National Energy Research Institute

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Feedback on Hydrogen Green Paper

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Key Points

- Any consideration of the potential for Green Hydrogen, particularly electrolytic hydrogen, needs to occur in the context of the potential for both other New Zealand renewable energy resources and the opportunities from the demand-side:
    - Not doing so risks other world class opportunities being missed.

  The Renewable Energy Strategy foreshadowed by the Government provides the opportunity to do this.

- New Zealand's energy situation is relatively unique globally, so international experience doesn't necessarily directly apply. Further, energy futures are facing uncertain disruption from technologies and demand-side changes that will impact on our economy, society and environment in novel ways.

  This calls for New Zealand relevant renewable energy RS&I, including Green Hydrogen, directed at:
    - Addressing those areas where actions are clear cut;
    - Increasing our options and de-risking them where there is uncertainty.

  Developing New Zealand as a leader in aspects of Renewable Energy RS&I, also foreshadowed by the Government, provides the opportunity to do this.

Introduction

The National Energy Research Institute (NERI) welcomes the opportunity to comment on the Draft Hydrogen Green Paper.

NERI is a Charitable Trust incorporated in New Zealand. Its primary purpose is to enhance New Zealand's sustainability and to benefit the New Zealand community by stimulating, promoting, co-ordinating and supporting high-quality energy research and education within New Zealand.

Its research members are Victoria University of Wellington, Auckland University of Technology, GNS Science, Scion, University of Canterbury and the University of Otago, and its industry association members are the Bioenergy Association, BusinessNZ Energy Council, the Energy Management Association of New Zealand, the New Zealand Wind Energy Association, the Road Transport Forum and Tourism Industry Aotearoa.

This submission has been prepared in consultation with the membership but may not necessarily represent their individual views in the detail.

In what follows we first comment on the issue of Green Hydrogen production in New Zealand, and then comment on each of the matters raised in the Green Paper.

Government's role in Green Hydrogen Production

The Green Paper focuses on "Green Hydrogen"[1] (p.16), particularly electrolytic hydrogen. However not explicitly addressed is the basic question: "What is the Government's role in helping to economically produce Green Hydrogen in New Zealand?"

There are various ways to produce Green and Blue[2] Hydrogen for example Nikolaidis and Poullikkas (2017)[3] lists[4]:

- Green hydrogen:
  - biomass pyrolysis and gasification; direct and indirect bio-photolysis;
  - dark and photo fermentation;
  - electrolysis and photoelectrolysis;
  - nuclear and solar thermolysis.
- Blue Hydrogen, CCS with:
  - steam methane reforming, autothermal reforming, methane pyrolysis (all Green Hydrogen with biomethane);
  - coal gasification.

Each is at different stages of development internationally and have pros and cons for different applications and supply chains. Their relative economics and outlooks in New Zealand are not well understood[5].

For these reasons New Zealand needs to independently and systematically review its renewable energy options. This needs to be application-specific and consider other potential renewable fuels[6,7] and demand-side opportunities in the context of the full supply chains.

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[1] Throughout the term will be used to also cover the various hydrogen carriers where this is not inconsistent with the context.

[2] Only briefly addressed in the Green Paper (p. 28) lower cost Blue Hydrogen is the priority internationally, reflecting the need for GHG reductions rather than renewability per se. See the section on exports for one consequence for New Zealand.

[3] Pavlos Nikolaidis, Andreas Poullikkas *A comparative overview of hydrogen production processes* Renewable and Sustainable Energy Reviews 67 (2107) pp 597–611

[4] This type of list in slightly different forms can be found in a number of references e.g. the US Office of Energy Efficiency & Renewable Energy https://www.energy.gov/eere/fuelcells/hydrogen-production-processes accessed 20 October 2019.

[5] These will be sensitive to the target application, scale and duty cycle required, available resources, supply chains, technology development pathways and hydrogen's general position relative to other available renewable fuels in New Zealand.

