Interim Hydrogen Roadmap

AUGUST 2023

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Te Kāwanatanga o Aotearoa
New Zealand Government

MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Ministry of Business, Innovation and Employment (MBIE)
Hīkina Whakatutuki – Lifting to make successful

MBIE develops and delivers policy, services, advice and regulation to support economic growth and the prosperity and wellbeing of New Zealanders.

MORE INFORMATION

Information, examples and answers to your questions about the topics covered here can be found on our website: **www.mbie.govt.nz.**

DISCLAIMER

This document is a guide only. It should not be used as a substitute for legislation or legal advice. The Ministry of Business, Innovation and Employment is not responsible for the results of any actions taken on the basis of information in this document, or for any errors or omissions.

ONLINE: ISBN 978-1-991092-51-9

AUGUST 2023

Ministerial Foreword

We need to do things differently if we are to avoid the impacts of climate change. To play our part in limiting global warming to 1.5°C, the Government has committed to reaching net zero for all greenhouse gas emissions (excluding biogenic methane) by 2050.

Reaching this goal will require a substantial and coordinated effort, and a commitment from across government that we are not shy of making. The Government is focused on the long-term strategic work of system change to a high performing, low emissions future.

The energy system has a critical role to play. In 2021[1], emissions from energy made up 40 per cent of New Zealand's total gross emissions. Cutting emissions from energy is essential to meeting our international climate commitments and reducing the impacts of climate change.

New Zealand is coming from a strong starting point, with a highly renewable electricity system New Zealanders can be proud of. Compared to many other countries, New Zealand's energy sources are highly reliable, renewable, and affordable. The challenge now is to increase the share of renewable energy, while providing affordability and reliability.

The Government has already made substantial progress in decarbonising the New Zealand energy system, including through the Government Investment in Decarbonising Industry programme, improvements we have underway to speed up consenting for new renewable generation, and the Warmer Kiwi Homes programme to reduce New Zealand's energy use while providing healthier and more efficient homes.

To further this work, I am now releasing a package of consultation papers, each addressing a different challenge in the energy transition.

The Interim Hydrogen Roadmap forms one part of a package of papers on the next phase of New Zealand's energy transition.

The Interim Hydrogen Roadmap sets out the Government's initial thinking and the key opportunities we see for hydrogen as part of our energy transition. It provides an overview of the emerging hydrogen landscape in New Zealand, the actions the Government has taken to date to support hydrogen development and new commitments we are making.

We are seeking feedback on the Interim Hydrogen Roadmap, and the areas we need to consider further for the final Hydrogen Roadmap, which we aim to release in 2024 alongside the New Zealand Energy Strategy.

Hon Dr Megan Woods
Minister of Energy and Resources

[1] New Zealand's Greenhouse Gas Inventory 1990–2021 snapshot: https://environment.govt.nz/publications/new-zealands-greenhouse-gas-inventory-19902021-snapshot/#new-zealands-gross-and-net-emissions

Have your say

SUBMISSIONS PROCESS

The Ministry of Business, Innovation and Employment (MBIE) is seeking written submissions on the issues raised in this document by 5pm on Thursday 2 November 2023.

Your submission may respond to any or all of these issues. Where possible, please include evidence to support your views, for example references to independent research, facts and figures, or relevant examples. Please also include your name and (if applicable) the name of your organisation in your submission.

You can make your submission by:

- completing the survey on the MBIE website (recommended for shorter submissions only)
- sending your submission as a PDF or Microsoft Word document to hydrogen@mbie.govt.nz. Please use the submission template provided here. This will help us to collate submissions and ensure that your views are fully considered.
- mailing your submission to:

  Hydrogen Team

  Energy and Resource Markets Branch

  Ministry of Business, Innovation and Employment

  15 Stout Street

  PO Box 1473, Wellington 6140

  New Zealand

  Attention: Interim Hydrogen Roadmap Submissions

Please direct any questions that you have in relation to the submissions process to hydrogen@mbie.govt.nz.

PRIVACY STATEMENT - USE AND RELEASE OF INFORMATION

The information provided in submissions will be used to inform Government policy development process and will inform advice to Ministers. MBIE intends to upload copies of submissions received to MBIE's website at www.mbie.govt.nz. MBIE will consider you to have consented to uploading by making a submission unless you clearly specify otherwise in your submission. If your submission contains any information that is confidential or you otherwise wish us not to publish, please:

- indicate this on the front of the submission, with any confidential information clearly marked within the text; and
- provide a separate version excluding the relevant information for publication on our website.

Submissions may be the subject of requests for information under the Official Information Act 1982 (OIA). Please set out clearly if you object to the release of any information in the submission, and in particular, which part (or parts) you consider should be withheld (with reference to the relevant section of the OIA). MBIE will take your views into account when responding to requests under the OIA. Any decision to withhold information requested under the OIA can be reviewed by the Ombudsman.

The Privacy Act 2020 applies to submissions and survey responses. Any personal information you supply to MBIE in your submissions will only be used for the purpose of assisting in the development of policy advice in relation to this work programme. If you do not wish for your name, or any other personal information to be included in any summary of submissions that MBIE may publish, please clearly indicate this in the cover letter or e-mail accompanying your submission.

We may share this information with other government agencies, in line with the Privacy Act or as otherwise required or permitted by law. This information will be held by MBIE. You have a right to ask for a copy of any personal information we hold about you as a result of this survey, and to ask for it to be corrected if you think it is wrong. If you'd like to ask for a copy of your information, or to have it corrected, please contact us at hydrogen@mbie.govt.nz.

WHAT HAPPENS NEXT

MBIE will analyse all submissions received and then report back to the Minister of Energy and Resources on the feedback, with recommendations for the Minister's consideration.

This process will be used to inform policy decisions that will form the basis of the final Hydrogen Roadmap, to be developed in 2024. Your submission will help to inform this process.

Interim Hydrogen Roadmap – At a Glance

Diagram 1: Interim Hydrogen roadmap at a glance. Source: MBIE

Strategic Context

NZ has legislated net zero emissions from long-lived greenhouse gases by 2050

70 per cent of emissions abatement to meet this target can be electrified, but some applications are hard to electrify

Hydrogen could play a role in these applications, but a market and supporting infrastructure does not yet exist

We are developing the Hydrogen Roadmap to guide the development of a sector in line with the Energy Strategy

Potential Demand Pathways

2035:

- Demand of 180,000 – 600,000 tonnes per annum
- Mainly replacing grey hydrogen as an industrial feedstock
- Increasing uptake in long-haul heavy transport and auxiliary vehicles, and some backup power generation
- Possible emergence of export market

2050:

- Demand of 560,000 – 1,210,000 tonnes per annum
- Demand may reach scale in transport applications (particularly long-haul heavy transport, specialty vehicles and aviation and marine transport) and in steel production, electricity system services, as well as an export market for hydrogen-based derivatives such as ammonia or methanol
- Increasing centralised production depending on export scale

Outcomes

Hydrogen could contribute to:

- **Decarbonisation:** 2.6 – 3.9 Mt CO_2-e by 2050 for energy uses (equivalent to 8% of total energy emissions in 2021). Additional unmodelled abatement from industrial feedstock emissions could be significant.
- **Economic outcomes:** $2.3 – $5.1bn in value-add economic activity per year in 2050 from investment in hydrogen deployment.
- **Energy resilience & security:** 3.8 – 8.2TWh of demand response capacity, 0.87 – 1.36bn litres liquid fuels displaced between 2022 and 2050.

We want to ensure that hydrogen development is matched with sufficient renewable electricity generation capacity. Hydrogen could require build-out of at least 12.5GW of renewable electricity by 2050 assuming a mix of wind and solar, with the bulk of the rampup occurring in the 2030s. This could roughly double the generation capacity needed to electrify transport and process heat.

Policy Objectives and Position

Our overarching aim is:

Optimise the potential for hydrogen to contribute to New Zealand's emissions reductions, economic development and energy security and resilience in line with our broader electrification goals.

Position on export:

The Government welcomes private export activity, but we do not see a case for public financial support at this time. We want to ensure the necessary electricity generation and transmission required can be consented and built in line with hydrogen production, to avoid compromising decarbonisation in other sectors that will rely on electrification.

To achieve this, we need to:

- Ensure supply can scale up, including hydrogen production that is matched to electricity and other inputs.
- Enable the safe use of hydrogen and facilitate early projects that enable the sector to develop.
- Bring forward and support early demand for hydrogen, linked to the most viable use cases within New Zealand's energy system, and aligned with other Government priorities.
- Monitor outcomes and progress over time.

Actions

The Government is committing in the Interim Roadmap to:

- Establish a hydrogen government and sector coordination body.
- Progress regulatory work to enable safe basic operation of common hydrogen infrastructure and near-term use cases.
- A hydrogen consumer rebate.
- A clean heavy vehicle grant scheme.
- Develop or recognise, emissions-intensity standards, trading and guarantee of origin frameworks for hydrogen production.
- Continue and build on international relationships and cooperation.

Ahead of finalising the Roadmap in 2024, the Government will consider:

- How hydrogen fits into a wider mix of alternative fuels alongside the New Zealand Energy Strategy.
- More detailed workforce and infrastructure consideration with input from the government and sector coordination body.
- Opportunities to align hydrogen with New Zealand's national research priority-setting and investigating gaps in our funding support environment across research, development, and deployment.
- Whether further action from government is needed to support a green hydrogen industry in New Zealand to become commercially viable.
- The potential effect of hydrogen productionon electricity prices, including for an export market.

Next Steps

We want to hear your thoughts. Consultation is open until 2 November 2023.

We will release a final Roadmap alongside the Energy Strategy by the end of 2024.

Contents

Executive summary

ABOUT THIS DOCUMENT

The Interim Hydrogen Roadmap sets out the Government's emerging thinking on the role for hydrogen as part of Aotearoa New Zealand's wider energy transition and tests the strategic approach for how we might act.

It builds on the green paper *A Vision for Hydrogen in New Zealand* released in 2019 and forms a pillar of the forthcoming New Zealand Energy Strategy (due by the end of 2024) alongside other projects including the Energy Market Measures project, Offshore Renewable Energy regulatory framework project, the Gas Transition Plan, and the New Zealand Battery Project.

We are seeking public feedback on a proposed role for hydrogen to meet our energy system, climate and economic goals, and the government's role to help make this happen. We will finalise the Hydrogen Roadmap for release alongside the New Zealand Energy Strategy by the end of 2024.

Hydrogen has a strategic role to play in New Zealand's clean energy transition

New Zealand faces a major energy transition to meet our statutory target of net zero emissions of all long-lived greenhouse gases by 2050. This transition is an opportunity to create a highly renewable, sustainable, and efficient energy and industry sector that supports a low emissions economy and highly skilled jobs.

Much of the emissions abatement we need to meet our net zero target will be most efficiently met through electrification, but some critical activities are harder to electrify, such as long-haul heavy transport and aviation. Industrial processes rely on chemical inputs that cannot be replaced by electricity and are currently derived from emissions producing sources, such as fossil-gas derived hydrogen. These activities underpin critical activities and sectors that support New Zealand's economy.

Hydrogen is part of the suite of options under consideration as part the New Zealand Energy Strategy to reduce emissions in hard-to-abate sectors, smooth energy demand and supply mismatches across time, improve regional resilience to energy shocks and supply interruptions, and maintain energy affordability. Hydrogen is a high-density energy carrier that can power vehicles, provide heat, produce chemicals, store energy, and blend with existing fuels. It can be zero or low emissions at point of use when produced with renewable electricity. Other countries are enabling hydrogen at pace in order to make their own energy transitions.

Most of the hydrogen produced today is from emissions-intensive sources. The New Zealand Government's interest is mainly in green hydrogen production using electrolysis, but future low and zero emissions production sources such as naturally occurring hydrogen and biogenic hydrogen may also play a part.

The global market for low emission hydrogen is projected to grow significantly by 2050, but there are challenges to overcome to realise this scale. This includes high costs, the need for a market for hydrogen to emerge as well as uncertainty and differing views about its future uptake and role.

We will be building from the strong foundations of a vibrant hydrogen ecosystem already emerging in New Zealand today. There are a growing number of research projects, demonstration and deployment trials, and commercial partnerships across all aspects of the hydrogen supply chain. This has been supported by $88 million in already committed government funding and financing. A further $100 million for the Regional Hydrogen Transition consumption rebate and $30 million for the clean heavy vehicles grant was announced in Budget 2023.

Iwi have also taken leading roles in this early market through joint venture arrangements in hydrogen production, as well as partnership in research initiatives and regional planning processes that are considering transitions at a local level. There are growing international connections between the New Zealand government, companies and universities with valuable international partners that have a strong interest in hydrogen, including with Germany, Japan and Singapore. We expect these connections to expand over time and broaden to other countries with similar ambitions, such as Australia and South Korea.

We have received strong support from the hydrogen sector to develop a clear strategy to guide the development of the sector and outline what contribution it could make to national goals. We are publishing the Interim Hydrogen Roadmap as an opportunity to seek feedback on our understanding of the opportunities and trade-offs for using hydrogen in New Zealand, and the proposed role the government could play in supporting it.

There are opportunities for hydrogen to reduce emissions in areas that are hard to electrify, support economic development, and underpin our energy security and resilience

Our thinking to inform the Interim Hydrogen Roadmap has been supported through close review of international literature and extensive stakeholder engagement with the New Zealand energy sector, and other interested stakeholders including local councils, training providers and researchers. We have also undertaken modelling to explore potential scenarios for hydrogen production and demand and mapped this to policy outcomes such as emissions abatement and economic development. This modelling has been released alongside the Interim Hydrogen Roadmap. As there is uncertainty about how the hydrogen sector might develop, these scenarios are not intended to predict the future. Rather, they are intended to support our understanding of the potential for New Zealand.

Demand for green hydrogen is expected to grow significantly in the coming decades as the technology continues to develop and a market for hydrogen starts to scale. If it is adopted in line with our current understanding of its potential trajectory, domestic demand could reach 180,000 tonnes per year by 2035, rising to 560,000 tonnes by 2050.

This demand pathway could start in the 2020s with the growing use of hydrogen as an industrial feedstock, and in heavy transport demonstration trials and rollouts that are starting now. Demand might then scale up through the 2030s and begin peaking in the 2040s as established demand emerges from transport applications (particularly long-haul heavy transport, specialty vehicles, and aviation and marine transport), steel production, electricity system services, as well as an export market for hydrogen-based derivatives such as ammonia or methanol.

If this level of demand eventuates, meeting it could require 1.5 gigawatts (GW) of electrolyser capacity in 2035, rising to 4.5GW in 2050. This could require electricity demand of 11.5 terawatt-hours (TWh) in 2035 and 33.9TWh in 2050. This is based on hydrogen production through a combination of larger scale centralised plants, onsite production to service industrial demand, and smaller decentralised plants. Generation to support this electricity demand is estimated to be 4.3GW in 2035 and 12.5GW in 2050, but this could be higher or lower depending on how much hydrogen production can integrate with the existing energy system, the type of renewable generation and how additional renewable generation is deployed. The benefit of producing hydrogen in New Zealand is our highly renewable electricity sector, significant potential additional capacity generation being added as new projects come online.

These use cases could substitute transport and energy emissions by 0.44Mt CO_2e per year by 2035 and 2.6Mt CO_2e per year by 2050. In 2050, this amounts to 8 per cent of 2021’s energy emissions, mostly from transport.

Emissions reduced through the use of hydrogen in industrial feedstock and export were not part of this estimate. Emissions from industrial processes and product use made up 6 per cent of New

Zealand's gross emissions in 2021. Large single source emitters such as NZ Steel, Methanex and the Ballance ammonia-urea manufacturing plant at Kapuni have substantial abatement potential if green hydrogen is used as a feedstock for a proportion the production of steel, fertiliser and methanol in future. Emissions abatement relating to hydrogen or derivative exports would depend on what emissions-producing energy sources would be displaced in other countries by hydrogen or derivative exports and would not contribute to New Zealand's legislated emissions reduction targets.

To be consistent with our broader energy transition, hydrogen production needs to be matched with supporting renewable electricity generation

The Government's overarching aim is to optimise the potential for green hydrogen to contribute to New Zealand's emissions reductions, economic development, and energy sector to the extent compatible with our broader electrification goals.

To achieve this, we have set the following policy objectives:

- Ensure supply can scale up, including hydrogen production that is matched to electricity and other inputs.
- Enable the safe use of hydrogen and facilitate early projects that enable the sector to develop.
- Bring forward and support early demand for hydrogen, linked to the most viable use cases within New Zealand's energy system, and aligned with other Government priorities including economic development and supporting just transitions for key affected communities.
- Monitor outcomes and progress over time.

Potential future uses for hydrogen also have to be considered in the context of alternatives such as direct electrification and bioenergy, as part of a wider renewable energy system. We plan to explore this alongside the forthcoming New Zealand Energy Strategy to understand how electrification and other green fuels like hydrogen, biogas, biomass, and synthetic fuels could fit together to create a decarbonised energy system that remains affordable, reliable and secure into the future.

The key trade-off for hydrogen is the significant renewable electricity generation build-out it would require. Our estimates for hydrogen production could add to forecasts to date that require between 18 to 78 per cent additional generation capacity to meet the electrification needs of key sectors like transport and industrial process heat out to 2050.

However, investment in hydrogen production could benefit the broader energy system by helping underwrite the investment case for significant new renewable electricity generation development. This is because hydrogen production could either:

- Accompany dedicated renewable generation such as solar and wind, which could be sold back to the grid when it is not needed, or when wholesale electricity prices make it attractive to do so. Producers could overbuild dedicated renewable generation to account for the intermittency of these generation types.[2] Projects of this nature are already being explored.
- Bring forward additional generation capacity in the wider network, where long-term offtake agreements provide certainty for renewable electricity projects to progress to construction.

