Introducing Z 'house views'

As one of New Zealand's leading companies operating in an essential industry Z is committed to making a positive contribution to New Zealand.

Z's purpose is simply 'solving what matters for a moving world'. One of the ways we seek to deliver on this purpose is through living one of the organisation's values of 'share everything'.

Z thinks a great deal about our contribution to New Zealand – from the capital markets, to delivering for our customers, to the role we play in supporting the national economy, to delivering improved sustainability outcomes and a safer New Zealand, we believe Z has an important contribution to make to NZ Inc.

One of the ways we will contribute is by sharing our knowledge and the things that we learn through our business and strategy development. On an ongoing basis Z will publish its 'house views' on issues that we believe are consistent with the company's purpose of solving what matters for a moving world.

The purpose of these papers is to generate discussion, share perspectives and inform our stakeholders on issues we think matter both to our business and to New Zealand.

As always we encourage and welcome feedback and discussion on the views we publish. We believe it is initially through the sharing of information and the vigorous discussion and debate around ideas that we can start to solve what matters as a country.

Mike Bennetts
Chief Executive

"Solving what matters for a moving world."

House View

August 2019

Hydrogen

Making a positive contribution to New Zealand

Summary House View

1. Hydrogen is technically ready, and manufacturing scale-up can occur if market conditions are right. However, it currently has significant economic and affordability challenges.
2. Green electrolysis of renewables and blue reforming of natural gas (see below) are the most likely pathways for hydrogen production.
3. There are a wide range of views on the applicability of hydrogen for New Zealand.
4. Electrification is still the dominant theme of decarbonising in many use cases.
5. A substantive hydrogen economy would require interventions such as an export commitment, regulatory support or industry led establishment of a mega-scale production facility.
6. Exporting hydrogen could be challenging given NZ's relative competitiveness.
7. Different transport use case needs may lead to a broader range of fuel solutions in a decarbonised world.
8. Hydrogen (or a derivative fuel such as ammonia) is a real option to meet the needs of transport operators for certain use-cases but it will take some time for cost-effective hydrogen fuelled vehicles to grow to material volume.
9. A number of large-scale transport related asset replacement decisions (ferries, trains and buses) present opportunities to transition away from fossil fuels.
10. Conclusion: It is too soon to commit to hydrogen as a decarbonisation option, but neither should we dismiss it.

Common terms used in this document

Fuel Cell Electric Vehicle (FCEV) most common hydrogen fuelled commercially available powertrain. Fuel cell converts hydrogen to electricity which is often stored short term in a small battery. Motive power through electric motors.

Battery Electric Vehicle (BEV) vehicle with onboard battery storage powered via electric motors

Internal Combustion Engine (ICE) typical petrol / diesel fuelled engines

Green Hydrogen hydrogen produced from renewable energy

Blue Hydrogen hydrogen produced from hydrocarbons, but with a high degree (typically 90%) of carbon capture and storage

Brown Hydrogen hydrogen produced from hydrocarbons, with CO2 emissions to atmosphere

Carbon capture and storage (CCS) capture carbon either from the emissions of an industrial process (e.g. power generation, chemicals processing) with reinjection into suitable underground geological structures or depleted gas fields

Use Case description for the way in which a customer will use a product to achieve an outcome.

Hydrogen is technically ready, and manufacturing scale-up can occur if market conditions are right. However, it currently has significant economic and affordability challenges.

Hydrogen is used in a wide variety of industrial applications today, including at Refining NZ and the Ballance urea plant in Kapuni. Production, storage and distribution are relatively mature technologies, even though the solutions are designed for current demand use cases.

Hydrogen can also already be used as an "energy carrier" without additional technology R&D, such as by blending into pipeline gas.

There are a number of projects globally investigating various uses of hydrogen in different parts of the economy, such Port Lincoln Green Hydrogen Plant in South Australia. In other countries, subsidies and/or different market signals, such as substantially higher costs of mineral diesel, are stimulating early investments in hydrogen, such as the Hynor Project that will provide a "hydrogen highway" in the heart of Norway.

