Power to X

TRANSFORMING RENEWABLE ELECTRICITY INTO
GREEN PRODUCTS AND SERVICES

Concept paper, December 2021

Contents

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Foreword

Time to rethink our approach to energy

The world is currently at a crossroads considering the range of decisive actions required to reduce emissions. It is a tricky topic but one that requires a total rethink of our energy systems. A lot of the current discussions nationally only refer to meeting Aotearoa New Zealand's energy needs, in terms of electricity, based on the current size and nature of our economy. But what if our mix of economic drivers was different?

Imagine for a moment a more ambitious future, where electricity generation is more than just keeping the lights on during winter without having to fire up coal generators. What if New Zealand was a nation that had far more renewable electricity than we could ever need for todays' economy. Not only would it provide security during winter, but it could also sustain transformational growth that benefits communities around the country.

We could become a nation leading the way on the international stage on emissions reduction. We could become a nation with a surplus of green energy, ensuring domestic security for our enterprises and people. We could be a nation renowned for products and services developed in a sustainable way. We could be a magnet for global, energy-intensive firms seeking a cleaner approach to running their business. We could use this opportunity to protect the environment and build an energy system that supports our economy and creates high-value jobs. This is all possible if we pursue a future centred around *Power to X*.

This concept paper is the culmination of collective action from the Taranaki Energy Action Group – a coalition of the willing with shared ambitions to shape a more sustainable energy future by progressing actions from the region's Taranaki 2050 and Tapuae Roa strategies. This paper proactively seeks to lead discussions about how we talk about energy in New Zealand and to introduce the public and decision makers to opportunities beyond renewable self-sufficiency. Instead of limiting ourselves to what we need based on today, we need to lift the lid on our energy potential and transition in a way that meaningfully grows our economy.

Power to X is not a new concept, and New Zealand is not the first country to act. But now is an important time to take action in order to secure our place as a world leader, where we punch above our weight in terms of combating emissions, creating meaningful future-ready jobs, and taking our place in the technology-centric world of tomorrow.

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Venture Taranaki/Te Puna Umanga

1. The urgency of going green

Global, national, and regional action on emissions

New Zealand, like nearly 200 other nations, signed up to the Paris Climate Agreement in 2015. The goal of this agreement is to take steps to limit global warming to well below 2 degrees Celsius per year, compared to pre-industrial levels.

Implementation of the Paris Agreement requires economic and social transformation, and the New Zealand Government has set ambitious targets to reduce net greenhouse gas emissions to zero by 2050 through the Climate Change Response (Zero Carbon) Amendment Act 2019. This Act set clear targets that requires the government to develop and implement policies for climate change adaption and mitigation. Although 2050 is just under 30 years away, action needs to be taken now to ensure we reach our emissions goals.

If New Zealand is to achieve the net zero emissions targets, the current energy system will require major changes. There is consensus across many recent studies, including the Climate Change Commission's advice to the Government[1], that the emissions from fossil fuels (both imported and locally produced) will need to be massively reduced, and the electrification of many processes or tools (e.g. electric cars) will require more renewable electricity and bioenergy as primary energy sources.

However, another opportunity exists when considering changes to the energy system. It is possible to use large amounts of renewable electricity, such as that generated by offshore wind farms, to produce energy-intensive green products to an international scale. This process is called Power to X and the global export potential for these products may hold the key to not only ensuring a Just Transition (an economic transition that results in fair, equitable and inclusive outcomes) for New Zealand communities but an opportunity for an economic shift.

Power to X can result in 'green' versions of products such as ammonia, urea fertiliser, methanol, and liquid fuels. These can replace the uses of existing products produced from fossil fuels or be applied to new uses including to balance out fluctuations in the supply of renewable electricity. These demands are currently being met by gas and coal. Green products will have a use in the domestic setting, but value lies with the potential export markets that already exist in countries that are unable to meet their own renewable energy demands, such as South Korea and Japan. There is also value in advancing the growth of other high value sectors and services, such as advanced manufacturing and technology (including agri-tech). Emerging energy-intensive sectors, such as the production of aluminium and silicon, or the powering of data centres and cloud-services, also have the ability to become viable in a setting where vast amounts of renewable energy exist.

The Power to X prospect for New Zealand therefore offers the potential to not only accelerate our nation towards an enhanced 'state of green' but to underpin the foundation of a strengthened economic and social future. An energy system that incorporates Power to X pathways has the potential to create meaningful jobs and to sustain supporting industry and services that ensure the wellbeing of communities throughout New Zealand, as well as utilising and transitioning (over time) existing infrastructure.

It is possible to use large amounts of renewable electricity, such as that generated by offshore wind farms, to produce energy-intensive green products to an international scale. This process is called Power to X and the global export potential for these products may hold the key to not only ensuring a Just Transition (an economic transition that results in fair, equitable and inclusive outcomes) for New Zealand communities but an opportunity for an economic shift.

1 *Climate Change Commission, 2021*

FUTURE DECARBONISED ENERGY SYSTEM

The image below, developed by Sapere and Absolute Certainty, illustrates how a future energy system in New Zealand could work.

