy Carrier in Malaysian primary energy mix – Developing P2G case

51 Green Hydrogen in Mexico: towards a decarbonization of the economy https://www.energypartnership.mx/fileadmin/user_upload/mexico/media_elements/reports/Hydrogen_EP_volume_I.pdf

Economy	Current hydrogen Supply[39]	Current Demand Sectors	Predicted future hydrogen demand/supply 2030	2040	2050	Future Demand Sectors
New Zealand[52]	N/A	Industrial Feedstock in chemical and fertiliser production	0.7MTPA	N/A	N/A	Chemicals Transport Export
Papua New Guinea	N/A	Industrial	N/A	N/A	N/A	Support Electricity[53] Transport Industrial
Peru	25MW alkaline electrolyser plant[54]	Industrial	N/A	N/A	N/A	Industrial Transport Export
The Republic of the Philippines	N/A	N/A	N/A	N/A	N/A	N/A
the Russian Federation [55]	0.36 MTPA	Industrial	0.2MTPA by 2024	Export 2 MTPA	Export 15-50 MTPA	Transport Industrial Export
Singapore [56]	N/A	Industrial	N/A	N/A	0.13-0.43 MTPA *FCEV adoption* 0.39 MTPA for *Industrial*	Transport Industrial Manufacturing Chemical
Chinese Taipei	0.386 MTPA	Industrial	N/A	N/A	0.7 MTPA 0.2 MTPA produced domestically 0.5 MTPA imported	N/A
Thailand	N/A	N/A	N/A	N/A	N/A	N/A
The United States of America [57]	10MTPA 119.7ktpa from low-carbon sources	Industrial For refining petroleum, treating metals, producing fertiliser and processing foods.	13 MTPA 200 filling stations in California	17 MTPA	20-68 MTPA	Chemicals Transport Export
Viet Nam	N/A	N/A	N/A	N/A	N/A	N/A

52 https://www.mbie.govt.nz/dmsdocument/6798-a-vision-for-hydrogen-in-new-zealand-green-paper

53 Papua New Guinea National Energy Policy

54 Hydrogen Energy Council 2021

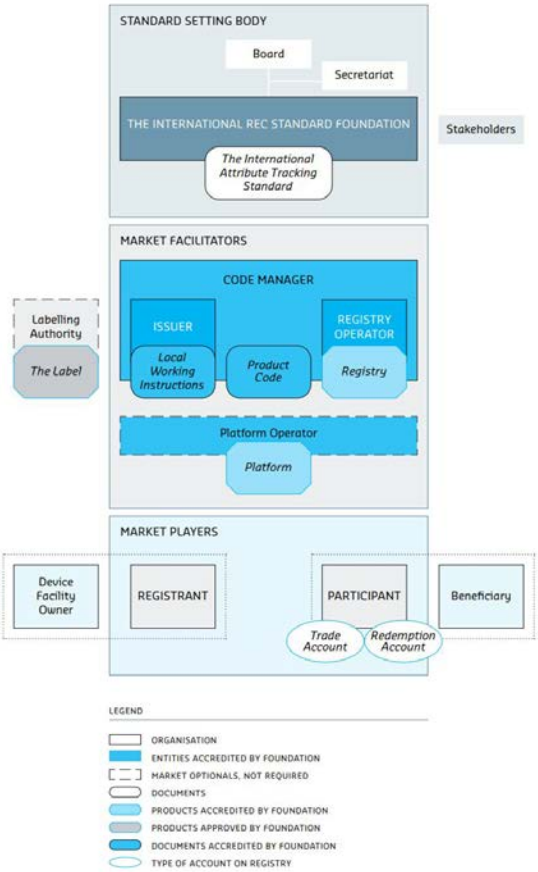
55 Russia's Hydrogen Development Roadmap and Production Plan, 2021–2050