"Green and blue hydrogen can refresh those parts of the energy system transition that electrification cannot reach."

Dr Angela Wilkinson, Senior Director, Scenarios and Business Insights, World Energy Council June 2019

"Hydrogen and fuel cell technologies have experienced cycles of high expectations followed by impractical realities. This time around, however, falling renewable energy and fuel cell prices, stringent climate change requirements and the discrete involvement of China are step changes. The combination of these factors is leading to realistic potential for hydrogen's role in the Grand Transition"
World Energy Council 2019

New use case examples include:

- Hydrogen as a fuel in combustion processes (such as power generation) would require investment but the obstacles can be resolved.
- Commercial transport use (heavy transport) is technically feasible and hydrogen vehicle manufacturing is transitioning out of pilot phase on the promise of a decarbonised energy future.

While these use cases can be met with hydrogen today the economic signal to use hydrogen (or alternative decarbonisation options) results in low or no uptake.

Z's view of what would be needed to encourage hydrogen uptake in new use cases such as transport include:

- New regulations, particularly around ensuring safety requirements are met.
- Technology adaptation, for example modification of equipment to use an alternative fuel.
- Achieving economies of scale to drive down cost.
- A carbon price that would improve the affordability of hydrogen against fossil-fuels.

The Government is currently working on a national green hydrogen strategy due for release in the second half of 2019, which will likely provide some economic and regulatory signals.

Green electrolysis of renewables and blue reforming of natural gas are the most likely pathways for hydrogen production in New Zealand

Renewable electricity can be used to produce hydrogen by a process called electrolysis, resulting in "green hydrogen". The technology has been around for a long time, and with renewed interest is attracting significantly more investment which makes its costs likely to fall.

However, there are currently significant energy losses in the process which means the cost of producing hydrogen is high. While the capital costs of equipment (electrolysers) and their efficiency will no doubt improve, there will still be a significant cost disadvantage for green hydrogen vs other means of producing hydrogen.

Industrial process in New Zealand and globally typically use steam and a catalyst to process natural gas (methane, CH_4) into hydrogen, at very large scale and lower cost than green hydrogen. However, the downside is that carbon dioxide (CO_2) is a by-product and is emitted to the atmosphere. This is known as "brown" hydrogen.

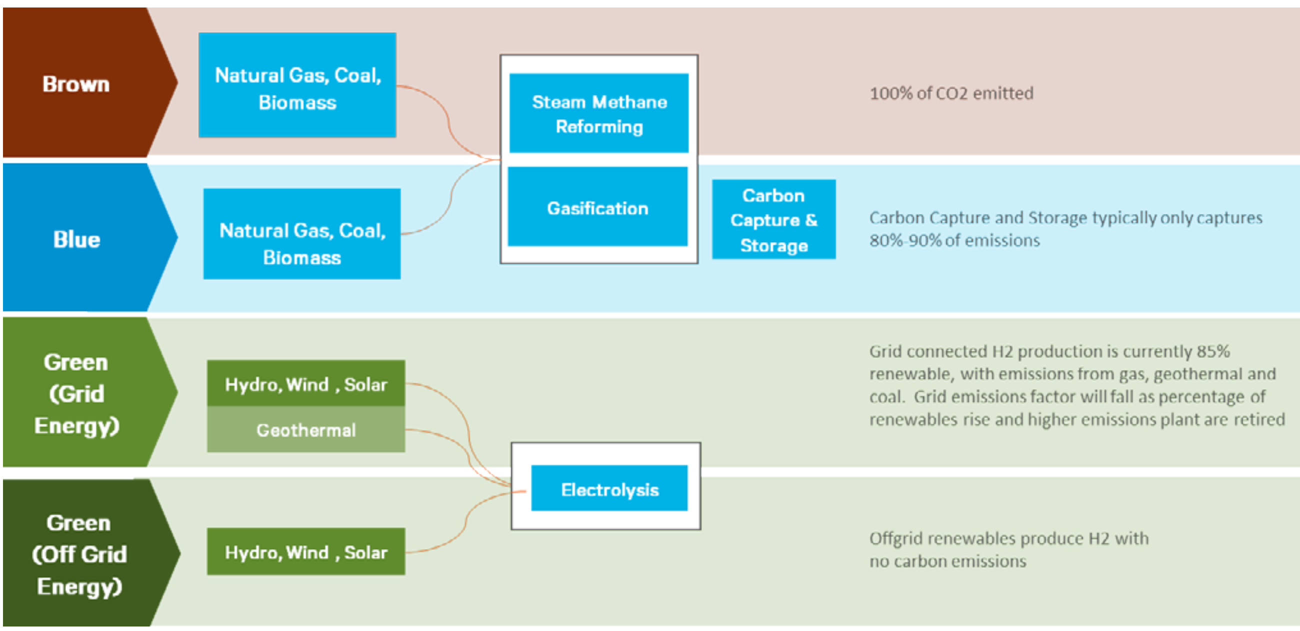
The CO_2 can be captured, although capture rates are not yet 100%, and the costs of doing so can be significant. Hydrogen produced through this method is known as "blue hydrogen". It's better than brown, but not as good as green, provided the electricity used to manufacture the hydrogen is renewable. A new engineering technology, called the Allam Cycle, claims to be able to fully capture carbon, but that is not yet proven at commercial scale.

