New Zealand's hydrogen regulatory pathway

Ministry of Business Innovation and Employment (MBIE)

July 2022

pwc

Ministry of Business, Innovation and Employment (MBIE)
15 Stout Street
Wellington 6011

15 July 2022

New Zealand's hydrogen regulatory pathway

Tēnā koutou,

Please find enclosed our report detailing our review of the regulatory frameworks applicable to hydrogen and potential reform pathways that may support the sector's future. We thank you for the opportunity to contribute to this important piece of work and trust it will help guide future efforts to develop a regulatory framework for the hydrogen economy.

The views and findings expressed in this report are based on views, analysis and available information as at the date of this report.

This report is subject to the terms and conditions of our Consultancy Service Order with MBIE, dated 4 March 2022 and the restrictions set out in Appendix A.

Ngā manaakitanga | Yours faithfully,

PwC Consulting

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1

Review Summary

Background

Context and scope

This report sets out PwC's review of the regulatory frameworks required to support a future hydrogen economy in New Zealand and the potential reform pathways that are needed.

Introduction

The Ministry of Business, Innovation and Employment (MBIE) has engaged PwC to undertake a review of whether existing regulatory frameworks are 'fit for purpose' in supporting the future New Zealand hydrogen economy and to advise on regulatory reform pathways to support the hydrogen roadmap.

The scope of our review includes:

- An assessment of the outlook for hydrogen to better understand how the market may develop in Aotearoa and to define the potential regulatory need. We considered hydrogen regulatory reform precedent in overseas jurisdictions and in New Zealand.
- A survey of the regulatory frameworks relevant to hydrogen and a high level assessment of whether they are 'fit for purpose' in regulating the future hydrogen value chain.
- Based on analysis of the regulatory need and current regulatory frameworks, we have recommended key areas for regulatory consideration and potential pathways to align with New Zealand's hydrogen goals.

This report sets out our key findings and recommendations for discussion and review.

Our key recommendations are provided in section 7 of this report, with a summary of our regulatory framework analysis provided in section 5.

This is a complex topic and there are several technical definitions and common terms that we use regularly. A glossary has been provided in appendix B to support this understanding. For the purposes of this report, the term 'hydrogen' means low carbon or 'green' hydrogen, unless otherwise specified. The distinction will be made when it is relevant to the discussion.

Context

Hydrogen is expected to play a critical role in decarbonisation of the global economy. The World Energy Council (WEC) projects that it will meet up to 20% of the world's energy needs by 2050 and the Asia-Pacific region will be a critical hydrogen market right on our doorstep.

The New Zealand hydrogen sector is currently small but the pace of investment is growing as investors realise its potential and the competitive advantage Aotearoa has in renewable energy.

While regulation exists for use of hydrogen as an industrial chemical, concern has been expressed that the existing regulatory structures may not support non-industrial uses, novel hydrogen applications and green hydrogen production methods.

Government agencies are starting to turn their attention to the policy and regulatory reform needed to support hydrogen (eg standards development, hydrogen roadmap, ERP), but progress appears to be hampered by uncertainty over the future of hydrogen in New Zealand and the absence of a clearly defined and specific national strategy on hydrogen.

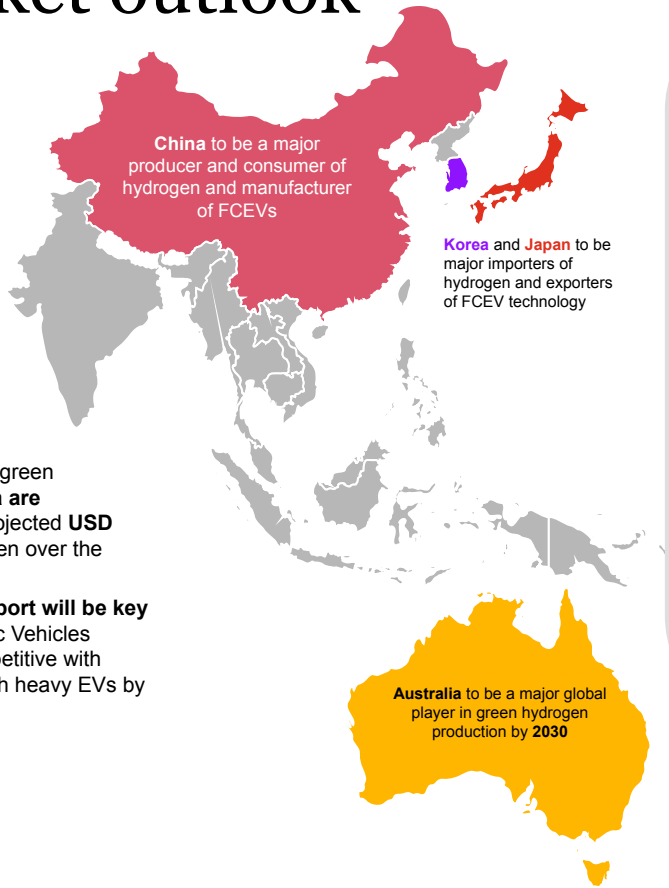
An independent and objective assessment of the required hydrogen regulatory structures and pathways for reform is necessary to unlock the development of this market, and to protect the future hydrogen workforce and users. There is some urgency in progressing some areas of reform, but we have time to monitor and consider other changes in response to market developments. Collaboration between the Government, regulatory agencies, business and iwi will be important going forward.

**World Energy Issues Monitor 2022, World Energy Council.*

Hydrogen market outlook

Global markets

- Green hydrogen is forecast to meet 15% to 20% of the world's energy needs by 2050 with a **650% increase in hydrogen demand** expected over the same period.
- The **Asia-Pacific region will be a key market** given Asia's strategic focus on hydrogen technologies to address its climate change goals.
- Hydrogen is one of the six **"industries of the future"** identified in **China**'s current 5 year plan.
- Europe and North America currently dominate green hydrogen production, but **Australia and China are expected to become major players** in the projected **USD 11 trillion global investment** in green hydrogen over the next 30 years.
- **The economics of hydrogen in heavy transport will be key to future demand**. Hydrogen Fuel Cell Electric Vehicles (FCEVs) will likely become commercially competitive with diesel within a decade and approach parity with heavy EVs by 2040.



New Zealand hydrogen

New Zealand demand for green hydrogen is still uncertain but will likely be driven by heavy transport, natural gas blending, energy firming, and as an industrial feedstock.

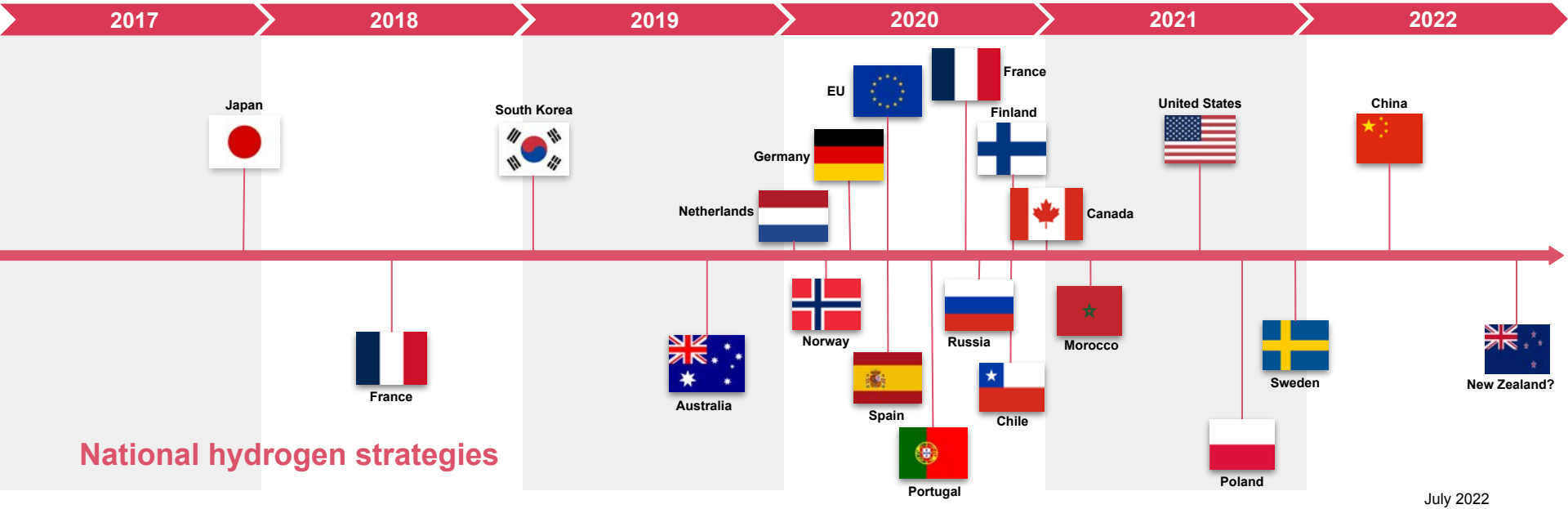
- Demand of over **1500 kt per annum** by 2050 is projected in the May 2022 "New Zealand Hydrogen Scenarios" report (Scenario Report) if aviation is included.
- The New Zealand green hydrogen sector is currently small but the pace of investment is growing as investors realise its potential and Aotearoa's competitive advantage in renewable electricity generation.
- **The scale of demand in Asia may provide opportunities for New Zealand to export alongside Australia.**

Hydrogen

Global response

Globally, the main government response to date has been to develop national strategies and roadmaps to navigate the hydrogen opportunity. Aotearoa has made progress on a roadmap but needs to develop a clear national strategy.

Japan published its hydrogen strategy in 2017, the first country to do so. In the intervening years, approximately 30 countries have published hydrogen strategies. Many are now starting to implement these strategies through the development of policy frameworks and industry support. Our closest neighbour, Australia has already made progress on its plans to be a hydrogen superpower, making its first export this year (refer Appendix D). New Zealand has yet to publish a national strategy on hydrogen, although it is exploring hydrogen's potential future role as part of MBIE's hydrogen roadmap project, which is due to be completed over the next year. The recent ERP also acknowledges hydrogen as a viable decarbonisation option for the transport sector and as a potential transition fuel for gas. We commend this work, but stress there is some urgency for New Zealand to articulate a comprehensive national strategy and a set of clear priorities and objectives that are specific to hydrogen.



National hydrogen strategies

Hydrogen

Global regulatory approaches

Regulation of safety and standards has been a clear focus of regulators. With clear policy direction from governments, regulators in other jurisdictions are now planning and preparing themselves for what's next.

No country has developed a comprehensive regulatory regime for the use of hydrogen as a fuel

20 or so economies are building a hydrogen economy successfully under their existing regulatory frameworks.

It has been more than four years since Japan published its first strategy - the first to be published globally. Publishing a strategy allows the industry to develop with confidence.

Safety and quality are the main concerns and there are many standards being developed. Using these standards as guidelines allows industry and regulators to take a risk-based approach to managing safety, and allows for commercial agreements to be made on technically qualified terms.

Regulators are taking an active role in testing feasibility and planning for market and system impacts

With government policy in place, regulators have the mandates required to investigate the role of hydrogen within their jurisdiction.

International regulators are taking the lead with investigative projects to determine the role of hydrogen in order to provide governments with the information they need to make good policy and regulatory decisions.

Government agencies are increasingly informed of the potential impacts of a hydrogen economy and incorporating the prospective scenarios into their planning.

The sentiment is that hydrogen may be slow in coming, but will scale quickly once it arrives.

Understanding, quantifying and certifying the low carbon aspect of hydrogen is a global priority

While decarbonisation is not the immediate goal of all national hydrogen strategies, the economic growth that can be gained from supplying those who are making this their priority may be the immediate goal. Green hydrogen is about making a global commodity out of renewable electricity generation. Some are looking to be self-sufficient and some are looking to trade.

How 'decarbonisation' is to be measured and certified across jurisdictions is essential to facilitate the global trade in low carbon hydrogen.

Consideration is also being given to how 'low carbon' hydrogen is transported. It becomes significantly less 'low carbon' if this is done by fossil-fuelled ships and over a long distance.

NZ Government work

Hydrogen as a climate change response

The Emissions Response Plan (ERP) sets out objectives for an "equitable transition" to achieving our climate change goals. These objectives can provide the framework to setting and prioritising Aotearoa's goals for hydrogen

New Zealand hydrogen roadmap

In 2019, the Government started a programme of work to better understand the potential future of hydrogen in Aotearoa. This included a green paper, 'A vision for hydrogen in New Zealand' (the green paper), which set out Government's intention to develop the roadmap.

Following this, Castalia was engaged to develop a hydrogen supply, demand and export model, the "Castalia-MBIE 2020 Hydrogen Model" (the roadmap model), to begin the development of the roadmap. This has since been updated by the release of "the New Zealand Hydrogen Scenarios" report in May 2022 (the Scenario Report) to the MBIE.

In a parallel workstream, Standards NZ has developed (but yet to publish) its draft "Standards Solutions Report" for integrating hydrogen into New Zealand's energy landscape. The report has been prepared after consultation with an industry Technical Advisory Group (TAG).

In February 2022, MBIE engaged PwC to develop a regulatory roadmap for hydrogen (this paper).

Shortly after this, in April 2022, MBIE formed the Hydrogen Regulators Working Group (the Working Group, the Regulators). PwC have been working directly with this group during the development of this paper.

Aligning to ERP objectives

"The Government's 2050 vision is for Aotearoa New Zealand to have a highly renewable, sustainable and efficient energy system supporting a low emissions economy." - ERP

In order to give effect to an "equitable transition" the ERP has the following objectives:

- Seize the opportunities of the transition
- Support proactive transition planning
- Enable affordable and inclusive transition
- Build the evidence base and tools
- Encourage informed public participation.

These objectives align well with the requirements for regulatory reform to implement the future hydrogen value chain. There are opportunities for economic growth in the implementation of green hydrogen. Seizing these opportunities now will support achieving the other four objectives over the near term.

The **hydrogen roadmap** is to be completed within the next year.

The **Gas Transition Plan** (GTP) firms up the Government position on repurposing gas pipelines for low carbon gas (including hydrogen).

The Aotearoa New Zealand Energy Strategy (Energy Strategy) provides the foundation for which to develop a specific national hydrogen strategy.

Role of regulators

Working Group

MBIE has formed a Hydrogen Regulators Working Group as a forum for sharing and working collaboratively on hydrogen regulatory reform.

Regulatory challenge: The future hydrogen value chain will be complex, and regulatory issues will span existing legislative boundaries due to novel technology applications, new markets and innovative ways of designing and using infrastructure.

Regulators are starting to explore how they will meet their legislative obligation in the hydrogen economy. The Working Group was recently set up to support this work. It provides a forum for government agencies with different mandates to share information, work collaboratively, and at greater pace, to achieve the Government's national hydrogen objectives.

The organisations that are currently party to the working group are identified below.

We recommend the membership is expanded to include the Electricity Authority (EA) and Taumata Arowai, as these agencies will be responsible for key inputs to the hydrogen sector.

Environmental Protection Authority
Te Mana Rauhī Taiao

Ministry of Business, Innovation & Employment
Hīkina Whakatutuki

Ministry for the Environment
Manatū Mō Te Taiao

GNS Science
Te Pū Ao

WorkSafe New Zealand
Mahi Haumaru Aotearoa

Gas Industry Co.

Commerce Commission New Zealand
Te Komihana Tauhokohoko

Te Manatū Waka
Ministry of Transport

Maritime New Zealand

Standards New Zealand
Paerewa Aotearoa

Fire Emergency New Zealand

New Zealand Customs Service
Te Mana Ārai o Aotearoa

Waka Kotahi
NZ Transport Agency

EECA
Te Tari Tiaki Pūngao
Energy Efficiency & Conservation Authority

NZ response

The commercial sector

We interviewed key hydrogen industry participants and regulatory agencies and reviewed existing work to understand the outlook for the sector and the need for regulatory reform.

The domestic hydrogen landscape is currently small and developing organically in response to commercial opportunities and strategies. We found a high level of activity and collaboration in the industry, an indication of the level of commitment to making hydrogen work.

Based on our discussions with key industry participants (identified below) and work done on the hydrogen roadmap and by others, we have formed a cohesive picture of the industry, its future and where the regulatory regime will need to adapt. We anticipate the sector developing as follows:

2020s

- Heavy land transport fuel
- Industrial feedstock (eg fertiliser)
- Export

2030s

- Gas transition fuel
- Hydrogen 'hubs'
- Marine and aviation fuel

Beyond

- Energy system integration support
- Domestic energy self-sufficiency

The organisations we engaged with are identified below:

Ballance	***Hiringa***	***Contact***	***First Gas***
Auckland Transport	***Hyundai***	***Fortescue Future Industries***	***Meridian***
Southern Green Hydrogen	***Waitomo***	***H2H Energy***	***BOC***

A number of other stakeholders were invited to contribute but did not take up the opportunity.

Regulatory frameworks

Fit for purpose

We found that none of the regulatory frameworks applying to hydrogen are strictly 'fit for purpose'. However, many of the issues that need to be resolved are not urgent or require relatively minor changes.

We have assessed the extent to which the existing regulatory frameworks applying to hydrogen are 'fit for purpose'. We have developed a compendium of legislation, regulations and standards that could apply to hydrogen and mapped this to key policy areas (e.g., safety, infrastructure and resources, uses, markets) and parts of the value chain. We assessed the regulatory frameworks against seven 'fit for purpose' criteria drawn from Treasury's 'Government Expectations for Good Regulatory Practice' guidelines. Each area was assessed in a stepwise manner, starting with the legislative purpose and working through each criteria in turn.

Hydrogen is generally accommodated within the purpose of legislation but the fit broke down quickly in one of two ways:

- The novel uses and forms of hydrogen caused potential misalignment across legislation (eg Part 4 of the Commerce Act potentially doesn't cover use of hydrogen in gas pipelines)
- Legislative descriptions were too prescriptive and therefore excluded hydrogen and its requirements.

We stopped assessing the less fundamental criteria, if the framework was determined to not be 'fit for purpose', as illustrated below.

Where the regime is not flexible, we consider generally that the issues are minor but some are urgent. Where the issue is one of alignment, we consider substantial work will be required although this is not necessarily urgent.

Key	
Fit for purpose	🟢
Not fit for purpose	🔴
Not assessed	🟡

	Purpose	Framework alignment	Flexible	International consistency	Complexity	Monitoring and testing	Impact on competition
Safety	🟢	🟢	🔴	🟡	🟡	🟡	🟡
Infrastructure & Resources	🟢	🔴	🟡	🟡	🟡	🟡	🟡
Use	🟢	🟢	🔴	🟡	🟡	🟡	🟡
Markets & Measurement	🟢	🔴	🟡	🟡	🟡	🟡	🟡

Regulatory frameworks

Fit for purpose

A future hydrogen value chain is covered by legislative purpose but the framework lacks the flexibility to evolve at the pace required in the near term. There are 'grey' areas and in the long-term this lack of alignment will cause regulatory issues.

Te Tiriti

In addition to our fit for purpose criteria we have considered the need for hydrogen regulation to conform with the constitutional principles of the Treaty of Waitangi and comply with its obligations. We have identified areas requiring review.

Immediate need

Safety should be the first priority in any regulatory regime relating to hydrogen, due to its dangerous nature. It is not fully covered as a hazardous substance and there are missing standards and specifications.