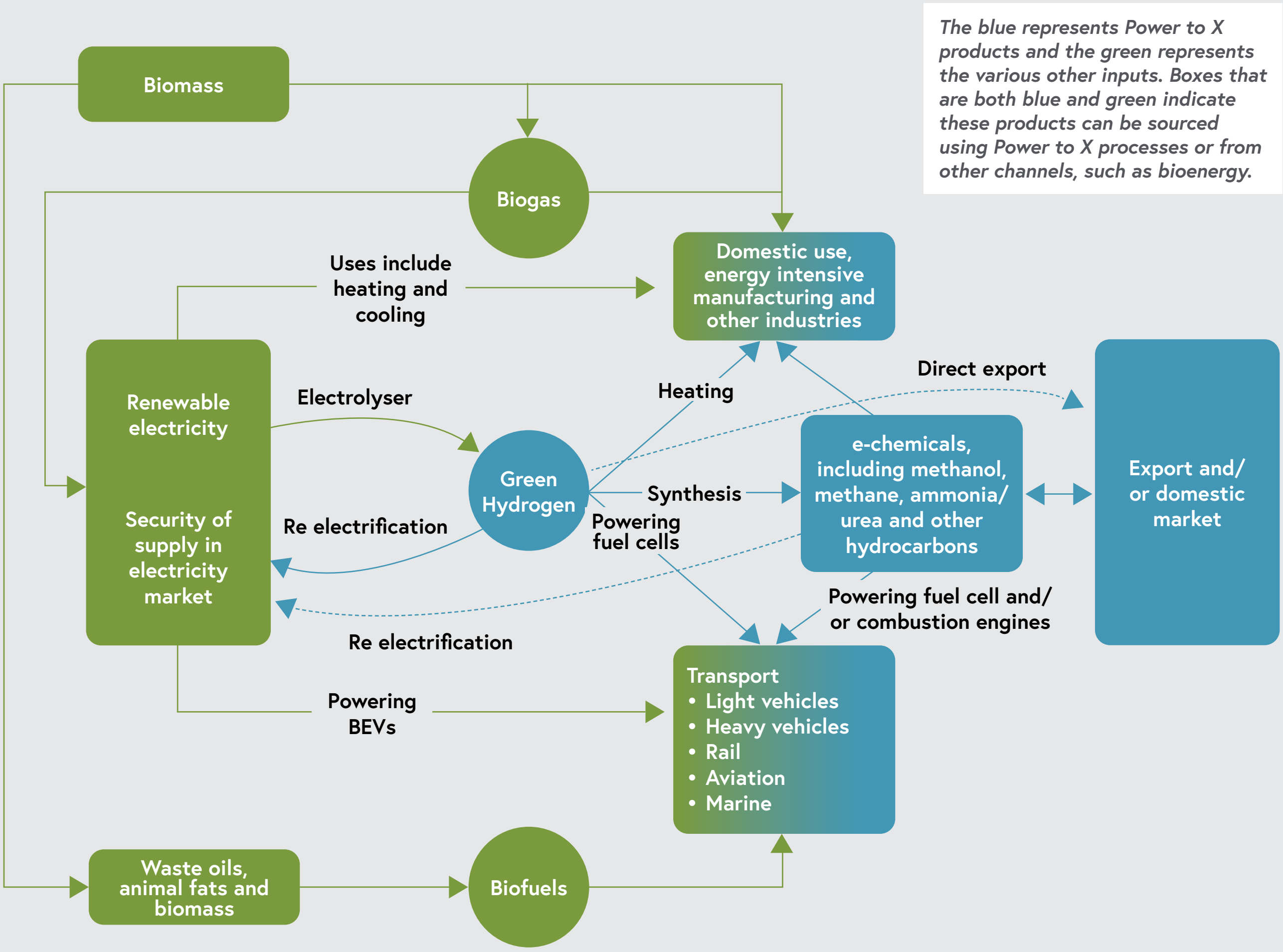


Diagram source: Sapere and Absolute Certainty

As the existing energy hub of New Zealand, Taranaki is one of the regions potentially most impacted by current and future policy change targeted towards reducing greenhouse gas emissions from energy (other than transport). However, it is also one of the regions best suited to capitalise on a Power to X energy system. Taranaki has the greatest potential to generate large-scale renewable electricity through the development of offshore wind farms, as outlined in the Offshore Wind Discussion Paper released by Venture Taranaki in 2020. It also has the required human and infrastructural resources to leverage its fossil fuel-based energy sector into a carbon-free sector capable of servicing both domestic and international markets.

This concept paper aims to:

- **Familiarise readers with the opportunities of the various Power to X pathways, with a particular focus on those that can replace products currently being supplied from fossil fuels;**
- **Explain the connections between established industry and energy resources in New Zealand; and**
- **Use Taranaki as a case study to explain what opportunities exist and what steps might be needed to achieve a future energy landscape driven by Power to X.**

2. Power to X

Green solutions powered by renewable electricity

Power to X is a process by which renewable electricity is used in energy conversion pathways. This results in 'green' versions of products such as ammonia, urea fertiliser, methanol, and liquid fuels.

Green products can replace the uses of existing products produced from fossil fuels or be applied to new uses including to balance out fluctuations in the supply of renewable electricity. The products created by using Power to X are not new and already have a wide range of existing applications, however, the input of renewable electricity results in products that have a significantly minimised (often nil) environmental impact.

The 'X' in Power to X is a blanket term used to refer to all the possible products that can be created through this process. Often, terminology and discussion on this subject will be more specific and refer to processes such as Power to Liquid. This is same process as Power to X, the final product has just been specified.

"POWER TO X" OR "POWER-TO-X"?

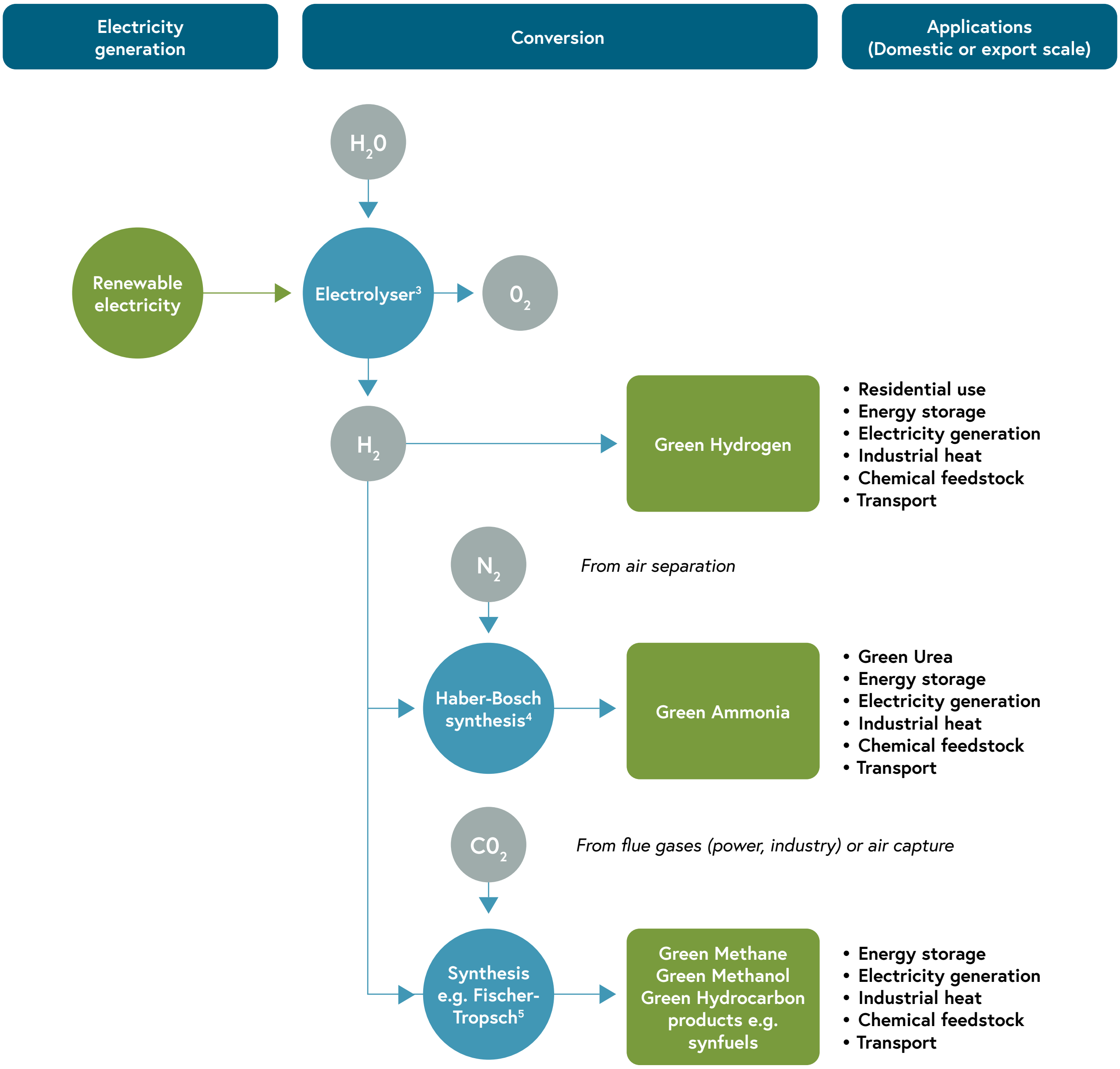
Both phrases are widely used in other documents on the subject. Within this paper, "Power to X" is used as a proper noun to describe the sector and "power-to-x" is used as an adjective to describe the processes and outputs of the sector.

Acronyms such as PtX and P2X are widely used in discussions about this subject, but they do not appear in this paper.

3. Creating a state of green

Making green products and substituting our carbon intensive ones

The image below shows the key power to X pathways that could exist in New Zealand. Renewable electricity could be used to produce green hydrogen, green ammonia, green methane, green methanol, and green synfuels. Those green products can then be used for residential use, energy storage, electricity generation, industrial heat, chemical feedstock[2], hard-to-abate transport uses, and green fertiliser production (notably urea).



2 *Feedstock: Any unprocessed material used to supply a manufacturing process – e.g., crude oil is a feedstock for the production of petrol.*
3 *Electrolysis: Process of using electricity to split water into separate hydrogen and oxygen molecules.*
4 *Haber-Bosch Synthesis: A chemical process used to convert nitrogen to ammonia by reaction with hydrogen under high temperatures and pressures.*
5 *Fischer-Tropsch synthesis: A collection of chemical reactions that converts carbon monoxide and hydrogen into liquid hydrocarbons.*

SUBSTITUTING PRODUCTS PRODUCED BY FOSSIL FUELS

This section further explains some of the products identified in the previous diagram.