CCS is receiving significant investment globally as it is seen as an essential transition pathway for a number of economies as they move from coal to gas for power production.

There are no CCS projects in New Zealand, although there is a similar project where the depleted Ahuroa gas field is used to store natural gas extracted from other gas fields in Taranaki, to provide flexibility in dry hydro years (like a large battery or lake). The storage part of CCS would be similar, except that the CO_2 would be stored permanently.

CCS involves capturing CO_2 released by industrial processes, compressing it and then transporting it to an injection site to be sequestered deep underground for safe, long term storage in suitable geological formations – similar to the way oil and gas has been stored underground for millions of years.

Both the International Energy Agency and Intergovernmental Panel on Climate Change believe that CCS can play an important role in helping to meet global emission targets



There are a wide range of views on the applicability of hydrogen for New Zealand

As a result of interviewing customers, participation in various working groups and meeting with sector participants, Z's view is that level of knowledge, awareness and understanding of hydrogen as a fuel is varied across government, industry and customers.

Z's customers, particularly commercial customers, are keen to find out more about alternatives to hydrocarbons and are genuinely considering their own role in decarbonisation their businesses. Common themes were that New Zealand is a technology taker, has unique issues (e.g. specific heavy transport vehicle configurations required for local conditions) and that they see significant lead times before real options exist to purchase alternative hydrogen fuelled vehicles.

Customers indicated they are generally not keen to pick winners but are open to options, whether they be electric, hydrogen fuel cell or biofuel-based alternatives. Customers have also indicated strong interest in biofuels as a transitionary fuel because it reduces emissions, and doesn't require specific infrastructure, vehicles or significant changes to operating practices.

A wide range of views exist on the acceptability of brown, blue, or green produced hydrogen. While most see brown as unacceptable and green as ideal, blue is seen as either an acceptable transitional compromise or a potential distraction that may derail a transition to a fully renewable energy source.

Z's view is similar to the most common view of green hydrogen being preferred, but that blue hydrogen, if proven to be low emissions and cost competitive through effective carbon capture, is an acceptable source of fuel while the hydrogen market is being established.

Electrification is still the dominant theme of decarbonising many use cases

Electrification is becoming the dominant "alternative fuel" choice as it can utilise established infrastructure, and considerable investment is resulting in rapidly growing availability of vehicle options and increasingly energy efficient battery technology. Direct use of electricity does not require new handling infrastructure that would be required with hydrogen, and is more efficient on a "well to wheels" basis (at least twice as efficient as hydrogen, due to lower conversion losses)

Globally, significant investment is directed towards electrification backed by renewable energy. Investment in hydrogen is substantially lower.