56 Study of Hydrogen Imports and Downstream Applications for Singapore, 2020

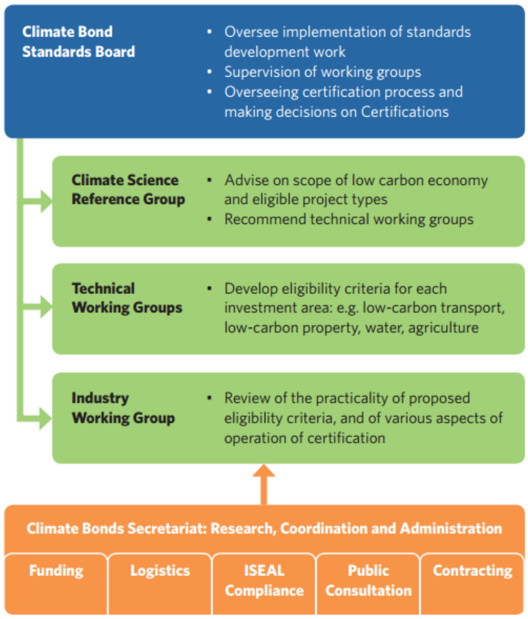
57 Department of Energy Hydrogen Program Plan, 2020

Appendix C: Governance Structures

I-REC Governance Structure[58]



Climate Bonds Standard Governance Structure[59]



58 https://www.irecstandard.org/governance-structure/#/
59 https://www.climatebonds.net/standard/governance

Appendix D: Summary of existing low-carbon standard structures

Low-carbon standard/ certification	Coverage	Units	Purpose	Regulator	Certification/Assurance requirements
CertifHy	European Union, European Economic Area and Switzerland.[xxiii]	Unit of energy output (unit per MWh) – Guarantee of Origin (GO)	To advance and facilitate the production, procurement and use of hydrogen in an environmentally, socially and economically sustainable way.[xxiv]	Coordinated by Hinicio, with the Dutch Energy Research Centre ECN, TÜV SÜD and Ludwig Bölkow Systemtechnik.[xxv]	CertifHy Green Hydrogen additionally fulfils criteria of CertifHy low-carbon hydrogen, the GHG footprint of which is required to follow the methodology outlined by the International Organisation for Standardisation (ISO) standards, as well as relevant components of the Renewable Energy Directive. CertifHy is aligned to EU policies such as the Renewable Energy Directions (RED I and II). Participants must meet a minimum threshold of emissions intensity of hydrogen to be allowed to participate in the scheme. [xxvi]
Greenhouse Gas Reporting Program (GHGRP)	United States	Tonnes of CO_2e emitted from each unit of hydrogen produced	Reporting of GHG emissions data and other relevant information from GHG emissions sources. Aims to assess trends in emissions over time for use in policy and programs.	United States Environmental Protection Agency (EPA)	Mandatory for GHG source facilities and specific product suppliers that emit over 25,000 T CO_2e per year to report GHG emissions annually, including a GHG monitoring plan. Specifically, hydrogen production includes "process units that produce hydrogen by reforming, gasification, oxidation, reaction or other transformations of feedstock". Regulated by the EPA, who verifies data through automated error checks and may also conduct a review and/or audit to verify accuracy of emissions reporting. Regulations are in line with the Clean Air Act section 307(d). [x]
Standard and Assessment for Low-carbon Hydrogen, Clean Hydrogen and Renewable Hydrogen Energy	The People's Republic of China	Kg of CO_2e emitted from each kilogram of hydrogen produced	To promote the high-quality development of China's hydrogen energy industry and realize the targets to peak carbon emissions and achieve carbon neutrality [79]	China Hydrogen Alliance	The carbon emissions threshold for low-carbon hydrogen is 14.51 $kgCO_2e/kgH_2$ and 4.9 $kgCO_2e/kgH_2$ for renewable hydrogen. Renewable hydrogen must be produced using a renewable energy source. [60] Verification is by an independent third-party organisation, with requirements for verification bodies outlined within the standard. Certification is reviewed annually [61]
Hydrogen Economy Law – clean hydrogen certification (under development)	The Republic of Korea				Details to come, but establishment of a clean hydrogen certification institution was added to the Act in May 2021

[60] https://www.ceic.com/gjnyjtwwEn/xwzx/202101/e9147965a7e5465d8d3419fafdfa2355.shtml
[61] http://www.fuelcellchina.com/cnt_143.html

