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?

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1. **Safety**: There is no mention of program support for the safe transport of hydrogen. It is presumed that the network of hydrogen fuelling stations around the country will be serviced by tanker trucks carrying compressed hydrogen. As with any form of road transport, there will be accidents and local fire & emergency personnel will be needed to respond to these accidents. Compressed hydrogen presents serious safety risks to these personnel. For example:

   - Hydrogen has no smell and when prepared for fuel cells, cannot be oderised. Local firefighters will need special sensors to detect leaking hydrogen at an accident site.
   - Hydrogen burns with a flame that is invisible in daylight. Firefighters will need special equipment to detect burning hydrogen at an accident site.
   - Hydrogen has very low ignition energy and can spontaneously explode when decompressed. Compressed hydrogen presents a serious explosion hazard to rescue personnel.

   If hydrogen is to be transported around the country in tanker trucks, the skills and equipment of local emergency personnel nationwide will need to be upgraded. This should also be part of the hydrogen roadmap.

2. **Leakage**: One of the unavoidable realities of hydrogen is that it leaks through most materials, including the carbon composite fuel tanks of fuel cell vehicles. It is estimated that 2.7% of hydrogen produced leaked to the atmosphere in 2020. The International Energy Agency estimates that with increasing hydrogen demand could lead to as much as 5.6% leakage by 2050. Leakage from transportation applications (trucking & storage) is considerably larger than that from fixed industrial applications. Transportation leakage has been calculated to be 2.3% while that for industrial processes is assumed to be around 0.5%.

3. **Global Warming**: While the main focus on leakage has been to prevent hydrogen from reaching explosive concentrations in air (above 3-4%), there has been little attention given, until recently, to low level leakage which will have a climate impact. Recent studies have shown that hydrogen has a global warming potential of 11.6 times that of CO2 over 100 years (GWP_{100}), but an estimated GWP of over 100 times that of CO2 over ten years due to its short lifetime (~2.4 years). It is not itself a greenhouse gas; its warming effect is due to its rapid reaction with atmospheric hydroxyl ions, which results in prolonging the life of the intense greenhouse gas methane and contributing to the production of the other greenhouse gases, such as tropospheric ozone and stratospheric water vapour.

4. **Water Demand**: Simple chemistry suggests that it takes 9 kilograms of water to make 1 kilogram of hydrogen by electrolysis. This will put additional pressure on freshwater resources. Seawater can be used, but traditional methods of electrolysis produce toxic and corrosive chlorine ions (i.e., Cl^- and ClO^-) which should not be released to the environment. Many electrolysis processes use water treated with alkali or acid, which would similarly need to be disposed of safely and kept out of the environment. There is no mention in the assessment of the environmental risks presented by water demand and waste water disposal related to green hydrogen production.

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?

The assessment given in the consultation document is highly favourable toward green hydrogen while missing or only briefly mentioning some of the many downsides to hydrogen as an energy fuel. A more balanced assessment would include:

1. **Efficiency**: Green hydrogen used for combustion or fuel cell energy in transport is very inefficient compared to the direct use of electricity through batteries or overhead electrification, as with electric trains. Battery electric vehicles are approximately 3 times more efficient in the use of electricity than fuel cells or internal combustion engines fuelled by hydrogen.

   New Zealand is depending upon an ample supply of renewable electricity to replace fossil fuels, yet renewable energy supply will only grow at a pace that the wholesale price of electricity allows. In our current electricity market, increasing electricity prices are needed to promote growth in renewable generation. With an expectation of a long term
2 increase in electricity prices, it makes no sense to invest in low efficiency uses of electrical energy.

2. **Impact on Electricity Prices**: Electrical energy used to make green hydrogen will be energy not available to other consumers. Although hydrogen consumers are expected to help with generation, they can also simply purchase electricity from third party generators. It is wishful thinking that an over-build of intermittent renewable electricity will be sufficient to supply the power needed for the high capacity factor (80-90%) that electrolysers will require to be economic.

   Growth in hydrogen users, then, will create further demand for electricity. The laws of supply and demand dictate that greater demand will result in increasing price, as more "marginally economic" renewable energy projects will be needed to fulfil added demand due to green hydrogen production. In New Zealand's deregulated electricity generation market, we would expect to see average electricity prices rise due to the added demand from hydrogen producers.

   This does not meet with the expectation of a "just transition". Residents and businesses in New Zealand should not have to pay more for their electricity due to the electricity demand created by a hydrogen fuel production industry.