Products	Examples
GREEN HYDROGEN	
The current global production of hydrogen is around 120 million tonnes per year. Almost all of this is currently produced from fossil fuels. Most of the hydrogen produced currently, both globally and in New Zealand, is used as industrial feedstock in the production of ammonia and methanol, with the balance being used in processing to refine crude oil. In addition to substituting current hydrogen applications as an industrial feedstock (as described in the rows below), green hydrogen can also be used: • As a replacement fuel for heavy transport and marine vehicles, with testing also underway to service the aviation industry • To store and re-generate electricity. Forecast global growth of green hydrogen production is between 210 and 610 million tonnes per year by 2050.	*Taranaki-based, Hiringa Energy has entered into development agreements, with a range of other companies to provide a hydrogen refuelling network (Waitomo Group) and hydrogen-powered heavy vehicles (Hyzon Motors, TIL Group and TR Group).* *Maersk announced in August 2021 that it has commissioned Hyundai Heavy Industries to build eight large methanol powered ships with capacity for 16,000 containers.*
GREEN AMMONIA	
Currently, ammonia is produced by combining hydrogen extracted from fossil fuels with nitrogen, resulting in the emission of carbon dioxide (CO_2). Using green hydrogen in this process would result in zero emissions. Green ammonia can be used in: • Production of urea and other fertilisers • Production of other chemical products such as plastics and textiles • Industrial processes, such as refrigerant gas to purify water.	*Hiringa Energy and Ballance Agri-Nutrients plan to develop a 24MW wind farm at Kapuni, with the electricity generated being used to produce green hydrogen from water. The hydrogen will be used to decarbonise the production of ammonia and urea, for powering heavy vehicles, and also to partly fuel New Plymouth District Council's new thermal dryer at the wastewater treatment plant.*

GREEN METHANE

Methane (CH_4) is the main component in the natural gas[6] that is distributed in pipelines around the North Island of New Zealand. Natural gas is a significant part of New Zealand's energy system and is used for industrial process heat (such as food processing), as a feedstock to produce methanol and ammonia, and for commercial and residential heating and cooking requirements.

Green methane is produced by combining green hydrogen with green carbon dioxide through the methanation process (also known as the Sabatier Reaction). Methanation is already widely used in oil refineries using hydrogen and CO_2 from fossil fuels.

Green methane can be a simple substitute for natural gas (which is primarily methane) and could replace several existing important uses:

- For process heat
- For energy storage and re-generation of electricity
- For residential and commercial use – heating, cooking etc.

Green methane could use existing infrastructure for the other uses of natural gas without any changes required. It could use existing pipes, boilers, appliances and other equipment, be stored in the Ahuroa Gas Storage Field (near Stratford), and be used to generate electricity at existing gas fired power stations.

In many ways, green methane seems the perfect power-to-x product and is a seamless replacement for these existing uses of natural gas. The core issue that restricts its development and use is the high cost of production. If this could be reduced, it has considerable potential.

6 *The natural gas that comes out of the ground has a range of other components including propane and butane (that are used as LPG) and CO_2. These other components are removed before natural gas is distributed.*

Products	Examples
GREEN METHANOL	
Green methanol can be produced by combining green carbon dioxide and green hydrogen, resulting in water as a by-product. Green methanol can replace the range of existing uses of methanol, including: • As a chemical feedstock to produce acetic acid and formaldehyde, which in turn are used in products such as adhesives, foams, resins (including for wood products), and solvents. These products are then used to create or contribute to direct consumer products, such as clothing, home furnishings, or wallpaper. • As a transport fuel – it is blended with petrol in China and some other countries and is also used as a shipping fuel. Nearly 100 million tonnes of methanol are produced globally each year, with production by Methanex being an important part. The company's two Taranaki plants have the capacity to produce 2.4 million tonnes of methanol per year though production has been curtailed in 2021 due to the Waitara plant being idled and part of Methanex's gas supply being released for electricity generation.	*Methanex is a shareholder in Carbon Recycling International (CRI), which runs a plant in Iceland that uses geothermally produced electricity to make green hydrogen. This is combined with CO_2, also produced geothermally, to make methanol (which they brand as "vulcanol"). They claim vulcanol provides methanol with 90% fewer carbon emissions compared to methanol from fossil fuels.*
GREEN SYNFUELS	
There are some markets where liquid fuels will likely continue to be needed. This is because liquid fuels are more energy dense than gases or batteries, which means larger amounts of energy can be stored in the same space. Synfuels are currently produced at a number of plants around the world by using fossil fuels as part of the Exxon-Mobil and Fischer-Tropsch synthesis processes. Green synfuels can be produced by using the same processes, but by inputting green methane, hydrogen or methanol.	

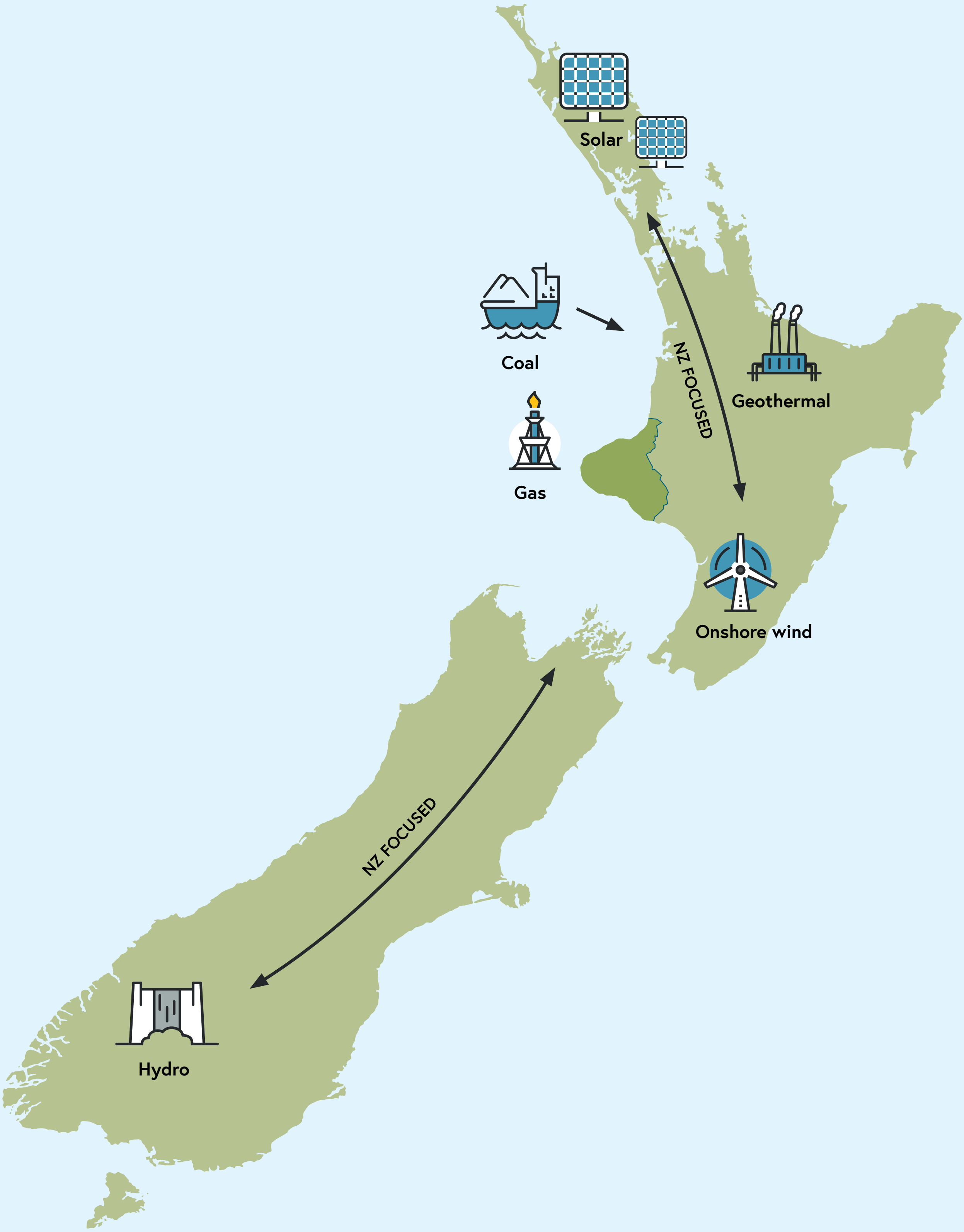
OTHER POSSIBLE PRODUCTS AND SERVICES

This section highlights some other power-to-x opportunities that could be developed in New Zealand.