We found the purposes of relevant Acts to be sufficiently broad that the novel applications of hydrogen could be accommodated. We consider the Gas Act 1992 to be the primary piece of legislation that currently covers the emerging industry. There are a number of pressing issues with how legislation is aligned due to the definitions or absence of definitions - for (natural) gas and (engine) fuel in particular.

At the tertiary level - the standards - there are barriers to very basic operation. This is the issue causing delays in implementation right now. The prescriptive nature of some of New Zealand's safety regulations is creating a lack of flexibility for novel uses of hydrogen. More flexible risk based approaches would support uptake of hydrogen. All parties agree that standards are critical to the safe use of hydrogen, but there is frustration that there are applicable international standards or draft standards that are available but that could be adopted to expedite compliance. Regulators also need support to understand the unique hydrogen risks in order to fulfil their legislated duties.

Regulatory frameworks relating to use of hydrogen should be reviewed to align incentives with other renewable technology and to be more flexible and responsive to the introduction of new hydrogen technologies.

The long term

Regulation relating to use of green hydrogen in infrastructure and resource management is the area posing the most uncertainty and complexity but there is time to consider the issues and respond.

At a high level, it is the disparate legislation and regulatory regimes around energy, infrastructure and climate, that are likely to pose issues as the sector evolves. Hydrogen at scale will integrate electricity, gas, water and transportation infrastructure and markets and increase the level of interdependence in these infrastructure systems. Consistent legislation across sectors will be critical to enabling green hydrogen to integrate effectively and efficiently with related markets. This integration has the potential to play a significant role in our climate change response, as well as wider goals related to the environment and outcomes for consumers. This will require ongoing consideration.

In participating in a new global commodity market there will be new domestic implications and considerations.

Analysis

Our analysis of whether the regulatory frameworks are fit for purpose was undertaken by:

- Applying an Act to an aspect of the future hydrogen value chain to assess if there were gaps or crossovers
- Assessing the interpretations in the Acts for relevance to green hydrogen, its production and its novel uses.
- Matching industry issues with the regulatory frameworks.

Recommendations

A pathway for reform

We recommend that the Government develops a national hydrogen policy strategy as a priority and works with the sector and regulators to ease regulatory friction around hydrogen uptake. A monitoring regime is required going forward to monitor trigger events where longer term regulatory intervention may be required.

1. Set national strategy

We recommend that the Government develops a clear national policy strategy for how Aotearoa will navigate the hydrogen opportunity. The development of the Energy Strategy, the GTP, and completion of the hydrogen roadmap, announced as part of the ERP, offers the opportunity to incorporate specific policy objectives for integrating hydrogen into our energy system. We need a standalone hydrogen strategy that regulatory agencies can reference in developing and planning for regulatory reform.

We acknowledge that the economics, timing and uptake of hydrogen in New Zealand are uncertain. But the sizeable investments being made and the policy direction of our closest trading partners in the Asia-Pacific region is undeniable.

A unifying strategy that fosters economic hydrogen opportunities across sectors will provide confidence to investors and underpin future regulatory reforms.

This will provide direction to Regulators on how to approach fulfilling their regulatory functions in relation to hydrogen.

2. Remove regulatory friction

Our review highlights a number of quick wins and areas of urgent action required to remove regulatory friction. These are mostly associated with standards, definitions and specifications in the regulatory systems.

In many cases what investors are looking for is the ability to bring projects effectively to market in a safe and timely way. Providing support to regulators to plan and flexibly address issues as they arise, in appropriate timeframes, such as through exemptions or risk based solutions will be important in allowing this nascent industry to grow.

Aligning incentives and policy support for hydrogen with other decarbonising options would also level the playing field for renewable solutions.

3. Monitor and respond

Once the basics are in place and government intentions are clarified, the pathway is clear for the industry to evolve.

We identified a number of regulatory issues that could require a response from regulatory agencies in the future, depending on how the market develops.

We recommend that a monitoring regime is set up to keep abreast of market developments. Government will be in the position to assess when intervention is likely to become necessary and plan regulatory reforms with relevant agencies.

This may require an ongoing role for the Working Group, which could meet on a periodic basis to assess market developments and cross-jurisdictional implications. We recommend that the scope of this group is broadened to include water and electricity.

Recommendations

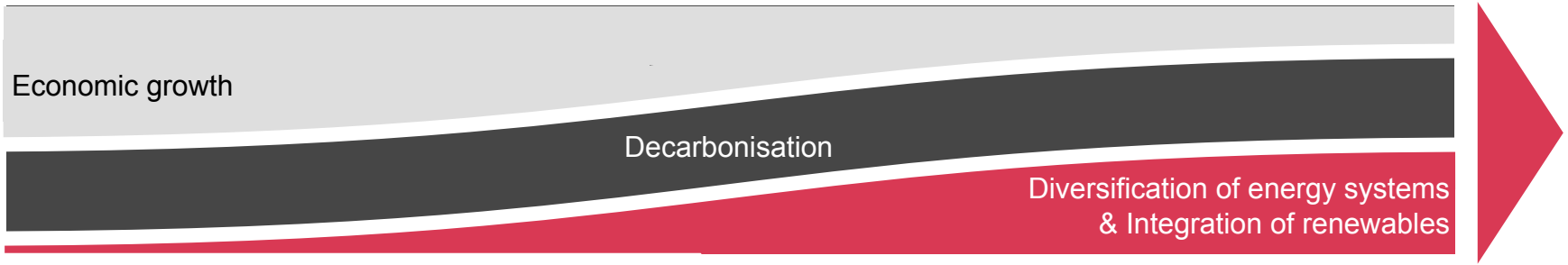
Setting national goals

We recommend that a national strategy identifies and prioritises several core strategic policy objectives.

Hydrogen's role in the **decarbonisation** of our economy has already been signalled as a core policy objective as part of the ERP. There has been some contention over whether hydrogen should be prioritised going forward, as the merits of hydrogen versus electrification have been debated. However, hydrogen's unique role in **decarbonisation of industry** (eg fertiliser, high temperature boilers) and **decarbonisation of heavy transport** (eg substituting diesel) should remain a focus, given these sectors reflect a sizeable proportion of our national carbon emissions.

Initially focusing on a goal of **economic growth** may be vital to support the development of hydrogen sector capabilities, infrastructure and capacity at what is a critical juncture in the development of the global hydrogen economy. While the economics of hydrogen appear challenging, we note that the premium on the price of green hydrogen will fall over time (as it has done for many renewable technologies, for example solar and wind generation). Further, there is an expectation that many businesses are willing to pay this premium in the interim to reduce their carbon footprint as their customers demand climate action now.

New Zealand can also not afford to rely on electrification alone to meet our decarbonisation goals. **The diversification of our energy systems** will need to become a key objective in order to provide security of supply and resilience as we transition away from fossil fuels. This requires a portfolio approach, in which hydrogen plays its part as a means of energy storage. Hydrogen can support the **integration of renewables** as green hydrogen may become both an input and output of our electricity system and can be distributed through our networks.



Recommendations

Reduce regulatory friction

Improving the flexibility of the regulatory system can be addressed relatively easily and quickly. Aligning incentives and policy support for hydrogen with those provided to other decarbonising options would also level the playing field.

There are a number of immediate actions that could be taken to ease the regulatory friction associated with new hydrogen initiatives. These issues do not require a change of policy but reflect a relaxation of the prescriptive aspects of the regulatory system:

- Provide support to Regulators (see slide 10) to develop their understanding of the hydrogen economy and their future role in it, and to progress regulatory reviews and the development of processes to accommodate hydrogen implementation. The could achieved through the Working Group.
- Allow for flexibility to showing compliance with health and safety regulations to accommodate novel hydrogen applications. The adoption of a risk management based approach, similar to that used in Australia, may be preferably to the current prescriptive approach applied to well established energy products.
- Place greater reliance on international standards and provide support to Standards NZ to accelerate the process of adopting hydrogen standards.
- Incorporate hydrogen into a Government Policy Statement (GPS) on renewable energy (which may subsume the current GPS on renewable electricity generation) to provide direction to a number of regulatory agencies. This should be informed or potentially capture the national hydrogen policy strategy.
- Consider whether hydrogen projects should be deemed projects of national significance for consenting (which we understand is being considered for some renewable generation as part of the RMA reforms) and allow a single centralised agency to inform and process consent applications. This would reduce the burden on Councils in understanding the unique risks associated with hydrogen. We concur with the ERP actions relating to streamlining consents but emphasise that reform may be too late for projects that are currently under consideration.
- Align policy incentives offered to EVs (eg Road User Charge (RUC) exemptions, clean car discount, scrap and replace scheme) to include hydrogen fuel cell electric vehicles (H-FCEVs) would allow for hydrogen vehicles to compete on an even playing field and recognise our Memorandum of Cooperation with Japan on hydrogen.
- The Regulatory Systems Amendment Bill (RSB) could be used to process a number of relatively minor regulatory changes. Examples include revising the definition of gas pipelines under Part 4 of the Commerce Act to explicitly allow for regulation of blended fuels in gas networks.
- Consider role of green hydrogen in the development of the New Zealand freight and supply chain strategy, which is currently under consultation by the MoT.
- Remove requirement to odorise hydrogen for vehicle fuel only.

Recommendations

Monitor and respond

We recommend that a monitoring regime is set up to keep abreast of hydrogen market developments and coordinate regulatory responses to 'trigger events' as they arise.

Establish a hydrogen sector monitoring function headed by a central government agency to monitor developments in the hydrogen sector. This should generate information from the existing monitoring functions of relevant regulatory agencies and from sector disclosures. The objective of this monitoring function would be to inform government policy decisions and provide feedback to regulators on potential triggers for regulatory reform. The Working Group could be a useful mechanism to facilitate information sharing across regulatory agencies. This supports our view (based on domestic and international feedback) that change may take a while, but that when it does it will happen fast.

Use this monitoring function to identify events or circumstances that may trigger regulatory reform. Examples of potential regulatory challenges that may require monitoring include:

- Workforce and consumer safety outcomes and performance of the regulatory monitoring system.
- The impact of hydrogen production on electricity markets, transmission capacity, and prices.
- The impact on hydrogen production water use on water catchment management and networks. This should include consideration of non-potable and treated wastewater solutions instead of using potable water.
- Uptake of blended hydrogen in the natural gas system and the impact on wholesale market functions (eg measurement and reconciliation), prices and on end user appliances and quality of supply.
- The use of hydrogen in end-user fuel markets, including impacts on competition, safety, fuel purity, storage and vehicle certification.
- Workforce training and accreditation.
- Efficiency of regulatory systems in facilitating novel hydrogen applications.
- Consideration of hydrogen in major legislative reform of the energy industry (eg GTP), Three Waters and Natural and Built Environments.
- The potential development of carbon intensity measurement standards and 'green' credential schemes and whether centralised approaches are required.
- The potential development of the market for high carbon hydrogen (as an interchangeable substitute for green or low carbon hydrogen) given it will not accelerate our decarbonisation goals.
- Use of green hydrogen in agriculture, and how it can be used to offset agricultural emissions.

2

Introduction

Background

Context and scope

This report sets out PwC's review of the regulatory frameworks required to support a future hydrogen economy in New Zealand and the potential reform pathways that are needed.

Introduction

The Ministry of Business, Innovation and Employment (MBIE) has engaged PwC to undertake a review of whether existing regulatory frameworks are 'fit for purpose' in supporting the future New Zealand hydrogen economy and to advise on regulatory reform pathways to support the hydrogen roadmap.

Our report draws on our analysis of applicable regulatory frameworks and is supported by:

- the Government's green paper
- the Scenario Report and the roadmap model
- the 'Standards Solutions Report' by Standards NZ
- the Government's ERP
- the GIC 'placemat' regulatory review completed for the gas regulator in 2021
- 'The New Zealand Hydrogen Opportunity' report completed for Meridian Energy and Contact Energy (McKinsey Report)

The scope of this project and our approach to it, is outlined in the following slide.

This report sets out our key findings and recommendations for discussion and review.

Initiating the roadmap

This report is a continuation of MBIE's hydrogen roadmap project and explores the regulatory change that may be needed to support the future hydrogen sector and a potential pathway for reform.

Hydrogen is expected to play a critical role in decarbonisation of the global economy. The WEC projects that it will meet up to 20% of the world's energy needs by 2050 and the Asia-Pacific region will be a critical hydrogen market right on our doorstep.

Since 2019, many of New Zealand's trading partners have substantially progressed their hydrogen strategies and New Zealand is some way behind. The McKinsey Report outlined that the opportunity to be a competitive exporter may be short lived. The Scenario Report highlights the large scale of production required to meet all domestic demand by 2050, particularly for aviation.

While no international jurisdiction appears to have implemented major regulatory reform, significant preparatory work has started under clear policy direction.

Government has identified the need for regulatory reform to support hydrogen, but progress appears to have been hampered by uncertainty (from both regulators and industry) over the future of hydrogen in New Zealand and the absence of a clearly defined national strategy.

For this work, we have brought numerous perspectives together into a cohesive view of the future hydrogen value chain in Aotearoa. We have found that each country's hydrogen objectives are unique to its circumstances and understanding New Zealand's circumstances as they relate to hydrogen is essential to moving ahead efficiently.

**World Energy Issues Monitor 2022*, *World Energy Council.*

Background

Our approach

Our review has considered what regulatory reform is needed within the context of the hydrogen sector outlook, the extent to which the existing regulatory frameworks are 'fit for purpose', and potential pathways for regulatory reform.

Our Scope	Approach	Importance
1. Hydrogen outlook We assessed the outlook for hydrogen to better understand how the market may develop in Aotearoa and to define the potential regulatory need. We considered hydrogen regulatory reform precedents in overseas jurisdictions and in New Zealand.	• We researched the global and domestic outlook for hydrogen based on the roadmap project, research undertaken by PwC globally, stakeholder interviews, and other sources. • We interviewed 22 hydrogen sector stakeholders and regulatory agencies to understand their views on the future of the sector, identify issues and determine focus areas for regulatory reform.	• Regulatory pathways must be developed with a robust understanding of how hydrogen markets may develop and informed by the views of organisations working at the forefront of sector developments.
2. Review of existing regulations We have undertaken a review of the regulatory frameworks relevant to hydrogen to understand whether they are fit for purpose in regulating the future hydrogen value chain.	• We developed a compendium of existing legislation (Acts and regulations) that could be used to regulate hydrogen and mapped this to key policy areas (eg safety, infrastructure, markets) and parts of the hydrogen value chain, (the regulatory frameworks). We identified issues and focus areas from stakeholder feedback and our research of overseas precedents. We assessed the regulatory frameworks against 'fit for purpose' criteria drawn from Treasury's 'Government Expectations for Good Regulatory Practice' guidelines.	• Understanding what we already have in place and its purpose and scope is important to defining the extent of required reform. Existing structures have been tested against 'fit for purpose' criteria and overseas precedent, where possible.
3. Regulatory reform pathway Based on analysis of the regulatory need and current regulatory frameworks, we have recommended key areas for regulatory consideration and potential pathways to align with New Zealand's hydrogen goals.	• We have compared the regulatory need that is implied by the sector's views on the outlook for New Zealand's hydrogen to the level of readiness of existing regulatory frameworks. Areas where reform may be required have been identified and the potential timing and pathway for development has been explored. Our recommendations are conceptual in nature, and although some 'quick wins' are identified, further detailed work is required.	• Signalling the key areas of regulatory reform and potential triggers and pathways gives confidence to hydrogen investors and helps regulators and policy makers develop plans.

Our approach

Stakeholder interviews

An important part of our approach was to talk to parties across the future hydrogen value chain about what issues they had encountered or considered. There was significant value in pulling together views from across the sector into a single picture.

We interviewed the following industry participants about their hydrogen journey

- Auckland Transport (AT)
- Ballance Agri-Nutrients (Ballance)
- BOC
- Contact Energy (Contact)
- Fortescue Future Industries (FFI)
- First Gas
- H2H Energy (H2H)
- Hiringa Energy (Hiringa)
- Hyundai Motors New Zealand (Hyundai)
- Meridian Energy (Meridian)
- Waitomo Group (Waitomo)

We interviewed the following regulators about hydrogen regulation

- Commerce Commission
- Energy Efficiency and Conservation Authority (EECA)
- Environmental Protection Authority (EPA)
- Fire and Emergency New Zealand (FENZ)
- Gas Industry Company (GIC)
- Maritime New Zealand (Maritime NZ)
- Ministry of Transport (MoT)
- New Zealand Customs Service (Customs)
- Standards New Zealand (Standards NZ)
- Waka Kotahi NZ Transport Agency (Waka Kotahi)
- WorkSafe New Zealand (WorkSafe)

A number of other stakeholders were invited to contribute but did not take up the opportunity.

Our approach

Research

We have drawn on the work done to date in Aotearoa, but also the vast resource we have available through the PwC global network. We have the advantage of being able to learn from economies that are already implementing their hydrogen strategy.

Domestic research

We have referenced existing analysis and research on the future role of hydrogen including:

- The Scenario Report and roadmap model
- The CCC's final advice to Government 'Ināia tonu nei - a low emission future for Aotearoa'
- The ERP
- First Gas' hydrogen feasibility study.
- McKinsey Report

We have also reviewed key regulatory frameworks to understand how they may be applicable to hydrogen.

Global research

We have leveraged detailed insights from research undertaken across PwC's global network, including work recently undertaken for the WEC.

We have supplemented this with specific research into regulatory reform observed in key overseas jurisdictions, such as Australia and the UK.

Overview

Hydrogen's domestic role

Hydrogen is not new in New Zealand - nor is low carbon hydrogen - with existing industrial applications. The future role for hydrogen lies in its potential to decarbonise industrial, agricultural, heavy transport and power generation processes.

What is hydrogen?

Hydrogen (H_2) is the smallest and most abundant element in the Universe. Our sun is 92% hydrogen by mass. Lighter than air, it is colourless, tasteless and odourless, and it is highly combustible. In New Zealand, as a gas, it is classified as a permitted hazardous substance by the EPA, and as a gas for fuel, it is covered by the Gas Act 1992

There are two methods used to produce hydrogen in New Zealand

1. **Electrolysis** is a method of making hydrogen by running an electrical current through water (H_2O) and splitting it into hydrogen (H_2) and oxygen (O_2).

2. **Natural gas reforming** is when the gas (which is mainly methane - CH_4) is reacted with steam (H_2O) creating synthesis gas - a mix of H_2, carbon dioxide (CO_2) and carbon monoxide (CO).

Most of the hydrogen that is made is from steam reformation of natural gas, which results in high carbon emissions. However low carbon hydrogen has been produced for several years in New Zealand via grid-based electrolysis at the Glenbrook steel mill.

Existing and future applications

Hydrogen is currently produced and used widely in New Zealand in:

- Refining fossil fuels (petrol and oil)
- Treating metals (steel)
- Producing fertiliser (from ammonia - NH_3)
- Food processing (hydrogenation of fats and oils).

Future uses for hydrogen which are being investigated include as an industrial feedstock (e.g., for fertiliser), as a transport and heating fuel, and as a renewable fuel for electricity generation.

When hydrogen is consumed it generally reverts back to water. Low carbon intensity hydrogen is therefore seen as a sustainable way to reduce (or even eliminate) carbon emissions from key sectors that drive Aotearoa's carbon footprint - agriculture, transport, heating, and power generation.

Production methods

The ‘colours’ of hydrogen

It has been common practice to use a colour coding system to define the production method of hydrogen. The production method and inputs determine the level of carbon emissions that are created in the production process. The table opposite illustrates all the hydrogen colour codes.