[6] Strictly speaking hydrogen is itself an energy carrier, but we use the term "fuel" throughout for ease of exposition. A related issue is that an energy carrier cannot of itself be renewable, this depends upon the feedstocks etc, however again "renewable fuels" will be used to reflect the nature of the feedstock.

[7] E.g. biofuels, better batteries/charging.

New Zealand's strengths, the opportunities to accelerate the development and adoption, and the challenges all need to be identified[8], viz:

- *Relative resource strengths:* renewable electricity[9], short-term electricity buffering from significant hydro, excellent wind, geothermal base load, a good electricity distribution system, good bioresources in a temperate climate, less pressure on our land than many countries.
- *Strong commercial capability:* bio production and processing (food, forestry[10]), renewable electricity, key resource areas (e.g. geothermal).
- *Strong RS&I human capital:* electricity systems, functional materials, aspects of bioprocessing, social impacts etc. For example, there are three directly relevant Smart Ideas investments[11]:
  - GNS: Low cost catalysts for electrolysis and fuel cells
  - UC: Biomass gasification for H2 production and CO2 capture
  - UO: Highly efficient nanophotonic solar-hydrogen systems

More systematic sustained investment will be required to accelerate local developments and to facilitate the changes required to allow local adoption of renewable energy[12]. These will need to include assisting both businesses and society to adapt, and particularly in the case of the latter in ways that protects vulnerable communities. This is not straightforward with many of the questions specific to New Zealand's situation, and will require investment in systematic research effort to address.

We will also need to rely upon an ongoing significant global investment in[13]:

- lowering the capital cost of electrolysis and improving its lifetime and efficiency[14];
- lowering the capital cost of hydrogen production from biomass gasification and pyrolysis and reducing and stabilising feedstock costs[15];

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[8] There is already a body of reports available addressing aspects of this, particularly the Concept Consulting 2019 reports *Hydrogen in New Zealand,* but some dating back a decade to the then FRST Contract CRLE601, "Transitioning to a Hydrogen Economy" remain relevant.

[9] We also have some limitations, e.g. winter supply in dry years; availability of low-cost renewable electricity if electrolytic hydrogen is widely adopted.

[10] There are also moves by the Government to investigate the potential for a step change in value-adding to New Zealand's forests, including the potential for biorefineries, see "*A forest strategy for Aotearoa New Zealand*" www.mpi.govt.nz/te-uru-rakau-forestry-new-zealand/about-te-uru-rakau/a-forest-strategy-for-aotearoa-new-zealand/ accessed 24 October 2019.

[11] https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/ accessed 24 October 2019

[12] The intent to do this is foreshadowed in the Minister's forward and in the draft RS&I Strategy, and this is welcomed.

[13] This list assumes the primary target processes for New Zealand will be in water electrolysis, biomass gasification and/or pyrolysis, and fermentation.

[14] See e.g. Schmidt et al (2017) *Future cost and performance of water electrolysis: An expert elicitation study* international Journal of Hydrogen Energy 42 30470-30492

[15] See e.g. https://www.energy.gov/eere/fuelcells/hydrogen-production-biomass-gasification accessed 20 October 2019)

- developing better microbes and bioreactor designs along with the use of nanotechnology to produce lower cost hydrogen from fermentation[16].

Recommendation: Green Hydrogen production in New Zealand

That New Zealand invest in research into Green Hydrogen (and other renewable fuels) to identify:

1. the best prospects for New Zealand;
2. our relevant resource constraints and how to address these;
3. how to economically produce and supply the fuels, and
4. the technical, commercial and social capabilities required to aid effective and equitable adoption and how to achieve this.

[16] See e.g. Mishra et al (2019) *Outlook of fermentative hydrogen production techniques: An overview of dark, photo and integrated dark-photo fermentative approach to biomass.* Energy Strategy Reviews 24 27–37

Government's role in Storage and Distribution

The Green Paper notes that the requirements for hydrogen storage and distribution are application specific. The key applications it identifies are: *electricity buffering for dry years*; *long-haul transport*; *industrial processing*; *decarbonizing natural gas (NG)*; and *export*.

Where significant storage and distribution issues arise that are specific to these applications they will be discussed in response to the subsequent questions in the questionnaire.