Products	Examples
ALUMINIUM	
New Zealand's first major power-to-x project was the concurrent development of the Manapouri Power Scheme in Fiordland and the Tiwai Point Aluminium Smelter in the 1970s. Closure of the Smelter has been threatened, and at the moment its owners are only committed to its operation until 2024. Discussions have already taken place publicly about the renewable energy potential of Southland and the possibility of green hydrogen production when Tiwai closes. However, the potential global demand for green aluminium may mean that there is still a future for the smelter beyond 2024.	
SILICON	
Another product for which demand is increasing is silicon suitable for photo-voltaic solar energy cells and potentially computer chips. This can be produced from mineral silica deposits (a mixture of silicon and oxygen). This is another opportunity for which Southland is ideally suited, as the region has high quality silica deposits. It would also require access to green carbon dioxide.	

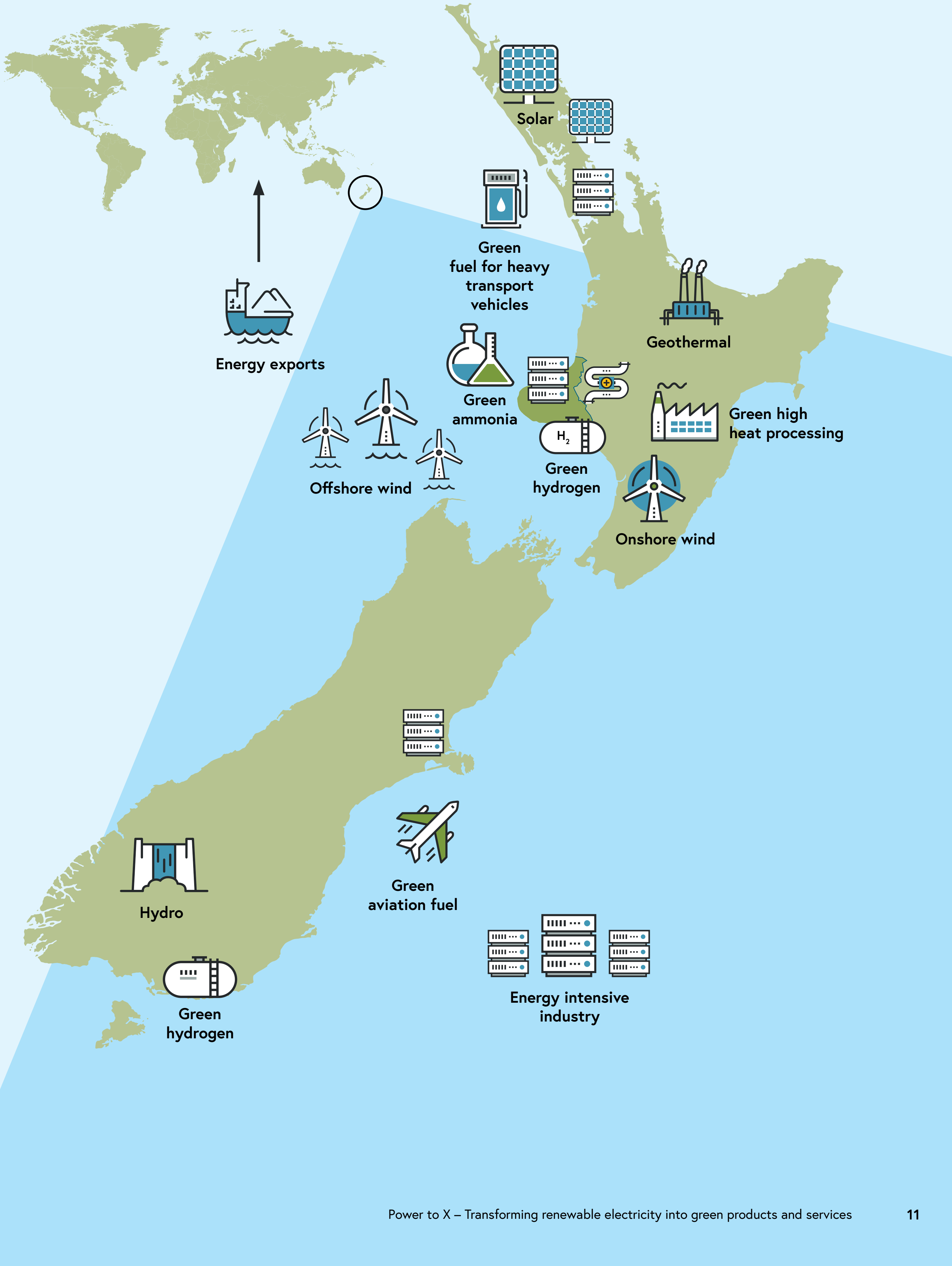
Products	Examples
DATA CENTRES	
Large data centres contain thousands of computer servers. Keeping these servers running and keeping them cool requires large volumes of electricity. Data centres also require access to fibre optic cables with plenty of capacity. New Zealand already contains several large data centres but not at the scale that occurs in other countries. However, there is potential for further and larger data centres to be established in New Zealand with Microsoft and Amazon Web Services having recently announced plans to establish data centres in Auckland.	*In September 2021, Amazon Web Services announced it would be investing $7.5 Billion over 15 years to build computing infrastructure in Auckland. AWS had previously committed to powering all it's operations with 100% renewable energy by 2025.*
MINING CRYPTOCURRENCIES	
The process of mining cryptocurrencies such as Bitcoin is also very energy intensive. It too requires large numbers of computers to be operating and kept cool. There is likely to be increasing pressure on cryptocurrency miners to reduce their environmental impact. For example, in May 2021 Tesla stopped accepting payment by Bitcoin due to concerns over its environmental impact. Similarly to data centres, there are now cryptocurrency miners targeting renewable generation for their electricity supply. Cryptocurrencies are only mined at relatively small scale in New Zealand, although this has the potential to increase as part of power to x developments.	*Bitcoin is reported to be using 129.2 TWh a year (or about three times New Zealand's total energy demand). Although it is the largest cryptocurrency, there are many others being traded.*

Simplified depiction of New Zealand's current (domestically focused) energy system



This map has been developed for illustrative purposes only, and isn't intended to fully represent New Zealand's complex energy system.

Power to X possibilities



4. Green energy when we want it

Storage and resilience

New Zealand's Government has an aspirational goal of a 100% renewable electricity system by 2030, and the Climate Change Commission has recommended New Zealand pursues a target of 50% of all energy consumed to come from renewable sources by 2035.

Achieving these targets will be challenging. The main challenge is balancing supply with demand, both within days and between seasons and years (particularly in dry years). It will be very difficult for New Zealand to meet electricity demand peaks if 100% of electricity is supplied only from renewable sources such as onshore wind, solar and marine as these cannot be turned on and off when needed. Storage of electrical energy will therefore be required to meet demand peaks.

Batteries will likely perform an important role in short-term electricity storage, but they are not the solution to storing electricity from month-to-month and year-to-year, as scaling up is expensive and batteries lose power over time. Green hydrogen offers excellent potential for medium-to-longer term energy storage when produced using renewable electricity. This green hydrogen can then be captured, stored and used later either in a fuel cell or peaker power plant (as hydrogen, or transformed to ammonia) to generate electricity as needed. Green hydrogen production plants, coupled with renewable energy, can also perform the role of providing virtual energy storage over the short-term, whereby hydrogen production can be turned off within seconds and the resulting excess power from the renewable generation can be fed into the electricity grid to meet demand peaks.

This option of using green hydrogen for storage and later re-generation of electricity is being explored in several countries. Turbines that can run on hydrogen (or with a dual fuel mixture of natural gas and hydrogen) are being developed by several companies including Mitsubishi Power and GE.

The option of using green hydrogen for storage is also being explored as part of MBIE's New Zealand Battery project[7]. Contact and Meridian's Southern Green Hydrogen project is exploring both energy storage and production curtailment to help manage New Zealand's dry year challenges.