Globally, we are starting to see a shift away from using colours to define hydrogen in favour of a more precise measurements of the carbon intensity of hydrogen.

For simplicity, references to the term hydrogen or green hydrogen in a domestic context both refer to hydrogen produced using electrolysis.

The strict definition of ‘green’ hydrogen requires it to be produced from 100% renewable electricity generation. Hydrogen produced from grid supplied electricity in New Zealand would still be very low carbon due to the high proportion of renewable electricity in the country. Hence, we are taking a more liberal definition of ‘green’ to mean a low carbon hydrogen made by electrolysis.

The economics of green hydrogen production are more challenging than fossil fuel based hydrogen due to:

- the higher capital costs of electrolyser plant
- the cost of electricity, which is generally a more expensive feedstock than fossil fuels
- the demand for hydrogen, relative to other cheaper fuel substitutes.

This report focuses on low carbon production methods of hydrogen based on electrolysis using 100% or high levels of renewable electricity generation.

Colour coding system – carbon emissions associated in hydrogen production

	Terminology	Technology	Feedstock / Electricity source	Carbon footprint
Production via electricity	Green hydrogen	Electrolysis	Wind, solar, hydro, geothermal, tidal	Minimal
	Pink / Purple hydrogen		Nuclear	
	Yellow hydrogen		Mixed-origin grid energy	Medium
Production via fossil fuels	Blue hydrogen	Natural gas reforming + CCUS gasification + CCUS*	Natural gas, coal	Low
	Turquoise hydrogen	Pyrolysis	Natural gas	Solid carbon (by-product)
	Grey hydrogen	Natural gas reforming		Medium
	Brown hydrogen	Gasification	Broan coal (lignite)	High
	Black hydrogen		Black coal	

*CCUS = carbon capture, utilisation and storage

Green hydrogen

Future use applications

Hydrogen will play a critical role in decarbonisation of the global economy where electrical and battery solutions are not feasible.

Transport fuel

Electrification will not always be possible for some end use applications, either where direct connection to generation is not possible or where battery weight is a problem. Where this is the case, it may be more practical to use green fuels, such as hydrogen and its derivatives. A key advantage of hydrogen, is that it has a higher energy content by compressed weight (kWh/kg) and volume (kWh/l) when compared to electric batteries. This makes it useful for heavy transport and aviation applications, improving the efficiency of transport movement and range. The general rule is that, the longer the range travelled and the higher the weight of the vehicle, then the less feasible electrification is (see diagram opposite). The sweet spot for hydrogen appears to be in heavy vehicles and shorter range aircraft.

Hydrogen also has a place as a precursor to the manufacturer of synthetic fuels to replace bunker oil in ships and jet fuel for long haul airplanes.

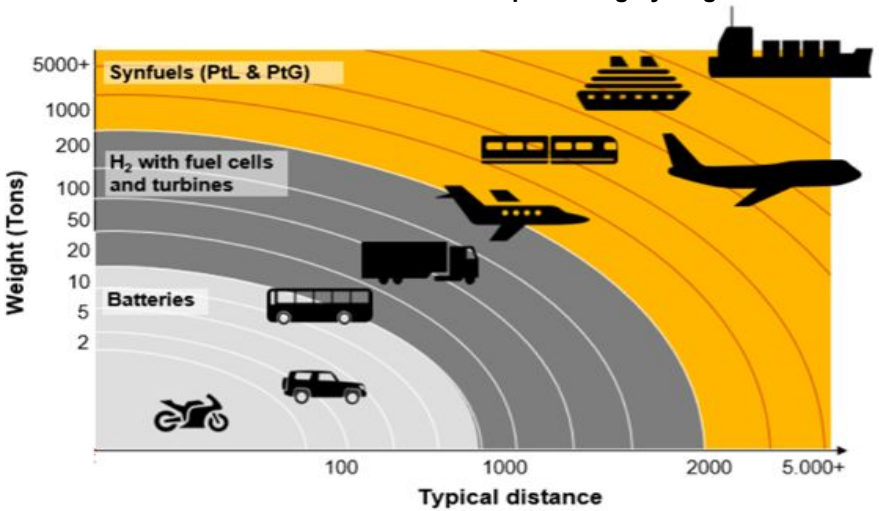
Industrial Feedstock

Green hydrogen may play an important role in decarbonising industrial processes such as fertiliser production. Grey hydrogen (made from natural gas) is currently used extensively for fertiliser production in Aotearoa.

Energy transition fuel

Green hydrogen or a derivative may be able to be used as a feedstock for power generation peaking units. It also offers a demand response option. For piped gas networks it offers a transition option away from natural gas and could be used in a pure form as a heating fuel for high temperature applications.

Potential decarbonisation solutions for transport using hydrogen



Source: Global Hydrogen Academy, PwC Global

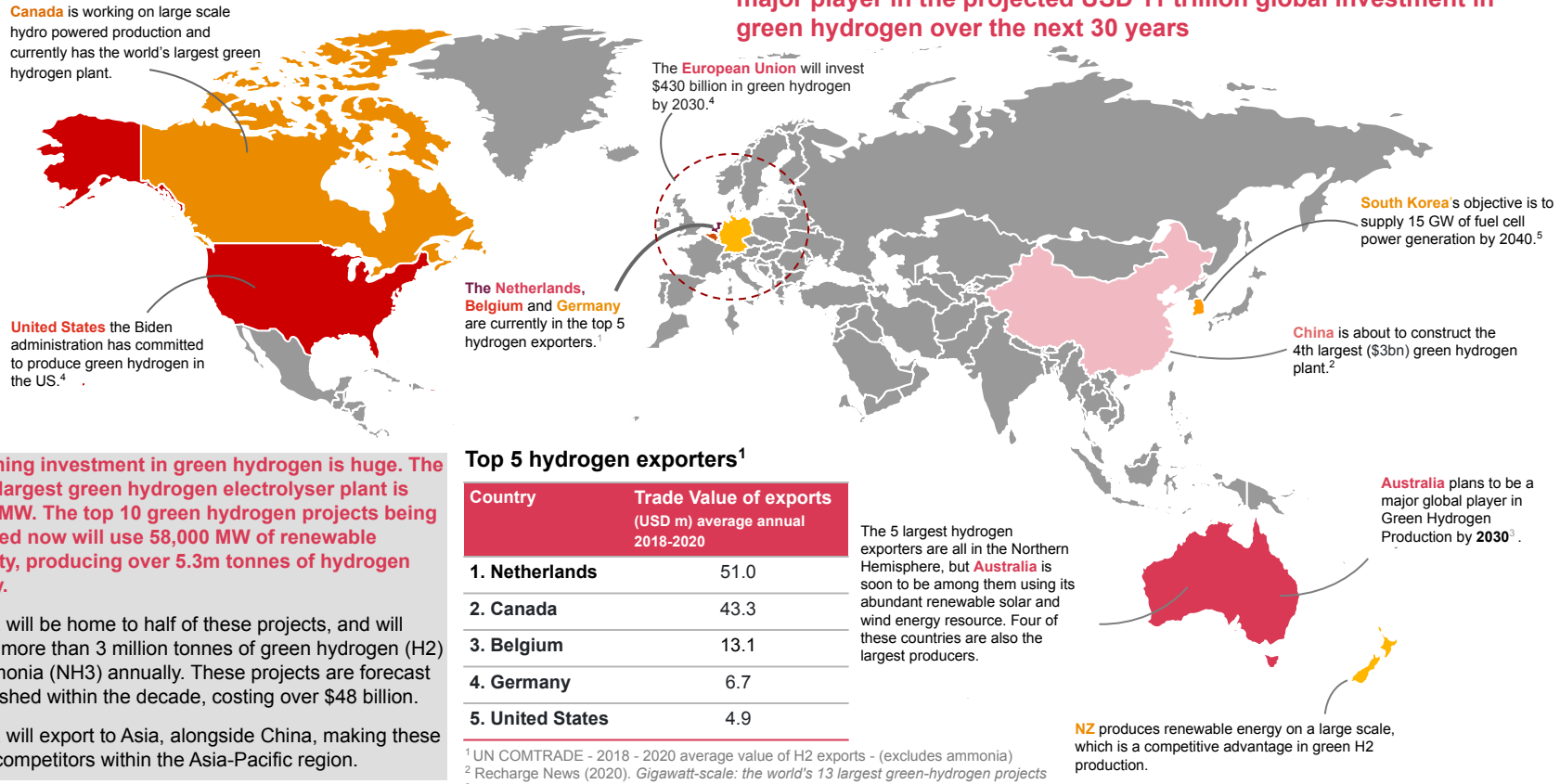
PwC's view is that green hydrogen will have has a place in the wider New Zealand energy sector as well as in industrial chemical processes - either directly or through 'Power to X' solutions - PtG = Power to Gas, PtL = Power to Liquid Fuel

3

Global Context

Global production

Europe and North America currently dominate green hydrogen production, but the Asia-Pacific region is expected to become a major player in the projected USD 11 trillion global investment in green hydrogen over the next 30 years



The coming investment in green hydrogen is huge. The world's largest green hydrogen electrolyser plant is only 20 MW. The top 10 green hydrogen projects being developed now will use 58,000 MW of renewable electricity, producing over 5.3m tonnes of hydrogen annually.

Australia will be home to half of these projects, and will produce more than 3 million tonnes of green hydrogen (H2) and ammonia (NH3) annually. These projects are forecast to be finished within the decade, costing over $48 billion.

Australia will export to Asia, alongside China, making these the key competitors within the Asia-Pacific region.

Top 5 hydrogen exporters[1]

Country	Trade Value of exports (USD m) average annual 2018-2020
1. Netherlands	51.0
2. Canada	43.3
3. Belgium	13.1
4. Germany	6.7
5. United States	4.9

The 5 largest hydrogen exporters are all in the Northern Hemisphere, but **Australia** is soon to be among them using its abundant renewable solar and wind energy resource. Four of these countries are also the largest producers.

[1] UN COMTRADE - 2018 - 2020 average value of H2 exports - (excludes ammonia)
[2] Recharge News (2020). *Gigawatt-scale: the world's 13 largest green-hydrogen projects*
[3] Australia's National Hydrogen Strategy (2019).
[4] State of the Planet (2021). *Why we need green hydrogen*
[5] IEA/IRENA Renewables Policies Database (2020). Korea Hydrogen Economy Roadmap 2040
[6] World Energy Council (2021). *The future of hydrogen in the Asia Pacific.*

Asia-Pacific region

Importance of our trading partners

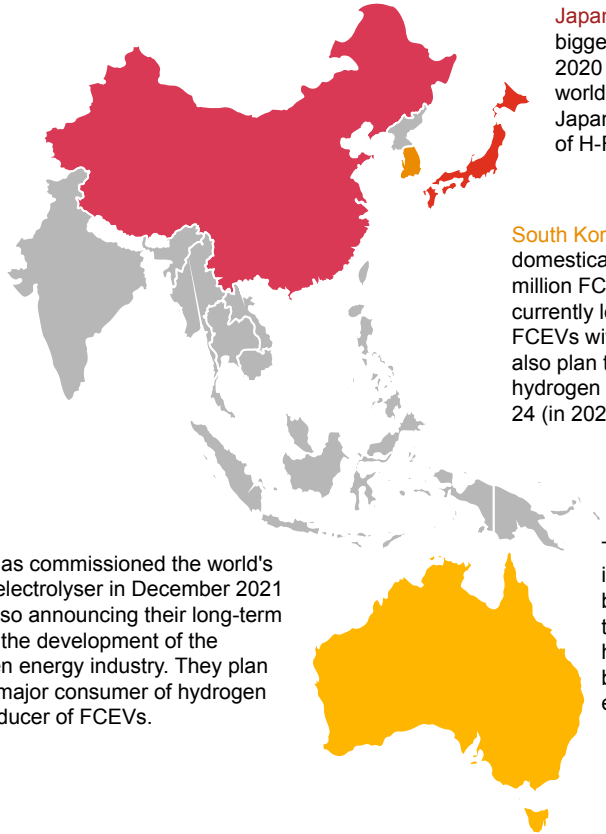
The Asia-Pacific region will be a key hub for hydrogen development with significant expected demand and technology development within the region. Being right on the doorstep of this activity, New Zealand should be open and ready for the opportunities this presents.

The global goal to reach net carbon zero by 2050 is challenging. While it is certain that renewables based electrification will play a lead role in decarbonisation of the global economy, green fuels such as hydrogen will also play a critical role.

Our regional trading partners in the Asia-Pacific have set strategies with a focus on hydrogen. This envisages the import of green fuels from renewable poor regions (eg Korea, Japan) from more renewable rich producers (eg Australia). On the demand side, significant investments in the manufacture of complementary hydrogen technologies are already underway (e.g., Fuel Cell Electric Vehicles - FCEVs).

The 'tyranny of distance' will be a key issue for New Zealand in participating in this trade. Transportation of hydrogen is technically challenging and currently expensive. However, we have overcome these challenges in the past and generally we have been adopters of technologies developed by our trading partners.

It therefore seems likely that there will be opportunities to participate in hydrogen trade (where economic) and to adopt overseas hydrogen technologies into our own economy (e.g., FCEVs). While there is still uncertainty over how this will play out, New Zealand is right on the doorstep of a major hydrogen market and needs to be open and ready for the opportunities this presents



Japan opened one of the worlds biggest green hydrogen plants in 2020 and in 2019 they unveiled the world's first liquid hydrogen carrier. Japan plans to be a major exporter of H-FCEVs.

South Korea has set a goal to domestically manufacturer three million FCEVs by 2040. They currently lead the world in FCEVs with over 10,000. They also plan to expand their fleet of hydrogen refuelling stations from 24 (in 2021) to 1200 by 2040.

China has commissioned the world's largest electrolyser in December 2021 whilst also announcing their long-term plan for the development of the hydrogen energy industry. They plan to be a major consumer of hydrogen and producer of FCEVs.

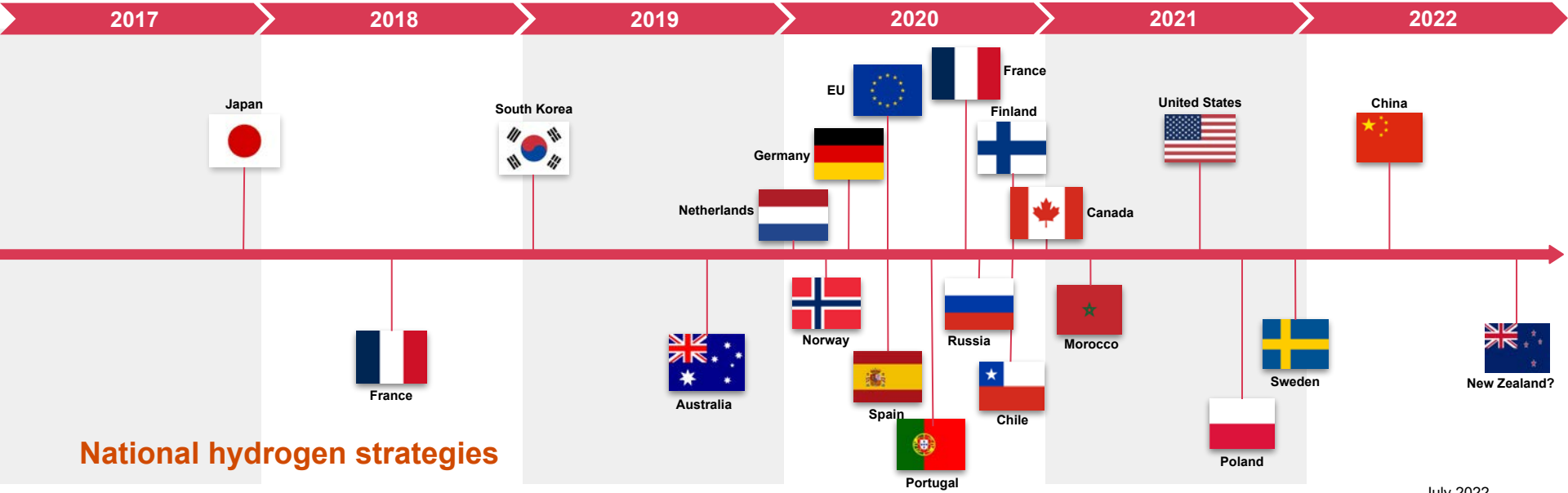
The Australian government is investing $1.4 billion in building a hydrogen industry to meet their national hydrogen strategy goals of being a major producer and exporter of hydrogen.

Policy response

What Governments are doing

The main global response to hydrogen from governments so far has been to develop national strategies and roadmaps to navigate the hydrogen opportunity. Aotearoa has made progress on a roadmap but needs to set out a clear national strategy.

Japan published its hydrogen strategy in 2017, the first country to do so. In the intervening years, approximately 30 countries have published hydrogen strategies. Many are now starting to implement these strategies through the development of policy frameworks and industry supports. Our closest neighbour, Australia has already made inroads into delivering on its plans to be a hydrogen superpower, making its first export this year. (Detail in Appendix D) New Zealand has yet to publish a national strategy on hydrogen, although it is exploring hydrogen's potential future role as part of MBIE's hydrogen roadmap, which is due to be completed over the next year. The recent ERP also acknowledges hydrogen as a viable decarbonisation option for the transport sector and as a potential transition fuel for gas. We commend this work, but stress there is some urgency for New Zealand to articulate a comprehensive set of clear national strategies, priorities, and objectives for hydrogen.



National hydrogen strategies

Policy response

National objectives

There are four main policy objectives emerging and the combination of priorities for each economy are unique. Our national hydrogen strategy will need to prioritise its own objectives in order to guide future regulatory reform.

National hydrogen strategies are being developed according a set of four prioritised objectives: **decarbonisation** as a pathway to meet national climate commitments; **diversification of the energy supply chain** away from fossil fuels and from reliance on electricity; **economic development** associated with the sizeable investment opportunities in hydrogen; and **integration of renewables** into existing networks.

New Zealand will also need to prioritise its objectives in its national strategy, to provide guidance to regulators and business. Feedback from industry and regulators is that the absence of strategic policy objective(s) is creating uncertainty on how to respond appropriately to the hydrogen opportunity.

Key	
Low Prioritisation	🟢
Long-Term Prioritisation	🟡
Immediate Prioritisation	🔴

	Asia Pacific			Europe								Americas	
	AU	Japan	South Korea	EU	France	Germany	Hungary	Holland	Norway	Portugal	Spain	Chile	Canada
Decarbonisation	🟢	🔴	🟢	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴
Diversify Energy Supply	🟢	🔴	🟡	🟢	🟢	🔴	🔴	🔴	🟢	🟡	🟡	🟢	🔴
Economic Growth	🔴	🔴	🔴	🟢	🔴	🔴	🟢	🔴	🔴	🔴	🔴	🔴	🔴
Integration of Renewables	🟢	🟢	🟡	🔴	🟢	🟡	🟢	🔴	🟢	🔴	🔴	🔴	🔴

Global response

Regulatory reform

There is limited international precedent for comprehensive regulatory reform relating to hydrogen. The current focus is on standards development and on regulatory planning and analysis, to support understanding of the sector, and inform government in the future.

In spite of the widespread development of hydrogen strategies, there is yet to be a jurisdiction that has completed a comprehensive review of its regulatory frameworks for hydrogen. This is partly due to the uncertainty over the timing and extent of hydrogen uptake.

