Submission on the *Interim Hydrogen Roadmap*

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Responses to questions

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

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

1

In our view, the Interim Hydrogen Roadmap presents a muted version of the international perspective of the urgency of the global energy transition. This urgency must be highlighted and taken to action. Beyond this, and perhaps more importantly for Aotearoa New Zealand, the Interim Roadmap is lacking a Te Āo Māori perspective throughout. We note that any implementable and acceptable solution must be consistent with our obligations and responsibilities as Treaty Partners, and therefore, must consider the unique bicultural context and commitments in New Zealand.

Because hydrogen does not exist naturally in significant amounts, it must be produced, and is therefore first and foremost an energy consumer. We note that in the mid-term any domestic (green) hydrogen production is a competitive use of electricity generation in addition to the challenges of electrification and growing demand. However, we agree that hydrogen is a useful energy vector that can have strategic applications, and if produced flexibly, could also help the integration of renewable energy. For example, projected hydrogen integration in South America has been shown to lower the *average* cost of electricity by enabling greater use of flexible generation [1]. In the long-term, solar might solve energy bottlenecks.

We agree that the domestic demand of hydrogen-derivatives likely must be met with domestic production. We also agree that there are obvious, immediate applications for hydrogen in terms of domestic decarbonisation/defossilisation, particularly for industries currently relying on fossil Hydrogen.

The most extreme export ambitions proposed in the Interim Roadmap (interpreted from the “maximal case”) envisions approximately 0.6 Mt/year of exports (with approximately another 0.6 Mt/year of domestic use). This represents 0.1-0.2% of the projected global hydrogen market by 2050 (most sources estimate the market to be between ~300 and 700 Mt/year). For context, see the figure below on global H2 market projections (compiled from references [2]–[6]). Given this small proportion of 0.2%, it is possible that exports could be flexible to complement seasonality and play a role in alleviating winter energy constraints. However, we note that this flexibility may need to be incentivised through policy or market mechanisms.

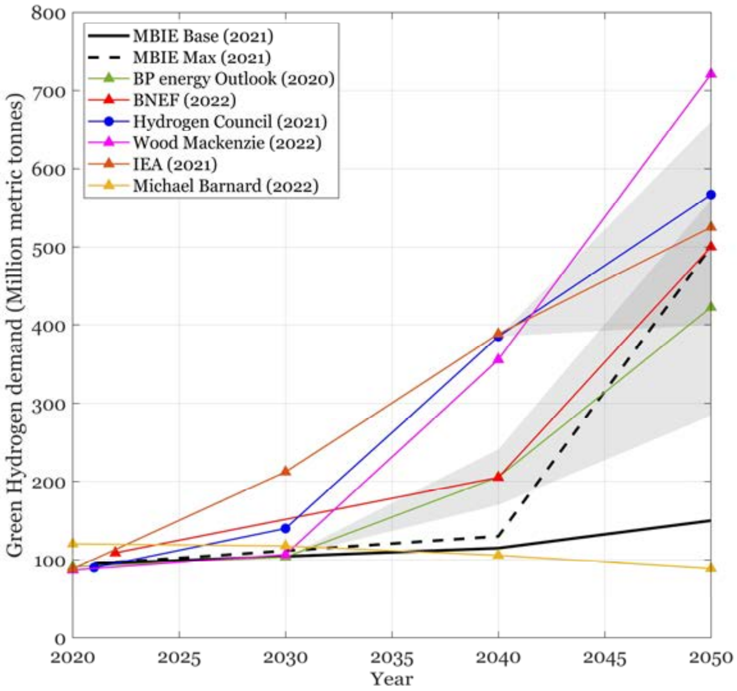


Figure 1. Global hydrogen demand based on various studies.

The range of scenarios assessed in the Interim Roadmap are relatively narrow. The “base case” and “maximal case” extremes seemingly differ only in export ambitions. In general, the transparency on how these different scenarios are constructed and how the corresponding hydrogen demands (including derivates) are calculated should be improved. The hydrogen scenarios should also consider the spatial distribution. We note that targeting only a 0.2% of the global market in the most extreme scenario seems unambitious.