The international investment in hydrogen storage projects and associated hydrogen powered turbines, allied with local investigations suggests this pathway has considerable potential. The technology is available and likely to improve and reduce in cost during the 2020s.

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7 *Ministry of Business, Innovation and Employment, 2021*

5. More green energy than we need

Harnessing our nation's energy potential

The key component underpinning the development of power to x pathways is the availability of renewable electricity.

For a small country, New Zealand has a large amount of untapped renewable resources. As identified by Venture Taranaki in the Offshore Wind Discussion Paper published in 2020, the resource with the most promising large-scale potential is offshore wind.

The offshore wind resource in many parts of New Zealand, but particularly off the coast of Taranaki, is of such a scale that it could not only provide all of New Zealand's electricity requirements through until 2050, but it could also be a major contributor to global decarbonisation ambitions. Through the use of power-to-x energy storage products, the electricity from offshore wind could also be used to cover domestic dry-year risk, which is of increasing concern. The green hydrogen or green ammonia produced could be used to provide energy storage and security especially for the North Island, which is particularly vulnerable to a 100% renewable electricity system.[8]

If fully developed these areas could deliver 12 Gigawatt (GW) and 2.4 GW respectively, and would double New Zealand's current electricity supply.

The size of the potential wind resource was set out in Venture Taranaki's Offshore Wind Discussion Paper (2020):

Initial analysis suggests the areas potentially suitable for offshore wind utilising fixed turbines in South and North Taranaki waters are 1,800 km^2 and 370 km^2 respectively.

If fully developed these areas could deliver 12 Gigawatt (GW) and 2.4 GW respectively, and would double New Zealand's current electricity supply.

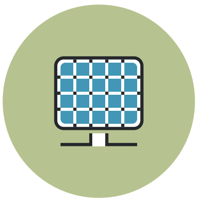
If floating wind turbines are to be considered then another 14,000 km^2 of suitable area developed could deliver an additional 90 GW into the New Zealand grid. This is considerably greater than the energy supply that New Zealand is likely to need in 2050. Such large-scale development could create opportunity for significant energy exports (e.g. in the form of green hydrogen produced by using renewable electricity to electrolyse or split water) while also reducing global emissions.

The total potential offshore wind resource in Taranaki waters is considerably larger than the energy currently extracted on an annual basis from Taranaki's existing oil and gas fields. It is an energy resource that has the potential to be globally significant.[9]

8 *The thermal generation is all in the North Island and there is a limit to flows from the South Island because it has to pass through the HVDC interconnector between the islands. 100% renewable electricity will remove the thermal generation in the market and exacerbate the risk of supply constraints in the North Island with the limited HVDC capacity than is currently the case.*

9 *Venture Taranaki, 2020 (https://www.venture.org.nz/assets/Offshore-Wind-Discussion-Paper.pdf)*

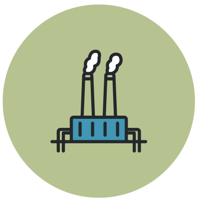
Other renewable resources exist, and The Ministry of Business, Innovation and Employment (MBIE) provides regular updates about the cost and opportunities of these various forms of resource through their generation stacks. The most recent reports were released during 2019 and 2020. However, various barriers limit their potential compared to offshore wind.



SOLAR

MBIE's solar report[10] suggests there is potential for development in New Zealand, although there are two constraints on larger-scale development and impact for Power-to-X projects.

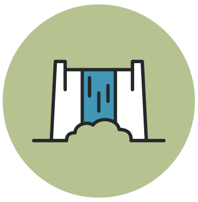
Solar has a low net capacity factor in New Zealand, meaning that electricity is only generated about 18 – 20% of the time. Comparatively, offshore wind in the right conditions has the potential to generate up to 50% of the time.



The land requirements of solar also limit its suitability for industrial production. A 1km x 1km solar cell can generate up to 35MW of solar. To generate the same total power as an 800MW offshore wind farm operating at 50% capacity, 57km^2 of land would be required for a solar farm – this is the equivalent of fifty-seven 100 hectare dairy farms.

GEOTHERMAL

MBIE's geothermal report suggests there is some potential for a further 1035MW of geothermal electricity generation to be developed in the next 40 years[11].



HYDRO

MBIE's Hydro report suggests that there is technical potential for new hydro schemes in New Zealand, but they will be *"more difficult to consent, and less attractive in a commercial sense – compared to other forms of generation"*.

ONSHORE WIND

Onshore wind is a clear possibility, and many sites have been developed or consented throughout New Zealand in recent years. However, as identified in MBIE's wind report, there are constraints on large onshore wind projects which include consolidating land and the effect on visual and physical landscapes. As a result, most sites identified only have a capacity of 100 – 300MW.

Information shows that onshore wind typically has net capacity in the range of 30 – 40%, far less than the 50% net capacity estimate of offshore wind based on data from the Maui Platform in Taranaki[12].

These MBIE generation stack reports suggest that there is potential for Power to X production from renewable sources other than offshore wind, however, offshore wind development clearly appears to have the most promise for large-scale generation. When compared to other forms of renewable electricity in the New Zealand setting, offshore wind is possible to develop in size and at scale that would make a meaningful difference to the system.

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10 Ministry of Business, Innovation and Employment, 2020 (https://www.mbie.govt.nz/assets/Uploads/utility-scale-solar-forecast-in-aotearoa-new-zealand-v3.pdf)

11 Ministry of Business, Innovation and Employment, 2020

12 Ishwar and Mason, 2019

6. Making it Happen

Resources required to enable the opportunity

In addition to renewable electricity, there are three other key raw materials that are required for Power to X products:

- **Water (H_2O) – which is needed to produce green hydrogen (H_2)**
- **Nitrogen (N_2) – which along with hydrogen is needed to produce ammonia (NH_3) and urea**
- **Carbon dioxide (CO_2) – which along with hydrogen is needed to produce the other hydrocarbon products currently manufactured from fossil fuels.**

WATER

The volume of water required for major development of power-to-x manufacturing is significant but not unreasonably large when compared to existing commercial water users.

By way of comparison, an existing large food processing plant in New Plymouth uses around 600,000m^3 (or tonnes) of water per year. This amount of water would be sufficient to produce around 67,000 tonnes of green hydrogen.

This could be used to produce:

- Around 379,000 tonnes of ammonia and around 667,000 tonnes of urea. That is about 2 ½ times the volume of urea currently produced at Kapuni by Ballance Agri-Nutrients and would provide much of New Zealand's total demand for urea (replacing imported, coal-generated urea).
- Around 350,000 tonnes of methanol. This is just under a quarter of Methanex's estimated current production of 1.5 million tonnes per year. It should be noted that the process of producing green methanol from hydrogen and carbon dioxide also releases water (1 tonne of water per 1.78 tonnes of methanol). With this recycled into further green hydrogen production, the volume of methanol that could be produced from 600,000kg of water would be significantly higher than 350,000 tonnes.

New demands from Power to X for this volume of water could provide challenges for existing regional water supply systems. Upgrades and investment in water treatment and storage facilities would likely be needed.

A by-product of hydrogen product is water, which can be reused to create more hydrogen.

NITROGEN

Processes for capturing nitrogen from the atmosphere are well established in industry and used at ammonia production plants around the globe. With nitrogen already making up 78% of the atmosphere, these processes are cost-effective.

CARBON DIOXIDE

Carbon dioxide is more difficult to capture cost effectively. Although carbon dioxide has major impacts on global climate change, it only makes up about 0.04% of the atmosphere. Separating CO_2 from the other 99.96% of the air we breathe is challenging.

Direct air capture technology is commercially available but expensive and it will need to be improved and costs reduced for it to become cost-effective at the scale required.

Another option for New Zealand is bioenergy and carbon capture (BECC). This involves using bio-resources (such as wood pellets) for purposes such as industrial heat (this is already being implemented at some Fonterra sites) plus the additional step of capturing CO_2 in the flue gases. It is much more cost effective to capture carbon dioxide in concentrated flue gases than from the wider atmosphere. BECC offers promise for net-zero emissions capture of carbon dioxide at the large-scale that will be required for production of some Power to X products.