National hydrogen strategies are starting to be incorporated into the long-term planning of government and regulatory agencies (see Appendix D). Countries are using this time to experiment with scenarios and test feasibility in order to inform future government decisions.

Standards development is a key area of focus to address novel applications like vehicle refuelling. We note that the International Organisation for Standardisation (ISO) is working on 17 standards related to uses of hydrogen and these are being quoted by industry even though they are still in working form.

We conclude from this that it is too early to undertake comprehensive regulatory reform, but specific areas of regulatory friction (eg standards) can be addressed along with the development of national strategic objectives and plans to respond to hydrogen developments.

We caution against using any single jurisdiction as a precedent, as the New Zealand's case for hydrogen and associated objectives are unique and require a tailored approach to regulatory review. Any reform also needs to be based on a clear set of national strategic objectives.

Examples of recent regulatory responses:

- The Australian Energy Market Operator (AEMO) has recently published its draft system plan for the electricity market and has included a "hydrogen superpower" scenario in its modelling. This demonstrates the consideration being given to green hydrogen and its impact on other energy markets.
- The UK energy regulator, Ofgem, is putting together a framework to support the development and delivery of the "Village Trial". This builds on the previous "Neighbourhood Trial" and tests repurposing gas networks for 100% hydrogen. Both trials will support the building of the evidence base needed for the UK Government to decide whether to promote hydrogen transported through the existing gas network infrastructure.
- The UK water regulator, Ofwat, has included hydrogen in its report "Meeting regional and national water resources needs: gap analysis of the current strategic infrastructure scheme portfolio". The report notes: *"It is likely that future water supply sources could benefit both the hydrogen economy and public water supply. Therefore, long term investment in water supply should consider where the hydrogen economy may develop and the potential for shared solutions".*

4

Domestic Outlook

Green hydrogen
In New Zealand

New Zealand requires a clear hydrogen policy which addresses both energy and industrial applications. The sector is already being driven by partnerships across sectors.

We have talked to many industry participants in the domestic hydrogen sector about their plans, views and perspectives on hydrogen in New Zealand.

Based on these discussions and:

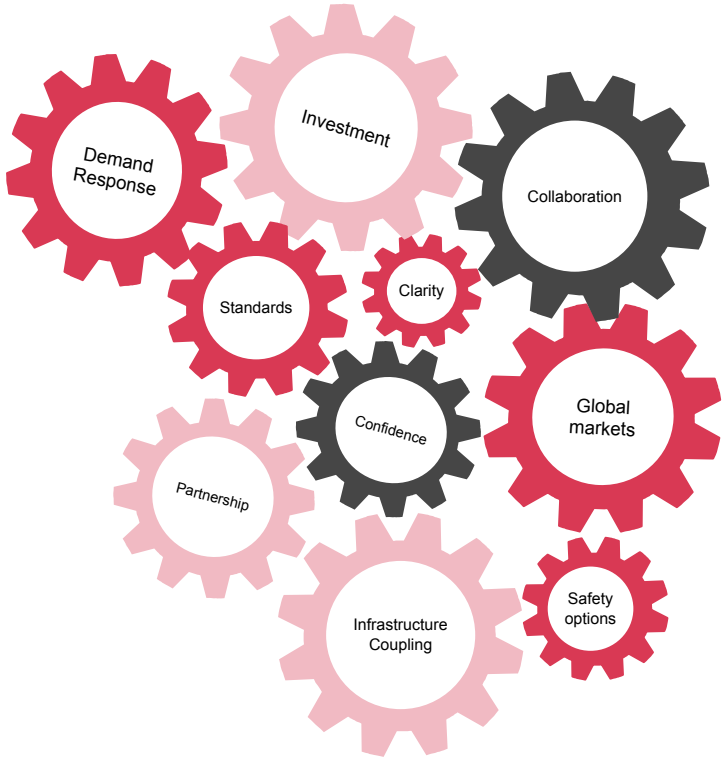
- work already undertaken to date by the Government, CCC, ERP and sector participants
- our interpretation of the development of global value chains, and
- our understanding of the domestic infrastructure and utilities sectors.

We have formed a view of how the hydrogen industry is likely to develop over the coming decades, as we approach our 2050 climate change target. We have summarised the “Domestic Industry Story” as we see it, in three parts on slides **40 - 42**.

We believe the following uses for hydrogen will be most important for New Zealand:

1. Heavy transport (including maritime and aviation in the long term)
2. Fertiliser (and other industrial feedstock uses in the long term)
3. Energy networks integration (including the gas network transition).

We believe that near term industry growth will be through the development of ‘hydrogen hubs’ (see slide **37**).



Future use applications

A transport fuel

Green hydrogen as a vehicle fuel emits only water. This makes it an attractive option for decarbonising transport. It's major drawback is that it is not as energy efficient as directly using electricity to power a vehicle.

How hydrogen became a transport fuel

The National Aeronautics and Space Administration (NASA) began using liquid hydrogen in the 1950s as a rocket fuel. NASA was one of the first to use hydrogen fuel cells to power the electrical systems on a spacecraft.

Hydrogen is very appealing for its energy storage properties in a world looking to decarbonise. The only emission from a fuel cell is water.

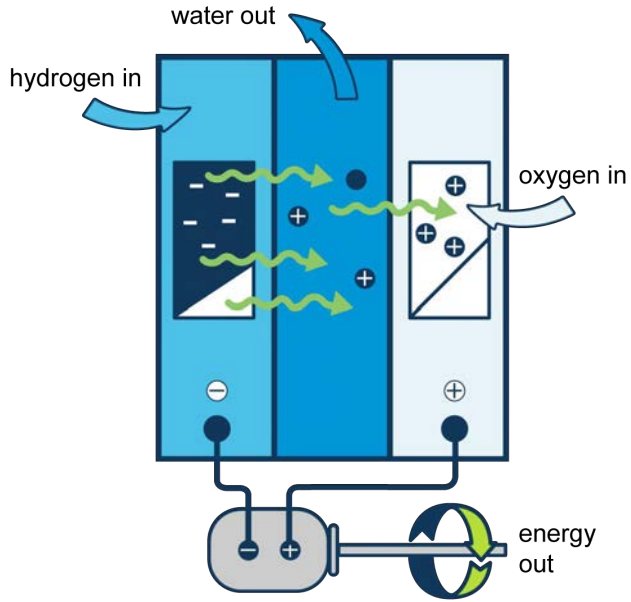
FCEV vs EVs

EVs are likely to dominate road transport in New Zealand due to the ease and efficiency of connecting to a grid which is dominated by renewables already. But there are clear cases where alternative fuels will be better suited for road transportation. As outlined previously, these cases are where the weight of the vehicle and/or the range travelled is large. Industry has identified that buses and freight trucks travelling longer routes are better suited to FCEVs than EVs. The main thing holding up the domestic industry in these two vehicle types is the ability to refuel. The commissioning of Hiringa's first refuelling stops is one example that will facilitate the use of these vehicles.

Future fuels

FCEVs are also feasible for harbour vessels (such as ferries) and short range aircraft. But at longer travel ranges they cease to be feasible in maritime and aviation applications. However, the same technology applies to the production of green fuels for these applications, in that green hydrogen is an input. It is the scale of production required to meet the demand in these applications that will be the biggest barrier to uptake.

Hydrogen fuel cell



Source: National Energy Education Project

Future use applications

An industrial feedstock

Hydrogen is already used widely in New Zealand industry, mainly based on grey hydrogen. Initiatives are already underway to substitute green hydrogen as a strategy for decarbonising our industrial processes

How hydrogen is used as an feedstock

There is a large existing market for hydrogen as an industrial feedstock in New Zealand, particularly for fertiliser manufacturing. For example, Ballance produces around 260,000 tonnes of urea per year using hydrogen produced from natural gas as a feedstock. Ballance generates large emissions from this process (for which it pays under the ETS) and has the incentive to reduce these.

The carbon footprint of goods is becoming a focus in many of our overseas export markets. As a primary sector exporter at the bottom of the world, with relatively high agricultural and international freight emissions, New Zealand will need to find more sustainable ways of producing our goods. The use of green hydrogen as a low carbon feedstock is one such area being investigated to decarbonise our industrial and agriculture base and make us more competitive overseas.

For example, Ballance is working on the premise of delivering ‘green nutrients’ to the world. It is planning to invest in a new green hydrogen electrolysis plant and wind farm in Taranaki to start production of low carbon fertiliser.

Potential hydrogen feedstock industries

MBIE’s strategy paper - ‘A vision for hydrogen in New Zealand’ - identified a number of areas were where hydrogen could be used for industrial purposes. Some of these will cease to exist as fossil fuels are phased out (petrol and oil refining). For example, hydrogen production at Marsden Point has been stopped due to closure of the refinery.

However most cases will remain and others may emerge.

- Ammonia production
- Agriculture
- Metal and metal products
- Dairy manufacturing
- Steel production
- Process heat
- Synthetic gas production

Future use applications

Energy networks integration

The process by which green hydrogen is made creates dependencies with the electricity system, and it also creates opportunities. As a carbon-neutral gas, it also offers opportunities in the gas network.

Natural Gas

New Zealand's gas pipeline businesses (GPBs) face significant stranding of assets as part of the transition away from natural gas. The major GPBs in New Zealand are investigating the repurposing of their pipelines to deliver hydrogen, biogas, or other low carbon alternatives to preserve the value of these assets.

The CCC recommended that new connections to gas pipelines and the sale of appliances should be banned from 2025. However, the ERP has signalled its preference for a managed and just transition for the gas sector which will be explored as part of the GTP. As part of this, options for repurposing gas infrastructure for low carbon gas (including hydrogen) will be investigated.

The pipes, in their current state, are not fit in an engineering sense to carry pure hydrogen. They are capable of being repurposed to be so over time. Work is being done on the pipeline standards required to achieve this transition.

It is possible that repurposing natural gas networks to store and transport hydrogen will provide a long-run economic benefit to the energy outcomes for New Zealand. Retaining this as an option is prudent.

Electricity

Electricity will undoubtedly do the heavy lifting in meeting our future energy needs and climate change objectives. The key issue for New Zealand's energy system is that renewable energy generation is intermittent. It is not necessarily available when it is needed. For electricity markets, this is important as supply must equal demand at all times, otherwise the system fails. In order to unlock and grow renewables, we need a way of storing energy to meet our energy security of supply and resilience objectives.

This challenge is being investigated by the Government's New Zealand Batteries project and the EA's Market Development Advisory Group. The key issue is how we serve our seasonal winter energy load, where our hydro generation capacity is at its lowest. About 5,000 GWh (about 12%) of firm energy storage is required to see us through our winter.

Combining green hydrogen fuel cells and electrolysers to produce electricity when demand is high, and hydrogen when demand is low, is one solution being investigated. It also highlights the potential symbiotic interplay between electricity and hydrogen markets in driving higher levels of renewables.

Future Infrastructure

Hydrogen hubs

We see the development of hydrogen hubs being the main driver of hydrogen growth in Aotearoa. This has implications and opportunities for both energy and infrastructure.

Hydrogen hubs are an infrastructure solution which embeds an energy solution with green hydrogen. Hubs remove the need to transport the hydrogen, which is one of the most difficult (and expensive) aspects of the value chain.

By building renewable generation and hydrogen production capacity near or at a point of high demand, the transportation issue is overcome. This is an efficient use of both energy and infrastructure.

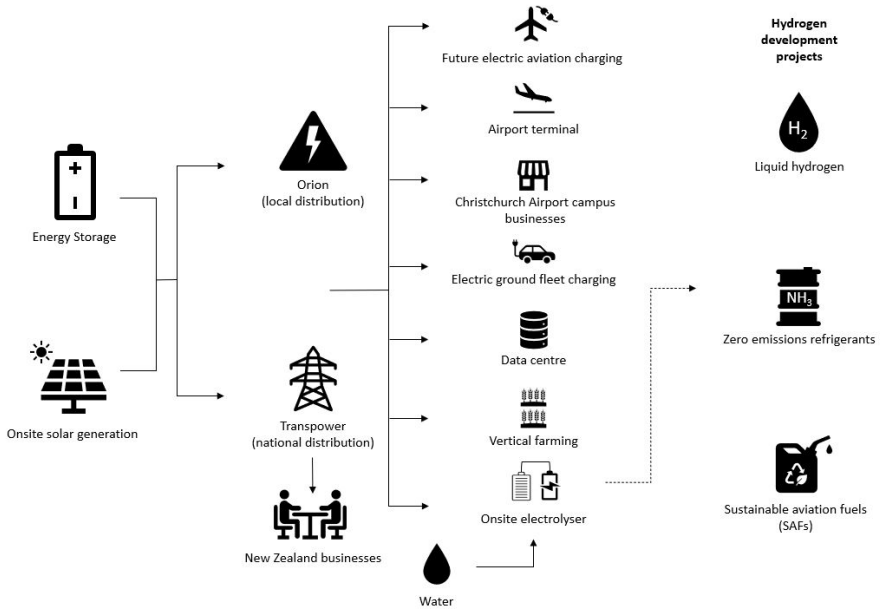
We see hydrogen hubs being the most common way the industry will evolve in the near term.

A proposed hub, Kowhai Park, is to be developed at Christchurch Airport. This is where a solar farm will be built to fuel a hydrogen plant. The hydrogen plant will offer a variety of energy solutions, including aviation fuel. We consider that the mandate for sustainable aviation fuel (SAF) will drive similar activity at other airports.

The facility at Ports of Auckland was also designed to be a hub. Ports make an ideal location for hydrogen hubs if renewable generation can be colocated.

The Hiringa Energy and Ballance joint venture (JV) project is also based on the hub model, where the demand is for fertiliser production.

Example of an airport hydrogen hub



The domestic industry

Who we talked to

We interviewed businesses across the value chain and used what they told us to build a single cohesive picture of how the industry will evolve. Partnership and collaboration is a fundamental aspect of the industry at the present.

Auckland Transport	AT is responsible for public transport in Auckland. It currently is trialling a single hydrogen fuelled bus (fuelled from the Port of Auckland facility) with plans to expand when refuelling capacity in South Auckland becomes available – see Hiringa Energy below.
Ballance	Ballance is a New Zealand farmer cooperative specialising in fertiliser manufacture. It has entered into a JV with Hiringa Energy (below) to build green hydrogen production capacity in Taranaki as a fertiliser feedstock.
BOC	BOC is part of the multinational Linde group. It has been producing hydrogen for 30 years, including low carbon hydrogen from electrolysis. It supplies hydrogen to Ports of Auckland and the Glenbrook steel mill as an example and has a national truck transportation network.
Contact	Contact is an electricity 'gentailer' and JV partner in Southern Green Hydrogen (SGH) with Meridian Energy (see below). SGH is a project to evaluate whether green hydrogen can be produced at scale in Southland, using electricity from the Manapouri scheme.
Fortescue Future Industries	FFI is a global green hydrogen supply chain investor and partner. It has been shortlisted as a potential partner for SGH. It also has a Memorandum of Understand (MOU) with NZ Refining for repurposing Marsden Point refinery, amongst other domestic and global projects.
First Gas	First Gas is a GPB operating both transmission and distribution networks. It is currently working towards trialling hydrogen blending into its networks with the view to repurpose both transmission and distribution networks by 2050.

The domestic industry

Who we talked to

We also spoke informally with a number of related parties. We found a high level of collaboration in the industry, an indication of the level of commitment being made to making the hydrogen industry work.

H2H Energy	H2H is an Australian supplier of technology and expertise to industry. It has supplied Ports of Auckland amongst others in New Zealand.
Hiringa	Hiranga is a producer and supplier of green hydrogen, particularly for vehicle refuelling. It is in partnership with Waitomo to set up refuelling stations and in a JV with Ballance to set up a hydrogen hub based around fertiliser production.
Hyundai	Hyundai is an importer and supplier of Hyundai vehicles in New Zealand. It brought the NEXO (light passenger vehicle) to New Zealand and recently has imported its first hydrogen truck. Hyundai is waiting on Hiringa to commission first of its refuelling network so that it can commence wider scale importation of hydrogen vehicles. Hyundai is a leader in H-FCEV technology.
Meridian	Meridian is an electricity ‘gentailer’. It is a JV partner in SGH with Contact Energy (see above). Meridian has hydro generation assets across the lower South Island and are the lead supplier of electricity to Tiwai Point Aluminium smelter.
Waitomo	Waitomo is a vehicle refuelling group, partnering with Hiringa Energy on hydrogen refuelling stations.

Domestic industry story

Production of green hydrogen

We see production evolving as a combination of mainly smaller scale hub-based plants and a few large scale plants with networking or export capacity.

2020s

Medium scale electroliser production of hydrogen using electricity from national grid for use in domestic industrial process.

Development of dedicated **small-medium scale renewable generation** for direct connection to electrolysers to be used in hydrogen 'hubs'.

Feasibility and commissioning of 1-2 **large scale electroliser production** plants fed from national grid to be used for export hydrogen.

2030s

Expansion of electrolysed production of hydrogen using electricity from national grid for mixed use.

Large scale production for export increasingly diverted for use in domestic economy.

Increasing numbers of small-medium scale production from off-grid distributed renewable generation to form the base of hydrogen 'hubs'.

2040s

Large scale production providing bulk domestic supply of hydrogen for mixed uses and being in the position to support electricity security of supply.

Well-established 'network' of small-medium scale production supplying hubs and in the position to support piped gas transition.

Domestic industry story

Use of hydrogen

We see expansion and growth in the three major use cases, with industrial feedstock driving demand, as use as a fuel for all transport increases. A level of maturity will be reached and network uses will start to fully integrate.

2020s

- **Small percentage of blending** in natural gas piped networks.
- Pilot and **small scale use in public transport** (buses, ferries and passenger aircraft).
- **Use for industrial processes increases** as companies decarbonise industrial processes (ie fertiliser).
- **Small scale PtL** in marine.
- **Introduction of H-FCEV heavy vehicle fleet** for freight and similar.
- Small scale introduction of passenger cars.
- Conversion of existing heavy vehicle fleet to **dual fuel** (hydrogen injection into diesel).

2030s

- Significant **uptake in heavy vehicle** sector as supply options for new vehicles are restricted to alternative fuels only and fleets are up for renewal.
- **Blending up to 20%** in natural gas networks.
- **Increasing PtL and PtG** in marine, rail and aviation.
- **Small scale** but wide **use in public transport** sector.
- **Increasing use for industrial process decarbonising**
- Significant **uptake in specialty vehicles** (ports, mining, farming).