[2] Overbuild in this context means the full or peak capacity of the intermittent generation when all of it is running exceeds the maximum demand from hydrogen production, allowing any excess to be sold to the grid.

If these arrangements were to occur, hydrogen production has the potential to provide valuable flexibility in a highly renewable electricity system.

We will need to ensure that sufficient electricity generation and transmission is being consented and built in line with the demand for electricity from hydrogen production. This issue will be a key area to explore further ahead of the final Hydrogen Roadmap and New Zealand Energy Strategy, supported by our related work on electricity market measures. Te Waihanga, the New Zealand Infrastructure Commission, recently published research indicating that from 2028, consent processing times would need to be 50 per cent quicker than they are projected to be under the Resource Management Act 1991.[3] The Government is already taking steps to address this, and recently consulted on an updated National Policy Statement for renewable electricity generation to help speed up renewable generation consenting.

The need for new renewable generation to underpin hydrogen development also affects New Zealand's consideration of whether to foster an export industry for hydrogen or its derivatives like ammonia. While there are potential opportunities for large scale export, this may risk New Zealand ensuring its domestic electricity system will meet our own transition needs while maintaining affordability and security.

For this reason, while there is an immediate role for government to support the development of a domestic hydrogen sector that can help reduce emissions, we do not currently see a case for public financial involvement to support the development of a hydrogen export market until it is clearer that sufficient renewable electricity generation can be built to support it without compromising our other energy transition goals.

At the same time, the Government welcomes private initiatives that are exploring hydrogen production for export. We remain open to the prospect of New Zealand becoming an exporter of hydrogen, and welcome further investigation on this. We acknowledge that export could also play a role underpinning the commercial viability of hydrogen production in New Zealand by allowing an industry to scale ahead of domestic demand, and we are interested in any evidence we should be considering to inform this judgement.

[3] New Zealand Infrastructure Commission Te Waihanga (2023). Infrastructure Consenting for Climate Targets. https://www.tewaihanga.govt.nz/policy/reports/infrastructure-consenting-for-climate-targets/

The Government has a key role to play to support a safe and productive hydrogen sector to develop

The development of a hydrogen sector will be a joint effort between government, the private sector, Māori, territorial authorities and consumers. Ahead of the final Hydrogen Roadmap, the Government is committing to the following broad focus areas that are important to achieve our objectives in the near-term:

- **Governance, oversight and monitoring:** Hydrogen is an emerging sector, and a clear vision will be needed between public and private organisations on where we are heading. We will establish a joint government and sector coordination body to help coordinate necessary actions, based on similar groups such as Sustainable Aviation Aotearoa.[4]
- **Building a market for hydrogen:** As an early-stage market, parties face uncertainty on both sides of the market when making investment decisions. The Government signalled its clear support for New Zealand's growing hydrogen industry through Budget 2023, delivering a $100 million hydrogen consumer rebate over ten years to bridge the price gap between hydrogen and fossil fuels, and support just transition outcomes in priority regions like Southland. The Government is also implementing a clean heavy vehicle grant scheme, which will provide co-investment with industry to boost the number of hydrogen fuel cell heavy vehicles, alongside battery electric heavy vehicles. We are also considering further work to look at ways to recognise and verify the production source and emissions-intensity of hydrogen to build confidence in a market for green hydrogen. A number of schemes are already under development internationally.
- **Regulatory settings:** Clear and fit-for-purpose regulations and standards are important to support the safe production, storage, transport, and use of hydrogen. They also underpin certainty to the hydrogen sector to support investment decisions. The Government has made it a priority to develop appropriate regulatory settings and standards to facilitate the uptake of hydrogen and as a first priority, will progress a regulatory work programme to enable safe basic operation of common hydrogen infrastructure and near-term use cases like heavy transport.
- **Workforce:** Hydrogen projects will require highly-skilled workers and may support economic transitions in key regions like Southland and Taranaki. Regional bodies are already starting to consider this. Helping to address supply chain and workforce needs is also part of the Just Transition Partnership team's work to support the hydrogen consumption rebate. The government and sector coordination body could also work with education sector stakeholders to understand at a national level what workforce skills will be required to support the sector, what transferable skills may already exist and what gaps may need to be filled.
- **Planning and infrastructure:** Coordinated investment in infrastructure across a range of inputs will be needed for hydrogen production, storage and conversion, distribution and use. This includes water supply and renewable electricity generation. The government and sector coordination body could inform a more coordinated spatial view of the infrastructure requirements to support hydrogen production and use.
- **Research, development and deployment:** A dynamic research, development and deployment system helps us to learn from others, test what works here, and deploy

---

[4] Ministry of Transport (2022). *Sustainable Aviation Aotearoa Terms of Reference – November 2022.* https://www.transport.govt.nz/assets/Uploads/November-2022-Sustainable-Aviation-Aotearoa-Terms-of-reference.pdf

hydrogen on a commercial scale. This could also create economic opportunities through export of the knowledge we develop. We are considering opportunities to align hydrogen with New Zealand's national research priorities and investigating gaps in our funding support across the research, development and deployment pipeline.

- **International partnership and cooperation:** New Zealand will benefit greatly from working with and learning from other countries. Strong international relationships are vital to an emerging hydrogen industry. We are committed to continued engagement in a range of multilateral forums including the IEA Clean Energy Ministerial Hydrogen Initiative, APEC, the COP27 Breakthrough Agenda and the Hydrogen Energy Ministerial Meeting, our bilateral cooperation arrangements with Japan and with Singapore and our green hydrogen research agreement with Germany. We will look to deepen our existing hydrogen relationships with partner countries and increase our breadth by developing relationships with other countries that hold similar ambitions for hydrogen. We will seek to leverage New Zealand's international trade footprint to ensure New Zealand can access international supply chains when needed.
- **Public perception:** As a new technology, public familiarity with hydrogen varies, and there are also general concerns about its safety in public-facing settings. Government has a role to address safety concerns by providing an appropriate regulatory environment to manage risks, and to help support public awareness and confidence about the role hydrogen could play in our energy transition.

WE WANT TO HEAR FROM YOU

This Interim Hydrogen Roadmap reflects our current thinking on the opportunities for hydrogen and possible roles for government, actions we could take, and how we might need to respond to enable hydrogen uptake and mitigate any risks. We want to hear from you. Key questions include:

- What opportunities and risks are you seeing in your sector?
- What evidence should we be considering?
- Do you agree with the actions we have proposed?

We will consider your feedback as we finalise the Roadmap for release alongside the Energy Strategy. Phase Two of our work will involve confirming our judgements on the role for hydrogen and the role for government to support it, as well as further detailed work on the policy initiatives we might need to support it.

Section 1: Hydrogen is emerging as an important part of the future global energy system

GLOBAL CONTEXT

The world faces an energy transition to reduce emissions and address climate change

The world is mobilising to transition the global economy to mitigate and adapt to the devastating impacts of climate change. For most economies, electrification will be the backbone of decarbonisation in the energy sector. Powering applications like cars, building heating and many industrial heat applications through direct electrification is generally the most cost- and energy-efficient option, is highly reliable and is available with current technology.

However, some critical sectors and activities are more challenging or may be impractical to electrify. These include some of the heaviest-emitting global sectors today, including steel and chemical production, aviation, long-haul heavy road transport and marine transport.

There is also expected to be a growing need for energy storage and more flexibility in the energy system to manage peaks in energy demand and the intermittency of energy supply. Renewable generation sources like solar and wind energy do not always produce the right amount of energy needed by consumers at the right times because they generate intermittently based on weather patterns. This also presents an opportunity for technologies that can store energy to be released at times when it is needed, and to utilise intermittent generation that would otherwise be curtailed without time-matched demand.

Hydrogen has advantages that make it attractive, as well as limitations and challenges to overcome

Hydrogen is increasingly part of global decarbonisation strategies as a complement to electrification, particularly in hard-to-abate sectors.

Hydrogen is now being used increasingly for decarbonisation purposes in a range of new uses, produced as 'green' hydrogen through a process called electrolysis, and powered by renewable energy. The Government is mainly interested in green hydrogen, and to date, the private sector has shared this aim. There is also emerging interest in exploring whether naturally occurring hydrogen in underground geological formations may exist in commercially viable quantities, and biogenic hydrogen produced from wood.

Hydrogen is attractive because it is:

- **Zero emissions at the point of use:** Hydrogen produces no emissions at the point of use used through a fuel cell. The only by-products are water and heat.
- **Versatile:** Hydrogen can be used in a range of applications and can take many forms. It can power vehicles in a fuel cell, be a source of process heat through direct combustion, store energy for use when it is scarce or be used as a chemical feedstock for industrial processes. It can be liquified, compressed, or converted to a derivative energy carrier should different attributes be required.
- **Energy dense:** Hydrogen has higher energy density than similar fuels. In applications where weight is an important constraint (such as heavy trucking and aviation), hydrogen offers

possible advantages over batteries. In situations where space is a constraint it is commonly compressed, liquified, or converted to a carrier like liquid ammonia or methanol to reduce its volume and make it easier to store and transport.

In 2021, total global demand for hydrogen was 94 million tonnes (Mt), mostly for oil refining and chemical production. Of this, 96 per cent was produced through emissions-intensive methods. The International Energy Agency (IEA) forecasts that global demand could grow to 115Mt by 2030 driven by growth in existing uses, or up to 130Mt by 2030 if 25 per cent was used in new applications and with low-carbon and renewable hydrogen.[5] Estimates for global demand for 2050 vary depending on the level of ambition in reducing greenhouse gases and competing technologies, but could be at the scale of 150-500 Mt[6] or 4-11 per cent of global final energy consumption.[7] The main assumed growth driver in the 2030s and 2040s is uptake in transport.

There remain challenges to scaling hydrogen. These challenges are being addressed through hydrogen strategies and supporting policies globally:

- **Energy use:** Currently electrolysers use around 55kwh of electricity to produce one kilogram of hydrogen, which contains 33.33kwh of equivalent energy (about 1.5 times the average daily household electricity use). Energy is then expended at each stage of the hydrogen supply chain including when it is compressed or converted, transported, stored, and applied to an end use. One of the key technological challenges to hydrogen becoming an economically viable alternative to emissions-intensive fuels and feedstocks is this end-to-end efficiency.
- **Cost:** Green hydrogen is currently more expensive than alternatives such as direct electrification and bioenergy, and the fuels and energy sources it would replace, namely diesel and fossil gas. Green hydrogen in New Zealand currently costs around $8 NZD per kilogram to produce, around six times the cost of hydrogen from emissions-intensive sources. These costs are anticipated to fall over time as technology becomes more efficient and benefits from economies of scale. Some practices such as co-locating supply and demand to eliminate transport costs are helping to mitigate cost barriers. However, green hydrogen is likely to always remain more expensive than direct electrification.
- **Missing market:** While there have been rapid advances in hydrogen in New Zealand, a market for low-carbon hydrogen does not currently exist and there is uncertainty that a future market will emerge on its own. This ‘chicken and egg’ or ‘missing market’ problem affects investor confidence.
- **Infrastructure:** It will take time to build the physical, regulatory and knowledge infrastructure to make use of hydrogen. There are also technical challenges to storing hydrogen, which can leak out of and embrittle storage vessels commonly used to contain fossil gases that are constructed from steel.
- **Perception:** There are varying levels of understanding, and differing views about the role of hydrogen as part of the energy transition. This includes concerns about the efficiency and safety of hydrogen for everyday use.

---

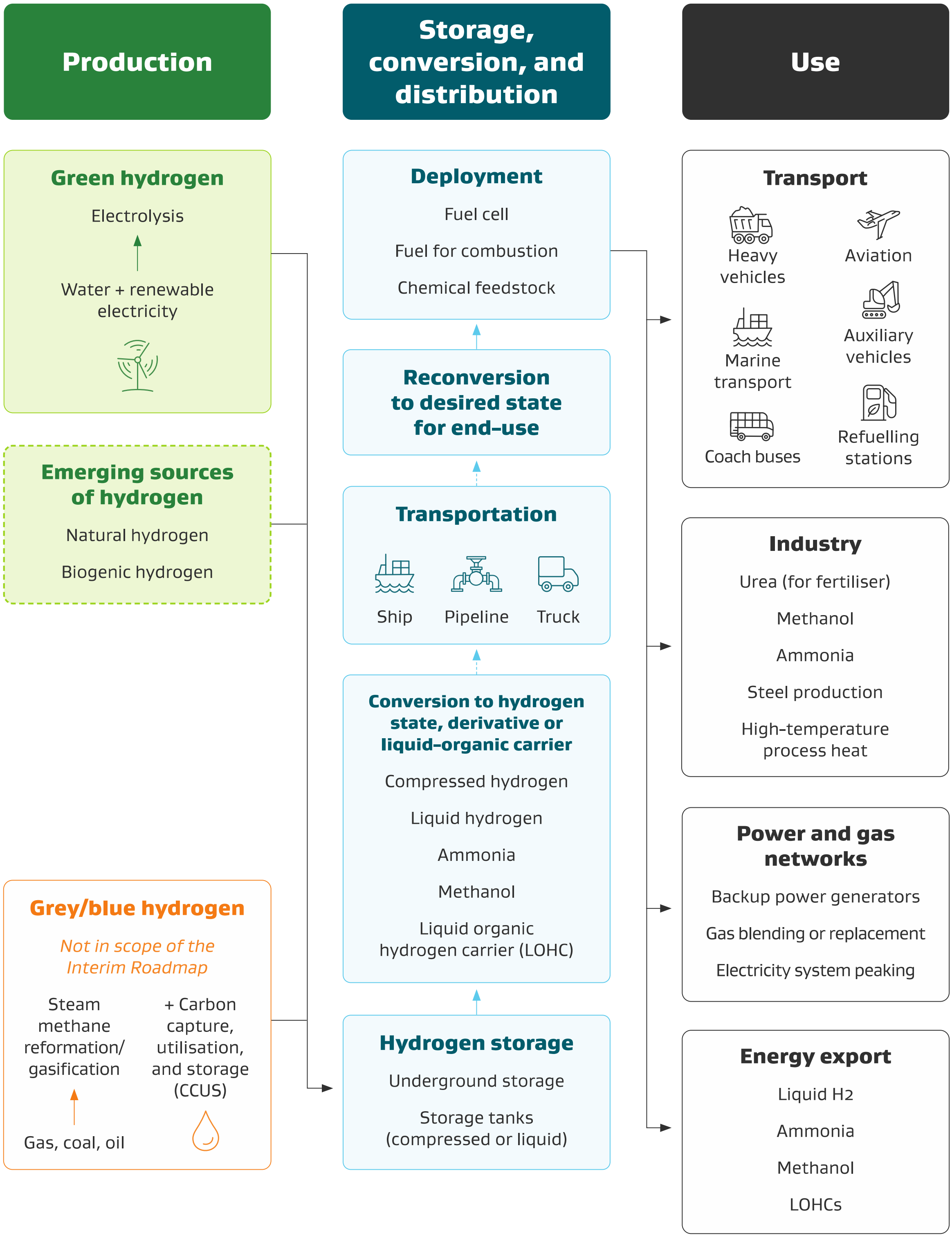
[5] International Energy Agency (2022). *Global Hydrogen Review 2022*. https://www.iea.org/reports/global-hydrogen-review-2022

[6] PwC (2023). *Predicting the decarbonisation agenda of tomorrow*. https://www.pwc.com/gx/en/industries/energy-utilities-resources/future-energy/green-hydrogen-cost.html

[7] Riemer et al. (2022) *Future hydrogen demand: A cross-sectoral, global meta-analysis*. https://publica.fraunhofer.de/entities/publication/e4910b11-a81d-4c4d-8845-9ea36141a655/details

Diagram 2: A simplified overview of how hydrogen is produced, transported, and used. Source: MBIE

Simplified hydrogen value chain



There is significant international interest in hydrogen

There is growing momentum around establishing a global hydrogen economy. As of September 2022, 25 countries and the European Union had adopted hydrogen strategies, and another 20 had strategies underway.[8] The goals for these strategies vary across countries depending on the make-up of their national energy systems.

As well as this, countries are undertaking a range of policy steps which typically include setting targets for hydrogen supply and use, supporting research and development, ensuring facilitative regulatory rules and regulations, and putting in place mechanisms that support the development of a market for hydrogen over time.[9]

The specific mix of policies depends on national strategic goals and circumstances. New Zealand needs to consider its own goals and how it will fit into the wider energy and hydrogen ecosystem. Countries are taking different approaches:

- North Asian countries such as **Japan** and **South Korea** are pursuing domestic hydrogen production for use in transport, reticulated gas and industrial processes. These countries are also looking to import hydrogen in the form of ammonia as a co-generation fuel for electricity production. They are highly active in building international cooperation to support global supply chains for hydrogen. Developers from these countries are actively exploring opportunities in New Zealand.
- **Chile** and **Australia** are pursuing export-driven hydrogen production industries, backed by a mixture of renewable resources and in Australia's case, 'blue' hydrogen from fossil gas with emissions capture technology, alongside renewable sources.
- The **European Union (EU)** is generally pursuing hydrogen production for domestic use to reduce reliance on imported fossil gas, support domestic industries such as steel and chemical production, and build supply chain resilience. The EU has implemented production subsidies for hydrogen through their Green Deal legislation. EU nations are exploring arrangements to pipe imported hydrogen from North Africa and import from further afield in the form of ammonia, methanol and other chemicals.
- The **United States of America** and **China** are developing hydrogen markets that are sufficient for both domestic decarbonisation and major export operations. Both countries have strategies to be cost leaders. For example, the US aims to reduce its export price to 1 USD/kg by 2031. Through recent legislative budget packages, the US Government has funded four regional clean hydrogen hubs, a programme to reduce the cost of electrolysis, and tax credits for investment and production.