But there are two general issues:

1. Centralised vs decentralised production

With bulk supplies to a small number of locations there are trade-offs between more expensive decentralised production at those locations but using cheaper and simpler distribution of feedstocks (e.g. biomass, electricity)[17], and lower cost centralised production[18] but with more complex bulk supply of hydrogen.

Long-haul transport, industrial processing and *export* all potentially require bulk supplies to a small number of locations. Because economic hydrogen projects in these applications will arise before any mass distribution system is available early projects won't have access to bulk distribution infrastructure. This will favour building scale at hubs where the applications permit[19] and developing supply chains from there[20].

Pipelines appear the best prospect to overcome the high costs of using vehicles for longer distance bulk hydrogen, but hydrogen-only pipelines will require new investment and both international and local R&D to address[21].

2. Standards

Standards for storage and handling of all renewable fuels will need ongoing review to ensure the regulatory framework accommodates a shift to greater use of renewable fuels. This is a common need across all applications and points of production, distribution and use. As such there are common concerns particularly with users and the general public, and this will need systematic understanding and be addressed.

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[17] Both are available in New Zealand, with our electricity distribution system often better than in other jurisdictions.

[18] Centralised production favours electrolysis but decentralised potentially biological. More information is needed.

[19] E.g. at Kapuni as the Green Paper identifies (p. 60).

[20] This is type of investment pathway foreshadowed in a number of international studies e.g. IRENA (2018) *Hydrogen from Renewable Power: Technology Outlook for the Energy Transition*

[21] Nikolaidis and Poullikkas (2017)

Recommendations: Government's role in developing storage and distribution

That New Zealand invest in research into:

- the trade-offs between more expensive decentralised production using cheaper and simpler distribution of feedstocks, and lower cost centralised production but with more complex bulk supply of hydrogen; and
- the use of pipelines in New Zealand to transport hydrogen.

That New Zealand review its standards for storage, transporting and handling of all emerging alternative fuels, and include in this systematic multidisciplinary research to support public engagement and technological literacy.

Challenges for Hydrogen

Limitations in existing storage and distribution infrastructure for pure hydrogen; cost of implementation; competition from other renewable fuels; adequacy of standards.

Opportunities for Hydrogen

To develop short-haul distribution and storage hubs around locations where significant Green Hydrogen use is an early economic opportunity.

Government's role in Hydrogen and Electricity

The Green Paper suggests *dry year support*, *seasonal buffering* and *remote area power storage* as the main potential applications for electricity in the electricity system.

1. Electricity buffering for dry years

Hydrogen in this application doesn't look promising viz. Concept Consulting[22], ICCC[23], lower-cost options from the demand side, efficiency[24], and other renewable fuels[25].

Renton[26] cited by the Green Paper in support of electrolytic hydrogen also concludes it will require a mix of these options but that the "*H2 vector is possible & more palatable than some greenfield* [sic]". Renton's lowest cost option within the electricity system[27] is synthetic methane because it allows the use of the existing NG infrastructure, particularly bulk underground storage[28]. Even here other alternatives such as using biomethane directly need to be tested.

2. Seasonal buffering

Shorter intra-seasonal buffering for grid stability is suggested internationally[29]. However, in New Zealand the high penetration of hydro makes this issue a lower priority[30].

In the longer-term with a significant increase in demand for renewable electricity from a shift from fossil fuels to electricity there may be buffering needs beyond the ability of hydro and other technologies to service competitively.

3. Off-grid opportunities

Some off-grid opportunities for electrolytic hydrogen could emerge, particularly if used for heat loads[31], but they too will need to compete with other forms of storage

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[22] Concept Consulting. (2019). *Hydrogen in New Zealand Report 2: Analysis*.

[23] John Culy Consulting. (April 2019) *ICCC Modelling: Dry Year Storage Options Analysis: Final Report to the Interim Climate Change Committee.*

[24] EECA. (2019) *Energy Efficiency First. The Electricity Story. Technical Report*.