3. **Practicality**: There are a number of hydrogen fuel uses proposed in the consultation document which show very marginal practicality. Examples include:

   a. **Aircraft:** compressed hydrogen, at the 350 bar pressure NZ standard, has the density of expanded polystyrene. The space requirement for hydrogen fuel tanks on even medium range aircraft is impractical. Liquefied hydrogen fuel is even more impractical because it takes roughly 40% of the energy embedded in the hydrogen fuel just to liquefy it. In addition, even in the most well-insulated storage vessels, liquefied hydrogen loses about 1% of its mass each day due to boil-off. In NASA space rockets, typically 45% of liquefied hydrogen fuel is lost before launch.

   b. **Energy Storage:** Storage of hydrogen for peak or back-up generating capacity is one of the least efficient forms of energy storage. Battery storage returns more than 80% of stored energy. Pumped hydro returns about 75% of stored energy. Green hydrogen storage, in compressed gas tanks or underground, will return, at most, 30% of stored energy. The Parliamentary Commissioner for the Environment, Simon Upton, recently emphasised this point when commenting on the early NZ Battery project option to store hydrogen for "dry year" back-up power. The option for green hydrogen storage has since been dropped from the NZ Battery project list of options.

3	**Do you support some of these uses more than others?**
	We support green hydrogen used in industrial processes and as feedstock for aviation and ship fuel, as there are few alternative technologies at this time and it is important, for strategic purposes, that New Zealand has its own source of aviation and ship fuel. We do not support the use of green hydrogen as a direct fuel for heavy transport. It is highly inefficient, hazardous to transport and store, and new research is showing that it is an intense indirect greenhouse gas. Existing battery electric heavy transport vehicles are nearly equivalent in performance and are much more efficient, safer and will require much less support infrastructure (i.e., refuelling stations, electrolysers, storage tanks, etc.). The greater infrastructure and equipment requirements of hydrogen transport fuel compared to that needed for battery electric vehicles will necessarily have greater embedded fossil fuel emissions and environmental impact. The less kit we have to buy, the less impact on our environment and biodiversity.
4	**What other factors should we be considering when assessing the right roles for hydrogen in New Zealand's energy transition?**
	Hydrogen, as a gas or liquefied, should not be used as a transportation fuel. Due to its ability to leak through nearly all storage materials, its explosivity and its global warming potential, hydrogen is most appropriately used as feedstock for other fuels or chemicals, or used in

industrial processes, such as steel making. In these instances, it can be created and used at the same site, reducing leakage and allowing for tight safety controls.

As a transportation fuel it will need to be transported, stored and transferred between storage tanks, allowing for significant leakage and global warming effects, as well as exposing the general public and emergency personnel to its inherent risk of ignition and explosion.

5 **Do you agree with this assessment of the potential for hydrogen supply and demand in New Zealand?**

The assessments are far too optimistic for the following reasons:

1. Electricity prices have been steadily increasing since the inception of the electricity generation market and are unlikely to fall as demand increases and new generation is added. The easy and cheap renewable generation projects have all been built and as demand increases the next generation projects will be the ones that are more expensive and more difficult to build, such as offshore wind. In addition, new generation from wind and solar are intermittent and will need some type of energy storage in order to be reliable, which will add to their cost. The assumption that electricity prices will fall due to an influx of cheap renewable power is highly unrealistic.
2. The assumption that electrolyser capital costs will drop to a fifth of their present level (from $1000/KW capacity to $200/KW) by 2050 is highly optimistic. The price of most electrical equipment has been rising in recent years.
3. Considering the high capital cost of electrolysers, they will need to run at high capacity factor, as mentioned in the consultation document. The need for high capacity factor is key to the economic success of industrial projects and is unlikely to fall as suggested in the consultation document. It is unrealistic to think that electrolyser operators will readily agree to demand response services (i.e., shutting down when electricity demand on the national grid it high) without compensation.
4. Operations tied to new renewable (and therefore intermittent) generation will require a contract for back-up power, which will likely come from the national grid. This would be expected to add to electricity demand and further increase electricity prices.

6 **Do you agree with the key factors we have set out that are likely to determine how hydrogen deployment could play out?**

The key factors put forward in the consultation document neglect to mention environmental and social factors.

1. Due to the hazardous nature of compressed hydrogen, many communities will not want hydrogen production and storage in their neighbourhoods.
2. Due to the fresh water and waste water demands of electrolyser plants, many communities will not want the potential pollution and fresh water allocation.