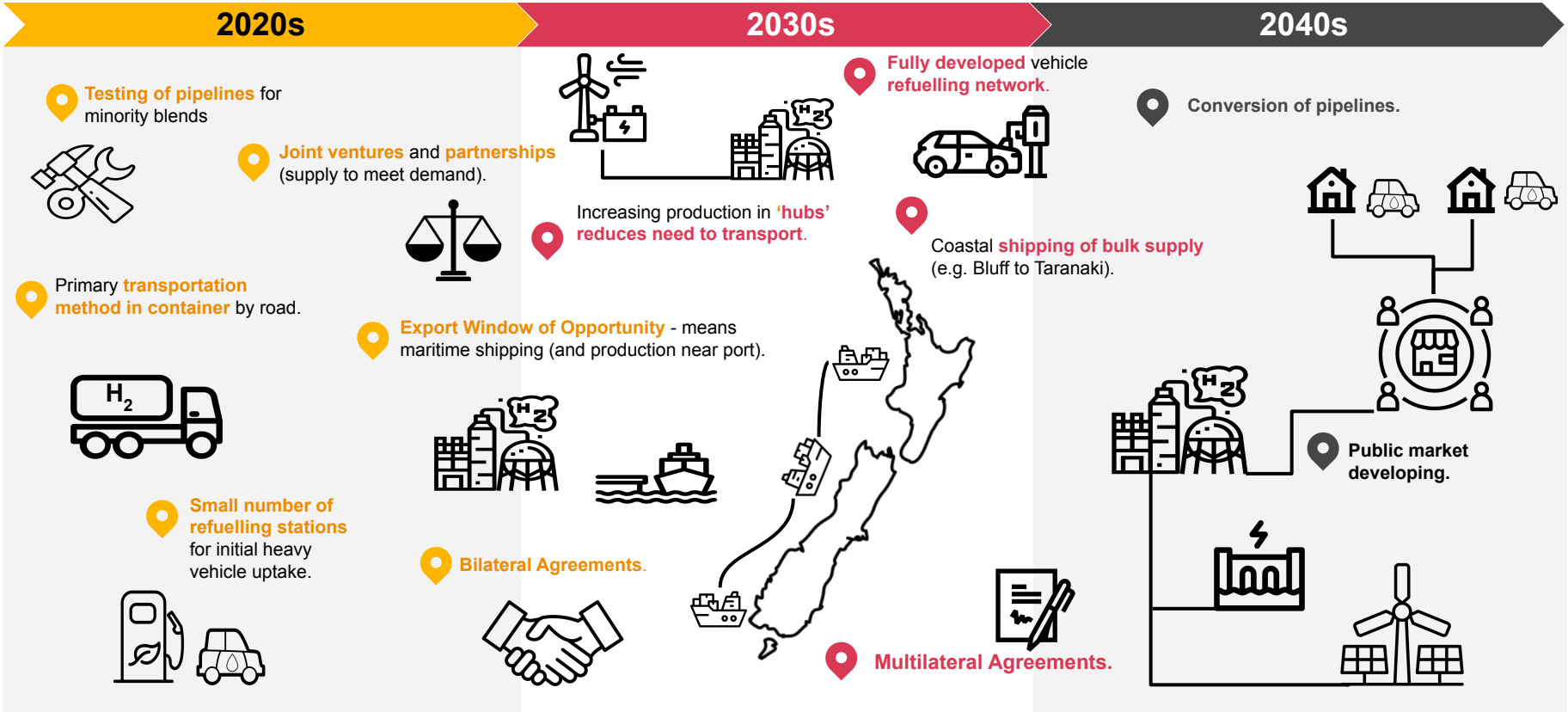
2040s

- ‘Piecemeal’ conversion of **piped gas to 100% hydrogen**.
- Stable or **increasing use for industrial processes**.
- **Increasing PtL and PtG** in marine, rail and aviation.
- **Majority of heavy fleet and specialty vehicles** on hydrogen or PtL or PtG
- Stable **minor role in public transport**.

Domestic industry story

Trade and logistics

We see freighting hydrogen by road as an interim solution while the hub model evolves. By co-locating supply and demand in hubs, we see multilateral agreements dominating trade in the immediate term, with a market not forming until pipelines have fully transitioned to hydrogen.



5

Regulatory Framework

Regulatory framework

How we approached our review

Our regulatory review was a high level assessment of the application of current legislation to the future hydrogen value chain and evaluation of whether it was fit for this purpose.

Identify Acts and Regulations which may apply to hydrogen

We used the following sources to identify legislation that may apply to hydrogen:

- GIC hydrogen placemat work
- review of Standards NZ work
- www.legislation.govt.nz
- interviews with regulators.

Based on our analysis, we identified

- 44 Acts
- 93 Regulations and Rules.

that may be relevant to hydrogen.

We considered the standards being developed by Standards NZ for hydrogen, and those developed by the ISO.

Consider applicability of Acts across the hydrogen value chain to identify gaps

We developed a future hydrogen value chain, as shown on the next slide. The value chain outlines how green hydrogen production would fit in the existing economy based on the identified use cases.

We used this value chain to assess if there were any gaps in the existing regulation by identifying what Act (by its purpose or objective) would apply to the activity, the parties engaged in the activity or had an overarching role.

We confirmed all proposed activities were covered by legislative purpose.

Issues analysis and Fit for Purpose assessment

We grouped legislation by four categories:

- Safety
- Use of hydrogen
- Markets and measurements
- Infrastructure and resources.

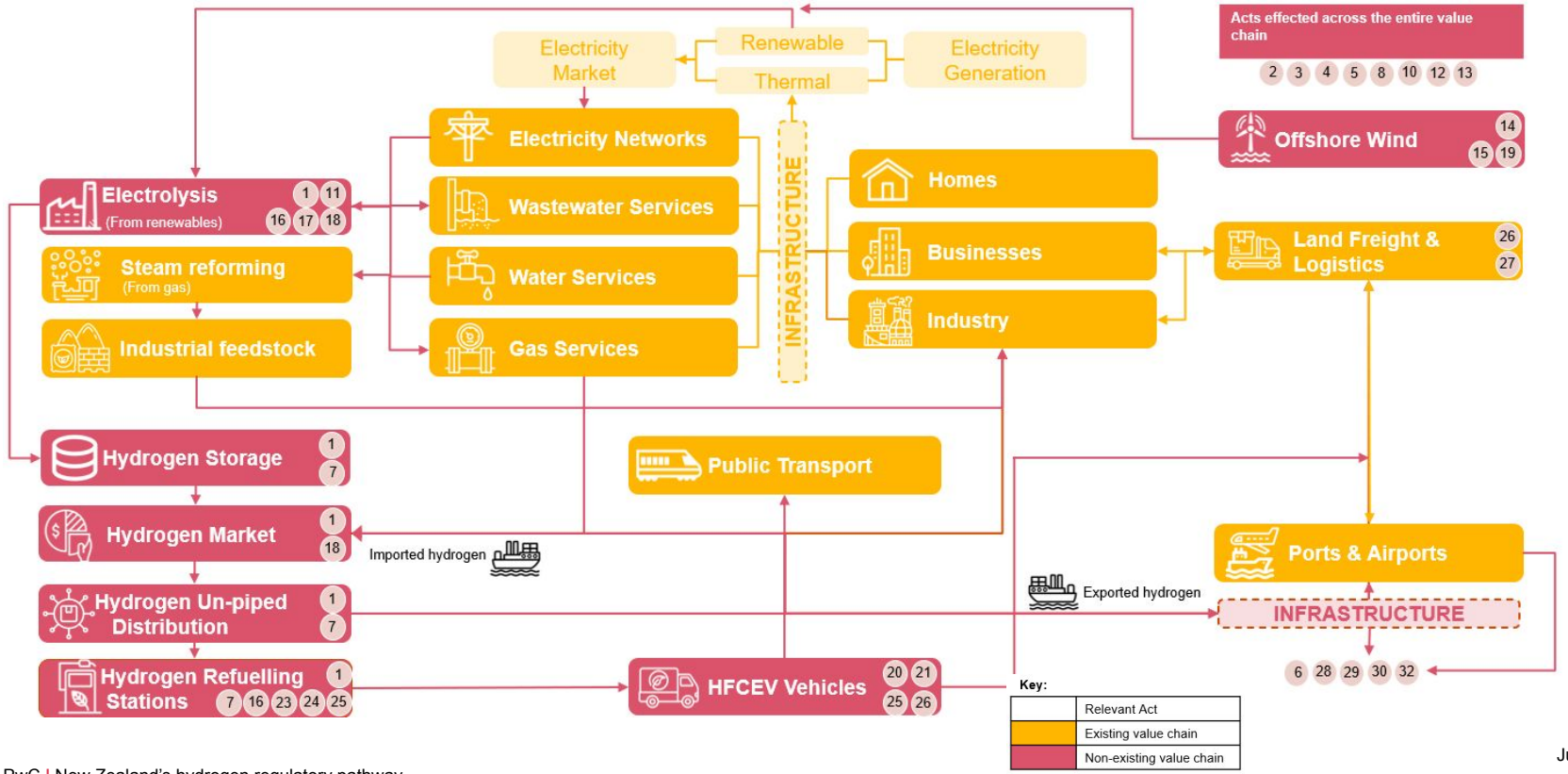
For each category we outlined the key issues identified by stakeholders, global research or our own understanding, and matched each issue with the relevant legislation. We assessed that legislation against the ranked fit for purpose criteria.

We found that the existing regulatory frameworks fell short on fundamental criteria.

The future value chain

Where the legislation applies

We mapped legislation to key parts of the hydrogen value chain based on the purpose of each Act. See overleaf for a list of Acts.



Acts

Key Acts in the future value chain

We mapped 32 Acts to the value chain. This is a subset of all the Acts identified, as some have a peripheral or uncertain role.

No.	Act
1	Gas Act (1992)
2	Hazardous Substances and New Organisms Act (2006)
3	Health and Safety at Work Act (2015)
4	Fire and Emergency New Zealand Act (2007)
5	Accident Compensation Act (2001)
6	Maritime Security Act (2004)
7	Plumbers, Gasfitters, and Drainlayers Act (2006)
8	Standards and Accreditation Act (2015)
9	Weights and Measures Act (1987)
10	Treaty of Waitangi Act (1975)
11	Water Services Act (2021)
12	Resource Management Act (1991)
13	Climate Change response (Zero Carbon) Amendment Act (2019)
14	Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act (2012)
15	Marine and Coastal Area (Takutai Moana) Act (2011)
16	Commerce Act (1986)
17	Electricity Act (1992)
18	Electricity Industry Act (2010)
19	Submarine Cables and Pipelines Protection Act (1996)
20	Road User Charges Act (2012)
21	Energy (Fuels, Levies and Resources) Act (1989)
22	Building Act (2004)
23	Consumer Guarantees Act (1993)
24	Fair Trading Act (1986)
25	Energy Efficiency and Conservation Act (2000)
26	Land Transport Act (1998)
27	Railways Act (2005)
28	Maritime Transport Act (1994)
29	Imports and Exports (Restrictions) Act (1988)
30	Customs and Excise Act (2018)
31	Tariff Act (1988)
32	Civil Aviation Act (1990)

Assessing the current regime

Defining "fit for purpose"

We have used Treasury's good regulatory practice principles to define criteria for evaluating whether the current regulatory systems are fit for purpose.

The New Zealand Treasury (Treasury) document "Government Expectations for Good Regulatory Practice" sets out the following principles that regulation should meet for durable outcomes of real value to New Zealanders:

- **clear objectives**
- achieves objectives in a **least cost** way, and with the least adverse impact on market competition, property rights, and individual autonomy and responsibility
- is **flexible** to allow regulators to adapt their regulatory approach to the attitudes and needs of different regulated parties, and to allow those parties to adopt efficient or innovative approaches to meeting their regulatory obligations
- has processes that produce **predictable and consistent** outcomes for regulated parties across time and place
- is **proportionate, fair and equitable** in the way it treats regulated parties
- is **consistent with relevant international standards and practices** to maximise the benefits from trade and from cross border flows of people, capital and ideas (except when this would compromise important domestic objectives and values)
- is **aligned** with existing requirements in related or supporting regulatory systems through minimising unintended gaps or overlaps and inconsistent or duplicative requirements
- **conforms to established legal and constitutional principles** and supports compliance with New Zealand's international and Treaty of Waitangi obligations
- **sets out legal obligations and regulator expectations** and practices in ways that are easy to find, easy to navigate, and clear and easy to understand
- has **scope to evolve** in response to changing circumstances or new information on the regulatory system's performance.

Photo credit: Kristen Louis PwC

We have distilled the key principles into a set of criteria for evaluating whether the current regulatory systems are fit for purpose.

Regulatory framework

‘Fit for purpose’ criteria

We ranked the criteria based on their relevance for our fit for purpose analysis. This was so the criteria could be assessed in terms of their fundamental relevance to this application.

We assessed whether current legislation is fit for purpose based on a ranked set of criteria below.
We assessed each of these criteria in turn and identified at which point the legislation fell short of the requirements for the future hydrogen value chain. The rationale for ranking the criteria is that if a more fundamental criterion is not met, then the Act falls short, and there is little importance as to whether subsequent criteria are met.

Criteria	Description
1. Purpose	Purpose, objective or intent is clearly relevant to aspects of the hydrogen value chain.
2. Alignment with framework	Proposed activities for hydrogen align with the existing framework (no gaps or overlaps).
3. Flexible	Provides flexibility to accommodate and evolve with the hydrogen economy.
4. Consistent with international frameworks	Consistent and conforms with international approaches to hydrogen implementation.
5. Complexity	Obligations and expectations are easy to understand and apply in relation to identified applications to hydrogen.
6. Monitoring and testing	Regulation can be effectively monitored and tested by regulator for this application.
7. Impact on competition	Does not impact on competition in related markets.

Fit for purpose

Testing regulatory frameworks

We found that none of our regulatory frameworks are strictly 'fit for purpose' to facilitate the future hydrogen economy. However, many of the issues that need to be resolved are not urgent or are relatively minor changes.

We categorised New Zealand's regulatory frameworks into four areas: Safety, Infrastructure & Resources, Uses, Markets & Measurement.

We found the legislation broke down quickly in one of two ways, although the purpose was clear.

We considered the novel forms and uses of hydrogen either caused potential misalignment across legislation (eg is it a gas used as a fuel under the Gas Act or is it an engine fuel under the Energy (Fuels, Levies and References Act)), or the legislation was too prescriptive and therefore excluded hydrogen and its requirements (eg gas has to have an odour) as a possibility. Where the regime is not sufficiently flexible, we consider that the issues are generally minor but some are urgent. Where the issue is one of alignment, we consider substantial work will be required although this is not necessarily urgent.

	Purpose	Framework alignment	Flexible	International consistency	Complexity	Monitoring and testing	Impact on competition
Safety	🟢	🟢	🔴	🟡	🟡	🟡	🟡
Infrastructure & Resources	🟢	🔴	🟡	🟡	🟡	🟡	🟡
Use	🟢	🟢	🔴	🟡	🟡	🟡	🟡
Markets & Measurement	🟢	🔴	🟡	🟡	🟡	🟡	🟡

Key	
Fit for purpose	🟢
Not fit for purpose	🔴
Not assessed	🟡

Regulatory assessment

Safety

Safety regulation and the approvals process needs to be reviewed to bring hydrogen out from 'behind the (industrial) fence'. This has been identified as a priority by industry.

Gas (Safety and Measurement) Regulations (2010) set out responsibilities, obligations and standards for the safe supply of gas. It sets out regulations that may be relevant to certification of hydrogen installations, appliances, and fittings and supply of both reticulated and containerised hydrogen. It references various gas standards which require odorisation which is **not fit for purpose** for hydrogen. **Exemptions currently required for vehicles, recommend review.**

WorkSafe regulates the management of hazardous substances in the workplace under the **Health and Safety at Work Act (2015)** and has powers under the **Gas Act (1992)** to develop codes of practice for the design, installation, operation, and maintenance of gas distribution systems, installations, fittings and appliances. Covers vehicle refuelling

The EPA approves and controls hazardous substances, including hydrogen, for use in New Zealand under the **Hazardous Substances and New Organisms Act (1996)** - **refrigerated liquefied hydrogen not currently approved**

Electricity Act (1992) - Electricity (Safety) Regulations (2010) set out responsibilities, obligations and standards for the safe supply of electricity and should apply to generation connected to electrolysers.

Hydrogen gas fitters must be registered under the **PGDA (2006)** - Installations must comply with the building code under the **Building Act (2004) , RMA (1991)** and the **Gas (Safety and Measurement) Regulations (2010)** - **Need for specific hydrogen capabilities to be explored given high pressures which hydrogen operates at.**

Transportation of hydrogen by road and rail is regulated under the **Land Transport Act (1998), Railways Act (2005), and Land Transport Rule - Dangerous Goods (2005).** Key requirements for hydrogen include the use of safety features to prevent and detect leaks, dangerous goods driver endorsements, and labelling of hazardous goods. **The details for hydrogen need to be addressed. There is no vehicle specification for H-FCEV so there can be no formal criteria to meet roadworthy safety requirements**. International standards exist.

Maritime Transport Act (1994)
Maritime Security Act (2004)
Ships carrying bulk hydrogen must meet the IMO's ICG safety code. **Interim guidance has been issued.**

Safety

Standards NZ began its review of the standards required for hydrogen integration into our energy landscape in 2019 at the request of Worksafe New Zealand. It has developed an initial draft report for technical review, but does not expect to complete the project until 2025. Industry participants consider this process to be too long and a barrier to industry development. Safety for new uses of hydrogen (specifically for vehicles and refuelling) is being managed by exemption.

Refrigerated liquefied hydrogen

The current HSNO approval for hydrogen only covers compressed hydrogen, not refrigerated liquefied hydrogen. This needs to be addressed if refrigerated liquefied hydrogen will be used in New Zealand. Refrigerated liquefied hydrogen will also be regulated under HSW. This is the form of hydrogen Australia recently shipped to Japan. We understand that this was done under international maritime guidelines set by the MSC. New Zealand maritime safety regulations must be in line with international conventions.

Some other chemical alternatives of storing hydrogen (called vectors), such as ammonia, are covered under HSNO. These uses may need to be monitored and reviewed if used for non-industrial purposes.

Regulatory discussion

Safety

Safety should be the first priority in any regulatory regime relating to hydrogen, due to its dangerous nature. It is not fully covered as a hazardous substance and there are missing standards and specifications.

Vehicle refuelling safety

The use of hydrogen as a vehicle fuel is its most prominent new use and the one attracting the first standards exemption applications. This is the use that poses the most safety issues as it brings a dangerous industrial gas out 'beyond the fence' and into the public domain. Examples of two safety issues that have been identified include the high pressures that hydrogen is stored at and that it has a clear flame. Given H-FCEVs are on the road in other jurisdictions and able to be fuelled by drivers at refuelling stations, it is apparent that this activity can be made safe. There are relevant ISO standards and we note that the New Zealand standards adoption process is much quicker if an international standard is adopted. The communication of the intention to adopt international standards would assist in providing certainty to vehicle suppliers.

H-FCEVs certification standards

There is not a clear regulatory view on the required safety standards for H-FCEVs and hydrogen fuel tanks. The risks of adopting international standards in the interim are low while the industry is small. We understand this is the approach generally adopted for imported vehicles. This also allows time to develop the capability to assess New Zealand's specific risk factors. This is how demonstration models have been certified for safety on New Zealand roads.

Waka Kotahi currently interpret the Dangerous Goods Rule under the Land Transport Act to mean that hydrogen in a fuel tank is not classified as a dangerous good.

The fuel tank would need to have a separate certificate of fitness (CoF) in addition to the vehicle CoF or warrant of fitness (WoF). This would pose a capability and certification issue around who is qualified to perform these checks and to what standard. This would also apply to modifications of heavy vehicles fitted with an auxiliary hydrogen fuel tank for dual fuel conversions.

These are issues that have been addressed by the ERP.

Vehicle hazard labelling

FENZ have grave concerns over the lack of regulation in vehicles of this highly dangerous substance. They have a primary goal of mandatory vehicle labelling so their people are able to adequately assess their own risk if attending a callout. They are in the process of developing their own risk assessment and response frameworks. Information is essential to FENZ as this is a critical safety risk for them. These regulations can be made under Land Transport Rules (Vehicles Standards Compliance and Vehicle Equipment) with an appropriate standard, which would need to be defined.