[8] International Energy Agency (2022). *Global Hydrogen Review 2022*. https://www.iea.org/reports/global-hydrogen-review-2022

[9] International Renewable Energy Agency (2020). *Green hydrogen: A guide to policy making*. https://www.irena.org/publications/2020/Nov/Green-hydrogen

DOMESTIC CONTEXT

New Zealand needs to act to meet our legislated emissions targets

New Zealand's 2050 vision for energy and industry is for a highly renewable, sustainable, and efficient energy system supporting a low emissions economy. We have set a legislated target of net zero emissions of long-lived greenhouse gases by 2050. The Government is committed to an equitable transition for communities most impacted by the economic transition.

We already have a highly renewable electricity supply, but will need to increase renewable generation substantially to meet our emissions targets

Our electricity system already generates most of New Zealand's supply from renewable sources such as hydro, geothermal, and wind energy. In 2021, renewable sources accounted for 82 per cent of our total electricity supply.[10] However, there are challenges to meet our emissions targets and get to net zero by 2050.

Electrification is generally the most cost-effective and readily available option for energy decarbonisation. Analysis by MBIE forecasts that electricity demand could grow between 18 and 78 per cent between 2018 and 2050 across five different scenarios assuming different levels of economic growth, technological progress and policy changes. [11] This would require between 3,800MW and 10,800MW of additional generation capacity.[12]

However, direct electrification may not meet all of our decarbonisation needs. Fossil fuels currently provide most of our energy needs, particularly in transport and industry. Renewable sources accounted for 28 per cent of total final energy consumption in 2021. The Government has a target to increase total final energy consumption to 50 per cent by 2035.

At the same time, we need to ensure a resilient energy system in the face of growing challenges

As we decarbonise, we need to maintain energy system reliability, security, resilience and affordability. We already face challenges meeting peak demand in years where our hydro lakes do not receive sufficient inflows. In future, we will also need to manage an increased share of variable electricity generation from wind and solar.

Our energy infrastructure needs to be resilient to natural disasters, as we have experienced in recent weather events. Our fuel and energy security can be affected by geopolitical volatility and other supply chain shocks such as those experienced during the COVID-19 pandemic. Throughout the transition, energy needs to continue to be affordable for households and businesses to maintain living standards and economic competitiveness.

---

[10] MBIE (2022). *Energy in New Zealand 22: 2021 Calendar Year Edition*. https://www.mbie.govt.nz/dmsdocument/23550-energy-in-new-zealand-2022-pdf

[11] MBIE (2019), *Electricity Demand and Generation Scenarios*. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/electricity-demand-and-generation-scenarios/

[12] The reference case for this modelling, referred to in the companion discussion document on electricity market measures, estimated 6,400MW in additional generation capacity needed by 2050.

New Zealand currently meets much of its energy needs through domestic production. The transition to a more renewable energy system is an opportunity to further strengthen our energy independence and ensure our energy supply is affordable and secure in the face of global shocks. This will include:

- reducing our exposure to international oil markets by accelerating the uptake of low emissions vehicles and diversifying into new fuels
- using our highly renewable electricity system to further electrify industry and transport
- giving New Zealanders more control of their energy use so that they can save money.

There are economic and social costs if we do not address our emissions

Deloitte's '*Aotearoa New Zealand's Turning Point'* report estimated that inadequate global climate action would result in a reduction of $4.4 billion in New Zealand's GDP between 2023 and 2050. By 2070, this could grow to $48 billion. By comparison, it found that decisive global action could add $64 billion to New Zealand's GDP by 2050, through a combination of avoided climate damage, the emergence of new sectors that drive growth and employment, and transition support.[13]

New Zealand is committed to a just transition towards a low-carbon future. This means supporting communities to plan and manage the social, economic, and environmental impacts of the transition in a way that is fair. The Climate Change Response Act 2002 requires New Zealand's Emissions Reduction Plans to include a strategy to mitigate the impacts of reducing emissions and increasing removals on employees and employers, regions, Māori, and wider communities. A more detailed equitable transition strategy is currently under development.

The Government also has a Just Transitions Partnerships programme to support regions through economic change. Through this programme, the government has partnered with regional leaders in Southland to respond to the 2021 announcement of the planned closure of the New Zealand Aluminium Smelter in 2024. We have also partnered with Taranaki to adapt to the end of new permits for offshore oil and gas drilling. Diversifying local economies and supporting the emergence of new, low-carbon industries in emerging sectors can support New Zealand to realise its economic goals.

There is an opportunity for hydrogen to contribute to these goals

Hydrogen has the potential to support decarbonisation of hard-to-abate activities as a replacement for fossil fuels in industry, heavy transport, and electricity system services. It also has the potential to support a highly renewable electricity system a way of storing energy and as demand response. Potential use cases are discussed further in Section 2.

Hydrogen could contribute to New Zealand's energy security, independence and resilience and could integrate within our energy system in a number of ways, including by:

- storing energy to smooth short-term and inter-seasonal variability in electricity demand and provide regional resilience services
- providing demand response capability
- replacing liquid fossil fuels that we currently import, in particular diesel.

Electrolysers used to produce green hydrogen can be scaled down or turned off when demand for electricity is high, and scaled up when demand for electricity is low. This makes efficient use of renewable electricity generation that would otherwise be lost or where generation would otherwise

---

[13] Deloitte (2022), *Aotearoa New Zealand's Turning Point*. https://www2.deloitte.com/nz/en/pages/about-deloitte/articles/new-zealands-turning-point.html

be curtailed. Stored hydrogen could also potentially be used to generate electricity when demand exceeds generation supply, playing a role in replacing current peaking plants, which rely on coal and gas.

A key potential advantage of hydrogen production is its ability to be produced wherever water and electricity inputs are available. Depending on how hydrogen production is deployed, it could support local and regional-level resilience in the event of disruption to electricity and fuel distribution networks through back-up power generation and more generally through the existence of distributed fuel and energy storage. These potential benefits may prove valuable in the face of extreme weather events which are expected to become more frequent due to climate change. Cyclone Gabrielle highlighted this issue. Hydrogen could help support critical infrastructure that currently relies on diesel back-up generators.

Domestically produced hydrogen could help reduce our reliance on imported energy. While New Zealand does have domestic oil production, all of this is exported and nearly all of our liquid fuels, apart from a small amount of biofuel, are imported from international markets. Replacing some of these imported fuels with domestically produced hydrogen could provide economic benefits, such as improving our balance of payments, and contributing to energy security against global shocks or other events that cause volatility in global commodity markets. These benefits are also applicable to other domestically produced fuels and energy, such as biomass and biofuels.

Hydrogen also has the potential to help regions transition to low emissions activities and industries, by supporting New Zealand's future economic activity and employment, underpinning community resilience as we address our emissions.

This includes economic opportunities in key regions, particularly those with existing emissions intensive industries that will need to undergo transitions in the coming years and decades, as well as areas with complementary existing infrastructure, labour markets and other attributes. Many regions in New Zealand are already contemplating these shifts, including Southland and Taranaki.

There are significant potential opportunities for hydrogen or derivative products such as ammonia and methanol to be exported to countries that are planning to import hydrogen or hydrogen-derived products, which could also provide wider benefits to New Zealand as whole, such as contributing to our balance of trade.

A HYDROGEN ECOSYSTEM IS ALREADY EMERGING IN NEW ZEALAND, PRESENTING OPPORTUNITIES FOR OUR ENERGY SYSTEM

There is already a range of public, private and mixed-funded projects underway to develop a hydrogen ecosystem in New Zealand. These are highlighted in the diagram below.

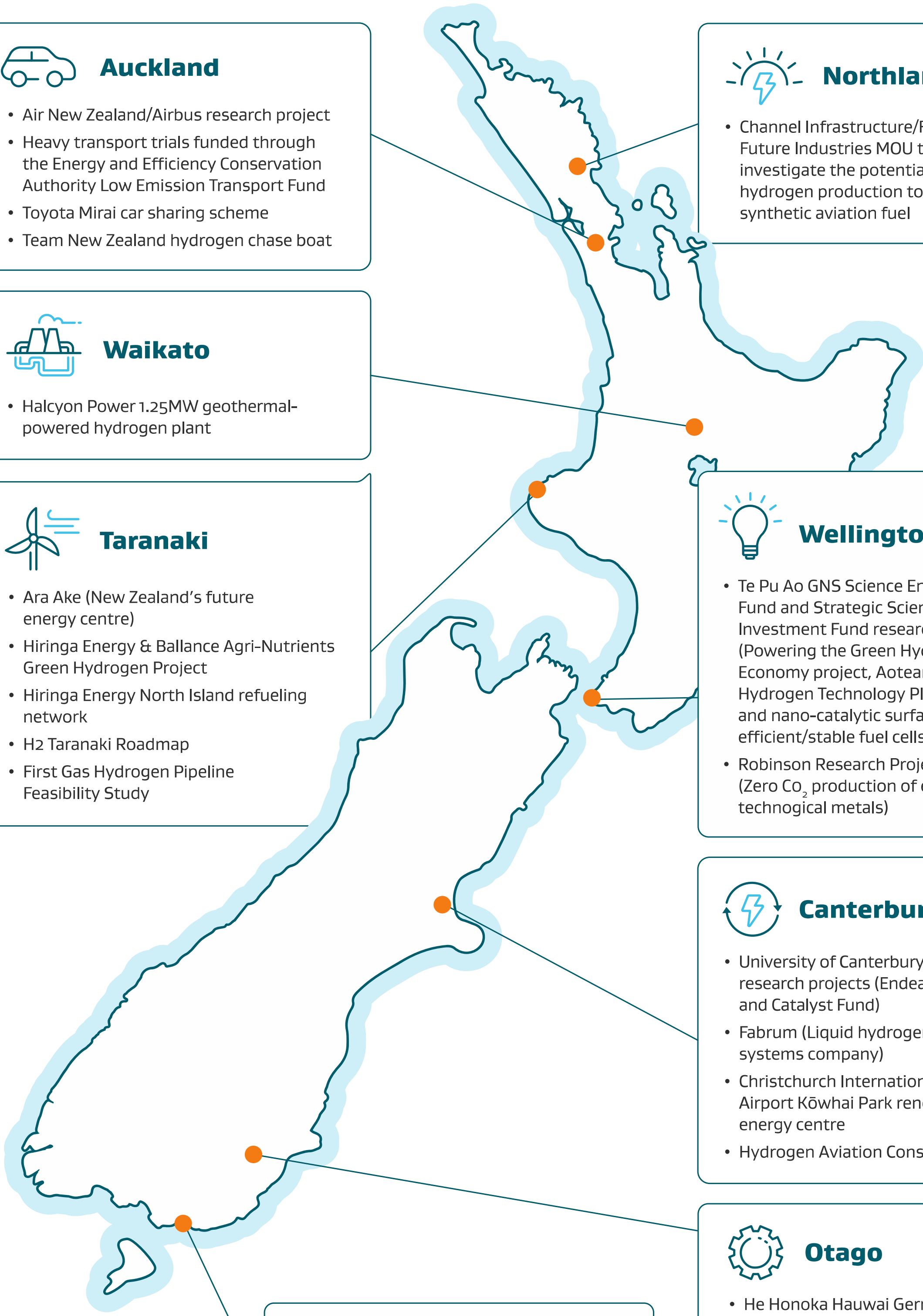
- Large scale production is being explored through the Southern Green Hydrogen Initiative in Southland and a planned green hydrogen plant for green ammonia for fertiliser and transport fuel in Taranaki. Marsden Point fuel import terminal is being considered for synthetic fuel production using hydrogen. Tuaropaki Trust and Obayashi Corporation have formed a joint venture to construct a green hydrogen plant powered by geothermal energy. This 1.25MW plant began operation in 2021 and is the first green hydrogen production facility in New Zealand.
- Hydrogen heavy vehicles are already on our roads. Taranaki-based company Hiringa Energy is rolling out the first hydrogen refuelling network in the North Island, while Southland-based trucking company HW Richardson is operating dual fuel hydrogen diesel trucks and is planning a refuelling network in the South Island. Fuel cell vehicles are also being tested on our roads in trucking and public transport applications. Toyota has established a Toyota

Mirai car sharing scheme, and Toyota fuel cells are in use in the Team New Zealand hydrogen chase boat.

- Industry is preparing for demonstration and early commercial introduction of zero emissions aviation technologies in New Zealand for the country's extensive short-range domestic network. The two main areas of activity are preparing the necessary infrastructure for zero emissions aviation and bringing aircraft models to market. Air New Zealand is investigating its infrastructure requirements for hydrogen with support from Airbus and Christchurch Airport. Air New Zealand has also joined the Hydrogen in Aviation Consortium with Airbus and Fortescue Future Industries alongside Fabrum, Christchurch International Airport Limited and Hiringa Energy to explore and prepare for the infrastructure requirements of zero emissions aviation using hydrogen. Air New Zealand is also investigating hydrogen aircraft technologies in its partnerships with Cranfield Aerospace Solutions and Airbus. Channel Infrastructure and Fortescue Future Industries are leading investigation into sustainable aviation fuel production using hydrogen in the North Island.
- New Zealand is playing a leading role in a range of local and international research and development projects, including exploring the use of hydrogen in steel production, investigating efficient catalysts for fuel cells and electrolysers, and more stable storage of hydrogen.

Diagram 3: Snapshot of hydrogen-related activities in New Zealand. Source: MBIE

Selected hydrogen projects in New Zealand



Auckland

- Air New Zealand/Airbus research project
- Heavy transport trials funded through the Energy and Efficiency Conservation Authority Low Emission Transport Fund
- Toyota Mirai car sharing scheme
- Team New Zealand hydrogen chase boat

Northland

- Channel Infrastructure/Fortescue Future Industries MOU to investigate the potential for hydrogen production to produce synthetic aviation fuel

Waikato

- Halcyon Power 1.25MW geothermal-powered hydrogen plant

Taranaki

- Ara Ake (New Zealand's future energy centre)
- Hiringa Energy & Ballance Agri-Nutrients Green Hydrogen Project
- Hiringa Energy North Island refueling network
- H2 Taranaki Roadmap
- First Gas Hydrogen Pipeline Feasibility Study

Wellington

- Te Pu Ao GNS Science Endeavour Fund and Strategic Science Investment Fund research projects (Powering the Green Hydrogen Economy project, Aotearoa Green Hydrogen Technology Platform, and nano-catalytic surfaces for efficient/stable fuel cells)
- Robinson Research Project (Zero Co_2 production of essential technogical metals)

Canterbury

- University of Canterbury hydrogen research projects (Endeavour Fund and Catalyst Fund)
- Fabrum (Liquid hydrogen systems company)
- Christchurch International Airport Kōwhai Park renewable energy centre
- Hydrogen Aviation Consortium

Otago

- He Honoka Hauwai German New Zealand Green Hydrogen Research Centre (University of Otago)
- Catalyst Fund: Safe, low-cost, hydrogen storage materials from New Zealand resources

Southland

- Southern Green Hydrogen project
- HW Richardson dual fuel trucking project

Many of the projects outlined above have involved government co-investment. The Government has supported the development of a hydrogen sector for a number of years, including through:

- providing strategic direction by producing the 2019 Vision for Hydrogen in New Zealand paper and has sought to further our understanding of future supply and demand for hydrogen in New Zealand. This work identified the opportunity for New Zealand to benefit from green hydrogen using electrolysis and renewable electricity.
- cooperating internationally, including through international forums like the Clean Energy Ministerial, Asia-Pacific Economic Forum, and Hydrogen Energy Ministerial Meeting. We are also leveraging our bilateral relationships, including our partnership agreements with Singapore, and with Japan, and the New Zealand-Germany Green Hydrogen research partnership.
- allocating $88 million of funding to support key hydrogen projects. This includes $45.5 million for research and development projects, $7.5 million across a range of trial and demonstration initiatives, and $35 million in capital grants and financing to support key early use cases and infrastructure.

We have received strong support from the sector to develop a clear strategy to guide the development of the sector and outline what contribution it makes to our national goals. The Interim Hydrogen Roadmap has been informed by extensive discussions and workshops with the sector and other organisations with an interest in hydrogen.

Discussion question:

- Are there other issues we should be considering in our assessment of the strategic landscape for hydrogen in New Zealand?

Section 2: The role for hydrogen in New Zealand's energy transition

HYDROGEN HAS A STRATEGIC ROLE TO PLAY IN NEW ZEALAND'S CLEAN ENERGY TRANSITION

As outlined in the previous section, hydrogen has potential to contribute to a range of objectives relating to our energy transition, and more broadly, national priorities and objectives. This includes supporting emissions reduction, creating or supporting economic activity and employment, and contributing to New Zealand's energy security and resilience.

The biggest potential advantages for hydrogen in New Zealand are:

- using green hydrogen in existing industrial processes to decarbonise large and hard-to-abate sources of emissions, such as in fertiliser, steel and chemical production. This has the added benefit that these strategic industries can continue to play a part in a decarbonised New Zealand economy in future.
- use across a range of transport applications where hydrogen appears to have an advantage, such as heavy road transport, aviation and marine transport.

Alongside these potential advantages, we need to carefully consider the role of hydrogen within our broader energy system. Hydrogen production from electrolysis uses significant amounts of electricity and is fundamentally less efficient than using electricity directly where possible. If the electricity market is unable to meet the combined demand of electrification and hydrogen production, this could impact electricity prices and risks slowing uptake of electrification in other areas.

Our findings and analysis for the Interim Hydrogen Roadmap have been informed by this and previous New Zealand specific modelling, international literature and stakeholder engagement.

WE SEE A KEY ROLE FOR HYDROGEN IN NEW ZEALAND IN A NUMBER OF HARD-TO-ABATE AND HARD-TO-ELECTRIFY APPLICATIONS

This section outlines the potential for hydrogen in a range of use cases that we consider are most relevant for New Zealand as we transition our energy system. We are interested to hear if you have evidence we should be considering to inform our view of where hydrogen is most useful.