Z's view is that electrification will dominate the light vehicle fleet in NZ. Range anxiety issues are expected to be overcome with the newer generations of electric vehicles with significant improvements in range. A number of electrified light commercial vehicles and short-range electric buses are becoming available that are meeting the needs of transport operators and business owners.

That said, it is uncertain whether cost and weight improvements will be sufficient to enable electric vehicles to meet the needs of marine, aviation, heavy transport and some materials handling use cases.

Heavy transport vehicles use more energy, and coupled with longer range requirements, would result in a battery that would have a significant weight and space penalty impact on the transport operator.

Hydrogen is one of many alternative options for these applications. Others include biofuels (biodiesel, bioethanol, biojet), biogas (biomethane, gasified biomass), and synfuels (synthetic fuels produced to similar specifications to existing liquid-based fuel).

Hydrogen carriers, such as ammonia and methanol, can also be combusted directly or converted to electricity at the point of use.

Hydrogen can be used to couple different energy systems (e.g. natural gas, electricity, renewables). It can act as a storage mechanism, storing surplus energy from one energy system (e.g. renewable energy) and converting it back to electricity at a later stage, similar to batteries.

While technically possible, more work needs to be undertaken to fully develop the understanding of the economics and practicality of doing this (such as the cost of storage and the impact of conversion losses), similar to activity being undertaken to determine the role of batteries in the electricity system.

A substantive hydrogen economy would require interventions such as an export commitment, regulatory support or industry-led establishment of a mega-scale production facility

Hydrogen may have a role in some specific uses, but it is unlikely to have a widespread role in New Zealand in the short term unless there is a large-scale intervention.

The factors which support this view include:

- Hydrogen is an energy carrier that has a high cost of production, storage, distribution and would require significant investment to establish a new New Zealand wide supply chain
- Light vehicle transport is likely to be electric, given the weight of investment from all the major manufacturers globally and the speed at which they will come to market. Even if hydrogen was comparatively efficient to electricity for light vehicles, electric vehicles will be reaching market at scale a number of years ahead of hydrogen vehicles and will not require major new refuelling and supply infrastructure.

Where hydrogen may have a role include:

- Specific direct uses such as process heat or reducing or replacing coking coal in steel production.
- Blending hydrogen into existing gas networks (to reduce overall carbon intensity of delivered energy).
- Transport applications where payload, range and utilisation factors give hydrogen a distinctive advantage over an electric alternative, such as longer-range buses, forklifts, long haul heavy transport, rail and some marine applications.

A large-scale hydrogen economy would need to be stimulated by:

- Establishing an industrial scale facility that can produce large volumes of hydrogen at low cost.
- Government led export market; for example, exporting low cost hydrogen from hydrocarbons (with carbon capture) or from green hydrogen produced from renewable energy.
- Government led legislative and policy interventions that create a requirement for hydrogen, for example minimum blend rates in gas networks or acquisition of FCEV vehicles for public transport.

"Hydrogen can help tackle various critical energy challenges. It offers ways to decarbonise a range of sectors – including long-haul transport, chemicals, and iron and steel – where it is proving difficult to meaningfully reduce emissions"

The Future of Hydrogen, International Energy Agency, June 2019

Export hydrogen could be challenging given New Zealand's relative competitiveness

Decarbonisation efforts are gaining momentum internationally and hydrogen is becoming a component of several countries' energy strategies

Decarbonisation efforts are gaining momentum internationally and hydrogen is becoming a component of several countries' energy strategies.

Energy importers such as Japan, South Korea and China have limited local low-carbon energy sources and there is reliance on importing energy – resulting in demand led strategies. Hydrogen becomes a candidate where electrical interconnection (such as through undersea cables) is not viable.

In response, a number of energy exporters (Australia, Middle East, South America) have supply led strategies, and are establishing hydrogen-based supply chains to meet the potential demand of energy poor nations.