Regulatory assessment

Infrastructure and Resources

Regulation relating to use of green hydrogen in infrastructure and resource management poses the most complexity but there is time to consider the issues and respond.

The **Gas Act (1992)** provides the legislative framework for the regulation, supply and use of gas in New Zealand (including hydrogen) and the protection of public health and safety and property. The integrated nature of green hydrogen with other energy and infrastructure sectors is likely to cause **grey areas and cross-jurisdictional issues.**

Input fuels: Water extraction permits are issued by regional councils under the **Resource Management Act (1991) [under reform].** Electricity is covered under the **Electricity Industry Act (2010)** [under reform] and the **Electricity Act (1992).**

Consent applications for offshore wind farms in the exclusive economic zone must be made with the EPA under the **Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act (2012) (EEZ)**. If the wind farm lies in a Coastal Marine Area, there will be impacts under the RMA for regional councils. Submarine infrastructure may need protection under **Submarine Cables and Pipelines Protection Act (1996).**

Pipeline price-quality regulation: prices for reticulated natural gas pipeline services and quality of supply are regulated under the **Commerce Act (1986)** by the Commerce Commission; **inclusion of blended hydrogen is unclear.**

Green hydrogen use will have a profound impact on electricity, gas and water sector infrastructure. Regulators in other countries are considering the impact of hydrogen on energy and water systems in their long-term planning. In New Zealand, these three sectors are undergoing policy review to various degrees, which presents an opportunity to incorporate hydrogen considerations.

Water

Government water policy and eventually Taumata Arowai (the water regulator) will need to consider hydrogen's role in the water sector.

The water requirements for a large electrolysis plant are equivalent to a large dairy factory, and therefore water management needs appropriate consideration. Treated wastewater may also have a role in hydrogen production.

The impacts at a local level could be significant depending on the water catchment. Māori partnership in water, which may be used in hydrogen projects, will also require consideration.

Gas

Uncertainty over the future of hydrogen (and biogas) has recently been considered in a review of the regulatory settings for GPBs under Part 4 of the Commerce Act. Debate has focused on potential asset stranding and repurposing of pipelines for alternative green gases. It is unclear to what extent natural gas pipelines conveying hydrogen blends may be regulated under current settings, given the Commerce Act makes no explicit reference to blends of gases. The ERP however potentially clarifies the Government's position over the need to transition the gas sector to low carbon fuels in its GTP.

Regulatory discussion

Infrastructure and Resources

Green hydrogen does not stand alone. It brings together water, electricity and gas networks. The impact of each on the other must be considered.

Gas (continued)

The GIC and sector stakeholders will also need to consider the impact of hydrogen on gas pipeline operations and wholesale markets. Blending hydrogen into pipelines may impact settlement, reconciliation and balancing by redefining what piped natural gas is. It could also impact pipeline operations, system losses, and maintenance. First Gas is leading work to investigate the impact of hydrogen, but there will be a role for Government and the GIC as hydrogen is introduced into the gas system.

Electricity

The commercial viability of hydrogen is heavily dependent on the supply and price of renewable electricity inputs. The potential interplay between green hydrogen production and electricity generation creates market scenarios that have not previously occurred. These scenarios will require careful consideration by both Government and energy regulators. Examples of potential impacts include:

- Major hydrogen production may create constraints on electricity networks and for renewable generation, impacting pricing and system security.
- The potential multiple roles for hydrogen plants as a means of energy storage, dispatchable demand (eg turning off electrolysers) and generation (via hydrogen fuel cells) may require a review of wholesale market trading.
- Hydrogen plants may impact hydrology, diverting water resource away from electricity generation, but also reducing water spill resulting in more efficient use of water.

Resource consenting

New hydrogen plant, along with the associated renewable generation and infrastructure projects, as well as water access, will require resource consents. This legislation is under review. No specific impediments were raised by stakeholders relating to recently consented hydrogen projects. However, it was identified that it may be more difficult for local authorities to consider the unique risks of hydrogen and it may be better for a central body, such as the EPA, to manage the consenting process. The EPA manage the decision-making process for proposals of national significance under part 6AA of the RMA. The EPA also manage consents in the Exclusive Economic Zone (EEZ) which may be relevant for hydrogen plants that rely on offshore wind farm resource. Hydrogen projects meeting a specific set of criteria of being nationally significant may experience streamlined risk assessment and resource consent processes.

This general issue is addressed in the ERP.

Regulatory assessment

Use of hydrogen

Regulatory frameworks relating to use of hydrogen should be reviewed to align incentives with other renewable technology and to be more flexible and responsive to the introduction of new hydrogen technologies.

EV incentives

The current EV RUC exemptions only apply to 'plug-in' vehicles. This disincentivises hydrogen FCEV (H-FCEV) despite the two technologies achieving similar outcomes in terms of carbon emissions reduction. We recommend that incentives for renewable technologies are aligned to carbon reduction outcomes rather than a specific technology. A similar issue applies to the clean car discount.

This issue is identified for action in the ERP.

Hydrogen as a engine fuel

The Gas Act covers 'gas used as a fuel' by definition. However 'engine fuel' means 'any gaseous or liquid fuel that can be used as a fuel for engines' under the Energy (Fuels, Levies and References) Act 1989 and Engine Fuel Specifications Regulations 2011. While a fuel cell is not an engine this will need clarification.

Aviation fuel

Under the ERP there is a mandate to transition to SAF standards. This transition will need to be in keeping with international precedent. The Civil Aviation Authority is responsible.

Maritime Fuel

Ammonia is the most likely form of maritime fuel for shipping. There are no regulations for the use of ammonia as a fuel but there is a process underway for the IMO to define it for this use.

Hydrogen as a fuel in a tank is not considered a dangerous good under **Land Transport Rule - Dangerous Goods (2005)** **Waka Kotahi need to confirm this is suitable.**

HSNO covers dangerous goods in the home (regulated by EPA). This may apply if hydrogen cylinders are used for BBQs for example. (cf LPG)

The Government has made various subsidies applicable only to EVs (eg RUC, clean car discount etc). This provides a benefit which is not accessible to H-FCEVs purchasers which is a disincentive for a 100% renewable vehicle. **Review alignment of incentives between EVs and FCEVs.**

MOSS which covers most domestic vessel has gaps. There are no rules relating to hydrogen as a maritime fuel. The Minister can set rules under the **Maritime Transport Act (1994).**

Civil Aviation Act (1990) determines rules relating to aircraft fuel. Under the ERP there is a SAF mandate which will need to align with international rules.

Commerce Commission monitoring and enforcement under **Fair Trading Act (1986)**, **Consumer Guarantees Act (1993)** and **Commerce Act (1986)** will apply.

Consents for fuelling stations and plant are granted under the **Resource Management Act (1991).**

Hydrogen as an engine fuel may be covered by the Energy (Fuels, Levies and References) Act (1989) when it comes to fuel specifications. **Need to clarify cross over with Gas Act**

Regulatory assessment

Markets and Measurement

The effective measurement, qualification and certification of hydrogen is imperative to making functional markets and will need to be reviewed to support hydrogen uptake and integration into energy systems.

Hydrogen fuel in transportable forms

Hydrogen cannot be efficiently transported at scale in gaseous form. A number of more efficient methods for transportation of hydrogen are being explored, called 'energy vectors' or carriers such as ammonia and methylcyclohexane (MCH - a recognised liquid organic hydrogen carrier, or LOHC). These are certified under HSNO but the third form of transportable hydrogen, liquid hydrogen is not, as previously outlined.

The Gas Act is clear in its definition of the conditions (pressure and temperature) at which a substance is a gas. So it can be interpreted that liquid hydrogen and ammonia would be covered by the Gas Act at the specified conditions they are gases.

Ammonia is already transported as an industrial chemical so there does not appear to be further work required. As a liquid, LOHC would not meet the definition of a gas under the Gas Act.

Uptake of LOHC, and any other novel forms of hydrogen, will need to be monitored to ensure it is covered by relevant regulatory frameworks. The Gas Act would not cover LOHC as it is a liquid at the stated conditions.

Weights and Measures Act (1987) applies to contained LPG (as a liquid) but not gas. The Gas Act does not cover gas containers. **Needs to be reviewed as not clear how measurement of contained gas for fuel would be covered.**

Efficiency of hydrogen appliances and vehicles will need to be tested by EECA who need to be mindful of the **Trans Tasman Mutual Recognition Act.**

Green credential may be necessary to support the economic case for green and low carbon hydrogen, to support marketing initiatives and give confidence to consumers. It will also help with the monitoring of the carbon intensity of hydrogen and potential development of non-renewable hydrogen markets.

Commerce Commission ongoing consideration and **monitoring** under the **Commerce Act (1986) Part 2.**

The **Gas (Safety and Measurement) Regulations (2010)**. **Piped blended gas will need to be metered correctly.**

Hydrogen can be stored as gas, liquid or other chemical form (e.g. ammonia). The **Gas Act** will not always apply (eg LOHC) **HSW Hazardous Substances Regulations (2017),** administered by MBIE set out guidance for the approval of gas containers, filling, handling, and marking of cylinders. L**iquid hydrogen is not covered by HSNO. This may impact local and export transportation.**

Customs and Excise Act 2018, Import and Export (Restrictions) Act (1988) Currently hydrogen is a permitted hazardous substance under HSNO and therefore can cross the border freely. If we mandate green credentials then this will pose issues at the border for imported hydrogen. **Monitoring and consideration of whether other forms of hydrogen are restricted and how to permit.**

Regulatory Discussion

Markets and Measurements

A pressing area for climate change regulation is how to incentivise the commercialisation and uptake of green hydrogen. Some form of green credentials will be important to support the premium that will be paid on hydrogen and give confidence to consumers.

Green credentials

Green credentials are something that industry almost universally considers to be a requirement for a domestic hydrogen industry. Measurement and verification of the carbon intensity of hydrogen products has a number of benefits, including:

- It will support the case for producers and end-consumers investing in green and low carbon hydrogen technology, which will likely initially be at a premium to fossil fuel based technologies.
- It will hydrogen users confidence over market claims and brands
- It will allow for monitoring and reporting of sustainability claims and the potential development of high carbon intensity hydrogen products (eg grey hydrogen) which may not be in New Zealand's interests.

The perspectives on how to verify the carbon intensity of hydrogen differs. Some consider that this should be mandatory to be in keeping with climate change response goals and 'brand New Zealand'. Others consider a voluntary market mechanism is appropriate which could facilitate more desirable climate response outcomes and innovation.

There is currently work being undertaken on international low carbon standards, including an MBIE-led project for an Asia-Pacific standard. This is likely the only standard required for New Zealand due to the viability of our international trade being restricted by transport distance.

The important next piece of work is to understand how these standards will be applied in the wider regulatory framework and whether they need to be applied in a local level scheme.

Work has already been undertaken to assess how a Green Certification system would work in New Zealand. It is a complex project in itself and beyond the scope of this report. However, our view is that any requirements could be provided for under the current regulatory regime.

At scale, in the near-term at least, exported and domestic green hydrogen is proposed to be produced from the grid based electricity. We do not have the independent renewable capacity in one place to make an otherwise commercially viable 100% green proposition. Verifying the carbon intensity of our electricity generation supply used in hydrogen production against international carbon measurement requirements will possibly be required.

Measurement

Metering of piped gas falls under the Gas Act and we have no reason to consider that there will be any regulatory issues in applying a differing calorific measurement system for gas-hydrogen blends. This is done now for differing qualities of natural gas. The principle appears to be the same, albeit an extreme application. Nevertheless this will be an area for further work by the GIC and gas sector.

There is potentially a gap in the regulations for measuring containerised gas. Liquid Petroleum Gas (LPG) is covered under the Weights and Measures Act but gases are excluded. We find no specific reference to contained gas under the Gas Act and note that containers for gas are specifically not covered.

Regulatory Discussion

Markets and Measurements

In participating in a new global commodity market there will be new domestic implications and considerations.

Importing hydrogen

While, not a likely scenario, there are some considerations that will need to be made around how New Zealand manages its position in the global hydrogen economy.

If global markets for hydrogen develop, then there are a wide range of practical issues which need to be considered relating to the border. As a currently permitted hazardous substance, hydrogen of any form can pass across the border without restriction. This means that theoretically high-carbon forms of hydrogen could be imported and used as a vehicle fuel, for example. The product is same regardless of how it is produced.

So the first issue to consider is whether there will be restrictions on imported hydrogen, and what are the domestic market implications of this. It could be expected that as the market is developing there will be supply and demand imbalances and a restriction on imports could cause a 'fuel shortage' for example.

This is an example of where policy prioritisation is essential to determining the prioritisation of regulatory review. In the short-term, is it more important to nurture the domestic industry or is it more important to restrict carbon emissions?

If we had a green credential certification system then we could require imported hydrogen to meet this.

We understand that this would require a permit under the Imports and Exports (Restrictions) Act, but there could be other levers under the CCRA as well. At the point of entry, Customs NZ would need to determine if the goods were permitted. This again brings the need for alignment in international green credentialing. If an import did not comply then it would have be disposed of by the regulating agency (not Customs NZ).

Exporting hydrogen

If New Zealand becomes an exporter of green hydrogen, we are essentially commoditising our domestic renewable electricity. As a closed market for electricity now, there are market implications to consider if that effectively 'opens up' to the rest of the world. Consideration needs to be given to:

- Balancing export revenues with good energy outcomes for domestic users of hydrogen and electricity
- Whether electricity generators have intrinsic market power in a hydrogen economy
- What should a participant in both the electricity and the green hydrogen market have to disclose and to whom
- What restrictions (if any) should be placed on foreign firms building green hydrogen plants in New Zealand, which essentially will reflect the export of our water and renewable energy resources.

Regulatory frameworks

Involvement of Māori in the hydrogen economy

Te Tiriti is accepted as the constitutional document guiding the relationship between the Government and Māori. The role of Māori in the hydrogen economy will need to be considered in any associated regulatory reform.

Te Tiriti o Waitangi

In addition to our seven fit for purpose criteria, hydrogen regulation will need to conform with the constitutional principles of the Treaty of Waitangi.

Iwi partnership

Māori partnerships are already playing a significant role in our nascent hydrogen industry:

- Halcyon is a hydrogen production JV involving Tuaropaki Trust
- Paranihinihi ki Waitotara are owners of the land on which wind generation will be developed for the Ballance and Hiringa hydrogen production plant
- Murihiku Regeneration (comprising four rununga of Ngai Tahu) have signed a collaboration agreement with FFI on green hydrogen projects in Southland.

We do not consider there to be a single iwi view and that any development will be on a case by case basis, depending on the needs of the rohe, through consultation and development of partnerships.

Specific relevance

As the hydrogen industry develops there will be dependencies and interactions across sectors that have not occured before. Although the Treaty is explicitly referenced in environmental legislation, it has no interpretation in key legislative frameworks (such as in the energy and transport sector) that will begin to crossover into environmental areas as hydrogen is implemented.

Energy legislation

There is no definition or interpretation of Treaty of Waitangi in the Gas Act, the Electricity Act and the Electricity Industry Act.

This suggests that core legislation relating to the energy sector requires consideration for Treaty impacts related to green hydrogen production and use.

Transport legislation

There is no definition or interpretation of the Treaty of Waitangi in the Land Transport Act, the Civil Aviation Act, the Railways Act and the Maritime Transport Act. We recommend a review of the use of hydrogen in transport legislation with respect to the Treaty.

Regulators

The role of the Working Group

MBIE formed a Hydrogen Regulators Working Group at the commencement of this project. We see an ongoing role for this group as the roadmap development progresses and beyond

The need to collaborate

The future hydrogen value chain will be complex and cross legislative boundaries through novel applications and integration of key infrastructure and markets. The Working Group offers the forum for government agencies with different mandates to understand how they can work collaboratively to achieve national objectives relating to hydrogen.

The hydrogen sector has demonstrated how effective working together can be in achieving a shared goal. Involving Government and regulatory agencies in this sector collaboration will only enhance the outcomes for New Zealand.

International precedent

Although globally there has been little done in terms of regulation, there is a lot of activity in planning and developing views on the future of the sector. The clear learning for New Zealand regulators is that they need to work together to develop a common understanding of the future of New Zealand hydrogen and plan for how they will respond to market developments.

The development of clear a national policy strategy and objectives for hydrogen will help direct regulators.

Who is missing

We view the water and electricity industry aspects to green hydrogen to be too significant to be absent from the working group. How these sectors are going to interact is integral to achieving the desired outcomes for hydrogen without compromising the existing goals of fairness and equity of outcomes for our people.

We recommend consideration of whether the Electricity Authority and Taumata Arowai should be involved in the working group.

What needs to be done

Apart from addressing some of the immediate issues with regard to standards, we consider the main role of regulators is to develop an understanding of how they *may* need to respond to the green hydrogen economy in the future and be prepared for that future.

This will require active participation and monitoring of both the domestic sector but also of what equivalent regulators are doing overseas.

6

Regulatory Pathways

Existing work

Government work done to date

Work undertaken as part of the MBIE hydrogen roadmap has highlighted potential roles for hydrogen. The CCC report focused on electrification which we have found to be a sentiment reflected across Government agencies.

New Zealand hydrogen roadmap

In 2019, the Government started a programme of work to better understand the potential future of hydrogen in Aotearoa. This included a green paper, 'A vision for hydrogen in New Zealand' which set out Government's intention to develop a roadmap for hydrogen in New Zealand (the roadmap).

Following this, Castalia was engaged to develop a hydrogen supply, demand and export model, the "Castalia-MBIE 2020 Hydrogen Model" (the roadmap model), to begin the development of the roadmap. This has since been updated by the release of the "New Zealand Hydrogen Scenarios" report in May 2022 (the scenario report) to the MBIE.

In a parallel workstream, Standards NZ has developed (but yet to publish) its draft "Standards Solutions Report" for integrating hydrogen in New Zealand's energy landscape. The report has been prepared after consultation with an industry TAG.

In February 2022, MBIE engaged PwC to develop a regulatory roadmap for hydrogen (this paper).

Shortly after this, in April 2022, MBIE formed the Hydrogen Regulators Working Group (the Working Group). PwC have been working directly with this group during the development of this paper.

The ERP confirmed this project would be completed within a year.

Climate Change Policy

The CCC report recommended wide ranging policies to Government for Aotearoa to meet its net zero emissions targets. These were focused mainly on renewables based electrification. There was limited focus on hydrogen, although there is general acknowledgement of the need to transition to low carbon fuels.

The CCC report recommended the making of firm targets for ending coal use in electricity generation, and the sale of gas appliances and new gas connections. Our analysis suggests that this was too onerous on the networks and was likely to cause security of supply issues.

In considering the potential of green hydrogen (and other low carbon fuels) we find it is preferable to retain optionality in the near term. This means making no firm decisions on existing fossil fuel supplies and networks until the potential alternatives is better understood.

In May 2022, MfE released Aotearoa's first ERP. The ERP has numerous implications for a future hydrogen value chain and specifies the development of the hydrogen roadmap as a targeted outcome for the coming year.

The ERP has taken a more technology-neutral and transition-focused approach to decarbonising our economy. This reflects the requirement to be pragmatic and fair in achieving our net-zero goals. The sentiment is the same as the CCC report but the path to achieving this is less onerous in the near term. We consider this to be highly beneficial to developing hydrogen as it provides the opportunity to explore issues before committing to regulatory change.