While direct air capture or BECC are being developed, existing processes, such as capturing CO_2 from fossil fuels will be required to supply the required volumes of CO_2.

CO_2 from fossil fuels is readily available. It is a by-product of several manufacturing processes, is produced by burning hydrocarbons, or is a component of raw natural gas, (e.g. Kapuni gas is around 44% CO_2 when extracted from the ground) that is stripped out before the gas is distributed and used.

Although using CO_2 from fossil fuels for Power to X processes may lower emissions associated with the products produced, it will not eliminate them. The use of CO_2 sourced from fossil fuels may nevertheless be part of the process of transitioning to full green Power to X production.

This challenge of cost-effectively capturing CO_2 has a significant impact on the likely timeline for the roll out and expansion of the Power-to-X products that include carbon.

7. Future proofing New Zealand

A platform for a more vibrant economy

Adopting a Power to X mindset challenges the existing thinking around energy, which currently tends to be limited to considering our domestic needs based on the current size and nature of our economy.

However, lifting the lid on our energy potential can allow for much more meaningful growth and diversification of our economy. Investing in such an approach certainly requires a much more ambitious action plan, but the outcomes have the potential to be truly nation building and genuinely advance our commitments to lower emissions.

Instigating a pathway that de-risks and supports the development of a Power to X roadmap including projects, products, and services has the potential to:

- Support the country to meet its emissions reductions targets, as well as extending our international green credentials and relationships
- Allow for the opportunity to partner with international industry seeking to de-carbonise
- Create and retain meaningful, high-value jobs including new jobs and careers within niche sectors and supply chains
- Extend our manufacturing base and foster a smart 'advanced' manufacturing and digital economy, supporting the Government's Industry Transformation Plans (ITP's)
- Support energy-intensive high-value services and infrastructure, such as the fast-growing tech sector.
- Catalyse entrepreneurship, innovation, research and development, linking to existing science and research investment priorities, as well as fostering new specialties in 'green science'
- Accelerate and facilitate the Just Transition approach in regions such as Taranaki, Southland, and Northland
- Encourage and support investors already established in New Zealand, who may be considered 'high emitters', to investigate and pilot greener initiatives
- Attract new investments to New Zealand, by connecting with New Zealand Trade and Enterprise and other inward investment activity
- Connect to local and social procurement potential, fostering extensive supply chain benefits, as opposed to importing
- Allow for infrastructure reuse and advancement opportunities
- Increase export growth of products and services
- Support broader and equitable social gains, such as increased household income, improved public services and enhanced lifestyle for future generations

Adopting a Power to X approach is certainly a much more ambitious pathway for New Zealand, but offers potential rewards that are significant and far reaching. Furthermore, as the imperative to adopt a green approach gathers momentum globally, the opportunity cost of failing to act sizably increases.

New Zealand is on a path to a low emissions economy. The Government has committed to making this process a "just transition"– one that is fair, equitable and inclusive. A just transition is about making sure that the Government works in partnership with iwi, communities, regions and sectors to manage the impacts and maximise the opportunities of the changes brought about by the transition to a low emissions economy.[13]

13 *Ministry of Business, Innovation and Employment, 2021*

8. Leading from the front

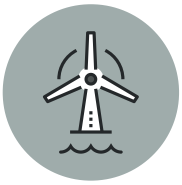
Capitalising on the Taranaki opportunity

Just as there are key centres or localities in the world where specific industries tend to be clustered, such as the oil and gas industry, Silicon Valley for IT or the film industry in Hollywood, there will be key centres in the global Power to X Industry which will establish.

These will be locations where there are natural resources, skills, supply chains, infrastructure, and proximity of raw ingredients to production or markets that comprise a logical and attractive geographical base for such an industry.

Taranaki, as the existing energy hub of New Zealand and a well-regarded location in the global oil and gas industry, is the ideal focal point for power-to-x production and distribution in New Zealand. It has the unique recipe of both world class potential for offshore wind development, thus high levels of green energy production, combined with an oil and gas industry with transferable skills, as well as infrastructure, and an exporting and manufacturing base with Power to X potential and early track record.

Taranaki Power to X strengths include:



SIGNIFICANT OFFSHORE WIND POTENTIAL[14]

- More than 16,000km^2 of suitable development area
- Space for over 100 GW of electricity generation
- Average wind speed of 10.1 m/s (36 km/h) in South Taranaki

INFRASTRUCTURE

- Port Taranaki (Deep-water port) – *Case study of application to future Power to X system in Appendix*
- Gas plants and distribution infrastructure including pipelines
- Offshore gas platforms

PHYSICAL RESOURCES

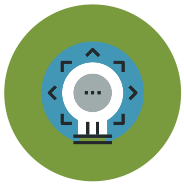
- Substantial water and industrial land available
- Proximity to domestic centres (Auckland and Wellington)
- Geographically close to Australia and Asia

SPECIALIST SERVICES AND SKILLS

- 4,300 direct energy sector FTEs[15]
- Western Institute of Technology, including ongoing development of the Energy Centre of Excellence and partnerships with other New Zealand universities
- Wood Training group facility
- Existing engineering expertise

TRANSFERABLE MANUFACTURING BASE

- Large scale food production processing plants (e.g. Fonterra)
- Methanol production
- Urea production
- Niche sectors, such as aluminium recycling



THOUGHT LEADERSHIP

- H_2 Taranaki Roadmap and Offshore Wind Discussion Document
- Local and regional government support
- Home to Ara Ake, New Zealand's new energy development centre
- Private sector support to Power to X

14 *Venture Taranaki, 2020*
15 *Martin Jenkins, 2015*

9. Taranaki case study

Detailing a possible Power to X future

	2021		2025	2030	
RENEWABLE ELECTRICITY	24 MW installed renewable generation (Kapuni project)	50 MW installed ren generation	800 MW wind farm by 2026	A new 800 MW wind farm is operationa	
UREA	Hiringa/Ballance Kapuni ammonia project		Scale-up of green ammonia production for urea, so that e-urea produ		
HYDROGEN FOR EXPORTS (E.G. AS AMMONIA)	New-build green ammonia production		Green ammonia export ramping up -->		
DIRECT H2 USE (E.G. STORAGE, POWER, COMMERCIAL HEATING, INDUSTRIAL PROCESS HEAT)	H2 pipeline injection trial		1% H2 blending	20% H2 blending	
	Dry winter H2 storage concept developed and infrastructure trials		Gradual ramp-up of hydrogen production to match 25% of dry-year storage needs by 2035	Annual storage	
	Blended H2 peaker plant trials		100% H2 peaker plant trials	100% H2 peaker plant conversion	
H2 FOR HEAVY EQUIPMENT/ MACHINERY, BUSES AND MEDIUM TRUCKS	Forklift pilots		Scale up forklift fleets		
	Bus pilot	Intercity bus pilots and expand regional fleet	Scale up bus fleet -->		
	Medium truck pilot (waste truck and civil contractor)		Full waste fleet adoption	Scale up medium truck fleets -->	
HEAVY TRUCKS	2021 - 8MW production for refuelling		Heavy long haul and short haul fleet trials	Fleet conversion and expansion to dairy, forestry, and other heavy vehicle uses	Stepwise fleet
MARINE FUEL (E.G. AMMONIA OR METHANOL)	Marine pilot projects and trials				Stepwise
METHANOL	Design and build of first plant				First plant
SYNFUEL	Carbon capture and synfuel pilot			Scale up of synfuel -->	
METHANATION	10 MW methanation plant pilot		100 MW methanation plant		Multipl
CO_2 FEEDSTOCK	Feasibility study into CO_2 capture from biomass feedstock, including CO_2		Pilot biomass plant		
WATER INFRASTRUCTURE	Investments in scaling-up water infrastructure start		Investments ramp-up		Investr
TECHNOLOGY SECTOR	Create industry attraction prospectus		Explore advanced manufacturing opportunites (e.g. Agri Tech)	Data centre development	

This Case Study outlines a pathway for concurrent development in Taranaki of offshore wind electricity generation (10.4 GW by 2050) and power-to-x production and distribution. This scenario is only one of many other possible options, however all scenarios would be constrained by the scale and pace of the offshore wind capacity build. This scenario is also consistent with the H_2 Taranaki Roadmap[16].