At the same time, large-scale hydrogen production presents an issue of scale for NZ. To supply 1% of the future hydrogen market, we would require about 70 GW of renewable capacity. (This number comes from assuming a global market of 300 MTon/year, an energy content of 33kWh/kgH2, and a modest 20% in conversion losses, yielding 12500TWh/y. 1% of this amount is 125TWh. Assuming an average capacity factor of 20%, we would need 125000GWh/8760h/0.2= 70GW of installed generation capacity. This is roughly 9 times the currently installed power capacity of NZ. Note that the NZ’s electricity sector is expected to grow by an n-fold anyways (to meet electrification and a growing population). Also note that NZ is not space-constrained as some countries in Europe, which will rely on clean energy imports. While deploying large-scale energy infrastructure is challenging, it can also be an opportunity for the country and citizens, if done correctly.

We do want to ask: Do these scenarios represent the full range of futures that NZ needs to assess and prepare for?

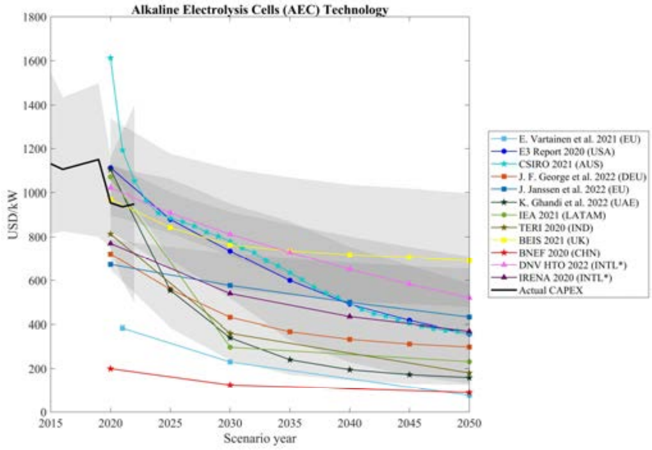
Finally, the successful integration of (green) hydrogen is, in part, dependent on costs. And the main costs for hydrogen are (1) electricity and (2) electrolysers. Global trends indicate that the costs of both renewable electricity technologies (solar and wind) and electrolysers are quickly decreasing but still expensive (see the figure below that we have compiled based on diverse reports [7]).

(1) In terms of electricity costs, we note that countries with significant hydrogen ambitions like Australia or Chile already have periods with near-zero marginal electricity costs, which is triggering new demands like electrolysers. But NZ also has several advantages for cheap electricity: (i) very cheap electricity prices at night, which can perfectly complement the generation from solar electricity; (ii) no significant space constraints for deployment of renewables (besides solar, off-shore wind is also just starting); (iii) a highly renewable electricity sector, and (iv) the solar sector in NZ is only in its infancy but quickly growing with already over 2 GW of capacity announced and/or under construction. The questions becomes: how to accelerate the deployment of cheap electricity to attract new demands like electrolyzers?

(2) In terms of electrolyzers, internationally, the costs are coming down because of incentives to mature the technology. Ripening local capacities and infrastructure in a timely fashion will be key for ramping up the market. While some electrolyzers will be imported, we underline that NZ has local electrolyzer manufacturing capacity, Fabrum, who are also involved in the large hydrogen project for Christchurch Airport.

At the same time, hydrogen could improve the energy security. We will revisit this point under question 8.

a. Projected CAPEX of Alkaline electrolyzers



b. Projected Levelized Costs of Hydrogen for Alkaline electrolyzers

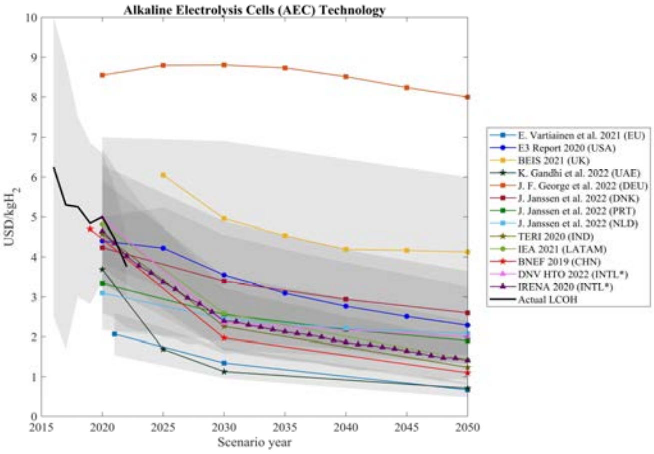


Figure 2. Systemized hydrogen cost projections from 2020 to 2050 from diverse sources [7]

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

Do you agree with our assessment of the most viable use cases of hydrogen in New Zealand’s energy transition?