Australian National Hydrogen Certification Scheme (under development, likely to be in place 2021-2022)	Australia	Likely to be guarantee of origins	To establish Australia as a global leader for renewable hydrogen, in support of the National Hydrogen Strategy	Clean Energy Regulator (suggested during consultation)	Currently in consultation phase by the Department of Industry, Science, Energy and Resources (DISER). Suggested alignment to the Renewable Energy Target scheme, the Australian National Greenhouse and Energy Reporting System, and the National Energy Market Rule. [xi]
Green Gas Certification Scheme (GGCS)	United Kingdom	Unit of energy output (unit per kWh) – Guarantee of Origin (GO) - Biomethane	An objective way of tracking commercial transactions of biomethane through the supply chain, to provide certainty for gas consumers, confidence in the green gas sector and an incentive for gas producers to use green gas.	Renewable Energy Assurance Limited (REAL)- subsidiary of Renewable Energy Association	Anyone involved in the green gas supply chain can voluntarily be a participant of the GGCS. The scheme tracks contractual flows of green gas, rather than physical flows, to prevent double-counting. Participants are green gas producers, gas suppliers and commercial end-use consumers. Auditors are appointed by the REAL and report to the Oversight Committee. Units expire after three years if not sold to an end customer. Regulation is driven by the gas industry's regulations, and members of the GGCS must be compliant with these. GOs can be imported/exported into/from other registries.[xii]
ERGaR (European Renewable Gas Registry) (under development)	Europe	Unit of energy output – Guarantee of origin (GO)	To ensure that domestic certifications are cancelled and transferred appropriately across borders, and that these certificates reconcile with the physical gas quantities	ERGar secretariat and elected executive board	ERGaR is a documentation scheme for distribution of renewable gases and biomethane through the European Gas Network, in order to provide a reconciliation of cross-border registries and certificates of origin. ERGaR is an independent body and participation is voluntary [xxx]

Renewable Fuel

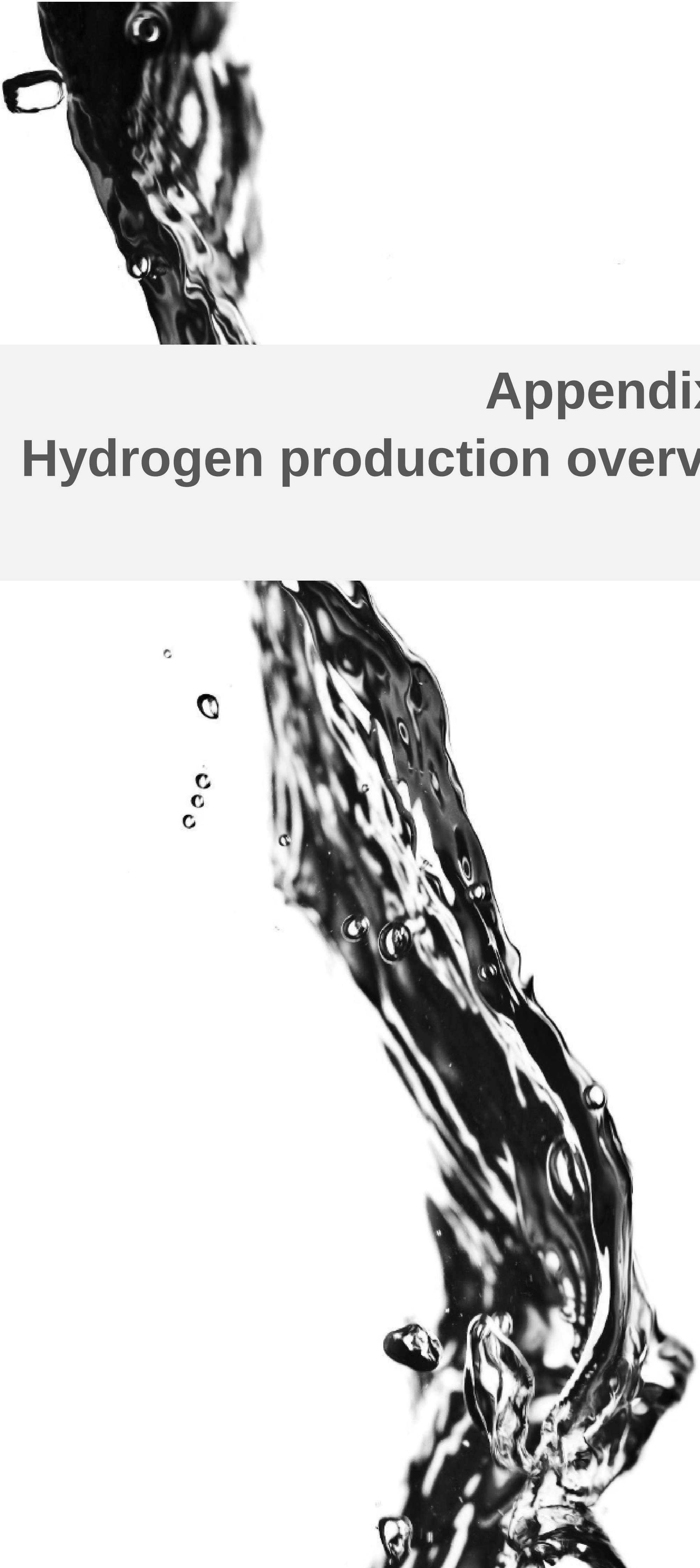
Low-carbon standard/ certification	**Coverage**	**Units**	**Purpose**	**Regulator**	**Certification/Assurance requirements**
Renewable Fuel Standard (RFS)	United States	Volume of fuel (Gallons): Renewable Identification Numbers (RINs)	To reduce greenhouse gas emissions and expand the economy's renewable fuels sector while reducing reliance on imported oil.	United States Environmental Protection Agency (EPA)	Compliance is achieved by blending renewable fuels into transportation fuel, or by obtaining credits to meet an EPA-specified Renewable Volume Obligation (RVO).[xiii] Endorses a "buyer beware" liability and compliance approach whereby regulated parties are expected to conduct due diligence to uphold a standard of quality. The 'Quality Assurance Plan' (QAP) is a voluntary program where independent third-parties may audit and verify RINs.[xiv]
Clean Fuel Standard (under development, to be implemented December 2022)	Canada	Mass of displaced carbon (tCO_2e)	To contribute to domestic emissions reduction targets of decreasing annual GHG emissions by 30 Mt by 2030, through increased use of lower carbon fuels, energy sources and technologies.[xv]	Environment and Climate Change Canada, Government of Canada.[xvi]	Reasonable assurance required following ISO 14064-3: 2019 Greenhouse gases - Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions. This is certified by the regulator. [xxxiv]