Existing work

Standards NZ

Standards NZ is progressing standards specific to hydrogen. Draft standards have been developed but will not be finalised until 2025. Developing flexible regulatory approaches that can make use of this work now is a key area of focus.

Standards NZ has recently produced (but yet to publish) its 'Standards Solutions Report' for integrating hydrogen in New Zealand's energy landscape. The report has been prepared after consultation with a TAG, comprising of a number of key industry participants.

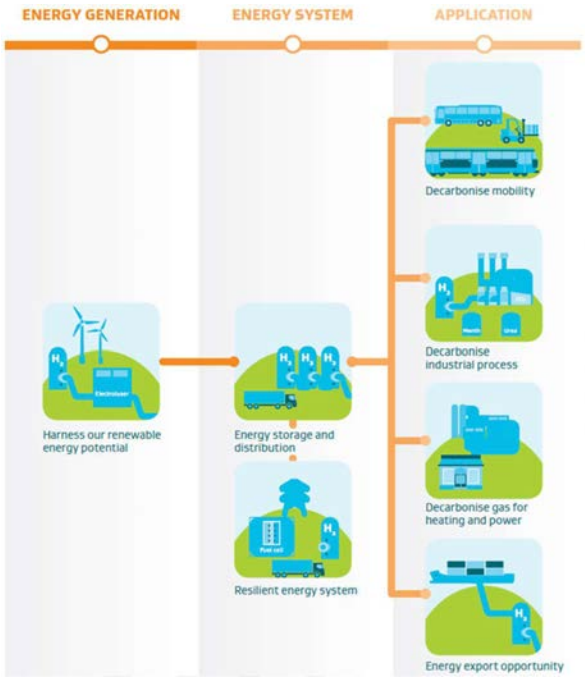
Our understanding of how hydrogen may evolve in New Zealand aligns with Standards NZ view (see Standards NZ diagram opposite).

The standards identified in the 'Standards Solutions Report' will provide regulators with a base of currently agreed practices across a number of safety regulations. It appears to be a comprehensive review of requirements.

However, the completion of the standards implementation is not expected until 2025 according to the report. We understand from members of the TAG that we have spoken to that there has been no further consultation on these standards. There is concern that the technology is evolving so quickly that these proposed standards may be out of date before 2025.

This detail is outside the scope of this work but we note the fundamental role this aspect of a regulatory regime plays in that regime being 'fit for purpose' and identify it as a priority issue.

Decarbonisation through hydrogen integration



Source: Standards Solutions Report, Standards NZ

Existing work

Emissions Reduction Plan

The ERP has specific outcomes specified relating to hydrogen. There are many targeted actions for which hydrogen will be part of the solution.

Objective Alignment

"The Government's 2050 vision is for Aotearoa New Zealand to have a highly renewable, sustainable and efficient energy system supporting a low emissions economy." - ERP

In order to give effect to an "equitable transition" the ERP has the following objectives:

- Seize the opportunities of the transition
- Support proactive transition planning
- Enable affordable and inclusive transition
- Build the evidence base and tools
- Encourage informed public participation.

These objectives align well with the requirements for regulatory reform to implement the future hydrogen value chain. There are opportunities for economic growth in the implementation of green hydrogen. Seizing these opportunities now will support achievement of the other four objectives over the near term.

Hydrogen Implications

We support the longer term and interconnected approach being proposed in the **The Aotearoa New Zealand Energy Strategy (Energy Strategy)**. We commend the broad approach to thinking beyond decarbonisation towards security and affordability as well as to the transition path. This wider strategy provides the foundation for which to develop a specific national hydrogen strategy.

The ERP announcements also confirmed that the **hydrogen roadmap** will be completed within the next year. This will be important to provide certainty for industry and regulators and for setting the strategy and priorities for Aotearoa's hydrogen economy.

The GTP firms up the Government position on repurposing gas pipelines for low carbon gas. This clears up much uncertainty in this part of the sector and allows for feasibility of piped hydrogen and blends to be given appropriate consideration.

Emissions Trading Scheme (ETS): the confirmation of the ETS and broad political consensus on its use sends a strong commercial signal to industry for the need to decarbonise. This will firm the economics of hydrogen and incentivise its uptake across the economy.

ERP

Alignment with our recommendations

We see clear alignment in many of our recommendations with the actions outlined in the ERP. These have particular relevance to the evolution of hydrogen 'hubs'.

Area	Relevant recommendations for hydrogen
Infrastructure	Streamlining the consenting process for new hydrogen plant (along with other renewables) would improve time to market and improve the economic growth potential of hydrogen in Aotearoa. Hydrogen hubs embed energy solutions in infrastructure solutions. Designing effective hubs will also be a valuable capability to build in Aotearoa and export.
Renewable Generation	Renewable generation is the enabler of a hydrogen economy and conversely hydrogen is an option or part-option to the NZ Battery Project.
Transition from fossil fuels	There is the need for greater monitoring of the wider energy sector to keep ahead of the requirements for regulatory change. A deeper monitoring of the energy system is necessary to orchestrate a cohesive response. The GTP provides the time to fully investigate and model energy and infrastructure scenarios.
Transportation	Mandates for buses and aviation fuel will increase uptake and incentivise hub development at points of major infrastructure, like airports.
Agriculture	The focus for reduction in agriculture emissions appears to be on biogenic methane but we see the opportunity for decarbonising fertiliser as another way to quickly reduce the indirect emissions of the sector.

A detailed summary is provided in Appendix C

Priorities for hydrogen

Issues not identified in the ERP

The ERP does not address some of the issues we have identified relating to the regulatory requirements for the future hydrogen value chain.

Seize the opportunities of the transition

The export window of opportunity has been identified by several industry participants, and supported by analysis from the McKinsey Report, as being near term and limited. Our analysis of the global market through PwC's global analysis corroborates this. There are economies far better placed than New Zealand, in terms of location and resources, to be hydrogen superpowers. But while the GCC focuses on exporting all of its green hydrogen to Europe, there is the immediate opportunity for New Zealand to supply Asia, alongside Australia. We are unlikely to be able to compete with Australia once it has a fully mature industry.

If New Zealand is to seize on this opportunity then it must address the regulatory requirements of an export industry as a priority. This means firming up Maritime Transport rules, HSNO certification of all forms of transportable hydrogen, and a low carbon standard are required urgently.

Support proactive transition planning

There is a place for the working group to facilitate the appropriate cross-jurisdictional planning required to meet the requirements of the future hydrogen value chain. This means keeping abreast of global and domestic developments, which are beginning to move at pace.

Enable affordable and inclusive transition

Growing the role of green hydrogen as in industrial feedstock is pivotal to increasing demand. This will ultimately bring down the cost of green hydrogen and bridge the gap in its commercial viability as an alternative fuel. Incentivising industry is a way to bring hydrogen options to the consumer. Green credentials are considered essential to making this transition commercially viable.

Build the evidence base and tools

The impacts on infrastructure and markets other than the traditional gas system cannot be underestimated. We see the need for a review of energy and infrastructure legislation in the future to meet the needs of a green hydrogen economy. Understanding the impacts of the gas and transport transition on these other networks is essential to determining when and where intervention is going to be required

Encourage informed public participation

Public perceptions of the safety of hydrogen may be an inhibitor to acceptance and uptake. Work into safety standards needs to be made public to provide assurances that this is being addressed appropriately.

How these further issues fit into the future hydrogen value chain is outlined on the next slide.

Towards 2050

What else is needed to meet industry's goals

Based on our interviews and analysis, we have developed this condensed view of the hydrogen evolution. From this we can identify other issues which the ERP has not addressed.

- **Comprehensive policy**
- **Pragmatic safety regimes (guidelines and risk based approach)**
- **HSNO certification of liquid hydrogen**
- **Water and electricity regulator involvement**
- **Low carbon standard**
- **Resolution of key interpretations in legislation**

Medium scale electrolyser production of hydrogen using electricity from national grid for use in fertiliser manufacture and transported by truck.

Development of dedicated **small-medium scale renewable generation** for direct connection to electrolysers to be used as hydrogen 'hubs'.

Small number of refuelling stations to service first heavy fleet.

Conversion of existing heavy vehicle fleet to **dual fuel** (hydrogen injection into diesel).

Feasibility and commissioning of **large scale electrolyser production** plants fed from national grid to be used for export hydrogen.

- **Green certification (with grid alignment)**
- **Agricultural incentives to convert to 'green' fertiliser**
- **Preparation for full conversion of gas pipelines**
- **Comprehensive review of energy sector operation**
- **Incentives for wastewater use**

Expansion of medium scale electrolysed production of hydrogen using electricity from national grid, which is close to 100% renewable, for mixed use.

Pilot use in specialised vehicles used at farms, factories, mines and ports.

Bilateral Agreements

Large scale production for export increasingly diverted for use in domestic economy - especially large users like aviation and shipping.

Developing vehicle **refuelling network** responding to increased heavy vehicle fleet.

Blending up to 20% in natural gas networks.

Increasing numbers of small-medium scale production from off-grid distributed renewable generation (possibly offshore wind) to form the base of hydrogen 'hubs'.

- **Legislative review across whole of energy sector**
- **Alignment of the sector with good outcomes for future water use**
- **Consideration of mandatory regime for green credentials**
- **Restrictions on imported fuels (hydrogen and derivatives)**

Large scale production providing bulk domestic supply of hydrogen for mixed uses and being in the position to support electricity security of supply.

Public market developing

Multilateral Agreements

Well-established 'network' of small-medium scale production supplying hubs and in the position to support piped gas transition.

7

Recommendations

Recommendations

Set a pathway for reform

We recommend that Government develops a national hydrogen policy strategy as a priority and works with the stakeholders to ease regulatory friction around hydrogen uptake. A monitoring regime is also required to monitor trigger events where longer term regulatory intervention may be required.

1. Set national strategy

We recommend that Government develops a clear national policy strategy for how Aotearoa will navigate the hydrogen opportunity. The development of the Aotearoa New Zealand Energy strategy, the GTP, and completion of the hydrogen roadmap, announced as part of the ERP, offers the opportunity to incorporate specific policy objectives for integrating green hydrogen into our energy system. We need a standalone hydrogen strategy that regulatory agencies can reference in developing and planning for regulatory reform.

We acknowledge that the economics, timing and uptake of hydrogen in New Zealand is uncertain. But the sizeable investments being made and policy direction of our closest trading peers in the Asia-Pacific region is undeniable.

A unified government strategy that fosters economic hydrogen opportunities across sectors will provide confidence to investors and underpin future regulatory reforms.

This will provide direction to Regulators on how to approach fulfilling their regulatory functions in relation to hydrogen.

2. Removing regulatory friction

Our review highlights a number of quick wins and areas of urgent action required to remove regulatory friction. These are mostly associated with standards, definitions and specifications in the regulatory systems.

In many cases what investors are looking for is the ability to bring projects effectively to market in a safe and timely way. Providing support to regulators to plan and flexibly address issues as they arise, in appropriate timeframes, such as through exemptions or risk based solutions will be important in allowing this nascent industry to grow.

Aligning incentives and policy support for hydrogen with other decarbonising options would also level the playing field for renewable solutions.

3. Monitor and respond

Once the basics are in place and Government intentions are clarified, the pathway is clear for the industry to evolve.

We identified a number of regulatory issues that could require a response from regulatory agencies in the future, depending on how the market develops.

We recommend that a monitoring regime is set up to keep abreast of market developments. Government will be in the position to assess when intervention is likely to become necessary and plan regulatory reforms with relevant agencies.

This may require an ongoing role for the hydrogen regulatory working group, which could meet on a periodic basis to assess market developments and cross-jurisdictional implications. We recommend that the scope of this group is broadened to include water and electricity

Recommendations

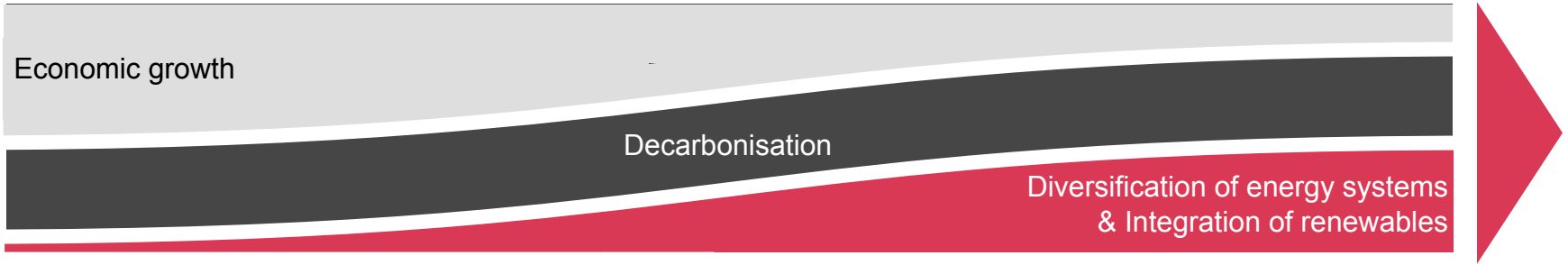
Set national strategy

We recommend that Government develops a clear and specific national strategy for how Aotearoa will navigate the hydrogen opportunity. This needs to identify and prioritise several core strategic policy objectives.

Hydrogen's role in the **decarbonisation** of our economy has already been signalled as a core policy objective as part of the ERP. There has been some contention over whether hydrogen should be prioritised going forward, as the merits of hydrogen versus electrification have been debated. However, hydrogen's unique role in **decarbonisation of industry** (eg fertiliser, high temperature boilers) and **decarbonisation of heavy transport** (eg substituting diesel) should remain a focus, given these sectors reflect a sizeable proportion of our national carbon emissions.

Initially focusing on a goal of **economic growth** may be vital to support the development of hydrogen sector capabilities, infrastructure and capacity at what is a critical juncture in the development of the global hydrogen economy. While the economics of hydrogen appear challenging, we note that the premium on the price of green hydrogen will fall over time (as it has done for so many renewable technologies, for example solar and wind generation). Further, there is an expectation that many businesses will pay this premium in the interim to reduce their carbon footprint as their customers demand climate action now.

New Zealand can also not afford to rely on electrification alone to meet our decarbonisation goals. **The diversification of our energy systems** will need to become a key objective in order to provide security of supply and resilience as we transition away from fossil fuels. This requires a portfolio approach, in which hydrogen plays its part as a means of energy storage. Hydrogen can support the **integration of renewables** as green hydrogen may become both an input and output of our electricity system and can be production can be distributed throughout networks.



Recommendations

Remove regulatory friction

Improving the flexibility of the regulatory system can be addressed relatively easily and quickly. Aligning incentives and policy support for hydrogen with those provided to other decarbonising options would also level the playing field.

There are a number of immediate actions that could be taken to ease the regulatory friction associated with new hydrogen initiatives. These issues do not require a change of policy but reflect a relaxation of the prescriptive aspects of the regulatory system:

- Provide support to Regulators (see slide 10) to develop their understanding of the hydrogen economy and their future role in it, and to progress regulatory reviews and the development of processes to accommodate hydrogen implementation. The could achieved through the Working Group.
- Allow for flexibility to showing compliance with health and safety regulations to accommodate novel hydrogen applications. The adoption of a risk management based approach, similar to that used in Australia, may be preferably to the current prescriptive approach applied to well established energy products.
- Place greater reliance on international standards and provide support to Standards NZ to accelerate the process of adopting hydrogen standards.
- Incorporate hydrogen into a Government Policy Statement (GPS) on renewable energy (which may subsume the current GPS on renewable electricity generation) to provide direction to a number of regulatory agencies. This should be informed or potentially capture the national hydrogen policy strategy.
- Consider whether hydrogen projects should be deemed projects of national significance for consenting (which we understand is being considered for some renewable generation as part of the RMA reforms) and allow the EPA to inform and process consent applications. This would reduce the burden on Councils in understanding the unique risks associated with hydrogen. We concur with the ERP actions relating to streamlining consents but emphasise that reform may be too late for projects that are currently under consideration.
- Align policy incentives offered to EVs (eg Road User Charge (RUC) exemptions, clean car discount, scrap and replace scheme) to include hydrogen fuel cell electric vehicles (H-FCEVs) would allow for hydrogen vehicles to compete on an even playing field and recognise our Memorandum of Cooperation with Japan on hydrogen.
- The Regulatory Systems Amendment Bill (RSB) could be used to process a number of relatively minor regulatory changes. Examples include revising the definition of gas pipelines under Part 4 of the Commerce Act to explicitly allow for regulation of blended fuels in gas networks.
- Consider role of green hydrogen in the development of the New Zealand freight and supply chain strategy, which is currently under consultation by the MoT.
- Remove requirement to odorise hydrogen for vehicle fuel only.

Recommendations

Monitor and respond

We recommend that a monitoring regime is set up to keep abreast of hydrogen market developments and coordinate regulatory responses to 'trigger events' as they arise.

Establish a hydrogen sector monitoring function headed by a central government agency to monitor developments in the hydrogen sector. This should generate information from the existing monitoring functions of relevant regulatory agencies and from sector disclosures. The objective of this monitoring function would be to inform government policy decisions and provide feedback to regulators on potential triggers for regulatory reform. Facilitation of monitoring will require appropriate resourcing.

Use this monitoring function to identify events or circumstances that may trigger regulatory reform. Examples of potential regulatory challenges that may require monitoring include:

- Workforce and consumer safety outcomes and performance of the regulatory monitoring system.
- The impact of hydrogen production on electricity markets, transmission capacity, and prices.
- The impact on hydrogen production water use on water catchment management and networks. This should include consideration of non-potable and treated wastewater solutions instead of using potable water.
- Uptake of blended hydrogen in the natural gas system and the impact on wholesale market functions (eg measurement and reconciliation), prices and on end user appliances and quality of supply.
- The use of hydrogen in end-user fuel markets, including impacts on competition, safety, fuel purity, storage and vehicle certification.
- Workforce training and accreditation.
- Efficiency of regulatory systems in facilitating novel hydrogen applications.
- Consideration of hydrogen in major legislative reform of the energy industry (eg GTP), Three Waters and Natural and Built Environments.
- The potential development of carbon intensity measurement standards and 'green' credential schemes and whether centralised approaches are required.
- The potential development of the market for high carbon hydrogen (as an interchangeable substitute for green or low carbon hydrogen) given it will not meet our decarbonisation goals.
- Use of green hydrogen in agriculture, and how it can be used to offset agricultural emissions.

Recommendations

The Working Group

We see the need for ongoing monitoring of regulatory issues across the future hydrogen value chain. The Hydrogen Regulators Working Group is the right forum to coordinate this activity.

Feedback domestically and internationally is that change is expected to take a while, but that when it does, the rate of the change will be fast. A coordinated response from Government will be required.

Many of the actions identified in the ERP are based on building evidence bases and monitoring impacts. This aligns with our recommendations to take the action now to inform Government, across its agencies, on the impacts of hydrogen uptake. We already see grey areas and consider that these will continue to emerge as the industry evolves.

The current regulators Working Group could be a useful mechanism to facilitate information sharing across regulatory agencies.