[25] NERI. (2019) *Meeting New Zealand's Winter Electricity Needs: Research Priorities.*

[26] Renton, A. (2019, June). *H2, Dry Winter and the next best alternative.* Paper presented at the EEA Conference and Exhibition 2019, Auckland.

[27] Once lower cost options from outside the electricity system (demand, alternative fuels) have been included this need will be significantly reduced, and could be manageable at a reasonable cost.

[28] The available of underground storage for hydrogen is not known but will be less straightforward than in other jurisdictions given New Zealand's geology. See Concept Consulting. (2019) *Hydrogen in New Zealand Report 3: Research* for a discussion. The high capital cost and minimum annual duty cycle make it and other storage options economically challenging in this application, see e.g. UK CCC (2018) *"Hydrogen in a low-carbon economy"*.

[29] E.g. International Renewable Energy Agency (2019) "*Hydrogen: A Renewable Energy Perspective*"

[30] The low round-trip efficiency and conversion losses to carriers are issues for hydrogen, particularly in the face of emerging technologies like redox flow batteries that have lower capital cost and simpler storage.

[31] E.g. HyLink www.hylink.nz accessed 20 October 2019.

particularly on intra week time scales. This is not likely to be a large market in the wider context of New Zealand's fossil fuel use.

Other applications may also emerge as the wider demand for Green Hydrogen grows and the marginal cost of production reduces.

Recommendation: Government's role in hydrogen and electricity

That New Zealand invest in further research and modelling of the full range of options to address the dry year and shorter-term resilience of the electricity system, taking full account of all supply and demand side options.

Challenges for Hydrogen

Low round-trip efficiency and additional conversion losses if hydrogen carriers are being using (e.g. synthetic methane); cost of large-scale longer-term storage, particularly for raw hydrogen gas; competition from other options.

Opportunities for Hydrogen

Appear limited. Other applications of electrolytic hydrogen may be able offer electricity services on a marginal cost basis.

Government's role in Hydrogen for Mobility

The Green Paper notes that FCEV's attractiveness in transport applications arise from: *FC efficiency*[32], *very low emissions*, *better range*, *shorter refuelling time*, and *safety at least comparable with gasoline* (p. 49). It sees applications in New Zealand in *maritime*, *long-distance road vehicles*, and *high duty cycle industrial vehicles* (p. 50).

There are a range of options in New Zealand for replacing fossil fuels in these applications, predominantly: hydrogen; better batteries/charging; biogas; liquid biofuels; and demand reduction, each with their particularly pros and cons and challenges[33,34,35].

Work has been undertaken in New Zealand on individual fuels[36], specific applications, and the demand side.

Demand-side initiatives are making ongoing and not insignificant improvements[37] and, for example, in the quite near-term disruptive ICT (e.g. 5G) will offer opportunities for vehicles, passengers and consignments all to communicated thereby delivering significantly more efficient passenger transport and logistics.

The future of the various fuels for transport is generally not clear cut, and all warrant further development, but there are some reasonably clear indications of the near-term prospects:

- BEVs and PHEV cars in New Zealand that meet user requirements are increasingly economic[38]. It is reasonable to assume given New Zealand's predominantly renewable electricity system that their penetration will grow to progressively address at least half of New Zealand's land transport fossil fuel use.
- Biofuels blended with fossil fuels are available in New Zealand and use will likely grow as additional types of fuel emerge. The issue is no longer technological or market entry for these fuels, simply economic[39].

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[32] Although not so for electrolytic hydrogen in comparison with BEVs across the whole supply chain, and not clear cut for biofuels in internal combustion engines.

[33] See e.g. New Zealand Productivity Commission. (2018). *Low-emissions economy: Final report.*

[34] Ministry of Transport (2019) *The Green Freight Project: Background Paper* accessed from https://www.transport.govt.nz/multi-modal/climatechange/green-freight-project/ accessed 18 October 2019.

[35] NERI (2019) *Working paper: New Zealand Clean High Duty Cycle Transport: Research Challenges* available from https://www.neri.org.nz/submissions-and-papers-by-neri accessed 15 October 2019.