Industrial feedstocks and 'Power-to-X'

Nearly 100Mt of hydrogen was produced in 2022, most of which was used in industrial processes as a chemical feedstock for processes such as oil refining and synthetic fertiliser production. Hydrogen is a key input into precursor chemicals that make up thousands of products and further refined chemicals. Almost all of this hydrogen is produced from steam methane reformation of fossil gas. This existing demand presents an early opportunity to decarbonise essential activities that already make use of hydrogen and provide scaled demand to help build a wider market for hydrogen and enable newer applications.

Fertiliser/urea

Hydrogen is an input into the production of synthetic fertiliser as it is a key ingredient in the production of ammonia, which is combined with a carbon source to produce urea. Currently, natural gas is used in this process to produce hydrogen and provide a source of carbon, but there are options to use green hydrogen to substantially reduce emissions. In New Zealand, Ballance Agri-Nutrients produces the majority of the fertiliser made in New Zealand. Fertiliser is one of the hard-to-abate sectors in New Zealand.

This sector also underpins our agriculture industry. Agricultural goods are New Zealand's largest export commodity group, accounting for around half of New Zealand exports by value in the year to April 2023.[14] These are critical sectors to New Zealand's economy and balance of trade. In 2019, 607,000 tonnes of urea-based fertiliser was applied to agricultural land, accounting for 36 per cent of fertiliser use.[15] Around one third of the urea used in New Zealand's primary industries is produced in New Zealand, with the remainder imported from overseas.

CASE STUDY: KAPUNI HYDROGEN PRODUCTION FACILITY

The Ballance Plant in Kapuni is New Zealand's only producer of urea, which is used to make synthetic fertiliser. In 2020, the Government invested $19.9 million to support a joint venture between Ballance Agri-Nutrients and Hiringa Energy to develop a green hydrogen production facility to enable the production of lower-carbon urea. The project also includes four onsite wind turbines to supply renewable electricity for the electrolysers, as well as some of the wider plant's electricity needs. Some of this hydrogen production is planned to be used as hydrogen fuel for the Hiringa Energy heavy transport refuelling network.

Ammonia

Ammonia is used in a wide range of industrial processes. It is produced by combining hydrogen with nitrogen taken from the atmosphere. It is an input in the production of urea but is also used as a refrigerant gas, in water purification and in the production of plastics, textiles, pesticides, dyes and many other chemicals.

Ammonia has attracted considerable interest as a derivative chemical to store, transport and use hydrogen. Ammonia's properties can help to overcome some of the challenges that arise from hydrogen's low density at atmospheric pressure and other challenges to its containment. It is liquid at ambient temperatures and its current use and transportation as an industrial chemical has advantages from established knowledge and infrastructure.

Ammonia is seeing interest in a range of applications outside of its established industrial uses, including as a potential marine bunkering fuel and as a fuel for power generation to replace coal and gas fired generation in modified existing or new plants. There appears to be limited use for ammonia-based power generation in New Zealand at present but is of key interest to countries in the Asia-Pacific looking to import hydrogen in the form of ammonia. Ammonia may form part of a future export market base for hydrogen.

While there is promise in this area, ammonia is also a highly hazardous substance that needs to be treated carefully. Combusting ammonia also produces nitrogen oxide (NOx), a highly potent

---

[14] Stats NZ (2023). *Overseas merchandise trade: April 2023*. https://www.stats.govt.nz/information-releases/overseas-merchandise-trade-april-2023/

[15] Stats NZ (2021). *Fertilisers – nitrogen and phosphorus*. https://www.stats.govt.nz/indicators/fertilisers-nitrogen-and-phosphorus

greenhouse gas. Some level of capturing technology is likely to be needed if ammonia is used in this way.

Methanol

Methanol is an ingredient in thousands of everyday chemicals and materials, including plastics, paints, car parts and construction materials. It can also be used as a clean burning fuel for transport, and in fuel cells, boilers and stoves. It is produced by combining hydrogen and carbon and is most commonly produced using natural gas.

The Methanex plant in Taranaki is New Zealand's only producer of methanol. The plant uses around 40 per cent of the country's natural gas supply for methanol production, which could be substituted for green hydrogen to reduce emissions. It produces approximately 2.4Mt of methanol per annum, all of which is currently exported.

Alongside its established industrial uses, methanol is attracting interest as a low-carbon marine bunkering fuel for heavy shipping, and as a derivative carrier to allow hydrogen to be more easily transported by sea.

Steel production

Steel production is an emissions-intensive process, contributing to approximately 2,600Mt of emissions globally in 2020.[16] New Zealand has one steel production plant operated by NZ Steel at Glenbrook near Auckland, which produces approximately 650,000 tonnes of steel per annum.

Hydrogen is being explored as a way to produce low-carbon steel by replacing parts of the iron reduction process where iron ore is reduced to iron for smelting, or in the smelting process as a source of high temperature process heat. However, production methods differ depending on the source of iron. Steel produced at Glenbrook is primarily made from iron sands, and a unique production method was developed in the 1960s to enable the use of this local resource.

In May 2023, the Government and NZ Steel announced that they are co-investing in an electric arc furnace to replace the existing steelmaking furnace and two of the four coal-fuelled kilns. With this investment, NZ Steel plans to reduce its steel production from iron sands and increase its production from scrap steel recycling, producing at least 50 per cent of its steel from scrap metal before 2030. This project is New Zealand's single-largest decarbonisation project.

CASE STUDY: ZERO CO_2 PRODUCTION OF ESSENTIAL TECHNOLOGICAL METALS (INCLUDING HYDROGEN)

In 2019, the Government partnered with the Robinson Research Institute at Victoria University of Wellington to support a project to develop entirely new process technologies (including hydrogen-based technology) to eliminate CO_2 from the production of iron, vanadium, and steel in New Zealand. The Institute has worked closely with NZ Steel to develop a pilot fluidised bed reactor to use hydrogen in the iron reduction process using domestically sourced iron sands.

---

[16] World Steel Association (2023). *Policy Paper: Climate Change and the Production of Iron and Steel*. https://worldsteel.org/publications/policy-papers/climate-change-policy-paper/

Process heat

Hydrogen can be combusted directly or blended with other energy sources like fossil gas to produce heat and is being explored as a potential replacement to fossil gas and coal for this use. Electricity is generally seen as the most viable replacement of fossil gas in applications under 300 degrees Celsius. Biogas may also play a role in low-to-medium temperature process heat. Hydrogen could play a role in higher temperature process heat applications above 300 degrees Celsius, although electricity is increasingly being seen as an option for some high temperature applications too.

HEAVY AND SPECIALTY TRANSPORT

Hydrogen may have particular advantages in some road transport applications. In the majority of cases, including most of the light transport fleet, New Zealand will decarbonise its transport fleet through electrification. However, there may be roles in parts of the vehicle fleet for hydrogen vehicles, particularly in very heavy transport and in specialty applications.

Heavy land transport

More than 90 per cent of New Zealand's freight by volume is transported by road. By 2035, we expect 20 per cent more freight will need to be moved, but we will also need to reduce our freight emissions by 35 per cent (compared to 2019 levels) as part of our transport emissions targets set out in the Emissions Reduction Plan.[17] Hydrogen has attracted interest in heavy road transport due to its potential for lower vehicle and fuel weight (meaning more cargo capacity), short refuelling times, long ranges and ability to operate in wide temperature ranges.

In the short to medium-term, hydrogen blending is an option to materially reduce emissions in the heavy road freight transport fleet. This is where hydrogen is injected into the combustion cycle of a modified diesel engine. The level of emissions reduced through hydrogen blending is proportional to the amount of hydrogen used in the process. Real world projects are aiming for 30-40 per cent hydrogen blending, while experimental settings have successfully blended up to 80 per cent hydrogen.

Hydrogen blending carries a number of potential advantages as a transitional technology in the early roll out of hydrogen use and infrastructure. Blending kits can be fitted to existing vehicles, giving the potential to achieve emissions reductions among trucks already on the road. In an early hydrogen market where hydrogen supply may not be readily available in certain areas, dual-fuel vehicles can revert to running on lower proportions of hydrogen or 100 per cent diesel, providing optionality as hydrogen infrastructure rolls out. This could potentially provide similar advantages to a hydrogen rollout, as hybrid battery-electric vehicles did ahead of full battery electric vehicles entering widespread adoption

---

[17] Ministry of Transport (2014). *National Freight Demand Study*. https://www.transport.govt.nz/assets/Uploads/Report/National-Freight-Demand-Study-Mar-2014.pdf

CASE STUDY: HW RICHARDSON DUAL-FUEL BLENDING TRIAL

The Government has co-invested with HW Richardson Group to purchase six hydrogen conversion kits and install them on six of their diesel trucks, to refuel out of the Gore refuelling site. The company will convert and operate an additional two vehicles at their own cost. The initiative will also produce valuable data on the performance of the dual-fuel vehicles in New Zealand conditions.

Manufacturers are starting to produce fuel cell trucks, which have a fully electric drive train powered from a fuel cell using hydrogen gas. Fuel cell trucks have the advantages of electric vehicle motors, such as greater power delivery, but are lighter and are faster to refuel.

While there are advantages, there are also challenges of new infrastructure, higher costs of fuel cell heavy vehicles, and some uncertainty about when these vehicles will become available at scale. For these reasons, it is uncertain how much of New Zealand's future heavy road freight fleet will use hydrogen.

CASE STUDY: HYUNDAI HYDROGEN FUEL CELL TRUCK TRIAL

In 2021, the Government co-invested with Hyundai New Zealand to purchase and deploy a demonstration fleet of five hydrogen fuel cell trucks into New Zealand and enter real world daily logistics operation trials. The first truck has been leased to NZ Post, which was announced on 18 July 2022.

Public transport and coach buses

Hydrogen may also play a role in the public transport fleet, for similar reasons as heavy road freight transport. Coach buses could also make use of hydrogen vehicles in key sectors such as tourism. The Government is working with the tourism sector to consider decarbonisation options as part of the Tourism Industry Transformation Plan.

CASE STUDY: GLOBAL BUS VENTURES AUCKLAND TRANSPORT HYDROGEN BUS

In 2021, the Government co-invested with Ports of Auckland Ltd and Auckland Transport to trial a hydrogen fuel cell electric bus. The bus was manufactured in Christchurch by Global Bus Ventures Ltd.

Specialty and auxiliary vehicles

There are a range of specialty and auxiliary vehicles, critical to national industries, that due to operational requirements may prove more expensive, difficult or impractical to electrify. There may be a role for hydrogen vehicles in key industries such as the primary sector, mining, construction and in remote and off-road applications.

While the majority of light transport is likely to be electrified, fuel cell light vehicles could meet some of the demand for transport applications that may not be suitable for electrification, including parts of the public sector fleet.

CASE STUDY: PUBLIC SECTOR FLEET DECARBONISATION TARGETS AND PLANS

In December 2020, the Government established the Carbon Neutral Government Programme. The Programme seeks to accelerate the reduction of emissions within the public sector and show leadership by demonstrating what is possible to other sectors in the New Zealand economy.

The Programme prioritises reducing emissions in the Government's light vehicle fleet, by requiring agencies to optimise their fleets with the aim of reducing fleet size and increasing purchase of battery electric (or plug-in hybrid where needed). Mandated agencies must prepare a fleet transition plan and update it each year, setting out how they will meet these requirements over time.

Hydrogen fuel cell vehicles are not currently part of the government light vehicle fleet work programme, as technological and infrastructure solutions for New Zealand are still emerging. However, the scope of the Programme could extend to include the use of alternative transport technologies such as fuel cell electric vehicles in the future. Hydrogen fuel cell vehicles could play a role in future use cases where there are not yet suitable electric alternatives, such as emergency response vehicles or vehicles in remote locations.

There may be other off-road applications which would benefit from using hydrogen where operational requirements make electrification unsuitable. For instance, the need for continuous operation or operation in areas with poor access to the electricity network may justify the additional costs. Off-road uses of liquid vehicle fuels accounted for approximately 6.6 per cent of New Zealand's total consumer energy use in 2019,[18] around two thirds of which (1,065 million litres) was diesel fuel.[19] This includes vehicles like forklifts, construction machinery, mining vehicles, farm equipment and recreational vehicles. There are currently limited offerings for hydrogen versions of these types of vehicles, but there could be a market for them in future.

Marine

As with land transport, it is likely that many smaller vessels will be electrified, with a role for hydrogen where the need for longer range or continuous operation justifies the additional costs of hydrogen. There are a number of projects in New Zealand that have employed hydrogen fuel cells in marine applications or are considering doing so. In 2022, Team New Zealand worked with Toyota to

---

[18] MBIE (2020). *Energy in New Zealand 2020*. https://www.mbie.govt.nz/dmsdocument/11679-energy-in-new-zealand-2020

[19] EECA (2021). *Off-road liquid fuel insights*. https://www.eeca.govt.nz/assets/EECA-Resources/Research-papers-guides/Off-road-liquid-fuel-insights.pdf

build a foiling chase boat powered by hydrogen fuel cells. Auckland ferry operator Fullers360 is investigating hydrogen-capable diesel-electric hybrid vessels for its ferry fleet.

New Zealand is situated at the end of a long global supply chain for sea freight, but it is essential as an island nation to our international trade and exports. Around 60 per cent of our economic activity takes place through international trade.[20] In heavier marine transport, including sea freight, hydrogen could offer a low-carbon marine bunkering fuel, in the form of either methanol or ammonia. Some shipping companies have announced plans to begin deploying new vessels powered by these fuels, including Maersk, which has a 16 per cent market share of sea freight in the Oceania region.

Other heavy marine vessels such as cruise ships are also starting to signal plans to utilise hydrogen. Along with using hydrogen-derived bunkering fuel, some operators have announced plans to use hydrogen fuel cells to generate electricity on board when at port, in order to avoid the need to run emitting engines for power when docked.

While limited marine bunkering currently takes place in New Zealand, alternative fuels may require different fuelling arrangements that could see a greater role in future for locally produced marine fuels.

CASE STUDY: MARINE FREIGHT DECARBONISATION

New Zealand is party to a number of international agreements that aim to address emissions from international marine freight, including Annex VI of the International Convention for the Prevention of Pollution from Ships and the Clydebank declaration to establish green shipping corridors.

International shipping lines are increasingly exploring methanol as a scalable pathway to significant emission reductions. Although the use of methanol as a marine fuel is still relatively novel, methanol engine technology is a proven concept, with the world's first methanol powered commercial ship operating since 2015.[21] As of May 2023, there are 77 methanol powered container ships on order[22] and this is anticipated to grow. Later in 2023, Maersk will take delivery of the world's first green methanol powered container ship. Other options for future marine fuels include ammonia, hydrogen, and biomethane.

Aviation

As one of the most geographically remote countries in the world, New Zealand heavily relies on aviation to connect with the international community. While less than 1 per cent of international trade by volume is carried by air, it accounts for around 16 per cent of exports and 22 per cent of imports by value.[23] Decarbonising aviation is critical to nationally important sectors such as tourism.

---

[20] Ministry of Transport (2023). *Freight and Supply Chain Strategy*. https://www.transport.govt.nz/area-of-interest/freight-and-logistics/new-zealand-freight-and-supply-chain-strategy/

[21] Offshore Energy (2023). *World's 1st methanol-powered commercial ship celebrates 5th birthday* https://www.offshore-energy.biz/worlds-1st-methanol-powered-commercial-ship-celebrates-5th-.birthday/

[22] Alphaliner monthly monitor (May 2023).

[23] Ibid

Aviation presents a significant potential source of demand for hydrogen in the long-term. New Zealand is an ideal network for hydrogen aircraft (hydrogen fuel cell or hydrogen propulsion), with our busy short-range domestic routes and highly renewable electricity network. When combined with electric aircraft for very short-range flights, the possibility of early commercial deployment of low emissions aircraft and prior investment in associated infrastructure, it presents a significant opportunity for emission reductions of a hard to abate sector in New Zealand. It could also act as a showcase to other parts of the world to benefit our reputation for tourism and trade.

New aircraft designs and other associated technology to support refuelling are needed for hydrogen-powered aircraft to become a reality, which are not expected to enter commercial production until the 2030s. Battery-electric planes are already in operation today but are currently considered unlikely to be used outside of shorter-haul flights due to limitations from battery weight and the reduced cargo or passenger capacity due to the space batteries require.

There are several ways hydrogen could be deployed in aviation. Hydrogen is an input to electro-synthetic fuels and could be used to produce sustainable aviation fuel (SAFs). SAFs are drop-in fuels that can be used in existing aircraft and infrastructure, and in blends of up to 50 per cent concentration with fossil-based jet fuel. Electro-synthetic fuels also require a carbon source alongside a source of hydrogen. Most SAFs in use today are biofuels derived from organic material. Depending on future technology development, SAFs may remain the best option for carbon-neutral long-haul air transport.

CASE STUDY: SUSTAINABLE AVIATION FUEL PRODUCTION IN NEW ZEALAND

There is emerging activity and interest in producing hydrogen-based sustainable aviation fuels in New Zealand.

In 2022, Fortescue Future Industries and Channel Infrastructure, owners of the Marsden Point fuel import facility, entered into a Memorandum of Understanding to explore the feasibility of green hydrogen production at the site for electro-synthetic aviation fuel. This site has the advantage of a connecting fuel pipeline from Marsden Point that currently supplies aviation fuel to Auckland Airport.

In July 2023, the companies announced they are progressing to the pre-feasibility stage, which will include more detailed engineering and design studies and developing further detail on the economic viability of the project. This is being supported by government through the Energy Efficiency and Conservation Authority.

In addition, the Government recently announced it is co-investing with Air New Zealand in two studies to assess the feasibility of establishing and operating a sustainable aviation fuel production facility in New Zealand.