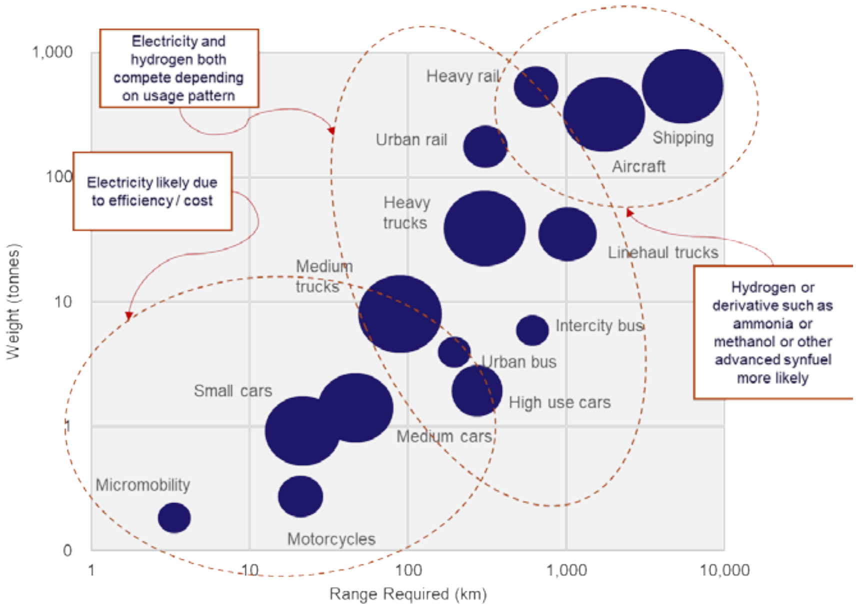
New Zealand would need to compete with countries with lower land costs, larger projects sizes, superior resources (such as all-year-round solar production) – all of which result in lower production costs.

Large scale onshore and potentially offshore wind development will require public acceptance which may be challenging, especially if these resources were developed only for energy export.

While hydrocarbon resources are out of favour, New Zealand still has significant gas resources. Should carbon capture and storage be utilised effectively, hydrogen could be produced at competitive prices as an export fuel. This may then enable a domestic use for hydrogen as it would likely be produced at substantially lower cost than "green" hydrogen, but with a low carbon emission footprint.

Different transport use case needs may lead to a broader range of fuel solutions in a decarbonised world

These are no "one size fits all" decarbonisation options. Even with hydrocarbon derived transport fuels in use today there are a range of derivative products for various segments – Jet fuel, aviation gas, fuel oil, diesel and petrol, and LPG



Indicative only: Bubble size indicates relative energy use
Source: Z Energy

> **"We believe that the future of goods and passenger transport in the city is electric."**
>
> Joachim Drees, Chairman of the Executive Board at MAN Truck & Bus AG