[36] E.g. Suckling et al. (2018) *New Zealand Biofuels Roadmap* Scion; Concept Consulting (2018) *"Driving change" – Issues and options to maximise the opportunities from large-scale electric vehicle uptake in New Zealand*; Concept Consulting (2019) *Hydrogen in New Zealand*; etc

[37] See e.g. https://www.eecabusiness.govt.nz/sectors/transport/ accessed 20 October 2019.

[38] E.g. Concept Consulting (2016) *Electric cars, solar panels, and batteries in New Zealand Vol 2: The benefits and costs to consumers and society*.

[39] E.g. Neste who produce a drop-in diesel replacement is currently expanding its 1 million tons per year refinery in Singapore and has indicated it would be available to sell in New Zealand at ~$1/l more than diesel.

- Methane from waste has been used as a transport fuel, although supplies are limited by feedstocks[40]. This may grow as a niche in places where there are suitable feedstocks (e.g. farms, wastewater treatment plants, landfills), or if larger scale biomethane production is developed[41].
- As the Green Paper notes (p. 7) the Ports of Auckland is in the process of commencing a demonstration that will involve a refuelling station and a number of FCVs. There are also several transport investigations underway e.g. freight operator TIL Logistics Group and these are yet to be finalised.

In terms of the target applications identified in the Green Paper:

- Emissions from New Zealand bunkered *marine fuels* come from international shipping (2/3[rds]) [42], with coastal freight, the fishing fleet, and Cook Strait most of the remainder. Cruise liners/ferries where emissions and noise are an issue could eventually move to all-electric systems using FCs with hydrogen carriers, and in the interim adopt lower emission auxiliary power systems[43]. However, for most applications it is likely that alternative renewables e.g. drop-in bio-marine fuel oils will be cheaper.
- All alternative fuels options have potential application for *long-distance road vehicles* in New Zealand, as noted, each with their various pros and cons. The relative mix of technologies will in part depend upon the specific duty cycles of the fleet. Some are potentially available now as drop-in fuels (i.e. Neste), and the degree of penetration of BEVs into the heavy transport market will evolve as battery and charging technologies improve[44]. All technologies would start to face feedstock constraints if they attempted to address this complete market[45].
- Green Hydrogen is virtually unique in its ability to service *high duty cycle industrial vehicles* where emissions are an issue.

Therefore, as the Green Paper notes (p. 57), any role for Government in hydrogen for mobility needs to take account of the wider context of renewable fuels.

Finally, there is again a need to review standards for all alternative fuels in transport.

Recommendation: Government's role in hydrogen for mobility

That New Zealand invest in further research on the full range of options to address emissions in high duty cycle transport in New Zealand with a view to:

- Clarifying the activities where either action is clear cut, and those where the returns are high but are uncertain;
- Addressing those areas where actions are clear cut; and

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[40] Use of LNG/CNG in diesel engines requires only minor modifications see e.g. DieselGas (www.dieselgas.co.nz).

[41] Renton (2019) *Op. Cit.* gives an insight into the value of being able to use existing infrastructure.

[42] On the international front we will be a technology taker.

[43] For example, the specification for the Kiwi Rail Cook Strait ferry replacements RFI call for Methanol/LNG auxiliary generators.

[44] PHEVs coupled with either FC or biofuels as range extenders will potentially expand this.

[45] There would be enough reasonably priced renewable electricity for BEVs where they are practical.

- Increasing our options and de-risking them when there is uncertainty.

That New Zealand review its standards for the use of all emerging alternative fuels in transport.

Challenges for Hydrogen

High "generator to wheel" losses for electrolytic hydrogen; capital costs of new infrastructure (generation, distribution, dispensing and vehicles) compared with drop-in alternatives; distribution and storage more constrained than other renewable liquid or gaseous fuels; the use of hydrogen carriers is immature; overall competition from other fuels; adequacy of standards.

Opportunities for Hydrogen

High duty cycle industrial vehicles where emissions are an issue; a potential option for renewable fuels for high duty cycle land transport; possible as a niche marine fuel, most likely using a hydrogen carrier.