Future direct uses of hydrogen in aviation could include direct combustion of hydrogen in a turbine engine, or the use of fuel cells to power electric aircraft motors. Early trials of hydrogen combustion in a jet engine in flight are starting to take place. The use of fuel cells to power aircraft is also attracting interest. Medium-ranged hydrogen-powered aircraft are likely to use liquified hydrogen, due to the need for high energy density within space constraints. However, liquified hydrogen aircraft are currently estimated to have about half the range of a jet fuel equivalent due to space limitations for aircraft fuel tanks. Direct hydrogen combustion or traditional jet aircraft fuelled by SAFs may fuel long-haul aircraft.

In addition to early commercial deployment, there is interest in research and development of zero emissions aircraft in New Zealand, in part because of our highly renewable existing electricity network. Subject to securing investment and funding, there are innovators that are actively exploring the feasibility of conducting trial flights in New Zealand. Such trials would not only increase the investment in research and development in New Zealand, but also have the potential to bring forward commercial deployment with associated emission reductions.

CASE STUDY: COMMERCIALISATION OF ZERO-EMISSIONS AVIATION IN NEW ZEALAND

New Zealand is increasingly viewed as a world-leading location for early-stage commercialisation of zero-emissions aviation technology.

In 2023, a Hydrogen Consortium was formed between Airbus, Air New Zealand, Fabrum, Christchurch Airport, Fortescue Future Industries, and Hiringa Energy. The Consortium aims to identify pathways to viable and sustainable commercialisation of zero emission aircraft technologies in New Zealand. They aim to produce a study to understand the challenges of hydrogen supply, infrastructure and fuelling for aviation, to support the development of a hydrogen aviation ecosystem in New Zealand. The Consortium builds on a 2021 agreement between Airbus and Air New Zealand to cooperate on a joint research project to better understand the opportunities and challenges of flying zero-emission hydrogen aircraft in New Zealand.

Rail

Hydrogen is being explored internationally for rail applications, as a replacement for diesel units across both passenger and freight transport. There may be some opportunity for the use of hydrogen in rail in New Zealand in the future. Around 14 per cent of New Zealand’s rail network is currently capable of running an electric train, and there is no electrification of the rail network in the South Island.[24] Almost two thirds of the North Island main trunk railway is electrified, which mostly carries freight services. Commuter passenger rail services operate in Wellington and Auckland and the majority of these services are electrified.

[24] WSP (undated). *Delivering Rail Decarbonisation to New Zealand.* https://www.wsp.com/-/media/insights/new-zealand/documents/cs2021_952_decarbonsing-rail-whitepaper.pdf

Rail transport makes up a very small proportion of New Zealand's transport emissions. Emissions from rail from the use of liquid fuels was 131ktin 2021[25], or around one per cent of total transport emissions, and carries around 13 per cent of New Zealand's freight by weight.[26]

These factors mean that the opportunity for hydrogen in rail is relatively limited compared to other use cases, and will largely depend on:

- The extent to which more of the existing rail network is electrified over time. Budget 2023 included $369.2 million over four years for the Rail Network Improvement Programme, which includes funding for a detailed business case to electrify the remainder of the North Island Main Trunk.
- Replacement plans for existing diesel units, which are very long-lived assets. While there may be some scope for diesel-hydrogen blend retrofitting of existing units, similar to heavy road transport, this technology appears to be less developed for rail.
- The extent to which mode shift to rail takes place as a way to reduce emissions from more intensive modes such as road freight transport, and support other objectives, such as reducing road congestion. This could increase the reliance on diesel-powered units in areas where networks are not electrified.

ELECTRICITY SYSTEM SERVICES AND POWER BACKUP

Electricity system services

New Zealand is expected to see a greater need for fast start peaking generation to provide the necessary electricity supply to meet demand peaks. Demand peaks are expected to become less predictable in a highly renewable electricity system due to a greater prevalence of intermittent solar and wind generation. This means that dispatchable peaking generation will need to be ready, come online at shorter notice and ramp up capacity more quickly. Existing thermal generation used for peaking is expected to be less fit for purpose in this environment. Current thermal peaking generators typically need several hours to start up unless they are already warm from recent operation.

Along with electrolysers acting as demand response, hydrogen could play a role in peaking services, either as a gas used in modified open cycle gas turbine generators, or through fuel cells to provide electricity. One advantage of fuel cells over contemporary batteries is that with sufficient hydrogen fuel they will be able to provide dispatchable generation over a longer time period.

Peaking issues are considered more broadly in our companion discussion document on Electricity Market Measures.

Power backup

Many businesses and critical infrastructure rely on back-up generators when electricity outages occur. Hydrogen storage with fuel cell electricity generators could supplant some existing diesel generators for back-up purposes. This application could hold benefits for power back-up services for critical infrastructure and activities, as well as wider benefits such as significant or large-scale grid disruption in regional and national emergencies, depending on how it could be deployed.

---

[25] Ministry for the Environment (undated). New Zealand's Interactive Emissions Tracker. https://emissionstracker.environment.govt.nz/#NrAMBoEYF12TwCIByBTALo2wBM4eg4xwCcSW0QA

[26] KiwiRail (2022). *KiwiRail Integrated Report 2022.* https://www.kiwirail.co.nz/assets/Uploads/documents/Annual-reports/2022/KiwiRail-Integrated-Report-2022.pdf

EXPORT

An export market for green hydrogen is in its infancy, but there is significant global interest based on global demand estimates noted earlier in this document. Export is expected to involve liquid hydrogen, or conversion to a derivative carrier such as ammonia for economic and practical transportation.

The Asia-Pacific region has potential as a major hydrogen trading area. Japan and South Korea have adopted hydrogen import strategies to fuel their domestic decarbonisation. Japan recently increased its target for total hydrogen supply to 12Mt per year by 2040 and has previously set import targets of 5-10Mt per year by 2050. South Korea has set targets for 5.3Mt of hydrogen consumption by 2040.

Export potential in New Zealand will depend on commercial viability and competitiveness with other exporting countries, particularly in a global environment characterised by increased price competition underpinned by significant industry policy intervention. The United States of America has set a target to produce green hydrogen for $1 USD per kilogram by 2031 and has committed billions of dollars in production and electrolyser manufacturing tax credits to achieve this. Asian importers could also be served by low-cost exporters like Chile, Australia and China. Key to this production cost will also be the availability and price of renewable electricity, as outlined earlier in this document.

HYDROGEN IN THE RETICULATED GAS NETWORK

There may be future potential for hydrogen distribution and use through the existing reticulated fossil gas network. Transporting 100 per cent concentration hydrogen by pipeline is attractive as it is the lowest cost method of transmission compared to other methods such as compressed or liquified truck transportation and has the potential for the reuse of existing gas infrastructure. Hydrogen also has the potential to be blended with fossil gas in concentrations of up to around 20 per cent while being compatible existing piping, valves, fittings and appliances. Hydrogen blending is being explored internationally and in New Zealand through pilot schemes for real world testing.

We do not see an explicit role for hydrogen in the reticulated network until at least the mid-2030s. This is because the main alternative, biomethane, is expected to be cheaper and more readily compatible with the existing network in the medium-term. Analysis being undertaken as part of the work on the forthcoming Gas Transition Plan also found that hydrogen for blending in the reticulated network is unlikely to be economic compared to the cost of continuing 100 per cent fossil gas use and incurring increasing emissions charges over time.

This does not prevent companies from investigating and progressing their own initiatives, and there is work underway both within government and the private sector to prepare for the possibility of hydrogen blending in the reticulated network. Standards New Zealand has recently announced it is starting work to review NZS 5442: 2008, which is the New Zealand specification for reticulated gas. The work will consider changes to update the standard to be appropriate for biogas and hydrogen blends of fossil-based methane gas in the reticulated network.

The future of the reticulated gas network is further considered the Gas Transition Plan Issues Paper, which was published alongside this document.

CASE STUDY: FIRST GAS HYDROGEN PIPELINE TRIAL

In 2019, the Government co-funded phase one of First Gas' hydrogen pipeline project to investigate the feasibility of blending hydrogen.

The first phase, the *Hydrogen Network Trial* report, was released in March 2021 and set out how hydrogen could be used in the network, how the gas grid could be converted, the role of hydrogen in decarbonisation, and selection of the best location for a closed network pilot. The report also examined the technical feasibility of converting the existing gas grid, including physical adaptations and gas metering, and the scale and capability of the necessary hydrogen support economy. First Gas is planning to start a blending trial this year in a gas distribution network.

DISCUSSION QUESTIONS

- Do you agree with our assessment of the most viable use cases of hydrogen in New Zealand's energy transition?
- Do you support some of these uses more than others?
- What other factors should we be considering when assessing the right roles for hydrogen in New Zealand's energy transition?

THE PATHWAY TO 2050

We commissioned Ernst and Young NZ Ltd to undertake scenario modelling to understand how different levels and types of uses for hydrogen might affect our core objectives of reducing emissions, supporting economic development and ensuring energy system security and resilience. This has supported our emerging thinking on the most likely roles for hydrogen in New Zealand's energy transition and informed our thinking on its impacts on the electricity market. The report summarising these findings in detail has been published on the MBIE website.

There is a high level of uncertainty in modelling a future market where technologies and supply chains are not yet mature. These scenarios represent possibilities rather than predictions of the future and are intended to provide a sense of scale depending on the different ways hydrogen deployment could progress. The scenarios assume a given level of demand for hydrogen in 2050 for each use case informed by best available information and apply an s-curve to model the scale-up in demand over time.

The scenarios represent a range of possible hydrogen futures:

- A base case, where hydrogen deployment is largely limited to near-term likely use cases for domestic decarbonisation such as in industrial feedstocks and transport applications that may not be fully met by direct electrification including some heavy transport, marine and aviation.

- An accelerated case, to account for changes in the pace or breadth of uptake in the use cases in the base case.
- A scenario where hydrogen plays a major role in energy security and resilience, including greater replacement of fuel imports and a higher proportion of hydrogen demand being met by smaller scale and more distributed production of hydrogen.
- A scenario where a large-scale export market for hydrogen in the form of ammonia and/or methanol develops. This assumes three large scale export orientated plants of 600MW in electrolyser capacity, similar in size to the facility being considered through the Southern Green Hydrogen Project in Southland.
- A maximal scenario, where in addition to the above scenarios, hydrogen is used extensively in the production of higher value green chemicals or other products, such as steel and other manufactured products that are more easily exportable. In addition to hydrogen production for export, additional growth in hydrogen supply and demand is assumed to increase alongside GDP growth to reflect growth in the production of steel and green chemicals.

Under these scenarios, hydrogen demand could be between 180,000 and 600,000 tonnes per year by 2035, rising to between 560,000 and 1.21Mt per year by 2050. This is slightly higher than demand volumes due to assumed conversion losses in storage and transportation. This would require between 1.5GW and 6GW of electrolyser capacity in 2035, and 4.5GW and 9.8GW in 2050.

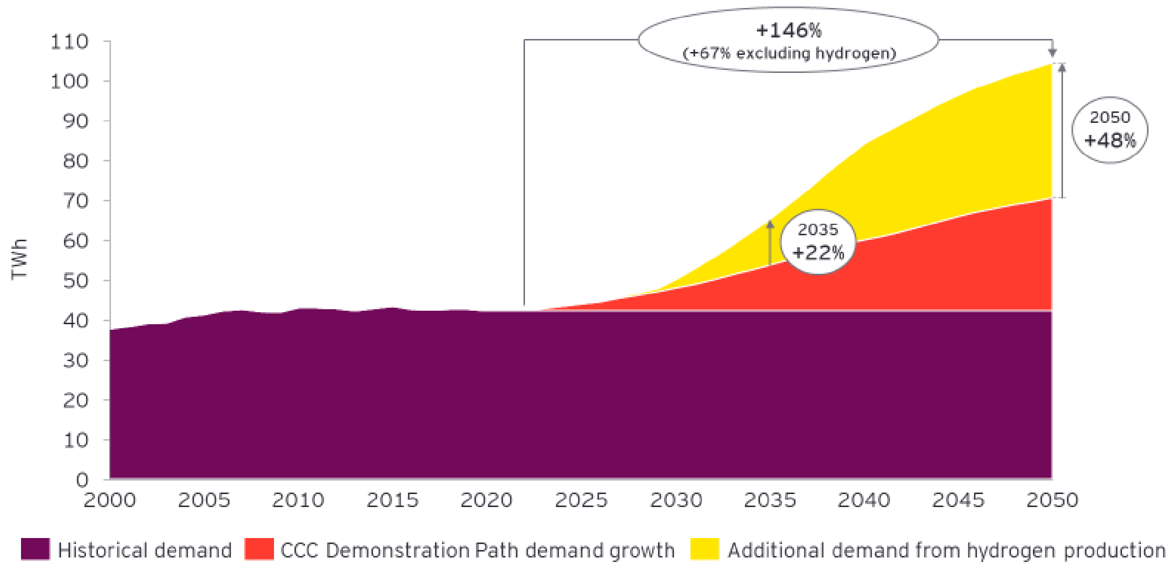
In our base case scenario, the highest source of demand would be for industrial feedstocks. This source is assumed to scale first, reaching 158,000 tonnes of demand in 2035 or over 85 per cent of hydrogen demand. This would continue to increase out to 2050 but make up a smaller proportion of demand in 2050 as other demand sources ramp up in the 2030s and 2040s, namely transport and high temperature process heat.

Maximal and export scenarios could represent over 1.2 million tonnes of total demand per annum in 2050. This would be nearly three times the demand compared to the base case in 2035, and more than double in 2050.

Each of the scenarios envisages a mix of larger centralised and smaller decentralised hydrogen production. In a domestic market envisaged by the base case, centralised production would make up two thirds of production in 2035 and be evenly split in 2050. Export orientated scenarios are more heavily weighted to centralised production.

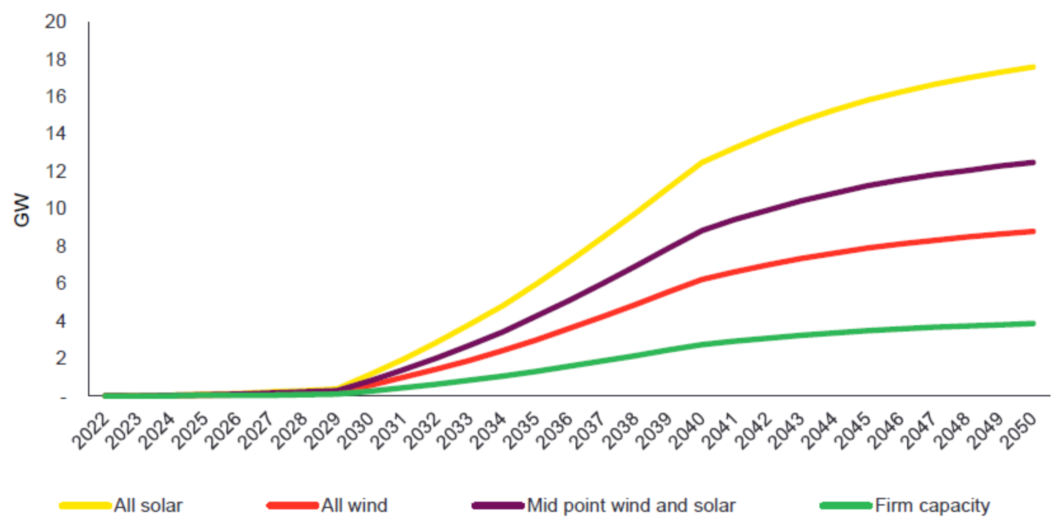
Electricity generation requirements to support this production would be significant and vary greatly depending on the type of generation that is used. The modelling indicated that hydrogen production in our base case could result in 22 per cent more electricity demand in 2035 and 48 per cent in 2050 under our base case scenario, compared to the Climate Change Commission's Demonstration Path. Meeting higher peak demand in this scenario using a mix of wind and solar would require an additional 4.3GW of generation capacity in 2035 and 12.5GW in 2050 from the Climate Change Commission Demonstration Path.

Diagram 4: Comparison of hydrogen induced electricity demand with the Climate Change Commission's electricity demand growth. Source: Ernst & Young



The total amount of generation required could be lower or higher than these estimates. This would depend on whether producers are able to utilise excess capacity in the existing electricity network and the additional supply that would need to be built for electrification. This would lower the total amount of generation required. Conversely, generation needed could be higher depending on where it is deployed. Concentrated solar and wind generation will be more highly subject to the same fluctuations in wind speeds or sunlight that is more distributed across different areas.

Diagram 5: Electricity generation build out breakdown for base case (2023-2050, GW). Source: Ernst & Young



Water is the other important input to hydrogen production. Requirements were estimated at 2.1 billion litres per annum in 2035 and 6.5 billion litres in 2050 for the base case. The value-add and export scenarios would require 150 per cent to 250 cent of this amount in 2050. In both cases, these are relatively small volumes compared to national water usage for agriculture, residential and commercial uses and would equate to less than 1 per cent of our total current water use from these sources. However, it is likely this would still constitute very large volumes at a local level in areas where there is already pressure on water supplies. Hydrogen production will require careful consideration of local water availability depending on where production emerges.