	2035	2040	2045 – 2050
l every two years starting in 2026 -->			
uction by 2050 reaches current production volumes from Ballance			
	Stepwise conversion of network branches to 100% H2 (through to 2050)		H2 storage starts operation (depleted gas field)
e of 25% of dry-year needs			
n -->			
expansion continues into the rest of the heavy truck		Accelerated expansion	
expansion into the rest of the marine sector		Accelerated expansion	
operating by 2035	Stepwise scale-up	Accelerated expansion	
e distributed methanation plants			
nents in water infrastructure accelerate			
	Continue leveraging regional engineering expertise		

16 Venture Taranaki, 2020

The case study identifies the following opportunities:

1. Green ammonia production for urea, starting with the Hiringa/Ballance Kapuni project, scaling up to replace (i) 140,000 tonnes of imported urea in the North Island by 2035, and (ii) all imported urea (400,000 tonnes) in North Island by 2050.
2. Green ammonia production for exports or energy storage starting in 2026.
3. Green hydrogen production for buses, medium trucks and other transport requirements (e.g. forklifts and straddle carriers), with some pilot projects running at the moment, and fleet expansion from 2023.
4. Green hydrogen production for heavy trucks,[17] with the following stages:
   - Pilot projects and trials taking place through to 2025.
   - Fleet conversion and expansion to dairy/forestry taking place through to 2030.
   - A stepwise expansion into the heavy vehicle fleet occurring through to 2035 such that 30% of heavy vehicle energy demand is replaced with green hydrogen by then.
   - An accelerated expansion into the heavy vehicle fleet occurring through to 2050 such that 50% of energy demand is replaced with green hydrogen by 2040, and 100% by 2050.
5. Green ammonia as marine fuel, with the following stages:
   - Pilot project and trials taking place between 2025 and 2030.
   - A stepwise expansion into marine fuel starts taking place afterwards, such that 15% of energy use by domestic and international and marine fuel is replaced with green ammonia by 2035 and 30% by 2040. We assume that take-up of hydrogen or hydrogen derivatives in marine applications is at a slower rate than for heavy trucks.
   - An accelerated expansion into marine occurring after 2040, such that 100% of energy demand by domestic and international marine is replaced with green ammonia by 2050.
6. Green methanol production, with the following stages:
   - The design and build of first plant between 2025 and 2035, such that the first plant is operational from 2035.
   - The scale-up of green methanol production after 2035, based on indications that the green methanol and fossil-fuel methanol production costs will start converging between 2030 and 2045. It is assumed that 1% of current NZ fossil fuel methanol production is replaced by 2035, and 20% is replaced by 2040.
   - From 2040, green methanol production accelerates to completely displace fossil-fuel methanol by 2050.

There are a number of other Power to X opportunities that, although not explicitly recognised above, provide alternative combinations with different trade-offs between electricity requirements. These opportunities include:

- Direct use of hydrogen for electricity generation, for commercial heating or industrial process heat.
- Production of green synfuels for transport (particularly aviation), although we note that Northland might have a comparative advantage in this space due to the existing pipeline to Auckland Airport.
- Replacing natural gas with green methane. While green methane has various uses it currently appears more cost effective to use other Power to X products.

17 These have a Gross Vehicle Mass of over 10 tons

10. Where to from here?

Enablers and next steps

In order to support the enablement and growth of Power to X pathways and the transformation of New Zealand's energy system and economy, priority should be given to progressing the following actions.

ENGAGING WITH IWI AND MĀORI

The thoughts and interests of iwi and Māori relating to the energy sector and Power to X opportunities are not yet well known. Extensive engagement needs to occur with mana whenua and tangata whenua, particularly in regions such as Taranaki, to discuss the potential opportunities that exist and ensure their perspective on energy production and use of resources are integrated.

IDENTIFYING RELEVANT CROSS-GOVERNMENT CONNECTIONS

Power to X is an opportunity that will have many different touchpoints. In order to gain momentum in this work, it will be important to identify and understand the connectivity of this work (and the energy transition more broadly) across government. A large number of departments and agencies, such as the Ministry for Business, Innovation and Employment, New Zealand Trade and Enterprise, Ministry for the Environment, Transpower, and the Energy Efficiency and Conservation Authority have the potential to add value to this work and may wish to be actively involved in its development.

DEVELOPMENT OF REGULATORY FRAMEWORK FOR OFFSHORE ENERGY GENERATION AND STORAGE

The primary input of green Power to X processes is large-scale renewable electricity generation. As outlined in this report, the most likely method of generating the amount of electricity required for Power to X processes is through offshore wind farms. There is no current framework that either enables or inhibits any renewable offshore energy generation, including wind, wave, or tidal.

Consideration should be given to developing a bespoke regulatory framework, independently of the current Resource Management Act amendments, to provide investors and developers with certainty when planning large-scale energy generation developments.

Consideration should also be given to understand what other regulation might be required to facilitate the Power to X to opportunities. For example, what new regulations might be required to transport hydrogen through natural gas pipelines (if any), or what regulatory changes (if any) might be needed to store gases, such as hydrogen or carbon dioxide, underground for future use.

FINANCIAL SUPPORT FOR ENERGY SECTOR TRANSITION

The energy sector is committed to supporting New Zealand to reach its net zero emissions goal. Private sector developments and investors have expressed interest and started investments in these opportunities. Ensuring settings are in place to encourage this significant investment to flow will be critical.

Central government support and funding could usefully help achieve this goal, and Power to X opportunities, through:

- Developing an offshore renewable energy regulatory framework
- Targeted resource and development projects, such as green methane
- Pilot projects, such as manufacturing developments
- Feasibility studies assessing the suitability of certain locations or environments
- Public/private partnerships with international investors and developers

FURTHER WORK REQUIRED TO DETERMINE VIABILITY

Most concepts introduced and discussed in this paper are not new and are already being tested, trialed and implemented around the world. A priority action should be to forecast future technology costs to understand the affordability and viability of specific power to x processes. Particular attention should be given to current international trends and what competitive market prices are required to be reached for export products.

Further thought should also be given to domestic electricity demand and how this may influence generation prices in the future.

EXPLORE, UNDERSTAND, AND LEVERAGE EXISTING INTERNATIONAL ENERGY LINKS

A number of New Zealand energy companies are subsidiaries or part of large multi-national organisations. Work should be completed to explore and understand the potential to build on these existing relationships, as a stepping stone to further develop a Power to X roadmap, or to identify possible export market opportunities.

NEXT STEPS

New Zealand has set an ambitious goal of net zero emissions by 2050. Transformation of the energy sector will go a long way to ensuring that this goal is met. Encouraging and promoting various Power to X processes and pathways will not only help ensure a just transition for the communities of Aotearoa New Zealand, but also has the potential to contribute to wider international emission reduction targets, and a high-value New Zealand economy.

The intention is for this paper to initiate discussions and views about the future economic mix for Aotearoa New Zealand. Any interested party wishing to provide feedback or understand more about this topic is encouraged to contact Venture Taranaki.