2 We agree that hydrogen has use cases in New Zealand and agree with the list of viable use cases provided in the Interim Roadmap. However, we note that there is no clarity on the priority of these use cases. We suggest that the prioritisation of these applications be made clear in the roadmap. This is not intended to prescribe a list of actions, but rather to gauge the magnitude and location of the demand (to then understand the required investments for generation and transmission capacity). We support the consensus that the market will enable the implementation of the best use cases.

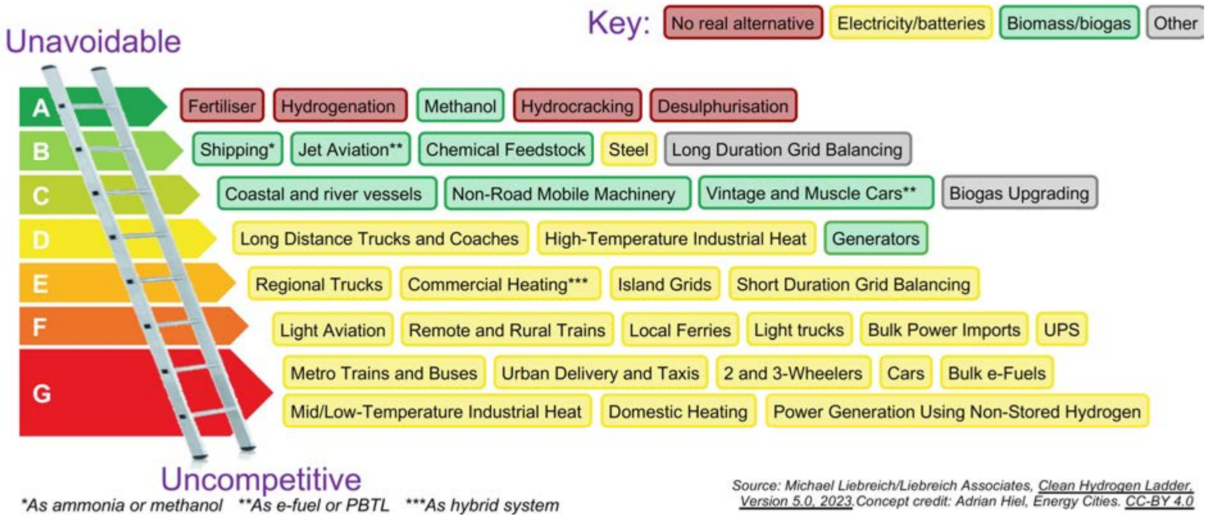
We further note that hydrogen as an energy vector is a component of the wider energy system and energy transition. It therefore cannot be treated in isolation from that wider transition. Clear engagement and coordination with the National Energy Strategy is positively noted.

Do you support some of these uses more than others?

3 Section 2 of the Interim Roadmap opens with the statement "HYDROGEN HAS A STRATEGIC ROLE TO PLAY IN NEW ZEALAND’S CLEAN ENERGY TRANSITION”. While we agree that some uses are unavoidable, many others are simply uneconomic or in direct competition with better options for decarbonisation, and others are yet to be decided and require further research.

We agree with the more specific statement “WE SEE A KEY ROLE FOR HYDROGEN IN NEW ZEALAND IN A NUMBER OF HARD-TO-ABATE AND HARD-TO-ELECTRIFY APPLICATIONS” on page 24. This is also supported by the academic literature on hydrogen applications and energy transitions [8]–[10].

In an attempt to prioritize the use cases, Michael Liebreich from BloombergNEF has just released (October 2023) version 5 of the quite famous “Clean Hydrogen Ladder” (see figure below) [11]. The ladder sorts the uses cases from unavoidable (Rung A) to decreasingly uncompetitive (Rung G). The colouring of each applications shows possible alternative options (like electric/batteries or biogas).



Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 5.0, 2023 Concept credit: Adrian Hiel, Energy Cities. CC-BY 4.0

Figure 3. Sorting use cases of hydrogen: The Clean Hydrogen Ladder

Comparing this ladder's new version (2023) to the previous version (2021) reveals interesting insights on the learnings of the international hydrogen community over the last two years: three use cases have been promoted, seven have been demoted, and four use cases have been added.

- The promoted use cases are: (1) Jet aviation (promoted to Rung B from Rung C, underlining the lack of large-scale alternatives), (2) regional trucks (to Rung E from Rung F, based on infrastructure synergies with long-distance trucks), (3) short-duration grid balancing (to Rung E from Rung G, based on infrastructure synergies with long-duration storage using hydrogen, or demand-side management).
- The demoted use cases are: Non-road mobile machinery (former Off-road vehicles), remote and rural trains (former remote trains), local ferries, uninterruptable power supply (UPS), bulk power imports (former clean power imports), domestic heating, mid/low temperature industrial heat.
- Additional use cases in the new ladder are vintage and muscle cars (an extension to the former vintage vehicles), light trucks, taxis (an extension to the former urban delivery), power generation using non-stored hydrogen.

For more details see reference [11]. There is clear scientific support for the transition of currently fossil (grey/brown/black) hydrogen use to green hydrogen. We agree with this most obvious use case for New Zealand.

There is scientific support for a potentially large role of methanol, produced from a green hydrogen feedstock and sustainable biogenic carbon sources [12]. Importantly, we note that there are competing uses between methanol and ammonia and in our understanding the use of one over the other is an ongoing debate in the industry and science. Anecdotally, Ammonia versus Methanol was debated in the "Hydrogen Week" held during October 2023 in Rotterdam.

We share a critical view on the longevity of hydrogen blending with fossil gas, in particular into the gas reticulation network. This pathway will likely incur significant capital, environmental, and other lock-in impacts, and faces the risk for continued long-term use of fossil gas. International evidence points to a rather soon phase-out of residential gas grids, like Switzerland's Zürich, Basel, and Winterthur, with decommissioning starting in 2035 [13].

The use of hydrogen in heavy-duty vehicles, including heavy freight trucks, buses and rails, and specialty vehicles remains under debate, and we share a cautious view on these use cases, as we will explain next.

On heavy freight trucks, we do note that hydrogen-blends are currently being trialled in New Zealand. This solution might be particularly relevant in the short term for shifting decarbonisation in the heavy transport sector. Recalling the Clean Hydrogen Ladder, long-distance trucks are just in the middle; meaning that they are not directly unavoidable but not directly uneconomic either. Although hydrogen is a possible solution, the international freight sector has also been surprised with increasing alternatives for battery trucks. Anecdotally, Pepsi just claimed successful results from their battery truck trials. Nextbigfuture [14] published in September 2023 an overview of existing battery trucks with several options with over 45000 pounds of payload. Perhaps most notably, the recently (October 2023) released World Energy Outlook by the International Energy Agency [15] pivoted away from fuel cell heavy-duty vehicles towards battery-electric alternatives ([15], page 45) but is somewhat vague on the specifics.

On buses and rail, trials abroad indicate these may already be uncompetitive with battery electric alternatives [16]. Trials for hydrogen-fuelled buses in Wiesbaden (DEU) [17], Montpellier (FRA) [18], and Dundee (GB-SCT) [19] showed higher costs than expected and were abandoned. Similarly, trials for hydrogen rail were also cancelled because of costs and switched to battery train trials [20].

On speciality vehicles (non-road road mobile machinery), while we agree there may be some cases where hydrogen is feasible solution (i.e., where there is no nearby electricity grid or generation), more competitive electric specialty vehicles are already on the market [21]. Regardless, we estimate that such edge-cases would not become a significant demand even if they all switched to hydrogen.

Again, we do not think the roadmap needs to prescribe use-cases (the market will figure them out) but gaining clarity on the probability of success can be helpful to gauge and address the infrastructure challenge (thinking of electricity generation and transmission capacities, as well as optimal location of hydrogen infrastructures).