Ultimately, whether these volumes of hydrogen production are realistic and commercially achievable depends on whether producers are able to efficiently organise to deliver hydrogen at a cost that potential users will accept. Actions for the Government to support this are outlined in the next section. The key factors that will determine whether these scenarios are achievable commercially are:

- **Electricity prices:** Electricity prices are estimated to comprise around half of the production costs for a hydrogen plant in 2022, increasing to around 80 per cent over time as other costs (such as capital costs) reduce. New Zealand's electricity prices averaged $133NZD/MWh between 2018-2023, with significant variation across time, generation type, and region. Electricity prices are forecast to fall as new and cheaper renewable generation is brought online to service electrification, but hydrogen production and other major sources of demand like data centres could mitigate or outweigh these price reductions as discussed in the next section. To reach a production price of $2NZD per kilogram of hydrogen in 2050, these estimates found an electricity price of $55NZD/MWh would be needed.
- **Capital costs:** Capital costs were estimated to comprise around 24 per cent of the levelised cost of green hydrogen in 2022. These are assumed in our modelling to drop over time from $1,000USD per kilowatt of electrolyser capacity in 2022 to $200USD per kilowatt in 2050. These capital cost curves are not guaranteed and largely depend on investments made in larger economies and the pace of innovation.
- **Optimising production, transport, storage, and conversion costs:** Optimisation of transport, storage, and conversion costs is essential for viability and energy efficiency. Conversion and transport costs are estimated to add between 30 to 80 per cent to the cost of green hydrogen in 2035, and 16 to 80 per cent in 2050, depending on the method used and level of transformation required. Early production is likely to benefit from being based close to use cases through onsite production or collating activities in hydrogen hubs/valleys, minimising the space and logistics required for storage. As scale emerges, longer-distance transport may become more viable.
- **Available workforce:** Hydrogen deployment will require skilled workers to construct, operate and maintain infrastructure and equipment.
- **Demand:** Producers need a clear demand trajectory and established market mechanisms for delivering their products to market. This could include links to export markets.
- **Value stacking:** Developers to date have expressed interest in building renewable electricity generation alongside hydrogen production or securing long-term offtake agreements from electricity suppliers who commit to building additional generation to meet this demand. These combined systems are likely to optimise their revenues from producing hydrogen, selling renewables to the grid, and offering demand response services. When electricity spot prices are high, they may opt to turn off their electrolysers, and vice versa. With current capital costs, an electrolyser needs to be used at a capacity factor of 80 to 90 per cent for the business case to be economically viable, but in future this capacity factor may fall, meaning producers may need a lower ratio of renewable energy to electrolysers to make these systems economic.

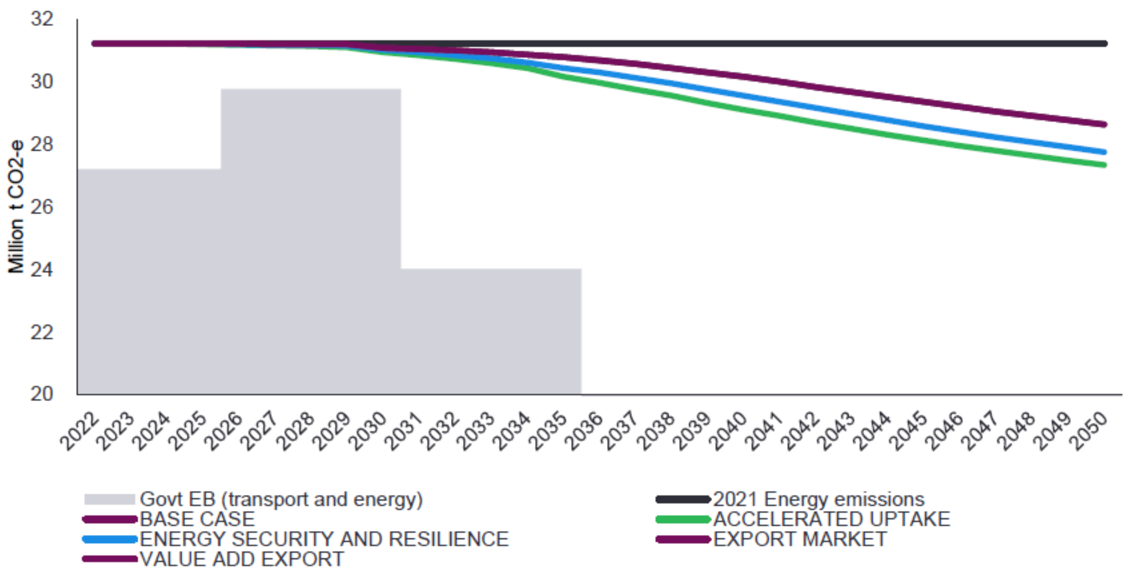
DISCUSSION QUESTIONS

- Do you agree with this assessment of the potential for hydrogen supply and demand in New Zealand?
- Do you agree with the key factors we have set out that are likely to determine how hydrogen deployment could play out?
- What do you think needs to happen to address these factors?
- Do you have any evidence to help us build a clearer picture?

HOW HYDROGEN COULD CONTRIBUTE TO OUR OBJECTIVES

If demand for hydrogen played out according to our scenarios, total emissions reduction would be between 0.44Mt Co_2-e and 0.78Mt Co_2-e in 2035 and 2.58Mt to 3.88Mt Co_2-e in 2050, which would represent a reduction in emissions equivalent to 1.4 to 3.4 per cent of New Zealand's 2021 energy emissions in 2035 and 8.3 to 12.4 per cent in 2050. As scale is expected to emerge from the 2030s, hydrogen is unlikely to make significant contributions to the first two emissions budgets but could support future emissions budgets. Emissions reductions would start to appear in emissions budget 3 in most scenarios. Emissions reduction in 2035 would equate to 0.91 per cent of the total emissions budget for that year.[27] Increased uptake in the accelerated uptake scenario would see the highest emissions reduction in 2050 of 3.88Mt Co_2-e per annum.

Diagram 6: Comparison of total emissions reduction by scenario (2023-2050, MtCO2-e). Source: Ernst & Young NZ



The emissions reductions estimated cover emissions from energy only, primarily in transport and use as process heat, and do not include emissions abated from replacing fossil-derived industrial feedstocks with green hydrogen. These uses make up a significant proportion of potential hydrogen and electricity demand from the 2030s onwards. Emissions abated from these uses for feedstock

[27] The annual average budget for the third emissions budget is 48Mt CO2e

would be material, as industrial process and product use emissions accounted for 6 per cent of New Zealand's gross emissions in 2021.

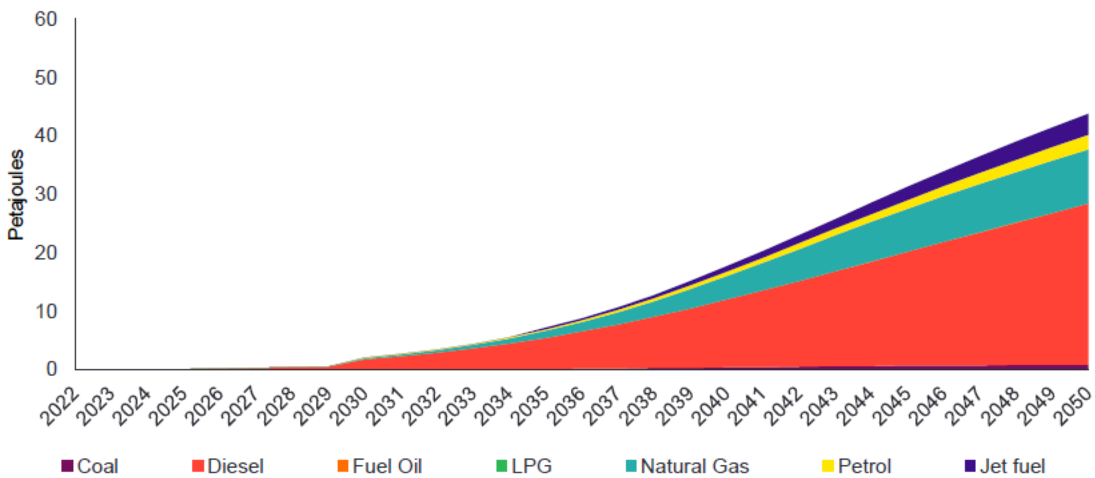
Export of hydrogen could also support global decarbonisation by supporting countries with more limited renewable generation potential to replace emissions-producing fuels and feedstocks with hydrogen, or with derivatives such as ammonia and methanol. These impacts were not modelled as they depend on the destination country and use case for exported hydrogen. Emissions abated in other countries using hydrogen or derivatives would not count towards New Zealand's emission reduction targets under current settings.

Energy security and resilience

Across the scenarios, we have considered the contribution electrolysers could make to the broader energy system through demand response. Based on the installed electrolyser capacity estimated across the scenarios and a capacity factor of between 85 and 90 per cent, the potential demand response capacity was estimated between 1.3 and 5TWh in 2035 and 3.8 and 8.2TWh in 2050.

Each scenario estimates the amount of energy imports that could be displaced if domestically produced hydrogen is used in placed of liquid fossil fuels like diesel. Reducing demand for imported fossil fuels in favour of domestically produced alternatives like hydrogen has the potential to enhance New Zealand's energy independence. In our base case around 7 petajoules of fossil fuels would be displaced in 2035, and 44 petajoules in 2050. The majority of this would be substituting diesel and fossil gas. While nearly all fossil gas used in New Zealand is produced domestically, total liquid fossil fuels displaced between now and 2050 would amount to 132 million litres of diesel, which would be the vast majority of total liquid fossil fuels displaced by hydrogen (83 per cent).

Diagram 7: Base case breakdown of fossil fuel displaced by hydrogen (2023-2050, petajoules). Source: Ernst & Young



Economic outcomes

If demand occurred in line with our base scenario, hydrogen could contribute to value-add economic activity[28] of between $0.9 billion and $3.4 billion per annum in 2035 and $2.3 billion and $5.1 billion in 2050. Employment is heavily driven by capital investment in hydrogen plants. Capex employment peaks in the early 2040s for all scenarios except for accelerated decarbonisation, which peaks slightly earlier in the late 2030s. Jobs supported by operational spending are estimated to grow over time to between 1,900 FTEs in 2035 to nearly 8,000 FTEs in 2050, based on the total value-add economic

[28] The market value of goods and services produced, deducting the cost of goods and services used in production.

activity supported by investment in a hydrogen supply chain. These estimates do not include the potential additional benefit from export income in the scenarios that include this activity.

Our modelling to date did not explicitly consider where in New Zealand hydrogen deployment would occur. Whether these scenarios take place would depend heavily on spatially dependent factors such as the availability of inputs such as electricity and water, co-location with specific activities and infrastructure such as industrial plants, ports and airports. However, based on early development and existing hydrogen projects in New Zealand, we expect this to include Auckland, Waikato, Taranaki, Canterbury and Southland. This is something we could consider further in our process to finalise the Hydrogen Roadmap.

DISCUSSION QUESTIONS

- Do you agree with our findings on the potential for hydrogen to contribute to New Zealand’s emissions reduction, energy security and resilience and economic outcomes?
- Do you have any insights we should consider on what is needed to make hydrogen commercially viable?
- Is there any further evidence you think we should be considering?

Section 3: Government position and actions

POLICY OBJECTIVES

The Government's overarching aim is to optimise the potential for hydrogen to contribute to New Zealand's emissions reductions, economic development, and energy sector to the extent compatible with broader electrification goals.

To achieve this overarching aim, we have set the following policy objectives:

- Ensure supply can scale up, including hydrogen production that is matched to electricity and other inputs.
- Enable the safe use of hydrogen and facilitate early projects that enable the sector to develop.
- Bring forward and support early demand for hydrogen, linked to the most viable use cases within New Zealand's energy system, and aligned with other Government priorities including economic development and supporting just transitions for key affected communities.
- Monitor outcomes and progress over time.

WE WANT TO ENSURE HYDROGEN DEPLOYMENT HAPPENS AT PACE WITH THE GENERATION AND TRANSMISSION CAPACITY TO SUPPORT IT

We see a role for the Government to support the development of a domestic sector that can help reduce emissions, alongside other tools like biogas and biomass to preserve options in the future. The scale of hydrogen deployment within our overall mix of energy sources remains uncertain. We expect this picture to become more certain over time as the industry continues to develop.

We plan to better understand how electrification and other green fuels like hydrogen, biogas, biomass, and synthetic fuels could fit together to create a decarbonised energy system that remains affordable, reliable and secure. This will be considered alongside the New Zealand Energy Strategy. The ultimate case for hydrogen will depend on its efficiency and cost-effectiveness relative to other fuels, and the sufficiency of the overall portfolio of options in meeting decarbonisation objectives.

Renewable energy

The key challenge for hydrogen is the significant renewable electricity generation build-out it would require. Hydrogen could underwrite the investment case for significant new renewable electricity generation development because hydrogen plants would likely be developed to overbuild intermittent renewables and sell electricity to the grid. If this were to occur, renewable overbuild, along with electrolysers could provide valuable flexibility in a highly renewable electricity system.

We will need to ensure that sufficient electricity generation and transmission is being consented and built in line with the demand for electricity for hydrogen production. The main point of pressure is likely to be in the 2030s where there is likely to be significant demand from electrification and for hydrogen production according to our estimated scenarios. Te Waihanga, the New Zealand Infrastructure Commission, recently published research indicating that from 2028, consent processing times would need to be 50 per cent quicker than they are projected to be under the

Resource Management Act 1991.[29] The Government is already taking steps to address this through the proposed updated to the National Policy Statement on Renewable Electricity Generation, and there is a strong pipeline of planned additional generation capacity totalling nearly $8bn in investment before 2034.[30]

We plan to explore these considerations in more detail ahead of the final Hydrogen Roadmap, the New Zealand Energy Strategy and our work on electricity market measures.

Export

Export could be a significant driver of the overall size of the hydrogen sector, and its corresponding renewable generation requirements. It could also bring significant benefits like economic development, employment and positioning New Zealand as a world-leader in hydrogen uptake.

Exporting hydrogen also has the potential to more directly link New Zealand's electricity prices to a global commodity market, although the extent to which this could occur is uncertain. Exporting producers may earn revenue through a mixture of domestic and export hydrogen sale, selling renewable electricity to the grid, and demand response contracts. When the electricity spot price is high, producers would be incentivised to turn off their electrolysers and sell electricity to the grid, and vice versa.

Producers could price hydrogen based on an importing nation's next best alternative, and this could influence the price they are willing to sell electricity to the New Zealand market, or the price they are willing to curtail production in times of tight electricity supply. On the other hand, exporters could face strong price competition for hydrogen they sell. For instance, the US has a target to achieve hydrogen prices of $1 USD per kilogram by 2031. Producers are also likely to enter into long-term electricity supply agreements where they are procuring electricity from the grid. This means that fluctuations in international prices for hydrogen would not directly or immediately flow through to wholesale electricity prices.

While we welcome private initiatives that are exploring hydrogen production for export, we do not currently see a case for public financial involvement to support an export market until it is clearer that the necessary additional renewable electricity generation can be consented and built in line with the demand for electricity this would create. We want to ensure the necessary electricity generation and transmission can be consented and built in line with hydrogen production, to avoid compromising decarbonisation in other sectors that will rely on electrification.

We acknowledge that export could play a role in underpinning the commercial viability of hydrogen production in New Zealand by allowing an industry to scale ahead of domestic demand, and we are interested in any evidence we should be considering to inform this judgement. This is also an area we will be considering closely as we finalise the Hydrogen Roadmap.

---

[29] New Zealand Infrastructure Commission Te Waihanga (2023). *Infrastructure Consenting for Climate Targets*. https://www.tewaihanga.govt.nz/policy/reports/infrastructure-consenting-for-climate-targets/

[30] Infometrics (2023). *Scale of Power Generation Projects Grows.* https://www.infometrics.co.nz/article/2023-04-scale-of-power-generation-projects-grows

ACTIONS WE ARE TAKING

As part of the Interim Hydrogen Roadmap, the Government is committing to some immediate actions that will support hydrogen rollout, while also indicating where more exploration of necessary actions needs to be done in collaboration with the hydrogen sector.

The Government has a range of tools and roles to support and influence direction in support of the objectives outlined above as a:

- strategic policy setter
- regulator
- funder and service delivery agent
- major participant/procurer in the economy
- owner and investor in infrastructure
- diplomatic actor on the world stage
- public source of information.

Across all of these roles, the Crown is a Treaty partner with Māori and needs to act in a way that uphold its Te Tiriti o Waitangi commitments.

The Government does not have all the necessary levers, and will not determine the future role for hydrogen in our energy transition, on its own:

- The private sector will need to determine which technology is most efficient for its uses and needs. Private organisations will direct their planning and investments accordingly.
- Iwi and Māori have a key role as Treaty partners and strategic leaders in their rohe. Commercial arms of some iwi are already heavily involved in hydrogen and other energy technologies.
- Consumer preferences will play a role where they decide what solution they think best meets their needs.
- Local and regional councils will need to make planning and consenting decisions that appropriately balance interests in their areas.

To help articulate the Government's efforts and positions, we have identified seven focus areas where we see specific opportunities and challenges in the deployment of hydrogen in New Zealand. Across these areas, we have set out:

- where the Government has already provided support
- where there is existing work to contribute to deployment
- new initiatives and areas where we further work and thinking is required as we develop the final Hydrogen Roadmap.

Governance, oversight and monitoring

Hydrogen is an emerging industry that is already seeing considerable activity in New Zealand. It is expected to draw on significant renewable energy resource to scale up. Getting this right will require a clear vision of where we are collectively heading, and effective coordination mechanisms to enable different parties to work together and monitor progress. We also want to make sure the Hydrogen Roadmap is an enduring document that stays relevant over time as the sector develops.

We therefore plan to establish a government and sector coordination body to help underpin ongoing action to support hydrogen deployment and monitor outcomes. There are similar bodies in place to support coordination across government and with private bodies to support emerging technologies. We will model the hydrogen group on similar existing groups, such as Sustainable Aviation Aotearoa. To enable the greatest impact and buy-in, we intend the group to come together and help to shape the Terms of Reference and set priorities, which we expect to be guided by the direction and issues set out in the Interim Hydrogen Roadmap.

Action

We plan to establish a government and sector coordination body to help coordinate ongoing action to support hydrogen deployment.