3. Hydrogen being an indirect greenhouse gas, it is likely that leaked hydrogen will be added to the NZ Emissions Trading Scheme at some point. This will add cost to hydrogen vendors which will be passed on to consumers.

7	**What do you think needs to happen to address these factors?**

While a reasonable case can be made for green hydrogen in the production of low emissions fuels and industrial process such as steel making, the use of green hydrogen as a transportation fuel will be expensive and problematic. People will not want hydrogen production or storage facilities in their communities. The odd accidental explosion of hydrogen fuel will further sour public perception of its safety, as we've seen overseas.

Continued revelations as to the climate impact of leaked hydrogen can be expected to further damage its reputation and desirability among consumers. Add to this the poor efficiency, expected high cost and impact of electricity prices that will accompany large scale green hydrogen production and distribution and we see no future for hydrogen as a transport fuel.

8	**Do you have any evidence to help us build a clearer picture?**

Recent research has shown that hydrogen is an intense indirect greenhouse gas. A peer reviewed journal article, by scientists Ilissa Ocko and Steven Hamburg (Climate Consequences of Hydrogen Emissions, Atmospheric Chemistry & Physics Vol 22, issue 14, 2022) lays out the science behind hydrogen's climate impact. A copy of this article is included with this submission.

To quote the article:

"*Scientists have long known and cautioned that hydrogen has indirect warming impacts (Ehhalt et al., 2001; Derwent et al., 2001, 2006, 2020; Prather, 2003; Schultz et al., 2003; Warwick et al., 2004, 2022; Colella et al., 2005; Wuebbles et al., 2010; Derwent, 2018; Paulot et al., 2021; Field and Derwent, 2021). When it escapes into the atmosphere, hydrogen has two main fates: around 70 %–80 % is estimated to be removed by soils via diffusion and bacterial uptake, and the remaining 20 %–30 % is oxidized by reacting with the naturally occurring hydroxyl radical (OH), yielding an atmospheric lifetime of around a few years (Rahn et al., 2003; Derwent, 2018; Paulot et al., 2021; Warwick et al., 2022). The oxidation of hydrogen in the atmosphere leads to increasing concentrations of greenhouse gases in both the troposphere and stratosphere, as described in Fig. 1 (Derwent, 2018; Derwent et al., 2020; Paulot et al., 2021; Field and Derwent, 2021; Warwick et al., 2022).*

In the troposphere, less OH is available to react with methane; given that methane's reaction with OH is its primary sink, this leads to a longer atmospheric lifetime for methane which accounts for around half of hydrogen's total indirect warming effect (Paulot et al., 2021). Moreover, the production of atomic hydrogen from hydrogen oxidation in the troposphere leads to a series of reactions that ultimately form tropospheric ozone, a greenhouse gas that accounts for about 20% of hydrogen's radiative impacts (Paulot et al., 2021). In the stratosphere, the oxidation of hydrogen increases water vapor, which, in turn, increases the infrared radiative capacity of the stratosphere, leading to stratospheric cooling and an overall *warming effect on the climate because energy emitted out to space is now from a cooler temperature; this stratospheric effect accounts for about 30% of hydrogen's climate impacts (Paulot et al., 2021).*

The key to preventing global warming due to hydrogen is preventing leaks and discharges. Unfortunately, it is not presently possible to quantify the amount of hydrogen leaking through production, storage and transport systems due to the very low detection limits monitoring equipment will require. Leakage from present systems is estimated in the above reference to be as high as 10%. If liquid hydrogen becomes widely used, this rate of leakage could be higher due to venting of boil-off.

The abstract to the article presents the conclusion that:

"green hydrogen applications with higher-end emission rates (10 %) may only cut climate impacts from fossil fuel technologies in half over the first 2 decades, which is far from the common perception that green hydrogen energy systems are climate neutral."

The last three of five recommendations of the article are:

"3. improve quantification of hydrogen leakage rates by developing technologies that can be taken into the field to accurately measure hydrogen emissions at low detection thresholds (i.e., ppb level);

4. include the likelihood of hydrogen leakage and its impacts in decision-making about where and how to effectively deploy hydrogen – such as co-located production and end-use applications; and

5. identify leakage mitigation measures and best practices before building out infrastructure."

Given the scientific findings on hydrogen's global warming impact and the lack of information about hydrogen leakage rates from production, transportation and storage, the precautionary principle dictates that we should wait to deploy hydrogen as an energy fuel until the leakage is better understood. We do not want to be in the position of simply trading one greenhouse gas emissions problem for another.