Finally, we agree with the role that hydrogen could play in terms of flexibilization of electricity demand. From an energy-system point of view, a flexible demand is the ideal client. However, the generation capacity to produce green hydrogen (including transmission lines), in addition to other electricity end-use growth, must be deployed at pace and scale to enable this outcome.

What other factors should we be considering when assessing the right roles for hydrogen in New Zealand's energy transition?

A critical element in evaluating the roles of hydrogen in the energy transition is awareness of competing uses and/or competitors. In the short and mid-term, it is likely that competition will not only exist between use cases, but also with planned electrification (in terms of the required expansion and the pace and scale at which that expansion can occur). Hydrogen integration may induce short-term stress even with clear long-term benefits in hard-to-decarbonise sectors, for example.

4 Decreasing gas consumption will likely result in the phase-out of fossil gas in the existing reticulation network. Repurposing this existing infrastructure system can be advantageous to avoid stranding valuable assets. However, we advise approaching the question of integrating hydrogen in this system with care. Blending fossil gas with hydrogen poses the risk of locking in a commitment to continued use of fossil gas in our energy system, which may inhibit progress towards the objectives under the Zero Carbon Act. We note that it is important to consider alternative uses for this infrastructure, including biomethane and even carbon dioxide (transmit sequestered carbon in the pipelines), which may be more in line with national decarbonisation efforts and enable further sustainable transitions. The competitiveness of any repurposed use of the gas network is rightly highlighted as uncertain and we note that there is room for further investigation of other use cases.

The sustainability of decision-making needs to be considered, and careful assessment of the environmental and social outcomes must be performed. We also note that the location of potential infrastructure deployments is likely to be an important environmental, social, and practical consideration. This is not emphasised in the current roadmap.

Allowing hydrogen to participate in diverse markets or ancillary services could be considered. For example, power system ancillary services (like frequency reserves), which in the case of batteries, can show very fast payback (e.g. the Hornsdale battery in South Australia [22]). Reaction times of electrolysers can be as quick as a few seconds to a few minutes for commercially available technologies [23], which technically would allow them to participate in that service. Here again, the market will figure out what technology or mix of technologies will be the winners but checking the legal framework (to allow hydrogen to participate in diverse services and markets) would be important.

Finally, managing the uncertainty and complexity of large-scale energy transitions is important and an active field of research. We think there is a need for robust-decision making and uncertainty quantification to be echoed in future research projects on the energy transition and hydrogen integration, and perhaps in also advanced energy education.

Section 3: Government position and actions

Do you agree with our policy objectives?

5

The report includes the statement of ensuring that hydrogen supply can scale up. We think it is important to consider the governance structure that will be needed to achieve this goal. The report proposes the creation of several committees, but it is unclear whether this is the most effective way to address the ongoing climate urgency.

The electric sector in New Zealand is monitored and regulated by the Electricity Authority, a dedicated regulator. The hydrogen sector, on the other hand, does not have a dedicated governance structure yet. Drawing on lessons from other countries, Germany has a dedicated Ministry for Energy and Environment for policy, as well as the Federal Network Agency (Bundesnetzagentur) as federal authority for gas and electricity grids (among other roles). Would perhaps such larger and persistent governance structures, inclusive of hydrogen as an energy carrier and chemical feedstock with a balanced perspective with other sectors like electricity, heat and transportation be a suitable governance structure for New Zealand?

Do you agree with our positioning on hydrogen’s renewable electricity impacts and export sector?

6

The Interim Roadmap correctly identifies a key benefit of hydrogen, especially when produced flexibly: integration of variable electricity generation (minimise energy spillage or curtailment), such as solar, wind, and run-of-river. This flexibility is important also at a seasonal timescale, potentially reducing the need for other long-term electricity storage.

On the exports, the most extreme scenario foresees to supply 0.2% of the global market. Is this a level where we can achieve economies of scale? And as mentioned earlier, is this the most extreme ambition we want to pursue as a country?

7

Do you agree with the proposed actions and considerations we have made under each focus area?

In general, the energy transition including hydrogen is the largest infrastructure challenge we are facing. Not necessarily because of the economics (decent payback times) but because of the speed it needs to happen! We think the main question is: How can we accelerate the transition?