Regulatory settings and standards

Clear and stable regulatory settings and standards are important for providing the confidence needed to enable actors to produce, store, transport, and use hydrogen safely. Hydrogen requires specific controls to account for its nature as a very light, highly flammable, invisible, odourless gas that is often compressed or liquified to save space and can embrittle or leak out of many storage materials.

The current regulatory environment is complex and in key areas the provisions do not explicitly account for hydrogen. This means that exemptions are commonly needed for hydrogen projects and the timeframes for processing exemptions can vary and appear uncertain to applicants. While exemptions are appropriate for early demonstrations, long-term reliance on these processes risks slowing the wider scaling of a hydrogen market. Voluntary standards are emerging, but some regulatory instruments directly cite technical standards that may not be fit-for-purpose for hydrogen.

The Government has made it a priority to develop appropriate regulatory settings and standards to facilitate the uptake of hydrogen. Work to date has included:

- Initiating the Hydrogen Regulatory Settings Project and forming a cross-agency working group to identify and prioritise regulatory barriers to the deployment of hydrogen. This has included commissioning a review of the regulatory landscape relating to hydrogen in New Zealand and set out a pathway for a fit-for-purpose regulatory environment for future hydrogen uses.[31] The review outlined that the potential regulatory landscape that could interact with hydrogen covered around 90 acts, regulations and technical standards across six portfolio areas. This has provided government with a strong foundation to assess and address potential regulatory barriers as a market scales up.
- Standards New Zealand has a project underway to review and consider revisions to electricity and gas safety standards to enable the integration of hydrogen. This work was commissioned by WorkSafe New Zealand - Energy Safety. The project includes an emphasis on the direct adoption of international ISO standards wherever appropriate.

We know enabling safe basic operation with appropriate safeguards is a top priority for the hydrogen sector. The Government has started the next phase of its regulatory work programme, targeted at enabling safe basic operation of common hydrogen equipment and near-term use cases. This work

[31] PwC (2022). *New Zealand's hydrogen regulatory pathway.* https://www.mbie.govt.nz/dmsdocument/25671-new-zealand-hydrogen-regulatory-pathway

will focus on making changes needed to enable safe use of near-term activities such as production, storage and distribution, and applications like heavy road transport, building on the discussions we have had to date with sector participants on the barriers they face in deploying hydrogen. The regulatory regimes in scope include (but are not limited to):

- Health and Safety at Work (Hazardous Substances) Regulations 2017
- Electricity (Safety) Regulations 2010
- Gas (Safety and Measurement) Regulations 2010
- Land Transport Rule: Dangerous Goods 2005
- Land Transport Rule: Vehicle Dimensions and Mass 2016

As the shape of a mature market becomes clearer, it is likely we will need to explore the wider regulatory landscape to ensure good competition, consumer and environmental outcomes, as well as regulatory considerations that may be required for hydrogen use in applications that are expected to scale in the medium to long-term, such as in marine and aviation transport.

CASE STUDY: STANDARDS NEW ZEALAND HYDROGEN INTEGRATION PROJECT

Standards New Zealand has led a comprehensive review of technical standards that cover the production, distribution and use of hydrogen on behalf of WorkSafe New Zealand - Energy Safety, New Zealand's workplace health and safety regulator. This has culminated in the report *Hydrogen Standards Review: Integrating hydrogen into New Zealand's energy landscape*, which was published in May 2023.

The next phase of the project is to consider the formal adoption of the standards identified in the report. This is being undertaken in three stages and is designed to match the expected rollout of hydrogen infrastructure and activities in New Zealand.

The first stage focuses on centralised stationary production and storage of hydrogen. Stage two will consider mobile applications for hydrogen, like transport and vehicle refuelling. The third stage considers large scale decentralised distribution. The project is intended to be completed by mid-2025.

The report recommends the direct adoption of fifteen international standards, as well as the modified adoption of an additional eight others. The report also recommends progressive updates to twenty joint Australia-New Zealand standards (AS/NZS) and the revision of eight New Zealand-specific standards (NZS).

This project is closely related to MBIE's regulatory work, to ensure fit-for-purpose rules for hydrogen. Many health and safety, and energy safety regulations directly cite standards when setting out what activities and practices are deemed to be compliant with safety regulations.

The report can be found here.

Actions

We are committing to regulatory work to enable safe basic operation of hydrogen projects to support near term use cases.

We will continue work to consider the wider regulatory environment on an ongoing basis as a market for hydrogen continues to develop.

Building a market for hydrogen

One of the key challenges to enable scaled deployment of hydrogen is incentivising supply and demand for hydrogen in tandem. As a market for hydrogen does not yet exist, parties face a high degree of uncertainty on both sides of the market when making investment decisions. The current high price of hydrogen compared to the fossil fuels it could replace, combined with the significant upfront investment needed in hydrogen equipment and infrastructure, present a barrier to a market forming on its own. As with other new technologies, costs for hydrogen are expected to fall over time, but this requires early investment to happen.

One way we can help to build forward certainty about a future hydrogen market is through clear government signalling through the Hydrogen Roadmap itself, in order to encourage investment by positioning hydrogen as part of New Zealand's clean energy transition. There are also practical measures we are taking to help build a market for hydrogen, and other areas we could signal and explore further.

Support for price and long-term certainty to allow hydrogen to scale for key use cases

Many countries are putting in place long-term financial supports to bridge the price gap between existing fossil fuels and hydrogen. These measures are designed to provide long-term certainty about the availability of hydrogen to encourage private investment in hydrogen supply and demand. Many are also designed specifically to bridge the price gap between existing fuels like diesel and fossil gas to make it economically viable to switch to using hydrogen. These schemes are typically time limited as they are designed to overcome the barriers to a functioning market emerging on its own and wind down support once an independently functioning market is established.

As part of Budget 2023, the Government announced the Regional Hydrogen Transition initiative. The initiative will provide rebates to help close the price gap between green hydrogen and fossil fuels through long-term contracts between government and commercial hydrogen consumers. The total funding available will be up to $100 million over ten years.

The Regional Hydrogen Transition initiative will target early adopters of hydrogen technologies in hard-to-abate sectors. This will help build skills, industry knowledge, and supply chains, supporting the emergence of a green hydrogen industry in just transition regions, starting in our just transition regions, Southland and Taranaki. The rebate will be limited to domestic users of hydrogen in order to encourage a local market to develop, and contribute to broader social, economic and cultural objectives. Applicants for the rebate will be required to demonstrate how they propose to support broader regional and national transition outcomes.

MBIE is currently consulting on a draft technical design document to seek feedback on the key elements of contract design for the initiative. The rebate is expected to begin operating from mid-2025.

Action

Budget 2023 included up to $100 million over ten years to establish the Regional Hydrogen Transition consumption rebate scheme, to support regional transitions.

Support for capital investment for hydrogen projects

The Government has also supported key hydrogen projects that aim to help build and test early-stage projects that are expected to help a wider market for hydrogen to develop. This includes financial support for the Ballance-Hiringa Energy hydrogen production facility at the Kapuni fertiliser plant, and support for the Hiringa Energy hydrogen refuelling network for the North Island. This support has helped to address the barriers and uncertainty around high upfront capital costs to initiating projects that will help to support a broader market for hydrogen to develop.

This is also an issue at the end use stage of hydrogen deployment. Similar to battery-electric vehicles, the total cost of ownership for hydrogen fuel cell vehicles is more heavily weighted to the purchase price of the vehicle than for internal combustion vehicles. High upfront costs can be a barrier to uptake of low and zero emissions vehicles.[32] Budget 2023 also allocated $30 million over three years to establish a Clean Heavy Vehicle Grant for zero emissions heavy vehicles, such as trucks, non-public transport buses and heavy vans. Hydrogen fuel cell vehicles will also be eligible to receive grants.

Action

Budget 2023 included $30 million over three years to establish a Clean Heavy Vehicle Grant for zero emissions heavy vehicles, including hydrogen fuel cell heavy vehicles.

Government as a purchaser of goods and services

Government can also influence the development of a market for hydrogen as a purchaser of goods and services and signalling future purchasing decisions to provide more certainty of demand. Two key areas where hydrogen could be a consideration in the future are in decarbonisation of the public sector vehicle fleet, and potential opportunities in the government’s property portfolio, such as emergency back-up generators for public buildings.

Supporting frameworks to allow market trading of hydrogen to occur domestically and internationally

Many countries and international organisations are working to set up frameworks to allow for the verification, tracking and certification related to hydrogen based on its production method and its associated emissions intensity. This is intended to support a market to emerge for lower-carbon hydrogen and derivative chemicals to achieve the higher prices users are willing to pay for green gases and chemicals. This is expected to be important while lower-carbon forms of hydrogen are more expensive than emissions-intensive forms.

---

[32] Ministry of Transport (2020). *Green Freight - Strategic Working Paper*. https://www.transport.govt.nz/assets/Uploads/Paper/Green-Freight-Strategic-Working-Paper_FINAL-May-2020.pdf

As a country with a focus on green hydrogen, it will be important to ensure that end users can be confident in the production source of the hydrogen they are purchasing. We have already supported work through New Zealand's co-sponsoring of a report for APEC on the value of a low-carbon standard for hydrogen to facilitate a trading market. These standards and frameworks are expected to become increasingly important during the energy transition, especially in areas where existing uses such as chemical production start to use a mix of green and more emissions-intensive sources of hydrogen. It will be important to know what production at which times can be considered 'green' in order to realise that additional value. We will also utilise our existing international relationships and agreements to foster the development of these standards.

CASE STUDY: APEC LOW-CARBON HYDROGEN INTERNATIONAL STANDARD

MBIE led the APEC low-carbon hydrogen international standard project, which was completed in July 2022.

The project has initiated an APEC-wide discussion on how to define low-carbon hydrogen, the benefits of certifying it, how an international standard could be implemented, and the value of developing a standard that reflects APEC's views.

The report can be found here.

Action

We will continue working with other countries to support the development of emissions-intensity standards and guarantee of origin schemes that allow for trading and certification hydrogen production sources, to support the development of a market for green hydrogen.

Workforce, skills and training

A new hydrogen industry will require a skilled workforce of engineers, technicians, specialists, business services, operations, trade and mechanical roles. Construction of hydrogen projects and the renewable electricity generation to support it is also expected to be a large source of workforce demand. Our hydrogen scenario modelling indicated that hydrogen deployment could support around 4,600 FTEs in 2035 and 11,900 in 2050 from direct spending on hydrogen infrastructure. This is comparable to estimates by McKinsey in 2021 that found a green hydrogen economy in the South Island could support 4,000 to 7,000 ongoing jobs by 2030.[33]

There is potential to utilise transferable skills from existing workforces. Most notably, this includes the existing oil and fossil gas workforce, which is an emissions-intensive sector that is expected to decline over time. Taranaki, New Zealand's most concentrated region of oil and gas sector activity, supports around 1,600 direct FTE roles in the energy sector,[34] and as many as 4,000 roles when

[33] McKinsey (2021). *The New Zealand Hydrogen Opportunity: A perspective on New Zealand's potential role in the emerging global hydrogen economy*. https://www.datocms-assets.com/49051/1626295071-the-nz-hydrogen-opportunity.pdf

[34] Stats NZ Business Demography statistics

considering indirect employment. The sector is also highly reliant on overseas workers due to the highly skilled and specialised nature of many roles.

In the near-term, we need to better understand the specific skills and workforce needs of these roles, when there are likely to occur and what gaps in the education and training system may need to be addressed to meet future workforce needs.

In the long-term, transitioning existing workers with transferable skills will not meet the demand for workers for a hydrogen rollout on its own. Globally and in New Zealand, the average age of workers in the oil and gas workforce is high, and the industry is already experiencing difficulties attracting new workers. This is both a long-term trend and more recently a result of the workforce contraction that occurred when world oil prices dropped substantially during the COVID-19 lockdowns.[35]

Employment in New Zealand's energy sector is also highly male dominated across most roles, and while statistics are not readily available, evidence based on interviews with the sector in Taranaki suggests Māori make up a relatively small proportion of the workforce.[36] There may be a need to place particular emphasis on removing barriers to entry and improving the attractiveness of the sector, particularly for currently under-represented groups, to encourage new entrants to the sector in future in order to meet workforce needs.

There are a number of existing initiatives underway in New Zealand that are working to develop an early understanding of the types of roles and skills required to support the deployment of hydrogen, enable a transition from sectors with transferable skills and ensure a future pipeline of skilled workers. These are largely regional initiatives taking place in areas that are already starting to see emerging activity in hydrogen projects. Some examples include:

- The work of the Southland and Taranaki Regional Skills Leadership Groups that are working to understand future workforce needs and opportunities. These are government-supported groups that bring together employers, training providers, iwi, unions and other interested parties to coordinate and resolve regional workforce issues.
- Organisations that oversee regulated occupations such as the Plumbers, Gasfitters and Drainlayers Board are considering training and certification requirements for gasfitters working on hydrogen equipment.
- Providers such as the Western Institute of Technology in Taranaki are planning training courses in new energy technologies such as hydrogen and solar energy.

As uptake gathers pace, there may be a need for a nationally coordinated view to build on this work. We see a role for the government and sector coordination body to play a role here. We could progress work to:

- further understand the domestic future workforce, skills and training requirements to enable hydrogen deployment, including the extent to which transferable skills in existing workforces may be able to support a hydrogen rollout
- build on work by international partners, particularly Australia, in areas such as skills and job mapping, as skills profiles are likely to be similar

[35] International Energy Agency (2022). *World Energy Employment*. https://www.iea.org/reports/world-energy-employment

[36] Energy Resources Aotearoa (2022), *Building Energy's Talent Pipeline: An Industry Skills Action Plan*, https://www.energyresources.org.nz/assets/Uploads/Building-Energys-Talent-Pipeline-Skills-Plan-5-October-22.pdf

- consider whether immigration settings remain appropriate to enable specialised hydrogen skill needs to be met internationally where necessary.

Action

The government and sector coordination body should work in coordination with relevant workforce entities to scope future skills and workforce requirements, challenges, and opportunities in more detail, to support a rollout of hydrogen.

PLANNING AND INFRASTRUCTURE

Infrastructure needs

Hydrogen deployment requires extensive new infrastructure across all parts of the value chain to allow for its production, distribution and use. This includes sufficient electricity generation and transmission capacity to support hydrogen production.

Capital investment needed in hydrogen infrastructure could be between $1.5 and $6.2 billion between 2022 and 2035, rising to between $3.4 and $8.2 billion in 2050, depending on the form a hydrogen supply chain takes. This does not include the investment that would be required in hydrogen end uses such as vehicles, or the investment required for associated renewable electricity production and transmission.

Early production is expected to be more decentralised through onsite production or smaller-scale hydrogen hubs, with limited infrastructure requirements beyond production. Large scale export is likely to involve larger and more centralised production facilities, facilities to convert hydrogen into more transportable forms like ammonia or methanol, and export terminals.

There may be opportunities to reuse parts of existing fossil gas infrastructure for large scale hydrogen use, but this depends greatly on future decisions on the existing gas network, such as whether biogas will be used in the system in the long-term.

Specific infrastructure will also be required for key hubs like ports and airports to support use cases such as green shipping fuels, hydrogen export and hydrogen-based aviation.

In the coming years, the hydrogen sector will need to coordinate its views on the scale and nature of infrastructure required. The Government will have an interest in understanding and managing the public implications of this infrastructure investment. This includes ensuring it is efficient, environmental and social impacts are appropriately addressed and there are adequate mechanisms to manage the additional demand on the consenting and construction system (including for renewable electricity).

Internationally, early hydrogen economies are developing around regional hubs where supply is located close to end use, and multiple users can share common infrastructure in order to spread costs. These hubs can minimise the transport, storage, and conversion infrastructure needed to use hydrogen, which ultimately means lower prices for consumers. The Regional Hydrogen Transition consumption rebate outlined above will support these aims.

While it will not be possible to have a complete view of hydrogen infrastructure requirements until the shape of the local demand and production market is clearer, it will still be prudent to set the bounds of investment needed, establish coordination, and identify and manage any issues that may arise. We a role for the government and sector coordination body to help inform this view.

Action

The government and sector coordination body should inform the scoping of future hydrogen infrastructure requirements, challenges, and opportunities in more detail.

Planning system

New Zealand's planning system influences how and where projects get built. Planning decisions are currently administered through the Resource Management Act 1991, which has been in place for over thirty years, but is being replaced.

A fundamental part of New Zealand's planning and consenting framework is allowing local communities to have a say in proposed changes and resource use that may affect them. There are also specific obligations to iwi and Māori as part of the consenting process, including the duty for those exercising functions and powers under the Act to consider the relationship of Māori and their culture and traditions with their ancestral lands, water, wahi tapu sites and other taonga. There is also the requirement to take into account the principles of Te Tiriti o Waitangi.

We did not identify any specific challenges relating to consenting of hydrogen-specific aspects of projects, but there was concern in our engagement about the ability to align project timeframes between the hydrogen components of projects and the renewable electricity generation to support it.

The Natural and Built Environments Bill and Spatial Planning Bill are intended to provide for a more coordinated approach to national spatial planning. The Government has also recently consulted on proposals to strengthen national direction for consenting renewable electricity generation and electricity transmission, to support speeding up the consenting of new renewable generation. While we do not see a case for specific planning instruments for hydrogen infrastructure at this point, we could revisit this if specific challenges to consenting hydrogen electrolysers, storage tanks and other equipment arise.

We also heard that on a practical level, the planning environment could benefit from a greater level of understanding of hydrogen projects and what is involved. As a new industry, there may be differing levels of understanding about hydrogen technology that could cause delays in consenting decisions. This is already being progressed through the New Zealand Hydrogen Council, which is producing training material on hydrogen aimed at consenting authorities.