Two key areas which may need representation on the working group are electricity and water. The appropriate regulators are:

- EA
- Taumata Arowai

To work effectively, the Working Group should:

- Collate information from the existing monitoring functions of relevant regulatory agencies and from sector disclosures. The objective of this monitoring function would be to inform government policy decisions and provide feedback to other regulators on potential triggers for regulatory reform
- Take a forward looking approach to hydrogen when conducting analysis. This is a growth area being driven globally by extraordinary levels of both private and public capital. The global commitments made already mean that green hydrogen will be commercially viable in the future

- Involve the sector to better understand developments
- Present a united approach to industry.

8

Appendices

Restrictions

Appendix A - Restrictions

This Report has been prepared solely for the purpose of presenting our findings from our review of the hydrogen regulatory frameworks for the Ministry of Business Innovation and Employment (MBIE) and should not be relied upon for any other purpose.

We give permission for MBIE to publish a copy of this report. It is made available to third parties for general information purposes only, and should not be used as a substitute for consultation with our professional advisors.

To the fullest extent permitted by law, PwC accepts no duty of care to any third party in connection with the provision of this report and/or any related information or explanation (together, the "Information"). Accordingly, regardless of the form of action, whether in contract, tort (including without limitation, negligence) or otherwise, and to the extent permitted by applicable law, PwC accepts no liability of any kind to any third party and disclaims all responsibility for the consequences of any third party acting or refraining to act in reliance on the Information.

We have not independently verified the accuracy of information provided to us by third parties as part of our interviews and research, and have not conducted any form of audit in respect of this information. Out of necessity we have had to distill and summarise third party information based on our own analysis and interpretation of this information at the time. Accordingly, we express no opinion on the reliability, accuracy, or completeness of the information provided to us and upon which we have relied.

The statements and opinions expressed herein have been made in good faith, and on the basis that all information relied upon is true and accurate in all material respects, and not misleading by reason of omission or otherwise. The statements and opinions expressed in this report are based on information available as at the date of the report and provided to us by third parties.

We reserve the right, but will be under no obligation, to review or amend our Report, if any additional information, which was in existence on the date of this report was not brought to our attention, or subsequently comes to light.

We have relied on forecasts, predictions, outlooks and assumptions prepared by third parties about future events which, by their nature, are not able to be independently verified. Inevitably, some assumptions may not materialise and unanticipated events and circumstances are likely to occur. Therefore, actual future of the hydrogen sector will undoubtedly vary from the forecasts upon which we have relied. These variations may be material.

This report is issued pursuant to the terms and conditions set out in the consulting services order dated 4 March 2022 and the Terms of Business attached thereto.

B

Glossary

Glossary

AEMO	Australian Energy Market Operator
APEC	Asia-Pacific Economic Cooperation
AT	Auckland Transport
CCC	Climate Change Commission
CCRA	Climate Change Response Act
CoF	Certificate of Fitness
DACC	Direct Air Carbon Capture
EA	Electricity Authority
EV (BEV)	(Battery) Electric Vehicle
EECA	Energy Efficiency and Conservation Authority
EEZ	Exclusive Economic Zone
EEZ Act	Environmental Effects Act 2012
EPA	Environmental Protection Authority
ERP	Emissions Reduction Plan
ETS	Emissions Trading Scheme
FCEV	Fuel Cell Electric Vehicles
FENZ	Fire and Emergency New Zealand
FFI	Fortescue Future Industries
FMG	Fortescue Metals Group Ltd
GCC	Gulf Cooperation Council
GIC	Gas Industry Company
GPB	Gas Pipeline Business

Glossary

GPS	Government Policy Statement
H2H	H2H Energy
HSNO	Hazardous Substances and New Organisms Act
HSW	Health and Safety at Work Act
ICE	Internal Combustion Engine
IMO	International Maritime Organisation
ISO	International Organisation for Standardisation
JV	Joint Venture
LOHC	Liquid Organic Hydrogen Carrier
LPG	Liquid Petroleum Gas
MCH	Methylcyclohexane
MfE	Ministry for the Environment
MOSS	Maritime Operator Safety System
MoT	Ministry of Transport
MOU	Memorandum of Understanding
MSC	Marine Stewardship Council
NASA	National Aeronautics and Space Administration
NBA	Natural and Built Environments Act
PGDA	Plumbers, Gasfitters and Drainlayers Act
PtG	Power to Gas
PtL	Power to Liquid
RMA	Resource Management Act

Glossary

RSB	Regulatory Systems Amendment Bill
RUC	Road User Charges
SAF	Sustainable Aviation Fuel
SGH	Southern Green Hydrogen
SOLAS	Safety of Life at Sea Convention
SPA	Strategic Planning Act
TAG	Technical Advisory Group
TTMRA	Trans-Tasman Mutual Recognition Act
WEC	World Energy Council
WoF	Warrant of Fitness

C

ERP Alignment

ERP

Infrastructure and resources

ERP actions relating to infrastructure have particular relevance to the evolution of hydrogen 'hubs'. These hubs integrate a number of hydrogen-based energy services, matching supply and demand in the same location.

Action	Proposed Output	Relevant recommendations for hydrogen
7.1 Improve the resource management system to promote lower emissions and climate resilience.	Embed climate outcomes in new legislation (e.g., the Natural and Built Environments Act and Strategic Planning Act).	Streamlining the consenting process for new hydrogen plant (along with other renewables) would improve time to market and improve the economic growth potential of hydrogen in Aotearoa. Hydrogen hubs embed energy solutions in infrastructure solutions.
7.3 Address infrastructure funding and financing challenges.	Policy changes to address infrastructure funding and financing challenges in a way that aligns with emissions reductions and climate resilience objectives (and other objectives).	Incentivising investment into hub development will build capability in the design and execution of this model. This will be a valuable capability to export as the larger countries rebuild infrastructure and emerging economies build green fields developments.
7.4 Improve the evidence base and tools for understanding and assessing urban development and infrastructure emissions.	Toolkit.	Hubs will impact across infrastructure and services. Learning from how these are evolving will facilitate better planning to improve and replicate the model.
7.7 Integrate climate mitigation into government decisions on infrastructure.	Review central government frameworks, guidelines and tools, to factor climate outcomes into decision-making on infrastructure investment.	The first hydrogen hubs are likely to evolve around existing infrastructure where there will be ready demand (eg airports). Factoring this into frameworks fundamentally embeds climate solutions with infrastructure investment.

ERP

Use of hydrogen

ERP actions relating to the road transport will incentivise the uptake of H-FCEV which will shore up demand for green hydrogen. The focus on buses is an effective way for the public sector to support demand growth.

Action	Proposed Output	Relevant recommendations for hydrogen
Action 10.2.1: Accelerate the uptake of low-emission vehicles.	Implement the Clean Vehicle Standard to increase the quantity and variety of low and zero-emissions vehicles supplied to Aotearoa.	This will improve the ability for importers to offer H-FCEV options to consumers.
Action 10.3.1: Support the decarbonisation of freight.	Provide funding to support the freight sector to purchase zero- and low-emissions trucks. Establish a freight decarbonisation unit to help decarbonise the freight sector through regulation and investment policy. Evaluate options for RUC to support emissions reductions, including whether to extend the heavy-EV exemption from RUC and whether to set RUC rates differently by fuel type/emissions..	Heavy transport is one of the three main use cases for hydrogen and incentives would improve the uptake rates. Could also consider subsidising or incentivising dual fuel conversions..
Action 10.3.2: Accelerate the decarbonisation of the public transport bus fleet.	Require only zero-emissions public transport buses to be purchased by 2025.	Not all bus routes are suited to EVs so hydrogen is a viable option for these. This mandate will speed up uptake and is commended.

ERP

Use of hydrogen

ERP actions relating to wider transport sector demonstrates the longer term commitment to growing demand, and the mandate for SAF will drive the development of hydrogen hubs at airports. More focus is required on the agriculture sector.

Action	Proposed Output	Relevant recommendations for hydrogen
Action 10.3.3: Work to decarbonise aviation.	Implement a sustainable aviation fuel (SAF) mandate.	SAFs can be hydrogen-based, so this mandate will increase uptake and incentive hub development at airports
Action 10.3.4: Progress the decarbonisation of maritime transport.	Undertake research to advance the development and uptake of alternative low and zero-carbon fuels for shipping in Aotearoa and develop safety and environmental standards for their use. All new large passenger, cargo, and offshore fishing vessels to meet highest carbon intensity reduction, as set by the IMO.	IMO is driving change in maritime fuels. Aotearoa needs to be proactive in implementing standards or guidelines as set.
Action 10.4: Support cross-cutting and enabling measures that contribute to the delivery of a low-emissions transport system.	Develop the skills and capability required to transition to a low-emissions transport system and support an equitable transition.	The capability to manage, assess and certify H-FCEVs is required to facilitate the development of this market.
13.2.5 Lead and contribute to global agricultural climate change mitigation.		The focus for reduction in agriculture emissions appears to be on biogenic methane but we see the opportunity for decarbonising fertiliser as a strong and fundamental way to quickly reduce the indirect emissions of the sector.

ERP

Infrastructure and Resources

ERP actions relating to electricity will form the foundation of renewable generation required to fuel green hydrogen production. They will also offer insights into how hydrogen could be used for security of supply.

Action	Proposed Output	Relevant recommendations for hydrogen
Action 11.2.1: Accelerate development of new renewable electricity generation across the economy.	A review of national direction tools for enabling investment in new renewable electricity generation and infrastructure, including small-scale generation. Determine whether, and how, resource consenting processes could be improved. Develop offshore regulatory framework.	Renewable generation is the enabler of a hydrogen economy. The process to achieve consents to build this plant needs to be efficient in order to facilitate growth. The offshore aspect poses a risk to timeliness of delivery of capacity to meet the cited ‘window of opportunity’ for hydrogen export.
Action 11.2.2: Ensure the electricity system and market can support high levels of renewables.	Investigate options for dry-year electricity storage through the New Zealand Battery Project.	Hydrogen is an option or part-option to the Battery Project. We see great potential in distributed hydrogen production and a demand response regime.
Action 11.2.3: Support development and efficient use of transmission and distribution infrastructure to further electrify the economy.	Renewable Energy Zones (REZ) pilot. Update electricity demand and generation scenarios (EDGS).	The REZ pilot could offer insights into how hydrogen hubs could improve energy outcomes on a localised level. The AEMO has included the “hydrogen superpower” scenario into its models. We recommend a hydrogen scenario is added to the EDGS.

ERP

Infrastructure and Resources

ERP actions relating to the wider energy sector pave the way to transition to low carbon fuels like hydrogen. This includes the GTP which provides more certainty to GPBs looking to repurpose their networks.

Action	Proposed Output	Relevant recommendations for hydrogen
Action 11.3.1: Manage the phase out of fossil gas.	Develop a GTP. Explore fossil gas issues as they apply to Commerce Act.	The repurposing of the gas networks to carry hydrogen or blends is a possibility requiring this level of feasibility assessment and legislative support. This is positive for a green hydrogen transition.
Action 11.3.2: Develop low-emissions fuels.	Develop a hydrogen roadmap Review hydrogen regulation Develop hydrogen standards.	All of this work is underway. We note that standards are set for adoption in 2022 which is not in keeping with our understanding. Some may be published by then but we reiterate the recommendations to review the process.
Action 11.4.2: Develop an approach for single-firm industries with emissions that are hard to reduce or remove.		We see the opportunity for hydrogen to decarbonise large single-firm industries like methanol production.
Action 11.5.1: Set targets for the energy system.	Develop secondary indicators for the energy system.	We see that there is the need for greater monitoring of the wider energy sector to keep ahead of the requirements for regulatory change. A deeper monitoring of the energy system is necessary to orchestrate a cohesive response.
Action 11.5.2: Develop energy strategies for Aotearoa		A hydrogen strategy should be developed in conjunction with the wider energy strategy.

D

International Government Activity

Strategic goals

Sector focus

Globally the priority sectors for green hydrogen implementation illustrates the ease of achieving change and the highest emitting sectors. Each country is unique and Aotearoa's position will be unique too.

Key			
No Prioritisation		Long-Term Prioritisation	
Low Prioritisation		Immediate Prioritisation	

	Asia Pacific			Europe								Americas	
	AU	Japan	South Korea	EU	France	Germany	Hungary	Holland	Norway	Portugal	Spain	Chile	Canada
Chemical Feedstock													
Power Generation													
Medium to Heavy Land Transport													
Buses													
Maritime													
Aviation													

Hydrogen
In Australia

Australia is setting itself up to be a hydrogen 'superpower'. With vast unused land resources, long sunshine hours and mature supply chains into Asia, it is well placed to achieve this.

Present

The hydrogen industry in Australia has seen a large amount of development since 2019, when the Australian federal government launched its National Hydrogen Strategy. The aim of this was to set a clear vision for the future of hydrogen development in Australia to position it to become a major global hydrogen player by 2030.

Australia is well placed to achieve this goal due to its abundant renewable energy resources (mainly solar and wind). As an economy that has been heavily dependent on mining, it has strong imperative to transition to renewables. Australia has the ability to use existing international supply chains and relationships to facilitate this transition. Japan and South Korea, who are advanced in their hydrogen strategies, do not have the same abundance of resources to produce green hydrogen. This makes them natural trading partners.

Hydrogen produced in Australia is mostly from non-renewable energy sources and is used for industrial feedstock. However, the first export of liquid hydrogen to Japan was made this year.

Future

The Australian government is investing $1.4 billion in building a hydrogen industry to meet their national hydrogen strategy goals. These goals include, but are not limited to:

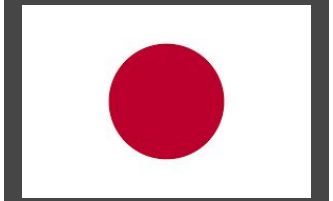
- Being in the top three exporters of hydrogen to Asian markets
- Creating up to 17,600 jobs and $26 billion a year in additional GDP by 2050
- Partnering with BOC to drive a hydrogen-fuelled future
- Establishing a world-class regulatory framework at a national and state level
- Creating the world's first fully integrated hydrogen supply chain, allowing Australia to meet the predicted high green hydrogen demand from Japan.

As Australia develops its hydrogen economy, current industry participants have indicated the need to align the various hydrogen state level road maps and create more consistent regulation so hydrogen operations can operate smoothly across state lines.

Hydrogen
In Asia

With a shortage of renewable electricity resources and large populations, both Japan and Korea are looking to import their renewable electricity in the form of green hydrogen. They are also leading the world in becoming hydrogen technology exporters.

Japan



Japan is a global leader in hydrogen implementation with arguably the most developed hydrogen economy to date. Japan's government was the first to release a hydrogen strategy, doing so in 2017.

Japan has goals for lowering the cost of hydrogen. They plan to develop commercial-scale supply chains by around 2030.

In 2019, Japan unveiled the world's first liquid hydrogen carrier.

In 2020, Japan opened one of the world's biggest green hydrogen plants.

South Korea

South Korea released their Hydrogen economy roadmap in 2019, which publicly announced their plans to become a global leader in hydrogen by 2040.

The government spent $701.9 million in FY2021 in efforts to develop the hydrogen economy.

South Korea has set a goal to domestically manufacturer three million FCEVs by 2040.

They currently lead the world in installation of FCEVs with over 10,000. They also plan to expand their fleet of hydrogen refuelling stations from 24 (as of the end of 2021) to 1200 by 2040.

Hydrogen
In the UK

With a reliance on fossil gas for home heating, the UK is focusing on how it can repurpose its gas networks to carry hydrogen into homes. If this can be accomplished then it will facilitate transporting hydrogen for other purposes, like transport fuel.

Present

The UK hydrogen market is mainly used in the industrial and agricultural sector. The UK currently produces around 700,000 tonnes of hydrogen a year for these industries, almost all of which is grey hydrogen. This grey hydrogen production is resulting in roughly six million tonnes of CO_2 emissions annually.

The UK government estimates that there are around 300 H-FCEVs on UK roads, most of which are either passenger cars or buses.There are currently two different models of hydrogen cars that are publicly available for purchase in the UK, the Hyundai NEXO and the Toyota Mirai. These vehicles can be filled by 15 publicly-available hydrogen refuelling stations located throughout the UK.

There is very little legislation that specifically relates to hydrogen. Instead, hydrogen projects must navigate the existing legislative landscape that applies to gasses more generally. There is no current regulation that affects who can fill up their hydrogen vehicles at the existing refuelling stations.

Future

In November 2020 the UK government announced its Ten Point Plan for a Green Industrial Revolution to help turn the UK into the world centre of green technology and finance. This included a pledge from the UK government to invest £12 billion to aid the creation of 250,000 ‘green’ jobs.

This plan aims to drive the growth of low carbon hydrogen in the UK. The UK government acknowledged the large potential of hydrogen in decarbonising the economy, and set the goal of achieving 5GW of low carbon hydrogen production capacity by 2030. This led to the release of the official UK hydrogen strategy in 2021.

The roadmap extends out to 2030 and sets out a strategy for the UK hydrogen supply chain. The UK’s strategy is not solely based on green hydrogen as it supports the growth of both green and blue hydrogen.

Scaling up hydrogen in the UK will require substantial amounts of private investment. The UK government has set up a grant programme for hydrogen production of up to £240 million.

Hydrogen
In China

Hydrogen is one of the six "industries of the future" identified in China's current 5 year plan. As the world's largest emitter it is expecting to turn around its carbon emissions in the early 2030s.

China has quickly become a world leader in hydrogen. They commissioned the world's largest electrolyser in December 2021 and announced their long-term plan for the development of the hydrogen energy industry.

China is currently the world's largest emitter of greenhouse gases but is a signatory to the 2015 Paris Agreement. Choosing to invest in the longevity of hydrogen as a renewable energy source sends a strong signal to the rest of the world about the future of hydrogen.

China currently produces 33 million tonnes of hydrogen a year, with the majority of this produced using coal and natural gas. Estimates put China's current green hydrogen production at around 27,000 tonnes per annum, but they have plans for reaching 200,000 tonnes per annum by 2025.

Hydrogen plans have been introduced at the national level and almost all provinces and regions in China are starting to create hydrogen development plans. Beijing has plans to have two million new energy vehicles, and developing a local hydrogen market worth at least CNY 100 billion, by 2025.

> **"Development of hydrogen is an important move for energy transition and a great support for China's carbon peak and carbon neutrality goals"**
> ~ Wang Xiang, the deputy director of the High Technology Department

Hydrogen

The Gulf Cooperation Council

Like Australia the GCC has vast unused land resource, long sunshine hours and mature supply chains. Its proximity Europe and its increasing demand for hydrogen, place it in a strong position to transition its economies away from oil.

The Gulf Cooperation Council

The countries with high renewable production potential are well aligned to succeed in the new age of renewable energy as the world transitions to a decarbonised economy. The Gulf Cooperation Council (GCC) countries are currently viewed as the oil and gas superpowers but they have the advantage of having large quantities of land, plenty of sunlight hours and high potential for wind energy. This, combined with a low cost of capital, and authoritarian governance, is facilitating a transition to being world leaders in renewable energy.

Saudi Arabia's hydrogen plans

Saudi Arabia has plans to become the world's biggest exporter of hydrogen as it diversifies its energy portfolio away from crude oils. Saudi Arabia is currently building a US$5b plant, Helios Green Fuels, which should be operational by 2025. It will produce 650 tons of green hydrogen a day, powered by four GW of solar and wind power. The hydrogen produced here will be converted into green ammonia and will be exported worldwide.

Saudi Arabia views the EU as their biggest export market for green energy. As the other GCC countries make a similar transition, the capacity of this region to export globally is likely to mean it will eventually dominate the global green hydrogen market.