Low-carbon standard/ certification	Coverage	Units	Purpose	Regulator	Certification/Assurance requirements
Renewable Transport Fuel Obligation (RTFO)	United Kingdom	gCO_2e/MJ of energy provided by the fuel	The Renewable Transport Fuel Obligation (RTFO) supports the government's policy on reducing greenhouse gas emissions from vehicles by encouraging the production of biofuels that don't damage the environment	Department for Transport	Suppliers of road and NRMM fuel supplying petrol, diesel, gas oil or renewable fuel totalling 450,000 litres or more in an obligation period have an obligation under the Order. Obligated suppliers may meet their obligation by redeeming Renewable Transport Fuel Certificates (RTFCs) or by paying a fixed sum for each litre of fuel for which they wish to 'buy-out' of their obligation. RTFCs are gained by supplying sustainable renewable fuels. Those wishing to apply for RTFCs must have an account with the Administrator. One certificate may be claimed for every litre of sustainable renewable fuel supplied. Fuel from certain wastes or residues, fuel from dedicated energy crops, and RFNBOs are incentivized by awarding double the RTFCs per litre or kilogram supplied. Data on the sustainability of fuel supplied must be independently verified before certificates will be awarded and the Administrator may require the evidence behind an application to be provided. RTFCs may be traded on the open market.
Low-Carbon Fuel Standard (LCFS)	California, and beginning to align policies with Oregon, Washington and British Colombia	gCO_2e/MJ of energy provided by the fuel	To reduce greenhouse gas emissions in California's transportation and provide increasing low-carbon alternatives in order to reduce petroleum dependency and achieve air quality benefits	California Air Resources Board (CARB)	Sets annual carbon intensity benchmarks. Takes the GHG emissions across the complete lifecycle of fuel into account. Certified carbon intensity (CI) credits are generated by providers of low-carbon fuel. These credits are verified by an independent third-party prior to issuing, with verification based on ISO 14064-3 and 14065. Verifiers must be CARB accredited. Various liquid fuel providers and importers are required to comply with the LCFS, and it is specified that hydrogen is an opt-in fuel until the California-wide use of hydrogen in transportation meets a threshold of 3,500 tons per year, at which point hydrogen fuel producers will be mandated to comply. [xvii]