8

Is there any evidence we should be considering to better target actions in the final Hydrogen Roadmap?

Becoming a hydrogen export nation comes with the above-mentioned risk of scale for NZ: supplying 1% of the future global hydrogen market implies building about 70GW of renewable capacity (9-times the currently installed capacity of NZ power sector). The roadmap's current export ambitions of supplying 0.2% of the global market is consistent (proportional) with these numbers and foresees the need for 13GW (see Interim Roadmap, page 5, Diagram 1).

A potential option to mitigate the risk of overbuilt renewable capacity and to improve energy security, is to export the electricity via cables to Australia. Napkin calculations for such a Trans-Tasmanian link to connect Wellington to Syndey with a 2200km long cable, based on values from a similarly ambitious project between Morocco to UK (XLinks, around €1.35 million per GW per kilometre of subsea cable), yield numbers within a reasonable order of magnitude. This would require a total investment of 5.3 BNZD/GW_installed (cheaper than the 15.7BNZD of Lake Onslow), about 15 NZD/MWh_transmitted (assuming a lifetime of 50 years and 0.9 of capacity factor). These costs would likely be split across countries and services, especially when motivated from an energy security point of view. This project would also allow cheap solar imports from Australia, increasing the diversity of energy resources in New Zealand [24]. This idea could at least be debated but is currently absent from the public debate as far as we can tell. And such massive transmission infrastructure project could at the same time act as enabler for a hydrogen hub.

Another alternative for energy security is to set up a strategic hydrogen reserve (think dry years), like the U.S. petroleum reserve. Alvear, Haas et al. (under review) found that in 2030 for New Zealand and Chile, it could make economic sense to use hydrogen as a strategic reserve. The cost of such a scheme in 2030 ranges from 0.11 to 0.27 USD/MWh, which is modest compared to total electricity costs [24].

Note that the two ideas above, the Trans-Tasmanian link and the strategic hydrogen reserve, are not intended as stand-alone uses but could perhaps be considered as part of a portfolio of options surrounding hydrogen.

General comments

Most countries are recognizing the need to deploy hydrogen infrastructure as soon as possible. However, the research and development of hydrogen systems is still ongoing with many open questions, like the choice between ammonia and methanol (and others) as a carrier, to mention one example. This choice, and many other choices, will have significant implications for the design and construction of hydrogen infrastructure (and upstream infrastructure) and requires careful assessment via research and planning. In the interim, nonetheless, there are many non-regret options that can be pursued (think unavoidable use-cases).

Furthermore, the interaction between the gas, electricity, and transmission systems when developing hydrogen infrastructure is relevant. Are we expanding our transmission networks and generation capacity quickly enough to accommodate the increasing electricity demands for hydrogen? This will be key for a successful deployment.

There is a strong need for workforce training and skills development in the energy and hydrogen sectors. At our university, we are genuinely trying to adapt our offerings to a quickly evolving market-need. However, it proves challenging given a rather uncertain future. Furthermore, there is a risk of brain-drain to countries like Australia, which has a more mature hydrogen market and is investing heavily in the sector. It is becoming increasingly urgent for New Zealand to train and retain national and international workers in the space. We have observed other countries setting up dedicated study scholarships (with the obligation to stay and retribute to the country, instead of forcing excellent candidates to return to their home countries) to succeed in this critical area.

The Interim Roadmap is lacking a Te Āo Māori perspective throughout. We note that any implementable and acceptable solution must be consistent with our obligations and responsibilities as Treaty Partners, and therefore, must consider the unique bicultural context and commitments in New Zealand.

The international perspective is somewhat muted in the roadmap. Just to mention one example: the largest international hydrogen trading platform in Europe (from EEX and H2Global [25]) seems to be missing. (We do note that the hydrogen industry is particularly dynamic and staying up to date is inherently challenging.) We would be interested in understanding how NZ plans to react to and interact with such platforms. In general, becoming part of an international hydrogen market requires strong international collaboration.

The roadmap conveys a sense of complacency, even though the energy transition in general, and hydrogen development in particular, are likely the largest infrastructure challenges of our time. Both the magnitude and pace of the challenge are significant, and the roadmap needs to reflect this urgency.

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