Actions

As part of our ongoing hydrogen work programme, we could consider:

- the potential to add hydrogen equipment to definitions of renewable/clean energy in planning legislation, and the fast-track consenting regime
- supporting initiatives that promote greater awareness and understanding of hydrogen technology for key decision makers, such as consenting authorities
- whether resource management regime settings are sufficient to incentivise the required renewable electricity generation to accompany investments in hydrogen production.

Research, development and deployment

As outlined above, there are technical challenges to using hydrogen across almost all parts of the supply chain from production to end use. Solving these challenges is likely to have a strong influence on how hydrogen is deployed as part of the clean energy transition, and to what extent it is used.

Along with early-stage research, deployment support is required to test hydrogen technologies in real world conditions and help them move to commercial settings and scales.

Research investment to help resolve technical challenges and improve hydrogen technology

New Zealand recognises the importance of research and the need to coordinate with the sector and other countries to resolve some of the common and highest priority challenges to enable hydrogen uptake.

Globally common challenges relate to the deployment of hydrogen equipment that will be used universally, such as electrolysers, storage tanks, compressors and refuelling equipment. These challenges include:

- improving the overall efficiency of production, compression and conversion of hydrogen
- improving the reliability of quality and purity of hydrogen
- developing more efficient and cheaper storage solutions
- understanding the scale and best responses to hydrogen leakage across the value chain.

There are also New Zealand-specific challenges and opportunities where it is likely we will need to play a leading role to resolve unique challenges or unlock decarbonisation potential. This includes:

- **Developing processes to use hydrogen in domestic steel production**. New Zealand's only steel mill at Glenbrook uses a unique process to produce iron from domestic iron sands. This involves a different reduction process to many smelters around the world that produce iron from iron ore. Smaller quantities of hydrogen are also used in metal coating and treatment processes.
- Locally available materials may be able to be used to provide **cheaper and more stable storage of hydrogen**. Existing research is looking at using locally available metal hydrides that could provide solid-state storage of hydrogen at ambient temperatures.

- **Underground storage**. Hydrocarbons are stored in underground geological formations around the world. In New Zealand, the Ahuroa Gas Storage Facility can store up to 18PJ of fossil gas. Underground storage is an attractive solution for hydrogen because of the potential for significantly lower costs and higher storage volumes compared to above ground compressed or liquified tank storage. While a number of countries have been exploring natural salt caverns for hydrogen storage, this geological feature is not known to exist in New Zealand. A research project funded through the MBIE Endeavour Fund is underway to identify the suitability of other formations in New Zealand for underground hydrogen storage.
- **Naturally occurring hydrogen**. Hydrogen is not commonly found outside of compounds such as water or hydrocarbons, but recent science indicates naturally occurring hydrogen could be more abundant than previously thought. Naturally occurring hydrogen could also be cheaper to produce than green hydrogen depending on the energy input required to extract it. Exploration would be needed to determine whether economically viable quantities of hydrogen are present in New Zealand at sites suitable for extraction. Work would also be needed to understand the environmental, social, and Māori interests at a given site.

There is already funded research taking place in New Zealand across these broad areas supported by MBIE’s Endeavour Fund, Catalyst Fund and Strategic Science Investment Fund. The diagram below outlines these projects and their funding.

Diagram 8: Research funding for hydrogen projects in New Zealand. Source: MBIE

Research funding for hydrogen projects in New Zealand

In our engagement, we heard views that New Zealand's research landscape can be fragmented and lack clear priorities, and the structure of research support can make it challenging to build and retain capability and capacity on specific research topics. Stakeholders highlighted relatively short funding contracts for research initiatives and the competitive allocation process as drivers of these challenges.

New Zealand's research system is undergoing a review as part of the Te Ara Paerangi – Future Pathways programme. The programme has committed to developing a system of National Research Priorities to facilitate attention toward nationally significant topics such as climate change. There may be scope to consider hydrogen-related research as part of priority setting to be agreed in 2024.

Actions

As part of our ongoing hydrogen work programme, we will continue to work collaboratively wherever possible on joint research challenges to deploying green hydrogen.

We will consider the long-term research environment for hydrogen alongside related work, such as the Te Ara Paerangi – Future Pathways programme.

Deployment and scaling of hydrogen technology is a key step to its broader adoption

The Government's Low Emission Transport Fund, administered by the Energy Efficiency and Conservation Authority (EECA), has supported a number of hydrogen demonstration projects across heavy vehicle applications in trucking and public transport. These trials are intended to produce valuable data on the operational performance of hydrogen transport solutions in New Zealand conditions, which will help to inform business cases for investment in the private sector. The table below lists these projects.

Table 1: Hydrogen demonstration projects funded by the Government

Project	Description	Funding amount ($NZD million)
Hiringa Energy Hydrogen Refuelling Network	Hiringa Energy received a $16 million loan ($5 million of which will become a grant if certain delivery milestones are met) to trial a long-haul minimum viable network of four hydrogen refuelling stations in Auckland, Hamilton, Tauranga and Palmerston North. These hydrogen fuelling sites will all be located at Waitomo fuel stations. Construction of the first site in Palmerston North started in May 2022. Construction of all four sites is scheduled for completion in September 2023.	16
Auckland Transport hydrogen bus	In 2019, Ports of Auckland Ltd (with partner Auckland Transport) received $0.160 million of co-funding from the Low Emission Transport Fund to trial a hydrogen fuel cell electric bus. The bus was manufactured in Christchurch by Global Bus Ventures. The bus is currently in operational trials in Auckland.	0.160

Table 1: Hydrogen demonstration projects funded by the Government		
Project	**Description**	**Funding amount ($NZD million)**
TR Group Trial	Heavy vehicle leasing and rental company TR Group received $4 million in co-funding from the Covid-19 Response and Recovery Fund and $2 million through EECA to purchase 20 Hyzon 58 tonne heavy hydrogen fuel cell trucks. TR Group will lease these trucks to its customers and use Hiringa Energy's hydrogen pilot refuelling network. The first of the trucks are scheduled to arrive in New Zealand in August 2023, with all 20 trucks expected to arrive by the end of December 2023.	6
HW Richardson trial	HW Richardson Group received $0.389 million from EECA in round three of the Low Emission Transport Fund and will purchase six hydrogen conversion kits and install them on six of their diesel trucks to refuel out of the Gore refuelling site. HW Richardson will convert and operate an additional two vehicles at their own cost and will provide valuable reporting on all vehicles in the Project.	0.389
Hyundai Trial	In 2021, Hyundai New Zealand Ltd received $0.500 million in co-funding from the Low Emission Transport Fund to purchase and deploy a demonstration fleet of five hydrogen fuel cell trucks into New Zealand and enter real world daily logistics operation trials. The first truck has been leased to NZ Post, which was announced on 18 July 2022.	0.500
Kiwi H2 dual fuel testing	In February 2022, Kiwi H2 Ltd was approved for $0.227 million of co-funding as part of the first round of EECA's new Low Emission Transport Fund. This project will see Kiwi H2 convert two diesel trucks to be able to run on 40 per cent hydrogen combustion, testing the emission reductions potential from the technology. The trucks are planned for piloting with three industrial customers.	0.227

The Government's main mechanism to enable large industrial users to decarbonise their activities is the Government Investment in Decarbonising Industry (GIDI) Fund. GIDI was substantially expanded in Budget 2022 as part of New Zealand's first Emissions Reduction Plan, with around $650 million across four years allocated to support capital investment projects. GIDI has had a focus on medium and large-scale energy projects but will expand to smaller projects over time, along with investment in renewable fuel supply infrastructure. Its core focus remains on process and building heat, where electrification and bioenergy are currently the most commercially viable and available technologies to achieve immediate emissions reduction in this area. Hydrogen has not featured in GIDI projects to date, in part because its higher current costs and lower level of technology readiness make it a longer-term option.

Through our engagement, we identified a potential need to support demonstration and commercial scaling projects for hydrogen that do not fit the eligibility criteria or core focus of existing initiatives, but have future promise for where we see hydrogen contributing to our national decarbonisation and other objectives. Currently, there may be limited options for support to demonstrate and scale hydrogen technologies outside of transport applications.

Action

As part of our ongoing hydrogen work programme, we will review available funding and support avenues, including whether there are gaps across the existing technology level readiness scale to help enable hydrogen use cases to become a commercial reality.

International partnership and cooperation

International partnership and cooperation are crucial to a global hydrogen roll out. New Zealand recognises the value of working closely with other countries and building relationships with governments, companies, researchers and other organisations around the world.

New Zealand currently has two cooperation agreements with key international partners on hydrogen. We signed a memorandum of cooperation with Japan in 2018, and an arrangement of cooperation with Singapore in 2021. These partnerships are designed to build relationships and cooperation on key areas of common interest relating to hydrogen, such as research and development, standards alignment and helping to build connections between private companies and other organisations across countries.

New Zealand is developing a strong relationship with Germany on green hydrogen research with the establishment of He Honoka Hauwai, the German New Zealand Green Hydrogen Research Centre. In 2022, the New Zealand Government announced funding for joint research with Japan on advanced technologies. Clean energy is within scope and officials are working to operationalise the funding. Hydrogen could potentially be within scope through this clean energy workstream. Research cooperation helps to build stronger international relationships beyond its immediate benefits.

New Zealand is also active in a number of multilateral international projects and forums that are dedicated to country coordination on common hydrogen challenges, including the COP27 Breakthrough agenda workstream on hydrogen and the IEA Clean Energy Ministerial Hydrogen Initiative. New Zealand also takes part in the Hydrogen Energy Ministerial group led and hosted by Japan.

International governments and companies are making significant investments and commitments to scaling up hydrogen deployment and reducing costs. In 2022, there was a global pipeline of announced hydrogen projects totalling USD $240 billion out to 2030, and global investment in hydrogen projects continues to grow.[37]

The scale of investment required to make a hydrogen supply chain in New Zealand a reality is immense, and we anticipate that domestic investment alone may not be sufficient. We expect that investment from international sources will be important to enable the construction of projects that allow hydrogen deployment to take place. Government organisations like New Zealand Trade and Enterprise plays a key role supporting international investors that are interested in opportunities in New Zealand.

---

37 Hydrogen Council (2022). *Hydrogen Insights 2022: An updated perspective on hydrogen market development and actions required to unlock hydrogen at scale*. https://hydrogencouncil.com/en/hydrogen-insights-2022/

CASE STUDY: NEW ZEALAND TRADE AND ENTERPRISE (NZTE)

NZTE is the government international economic development agency. NZTE helps connect New Zealand companies with the world by assisting with market information and investment preparation. NZTE also helps connect international businesses and investors with high-value growth opportunities in New Zealand. By supporting New Zealand businesses, NZTE helps to boost New Zealand's economy and reputation.

NZTE can provide local market information and context to international organisations with interest in growing operations in New Zealand either through development or investment. Its global team uses its network, commercial expertise, and deep knowledge of New Zealand to bring investment and opportunity together.

Action

As part of our ongoing hydrogen work programme, we will continue to build our international relationships on hydrogen through our existing cooperation arrangements, participation in international working groups. We will seek out new opportunities for collaboration in line with our positions set out in the Interim and upcoming Final Hydrogen Roadmap.

Public awareness

As a new technology, perceptions and attitudes towards hydrogen vary considerably.

Safety of hydrogen is a key concern among the public. One of the ways we are addressing this concern is placing high priority on ensuring New Zealand adopts appropriate and fit-for-purpose standards for the safe installation and operation of hydrogen equipment in New Zealand and amending regulatory regimes to account for these standards.

Improving public awareness and visibility of hydrogen technologies, including the opportunities and benefits it can bring, and the applications it is most suited to, is also important.

Demonstration projects funded through the Government's Low Emission Transport Fund help build the profile of key hydrogen use cases by acting as real-world examples of public-facing hydrogen technologies.

A number of initiatives from government, academia and the private sector are helping to build the profile of hydrogen and explore social issues around hydrogen uptake in New Zealand.

The New Zealand Hydrogen Council is the country's industry body representing companies that are active in the domestic hydrogen industry, universities and other institutions with an active role in the sector. MBIE sponsored the New Zealand Hydrogen Council to hold the inaugural New Zealand Hydrogen Conference in 2022.

CASE STUDY: GNS POWERING GREEN HYDROGEN ECONOMY PROJECT

Part of the GNS Powering the Green Hydrogen Economy project funded through the MBIE Endeavour Fund is exploring the socio and techno-economic barriers to the adoption of green hydrogen. Another workstream will develop forecasts of the potential economic and environmental benefits, and consider the policy implications of green hydrogen and ammonia production that utilises the novel catalyst materials. The social component of the research will undertake two series of interviews with key stakeholder groups and communities followed by a wider public survey to gauge the potential future social licence for hydrogen.

The goal of this workstream is to identify suitable pathways and actions necessary to fully prepare the industries, government and the public with the right knowledge, attitude and practices necessary to integrate hydrogen into our energy mix and lives.

Actions

As part of our ongoing hydrogen work programme, we will continue to raise the public profile of hydrogen through the development of the Final Hydrogen Roadmap.

The government and sector coordination body could also play a role to help shape public awareness of hydrogen.

DISCUSSION QUESTIONS

- Do you agree with our policy objectives?
- Do you agree with our positioning on hydrogen's renewable electricity impacts and export sector?
- Do you agree with the proposed actions and considerations we have made under each focus area?
- Is there any evidence we should be considering to better target actions in the final Hydrogen Roadmap?

Section 4: Next steps

The Interim Hydrogen Roadmap reflects our current thinking on the opportunities for hydrogen and the Government's role to help realise these opportunities. We want to hear from you on the questions we have posed throughout this document.

We will consider your feedback as we finalise the Hydrogen Roadmap for release alongside the New Zealand Energy Strategy. Phase 2 of our work will involve further work to:

- confirm our judgements and the assessment on hydrogen in a New Zealand context set out in the Interim Hydrogen Roadmap
- better understand:
  - the interaction between hydrogen deployment, and potential alternatives such as direct electricity use and bioenergy to form a more precise view of future hydrogen supply and demand
  - the integration of hydrogen in the broader electricity system, including if large scale hydrogen production to service an export market eventuates
  - consider whether further action from government is needed to support a green hydrogen industry in New Zealand to become commercially viable.

Glossary

Term	Description
Bioenergy	Energy that has been generated from organic material, such as wood, manure, municipal waste, plant material, sewage, green waste, wastewater and food waste. Examples include biofuel (liquid or gaseous fuels), biogas (renewable gas), and biomass (such as wood products that may be burned for heat energy).
Biogenic	Produced or brought about by living organisms. Biogenic hydrogen is hydrogen that has been produced from living material like wood. Biogenic emissions refer to emissions that have come from living sources like livestock.
Blue hydrogen	Hydrogen produced from fossil-based sources such as fossil gas, where resulting emissions have been captured through a carbon capture and storage technology.
Carbon capture and storage (CCS)	A suite of technologies that aim to remove, and store, carbon from the atmosphere. Sometimes referred to as CCUS where the carbon that is captured is utilised in another production process.
Co-generation fuel	The simultaneous production of electricity and heat energy.
Demand response	Demand response involves shifting or reducing electricity demand to help balance electricity supply and demand across time. Demand response is becoming increasingly important as our electricity system increases the share of generation coming from variable sources of electricity such as wind and solar energy.
Drop-in fuel	Alternative fuels that can be used in existing fossil fuel infrastructure and equipment.
Dry year	New Zealand's 'dry year problem' is when our existing hydro-power catchments don't receive enough rainfall or snowmelt over a period of weeks or months and the level of the storage lakes runs low, limiting the amount of electricity that can be generated from hydro dams.
Electrification	Replacing technologies and services that run on fossil fuels with solutions that run on electricity from renewable sources.
Electrolysis	Water electrolysis is the process in which hydrogen is produced from splitting water, through the application of electrical energy, into hydrogen and oxygen.
Energy carrier	A substance that is capable of transporting energy but is not a primary source of energy itself.
Feedstock	Any raw material that can be used or converted into a product, such as fossil gas into urea.

Term	Description
Fuel cell	A technology that produces electricity to power an application using the energy of a fuel (often hydrogen) and an oxidising agent (often oxygen).
Gasification	A process that converts biomass- or fossil fuel-based materials into gases.
Green hydrogen	Hydrogen produced by renewable energy, by splitting water through electrolysis.
Hydrogen derivatives	Any substance that is produced or derived from hydrogen. These include ammonia, methanol, liquid organic hydrogen carriers (LOHCs), and synthetic fuels.
Liquid organic hydrogen carriers (LOHCs)	Substances in liquid form that can store hydrogen, such as methylcyclohexane. Hydrogen is often converted to an LOHC, liquified, or compressed to reduce the space it takes up, thereby reducing storage and transportation costs.
Peaking generation	Electricity generated to meet demand at its highest point.
Power-to-x	A generic term that refers to turning primary energy (such as wind energy) into another carrier of energy (such as hydrogen or ammonia). Often this is done to enable long-term storage or transportation of energy, or use in an application requiring specific properties.
Process heat	Process heat is energy used for commercial purposes, manufacturing or heating; it is often generated by boilers. The heat is then used by businesses for a wide variety of applications such as timber processing and paper making, food processing or milk drying. Emissions from heat energy are direct emissions from combustion of fuel (eg, coal used in a boiler).
Renewable energy	Energy from a source that is not depleted when used, such as wind or solar power.
Steam methane reformation	Steam methane reforming is a process in which methane is reacted with high temperature steam ($700^{o}C$-$1,000^{o}C$) under 3-25bar pressure, in the presence of a catalyst to produce hydrogen, carbon monoxide and some carbon dioxide.
Sustainable aviation fuels (SAFs)	Biofuel and electro-synthetically produced fuels that are used to power aircraft and have similar properties to conventional jet fuel but with a smaller carbon footprint
Thermal generation	Electricity produced by converting heat energy (including from coal, hydrogen, and geothermal sources) into electrical energy.

Te Kāwanatanga o Aotearoa
New Zealand Government

BRM 9927