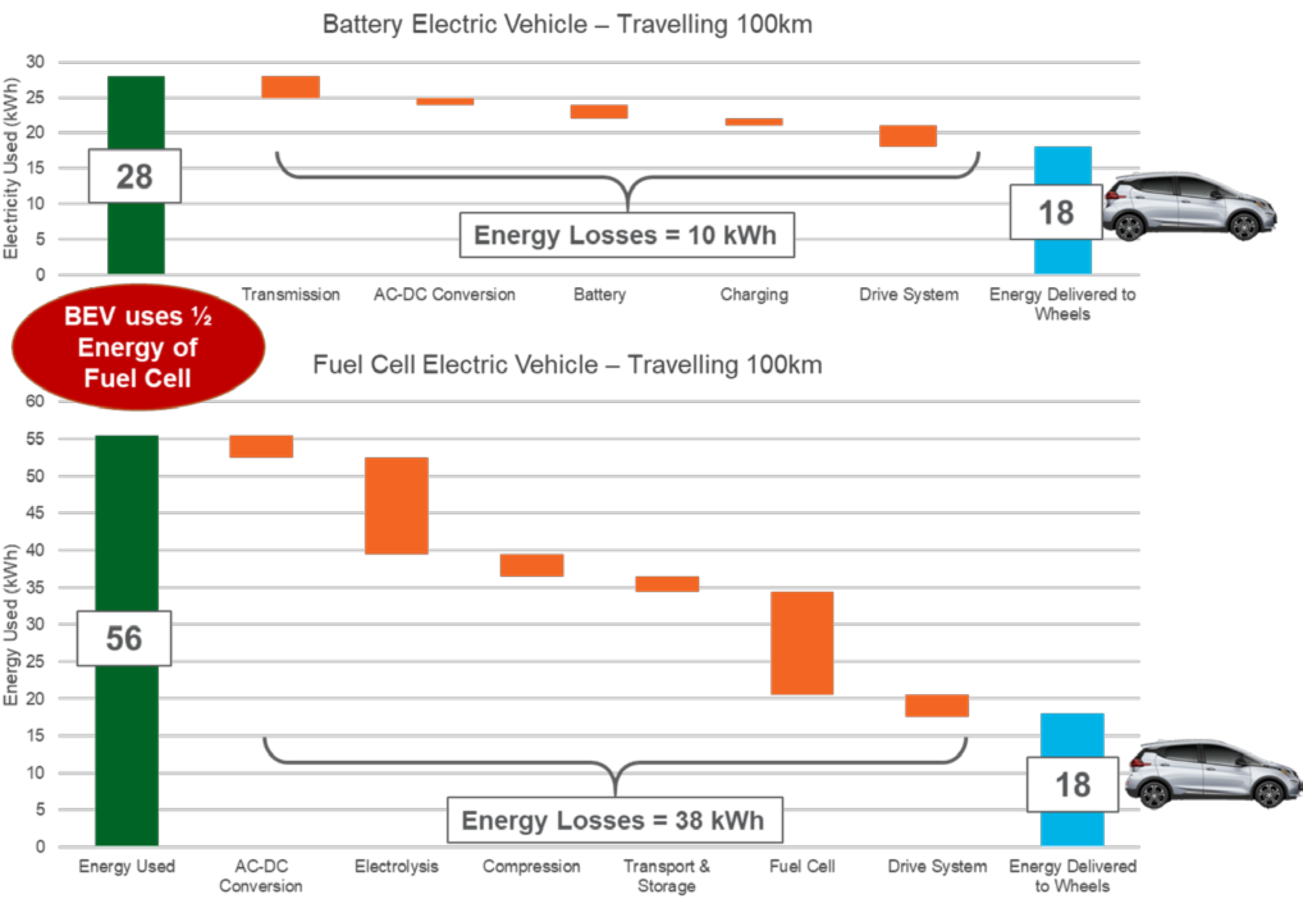
While electrification can technically meet the needs of all sectors, there are currently economic and practical limitations that restrict uptake. Typical demand and user profiles are summarised below:

	Demand & User Profiles	Use case	Issues / Opportunities	Customer Benefits
	• 4m light vehicles growing to 4.8m vehicles by 2040 • Average car usage ~10,000 km/year2, FCEV's travel around 150km/kg-H2	Fleets and private vehicle ownership	Sufficient refuelling infrastructure Residual values if a niche technology without nationwide usability	• Range • Faster refuelling time than EV • Better low temperature performance
	Logistics carriers and courier business. Metro delivery services 200km range meets 97% use cases	Fleets large and small	Focussed refuelling infrastructure (e.g city refuelling hubs)	• Lower noise and air pollution in city centres • Lower range requirement • Fast on-trip refuelling
	8 hours service in 1-3 min recharge time 10,000 in operation globally Deployment in high and low temp environments High availability (24x7 operations)	Warehouses, logistics, construction sites, manufacturing	Hydrogen storage required on-site Potential self-sufficiency with onsite renewables Additional on-site infrastructure	Avoids long overnight charging +30% operating range
	Inland and coastal ports 24x7 operation, fast refuelling time, no operational changes	Cranes, reach stackers and yard tractors	Forklifts have higher TRL and could be deployed early. Port ecosystem can be assembled over time. Potential refuel site for others	Significantly reduced noise benefits to community and employees
	6,000 buses, 2,000 urban, 2,000 school, 2000 charter/coach	City, school, charter, coach operators	Refuelling infrastructure can be depot based – but high cost of H2 Major city depot focus Refuelling sites for other users	• Urban air and noise quality • Suits longer bus routes / coach services that BEV unlikely to meet
	150k trucks, ~7% total vehicle km travelled and >25% of national carbon emissions Average usage ~40k km/year, H2 use o 12km/kg-H2 ~3.3 tonnes-H2/yr/vehicle.	Intercity freight, regional transport	Specific NZ requirements and small market Back-to-depot single shift operations	• Similar operating characteristics to diesel (range, refuel time)
	• 4,128km of track, 2,328km is freight-only. Majority of 163 locomotives are diesel-electric. • 15% of the freight (by km-tonnes) by rail • Wellington and Auckland have 110 and 67 trains respectively 250kg/km	Freight and passenger transport	Volume of hydrogen required Refuelling locations can form hubs for other transport modes	• Enhance value proposition for low carbon modal shift from road • Avoid electrification infrastructure