Government's role in Hydrogen for Industrial Processes

The Green Paper identifies *Industrial Process Heat* (replacing NG for medium and high-grade heat) and *Industrial Feedstock* (replacing hydrogen from fossil fuels) as the main targets for Green Hydrogen in industrial processes. In New Zealand these demands are at a small number of locations and predominantly require fuel 24/7.

In the medium-term Green Hydrogen will find it difficult to compete for *medium-grade heat loads* with high temperature heat pumps[46], industrial filament heaters, microwave and direct use of other renewable fuels.

Hydrogen could be more competitive in *high-grade heat processes*[47] but other renewable options remain including the much more efficient direct use of electricity (filament, microwave). The economics will be site specific.

Where Hydrogen is essential as an *Industrial Feedstock* Green Hydrogen (whether electrolytic or bio-sourced) will be required as a replacement. This will be a potentially significant entry market and is under active investigation.

Balance Agi-Nutrients is one of the main users of *industrial hydrogen* and is currently investigating electrolytic hydrogen for ammonia production to produce urea[48].

The other major user (and producer) is RefiningNZ. They are exploring electrolytic hydrogen for their needs, but with a move away from fossil fuels this market should diminish. But biorefining appears likely to be a significant area of growth in New Zealand[49] with implications for Green Hydrogen production (and other biofuels), and its use as a reducing agent.

Another area of potential growth for Green Hydrogen could be in synthetic fuels.

Finally, two of New Zealand's significant industrial sources of CO_2, Tiwai Point and Glenbrook, generate CO_2 by using carbon to reduce their feedstocks. In the latter case hydrogen is being explored to replace the carbon[50] as the reducing agent[51].

Recommendation: Government's role in hydrogen for industrial processes

That New Zealand particularly focus its development activities on hydrogen as an industrial feedstock/reagent and include the emerging biorefining industry as part of this.

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[46] See e.g. Zühlsdorf et al (2019) *"Analysis of technologies and potentials for heat pump-based process heat supply above 150 °C"* Energy Conversion and Management: X 2 (2019) 100011

[47] World Energy Council Netherlands. (2018). "*Hydrogen – Industry as Catalyst: Accelerating the decarbonisation of our economy to 2030*."

[48] There is the potential to use ammonia as a hydrogen carrier, and research is ongoing on its use as fuel.

[49] "A forest strategy for Aotearoa New Zealand" Op. Cit..

[50] The use of biocarbon has also been investigated.

[51] Endeavour Fund, VUW: Zero-CO2 production of essential technological metals.

Challenges for Hydrogen

For industrial heat loads, competing with other renewable fuels that are more efficient, have a lower capital requirement, and hence lower overall cost; process development when used as industrial feedstocks.

Opportunities for Hydrogen

To replace fossil fuel derived hydrogen as an industrial feedstock/reagent (whether electrolytic or bio-sourced).

Government’s role in Decarbonising NG Use

Decarbonizing NG is focused on using the existing NG distribution system with hydrogen. Increasing the proportion of hydrogen in the pipeline raises issues both about the impact on the pipeline but also on end users. Both are being studied extensively overseas with investigations proposed here (Green paper p. 66/8).

The dominant users of the pipeline are industrial users[52]. It is their equipment that has the lowest tolerance to hydrogen in NG (Green Paper p. 67). This and the extent to which existing underground bulk storage can be retained will be significant issues.

However, it is the large industrial users who are also likely to be considering a move from NG (e.g. industrial process heat) or seeing demand for their products falling (NG electricity generation).

The Government’s role will depend on the economics of Green Hydrogen compared with injecting biomethane[53] or synthetic methane rather than high concentrations of hydrogen. Renton (2019) (op. cit.) is suggestive that clean methane with existing infrastructure is more economic than electrolytic hydrogen.

Wholesale and retail distribution of high hydrogen content NG will require a review of standards.

Recommendation: Government’s role in decarbonising NG use

That New Zealand invest with the NG industry in the feasibility and relative economics of both Green Hydrogen and renewable methane for use in the NZ NG distribution and storage system (particularly underground).