Low-carbon investment

Low-carbon standard/ certification	Coverage	Units	Purpose	Regulator	Certification/Assurance requirements
Montreal Protocol on Substances that Deplete the Ozone Layer	Global – The protocol is a UN treaty that has been ratified by every economy.[xxvii]		To eradicate Ozone Depleting Substances (ODSs) from the atmosphere by restricting their consumption and production, with the purpose of eliminating damage to the ozone layer.	The UN Meeting of the Parties and supported by a technical working group and Ozone Secretariat.[xxviii]	Limits are placed on the consumption/production of ODS's for a 'step-wise' phase out approach. Different timelines are allocated for developed and developing economies, and each party is obligated to meet specific requirements for each ODS group through control of trade, reporting of data, and domestic licensing systems to manage relevant imports/exports.[xxix]
Low-carbon standard/ certification	**Coverage**	**Units**	**Purpose**	**Regulator**	**Certification/Assurance requirements**
Climate Bond Standard	International[xviii]	Project, asset companies	A labelling scheme for bonds, loans and other debt applications used globally to prioritise investments which genuinely contribute to addressing climate change.[xix]	Carbon Bond Initiative (CBI)	Requires limited or reasonable assurance from an approved verifier. Require to become an approved verifier set out by the CBI The Climate Bond "Certification Mark" is issued by the CBI on receipt of the verifier report.[xx]
EU Taxonomy[xxi] and EU Green Bond Standard	Europe	Project, asset companies	A tool to facilitate the transition to a low-carbon, resilient and resource-efficient economy through the finance sector and investment decisions.[xxii]	European Commission	External verification required from formally accredited and supervised entities, overseen by European Securities and Markets Authority

Appendix E: Hydrogen production overview



Hydrogen Production Overview

Brief overview of different production methods and key emission sources

Production Method	Brief Description	Key emission sources
Electrolysis	The electrolysis process uses a cathode and anode separated by an electrolyte (conductive solution). When connected to a direct current, electricity flows through the electrolyte and separates the water into hydrogen and oxygen	The source of emissions is the electricity used for the electrolyser.
Steam Methane Reforming (SMR)	Current leading technology for hydrogen production from natural gas or other hydrocarbons. This process releases carbon monoxide and carbon dioxide as by products. Carbon dioxide can be captured for CCUS	The primary source of emissions is hydrocarbon conversion to hydrogen as it has a by-product of carbon monoxide and carbon dioxide. Other emissions are related to the energy used to drive the process and any CCUS steps
Coal Gasification	Coal gasification is similar to SMR, except requires a preliminary step to turn coal into a gas which then undergoes SMR to produce hydrogen. This process releases carbon monoxide and carbon dioxide as by products. Carbon dioxide can be captured for CCUS	The primary source of emissions is hydrocarbon conversion to hydrogen as it has a by-product of carbon monoxide and carbon dioxide. Other emissions are related to the energy used to drive the process and any CCUS steps
Industrial By-product	Hydrogen can be produced as a by-product in other industrial processes. This can be through processes that use electrolysis in order to produce salts or other gases or through steam cracking which generally creates inputs to plastic production.	Hydrogen is often not the only commodity made through the industrial by-product method. Consequently, it will be allocated a portion of the emissions from the applicable process.

CCUS

Carbon dioxide capture, and storage requires three main operational units: separation and capture, compression and transport, and storage or utilisation. There are many different ways to capture carbon dioxide, with many in development and gaining momentum, however on a macro level capture process separate hydrogen and carbon dioxide using electricity and heat.

Once the gas has been separated, it is temporarily stored in a high-pressure vessel to be transported to its permanent storage place. In general, there are two broad carbon capture storage options: geological storage, and reaction-based mineralisation. Geological storage typically consists of injecting supercritical carbon dioxide into underground geological formations. Mineral sequestration uses reactions of carbon dioxide to form carbonates.