9 **Do you agree with our findings on the potential for hydrogen to contribute to New Zealand's emissions reduction, energy security and resilience and economic outcomes?**

No. There is no mention of the likely impact of hydrogen production on electricity prices. In New Zealand's electricity market, the added electricity demand for hydrogen production will increase electricity prices, since it will require the construction of what would otherwise be marginally economic electrical power projects. The cheaper projects will have already been built. These new projects will demand an increase in price in order to be economic. The law of supply and demand will dictate higher electricity prices for the added generation capacity.

An earlier statement in the consultation document that new renewable energy will be cheaper to install because cost for kit has been falling has not been borne out by experience. Wholesale electricity prices have only been going up for the last two decades even as lots of new renewable generation has been installed.

Flexibility in demand response, touted as a benefit of green hydrogen production, will undoubtedly come at a price. Operators will not agree to shut down electrolysers without getting something back for it – which is likely to be cheaper electricity. This can be expected to further raise electricity prices for the rest of the economy.

10 **Do you have any insights we should consider on what is needed to make hydrogen commercially viable?**

At the moment, green hydrogen is not a commercially viable energy fuel. We see little evidence that this situation will change in the near future.

11 **Is there any further evidence you think we should be considering?**

There is the very real possibility that the global warming impact due to the unavoidable leakage of hydrogen will make hydrogen unsuitable as a transportation fuel and will result in the failure of the hydrogen fuel industry. New Zealand should wait to develop widespread hydrogen use until hydrogen leakage and its global warming impact are better understood.

Section 3: Government position and actions

12 **Do you agree with our policy objectives?**

While the policy objectives mention a just transition, it is only for affected communities. There needs to be consideration as to the impact that green hydrogen production will have on electricity prices around the country. As explained in responses to questions above, the greater demand for electricity accompanying green hydrogen production will undoubtedly result in higher electricity prices.

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

We think it is wishful thinking that hydrogen production can be powered by intermittent renewable power. With the needed capacity factor of 80-90% (stated in the consultation document), electrolysers will need baseload power, from hydro or geothermal. The suggestion that there might be an over-build of renewable generation accompanying hydrogen production, appears to be a "red herring" to mask the impact hydrogen production will have on electricity demand and electricity prices.

Considering the environmental compromises that will need to be made in order to build the energy sources needed for hydrogen production, we do not support developing an export market for green hydrogen. We should not compromise our environment for the benefit of another export industry.

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

15	*<u>Support for price and long-term certainty to allow hydrogen to scale for key use cases</u>*: We do not support the $100m price subsidy for green hydrogen. This subsidy seems tailored to the use of hydrogen as transport fuel, which we do not support. *<u>Support for capital investment for hydrogen projects:</u>* We do not support Clean Heavy Vehicle Grant money used to buy hydrogen fuel cell vehicles. There is too much uncertainty as to the amount of hydrogen that might be leaked in its application as transport fuel and the global warming impact this would have. We urge the government to wait until leakage can be quantified and the resulting global warming understood before supporting hydrogen as transport fuel. *<u>Planning System</u>:* We do not support the use of an industry body (the New Zealand Hydrogen Council) producing training material on hydrogen aimed at consenting authorities. Industry bodies should not be telling consenting authorities what to think about hydrogen. This is a clear case of "the fox guarding the hen house"! Advice to consenting authorities needs to be free of conflict of interest and industry messaging. An academic panel would be more appropriate for this task.
	Is there any evidence we should be considering to better target actions in the final Hydrogen Roadmap?
	There needs to be consideration of the global warming impact of leaked hydrogen. This has gone un-mentioned in the Interim Hydrogen Roadmap consultation document. Information about the global warming impact of hydrogen gas in our atmosphere has been available for nearly a decade now, so it is surprising that this was overlooked in this consultation. Of critical importance here is the quantification of hydrogen gas leakage from production, storage and use facilities, since this is largely unknown and could have a significant global warming impact.

General comments

We have been disappointed in the one-sided, industry-friendly tone of the consultation document. While we recognise that the government is keen to decarbonise New Zealand industry and transport, it is important that we make informed and balanced judgements about how we do this. The consultation document has consistently downplayed or omitted many negative aspects of green hydrogen production and use, and repeatedly stressed impractical benefits, such as an over-build of renewable power. Another example of this bias is the suggestion that an industry council provide guidance to consenting authorities. This sort of unbalanced, industry-focussed viewpoint could lead us into supporting a set of "white elephant" projects, wasting valuable time and resources as we attempt to stem off the climate crisis we are in.