That New Zealand review its standards for the use of prospective NG/hydrogen blends throughout the distribution and storage system.

Challenges for Hydrogen

Compatibility of a hydrogen mix in the NG storage and distribution system, through to end use; competition from clean NG; reducing demand for NG.

Opportunities for Hydrogen

Potential to contribute to cleaning up NG use.

[52] Electricity generation, Co-generation, Food Processing and Chemicals account for 80% of NG’s use as energy in New Zealand (MBIE (2019) “*Energy Balance Tables*”).

[53] Upgrading cost and feedstock availability are issues, along with competition from direct local use in its raw form. The Bioenergy Association of New Zealand estimates there is about 6PJ of potential biogas, that would service around half of the current non-industrial NG demand www.biogas.org.nz/nz-biogas-opportunities accessed 20 October 2019.

Government's role in Hydrogen for Export

The Green Paper suggests New Zealand "is well placed to … export Green Hydrogen to Japan by 2030" (p. 72) but notes there is as yet no market and that importers might instead buy lower cost Brown Hydrogen.

The Japanese "*Outline of the Strategic Roadmap for Hydrogen and Fuel Cells*"[54] makes clear their intention is to import Blue Hydrogen from coal gasification in Australia, targeting the price of NG. Unlike New Zealand Japan's priority is GHG reduction, rather than renewables. Green Hydrogen in their Roadmap is limited to domestic buffering of distributed generation i.e. the Green hydrogen is produced on site in Japan.

New Zealand's Green Hydrogen exports won't compete in markets where the margin for Green Hydrogen (renewable) over Blue (low emissions) is small. It will need markets where the margin can be higher, i.e. high value products and services[55] rather than commodities like energy.

If there are large amounts of Blue Hydrogen being traded internationally by the 2030s and available for import, the impact on local production of Green Hydrogen will need to be considered.

Recommendation: Government's role in Hydrogen for Export

That New Zealand invest in identifying and developing products and services for export that can earn high margins from embedded renewable energy.

Challenges for Hydrogen

Competition from low cost Blue Hydrogen internationally and low margins internationally for Green over Blue.

Opportunities for Hydrogen

Potentially limited.

[54] Available off www.meti.go.jp/english/press/2019/0312_002.html accessed 18 Oct 2019.
[55] By way of example, food and tourism.

Recommendations

That New Zealand:

- Invest in research into Green Hydrogen (and other renewable fuels) to identify:
  1. the best prospects for New Zealand;
  2. our relevant resource constraints and how to address these;
  3. how to economically produce and supply the fuels, and
  4. the technical, commercial and social capabilities required to aid effective and equitable adoption and how to achieve this.
- Invest in research into:
  - the trade-offs between more expensive decentralised production using cheaper and simpler distribution of feedstocks, and lower cost centralised production but with more complex bulk supply of hydrogen; and
  - the use of pipelines in New Zealand to transport hydrogen.
- Review its standards for storage, transporting and handling of all emerging alternative fuels, and include in this systematic multidisciplinary research to support public engagement and technological literacy.
- That New Zealand invest in further research and modelling of the full range of options to address the dry year and shorter-term resilience of the electricity system, taking full account of all supply and demand side options.
- Invest in further research on the full range of options to address emissions in high duty cycle transport in New Zealand with a view to:
  - Clarifying the activities where either action is clear cut, and those where the returns are high but are uncertain;
  - Addressing those areas where actions are clear cut; and
  - Increasing our options and de-risking them when there is uncertainty.
- Review its standards for the use of all emerging alternative fuels in transport.
- Focus its development activities on hydrogen as an industrial feedstock/reagent and include the emerging biorefining industry as part of this
- Invest with the NG industry in the feasibility and relative economics of Green Hydrogen and renewable methane for use in the NZ NG distribution and storage system (particularly underground).
- Review its standards for the use of prospective blends throughout the system.
- Invest in identifying and developing products and services for export that can earn high value from their embedded renewable energy.