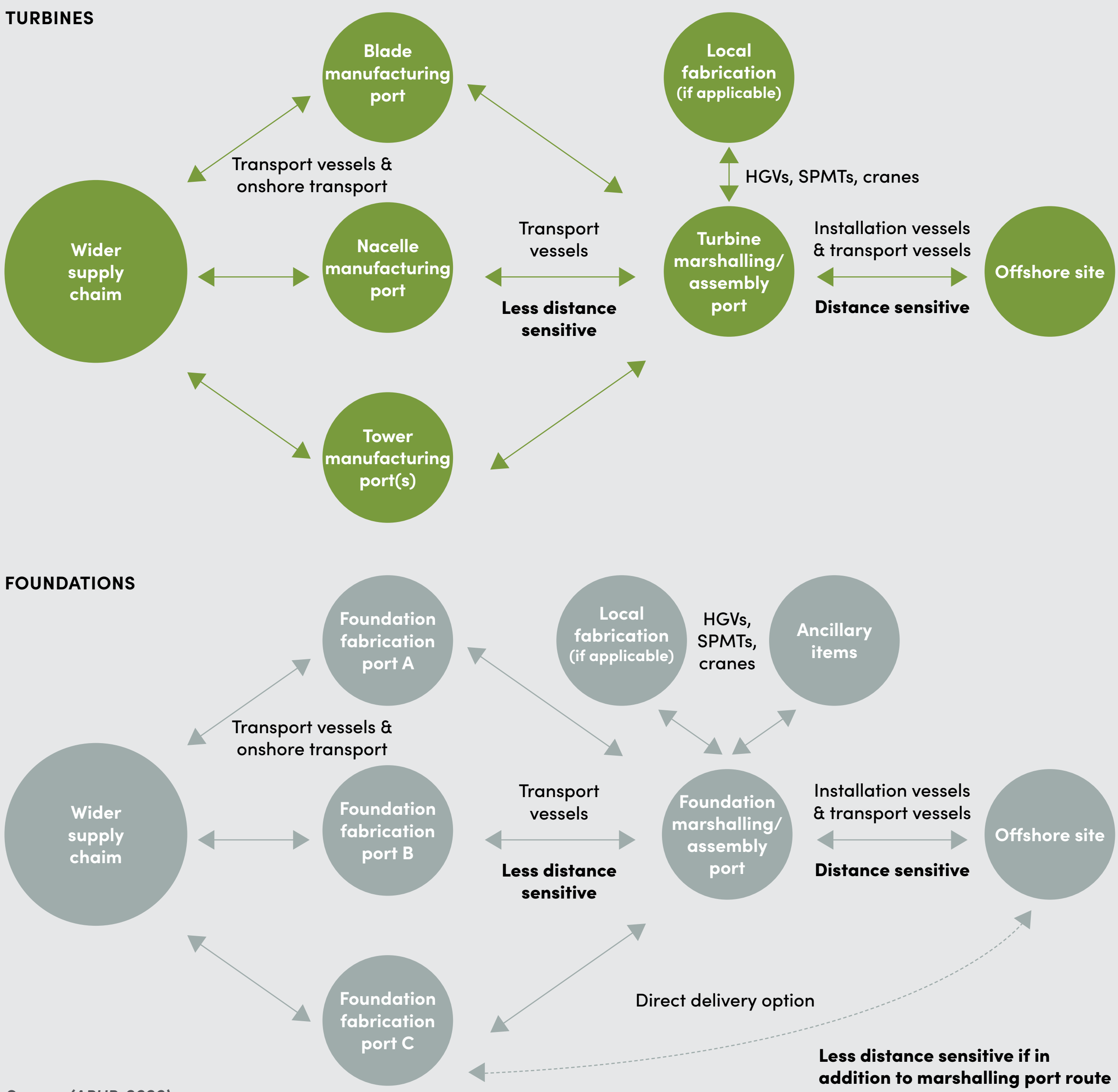
Appendix:
Port Taranaki case study

Port Taranaki is an example of how current infrastructure could be readily adapted to support a large-scale renewable electricity sector plus green hydrogen production and export port. The port has advised us of their view that Taranaki can be the offshore wind hub of New Zealand and Port Taranaki can be a key enabler.

MARSHALLING AND ASSEMBLY PORT DURING CONSTRUCTION (TYPICAL NORTHERN EUROPEAN MODEL)

The following reproduced from ARUP Study for the "Crown Estate Scotland" Ports for Offshore Wind 02 September 2020.

FIGURE 1 – SCHEMATIC OF TURBINE AND FOUNDATIONS TRANSPORT AND LOCAL FABRICATION CONFIGURATION FOR OFFSHORE WIND INSTALLATION



Source: (ARUP, 2020)

The typical primary requirements for marshalling/assembly port facilities for a single function (e.g. either foundations or turbines) for a nominal 1GW fixed-bottom project include:

ARUP Study Ports for Offshore Wind	Port Taranaki response
Onshore area for storage and marshalling of components, comprising an area of 4-8ha as an absolute minimum to partially fulfil requirements but ideally around 10-20ha. The size of area required is dependent on the logistics processes of a project. Storage areas must also have adequate load capacity for the components and sufficient access routes to the quays;	Port Taranaki has access to large laydown areas close to berth and has supported onshore windfarm projects including the Waipipi and Turitea windfarms by providing laydown space. Port Taranaki's Blyde wharf has a heavy lift pad capable of discharging windfarm components and two mobile harbour cranes that can support these projects.
Quays for simultaneous berthing of two major component transport and/or installation vessels, each of length 140-240m and requiring 6-12m water depth or greater;	Port Taranaki's Blyde wharf is 415m long, and has a draft depth of 12.5m.
Entrance width suitable for relatively wide beam installation vessels, ideally 50-60m or greater;	Port Taranaki's harbour entrance and berths support this.
Sheltered water areas and suitable quays or moorings for 'floating storage' of components for shorter time periods on vessels or on barges, or in the case of floating foundations in self-floating storage;	Port Taranaki can provide berthage for short period stays.
No or minimal vessel access restrictions that would prevent high-cost installation vessels having 24-hour access (e.g. tidal windows for shallower entrance channels or berths, locks, gates, overhead lines, opening bridges); and	Port Taranaki is open for business 24/7, 365 days per year.
Proximity to the offshore site or 'distance sensitivity'.	Port Taranaki is the only deep-water port on the West Coast of New Zealand and is the closest New Zealand Port to potential Taranaki offshore windfarm sites.

OPERATIONS AND MAINTENANCE (O&M) PORT FOR FULLY DEVELOPED OFFSHORE WINDFARM

An O&M port is used to host activities associated with the ongoing reasonably foreseeable operation and maintenance activities associated with an offshore windfarm during its design life.

The facilities established by a windfarm developer or future project operator at an O&M port are specific to the O&M strategy of the individual project (for example with respect to vessel choice).

Typical facilities can include dedicated or shared berthing facilities for the O&M vessels with utilities and craneage, and an onshore facility containing office space for operations staff, a marine control centre for directing activities, terminal facilities for turbine technicians (e.g. changing, welfare and briefing facilities), and a small immediate spares warehouse. The same port and facilities, or similar temporary facilities, can be used for monitoring and support activities during the construction phase of a windfarm.

Typically, northern European projects to date have adopted a Crew Transport Vessel (CTV) based O&M strategy, whereby the vessels and technicians only stay at sea for a single shift. Due to their relatively small size, CTVs are well suited to utilising historic ports and harbours that may have experienced declines in their traditional industries.

WHY PORT TARANAKI

This opportunity relies on Port Taranaki's proximity to prime offshore wind real estate. Port Taranaki's competitive advantage lies with its energy industry experience and linkage to the local engineering industry that would likely be critical in the success of this type of project. Port Taranaki's access to sizable areas of land suitable for laydown is a critical factor.

PORT TARANAKI CAPABILITY H2 PRODUCTION FACILITY

The 18.8 hectare former New Plymouth Power Station site could host a liquid hydrogen (LH2) production facility, supporting production of export liquid hydrogen from Port Taranaki to Asian markets. Proximity to the wharf improves economics as shorter distance cryogenic pipelines would only be required to transport product from the production facility to the wharf. Port Taranaki has experience with hosting Major Hazard Facilities. Port Taranaki has experience in exporting energy products to world markets.

Port Taranaki Model

- Provide land for building hydrogen plant supporting liquefication and storage
- Build hydrogen pipeline from LH2 facility to wharf for load out via loading arms. Wharf requirements to be determined
- Vessel storage capacity 50,000m^3
- Requires minimum 3,040 tonnes of LH2 storage capacity on port
- Major Hazard Facility
- Key strategic advantage is land at wharf side.

ABOUT VENTURE TARANAKI

Venture Taranaki is the regional development agency for Taranaki. The organisation is responsible for regional development strategy, enterprise and sector development, investment and people attraction, and major project initiatives which contribute to the inclusive and sustainable growth of the region. Venture Taranaki is a registered charitable trust and a New Plymouth District Council Controlled Organisation, supported by the three District Councils of the Taranaki region.

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