Appendix F:
Low-carbon hydrogen definitions and criteria

Low-carbon hydrogen definitions and criteria

Summary of hydrogen definitions by APEC economies

Low-carbon hydrogen **Conventional hydrogen**

Emissions Intensity: →

Economy	**Green**	**Blue**	**Grey**	**Black**	**Brown**
Australia[62]	Electrolysis of water using renewable energy	Natural gas reforming or coal gasification with CCUS	Produced using natural gas without CCUS **~8.5kgCO_2e/kg H_2**	Produced using coal without CCUS **~12.7-16.8kgCO_2e/kg H_2**	Produced using lignite without CCUS
Brunei Darussalam[63]	Generated from renewable resources – water not specified	Reference **CertifHy** low-carbon threshold **(36.4g CO_2e/MJ of H_2-derived energy)** (but generated from non-renewable energy sources	Produced using natural gas without CCUS	No published definition found	
Canada[64]	Electrolysis of water using renewable energy	Natural gas reforming or coal gasification with **CCS**	Produced using natural gas fuels without CCUS, **includes gasified coal as feedstock**	Produced using coal without CCUS	Produced using lignite without CCUS
Chile[65]	Electrolysis of water using renewable energy	No published definition found	Produced using **fossil fuels** without CCUS	No published definition found	
The People's Republic of China	Electrolysis of water using renewable energy	Natural gas reforming or coal gasification with CCUS	Produced using natural gas without CCUS	Coal/fossil fuel derived without CCUS	
Hong Kong, China	No published definition found				
Indonesia	No published definition found				
Japan[66]	No published definition	No published definition	No published definition found	No published definition found	
The Republic of Korea [67]	Electrolysis of water using renewable energy	Natural gas reforming or coal gasification with CCUS	Produced using natural gas without CCUS	No published definition found	
Malaysia[68]	Electrolysis of water using renewable energy	Natural gas reforming or coal gasification with CCUS	Produced using natural gas without CCUS	No published definition found	
Mexico[69]	Electrolysis of water using renewable energy and **nuclear** energy	Natural gas reforming or coal gasification with CCUS	Produced using natural gas without CCUS	Produced using coal without CCUS	Produced using lignite without CCUS
New Zealand[70]	Electrolysis of water using renewable energy	Produced using fossil fuels with carbon capture and sequestration (**CCS**).	Produced using natural gas fuels without CCUS	Produced using coal without CCUS	No published definition found

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[62] https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf
[63] https://www.eria.org/uploads/media/Research-Project-Report/RPR-2020-04-Brunei-Shifting-Hydrogen-Society/Brunei-Darussalam-Shifting-to-Hydrogen-Society-new.pdf references CertifHy for definitions
[64] https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf
[65] https://energia.gob.cl/sites/default/files/national_green_hydrogen_strategy_-_chile.pdf
[66] https://www.meti.go.jp/english/press/2017/pdf/1226_003b.pdf
[67] https://gggi.org/site/assets/uploads/2021/06/H2Korea-Presentation.pdf
[68] https://www.mida.gov.my/hydrogen-as-an-attractive-new-energy-source-carrier/
[69] https://www.kas.de/documents/273477/14464285/GREEN+HYDROGEN+IN+LATIN+AMERICA.pdf/265060b1-a3a5-2f10-d065-586c0dc0ddf2?version=1.0&t=1631649183030
[70] https://www.mbie.govt.nz/dmsdocument/6798-a-vision-for-hydrogen-in-new-zealand-green-paper

Emissions Intensity:	**Low-carbon hydrogen** →				**Conventional hydrogen**
Economy	**Green**	**Blue**	**Grey**	**Black**	**Brown**
Papua New Guinea	No published definition found				
Peru	No published definition found				
The Republic of the Philippines [71]	Electrolysis of water, **energy source not specified**	No published definition found			
The Russian Federation	Electrolysis of water from renewable energy	Natural gas reforming or coal gasification with CCUS	Produced using natural gas without CCUS	No published definition found	
Singapore[72]	Electrolysis of water from renewable energy, **solar thermochemical, biomass gasification**	Natural gas reforming or coal gasification with CCUS	No published definition found	Produced using fossil fuel sources such as coal, oil **and natural gas**	No published definition found
Chinese Taipei	No published definition found				
Thailand	No published definition found				
The United States of America [73]	Electrolysis of water from renewable energy with **carbon intensity 0 kg CO_2e/kg H_2**	Natural gas reforming or coal gasification with CCUS with **carbon intensity 0.93-1.8 kg CO_2e/kg H_2**	Produced using natural gas using thermal processing without CCUS with **carbon intensity 9.27 kg CO_2e/kg H_2**	No published definition found	Produced via gasification of goal with **carbon intensity 20 kg CO_2e/kg H_2**
Viet Nam	No published definition found				

[71] https://www.doe.gov.ph/press-releases/cusi-pushes-rd-hydrogen-energy?ckattempt=1
[72] https://www.nccs.gov.sg/docs/default-source/default-document-library/hydrogen-study-report.pdf
[73] https://www.mjbradley.com/sites/default/files/MJBA-Issue%20Brief_Introduction%20to%20Hydrogen_June2020.pdf