Z's view is that:

- hydrogen is more suitable for decarbonising high utilisation long-range use cases such as trucks, ferries, trains and buses, while battery electric will be the better choice for the shorter-range fleet.

BEV's are expected to outperform FCEV's due to efficiency, where long range or payload isn't a requirement.



Source: BNEF Data, Z Energy

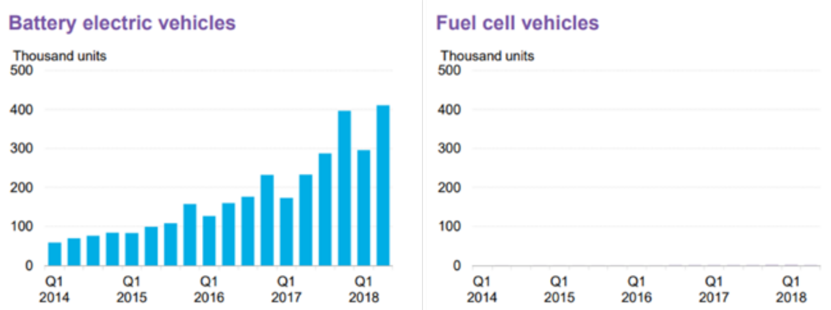
Export hydrogen could be challenging given New Zealand's relative competitiveness

Hydrogen is a real option to meet the needs of transport operators for certain use-cases, but it will take some time for cost-effective hydrogen fuelled vehicles to grow to material volume.

While Z believes that hydrogen (or a derivative fuel such as ammonia) could help meet the need for a low-carbon solution in certain use cases, the expected lead time until cost effective hydrogen fuelled vehicles are available is significant

The lead times we have already seen for BEV's give some insight into the challenge for fuel cell electric vehicles making it to market in significant volumes.

Bloomberg New Energy Finance track the production of FCEV's each year, and the following charts demonstrate how far ahead the BEV product is currently:



Source: BNEF

In the light passenger vehicle market, global FCEV cumulative sales total 10,000, compared to around 2,000,000 BEV's and 5,000,000 Plug in Hybrid (PHEV's).

In the heavy vehicle market, serial production (mass producing vehicles on a production line) is not expected until 2021/2022 and in some cases leading manufacturers (Nikola) production is already sold out for ~8 years (e.g. 2030).

Other OEM's may have vehicles earlier, but still expect at least ~3-5 years until customers can commence purchasing in any scale. Z's discussions with some heavy transport operators indicated that they didn't see themselves having the option to purchase fuel cell trucks for up to 10 years. Small commercial vehicles may be available sooner, but potentially at a premium to internal combustion equivalents.

New Zealand's market is small and is reliant on developments by manufacturers offshore. New Zealand is therefore a technology taker, and with significant limitations on availability of vehicles, it is expected that transport use will incrementally grow over the next decade.

Even in markets where fuel cell passenger markets are better suited (e.g. Japan, South Korea), targets are relatively low, and battery-electric have a high market share.

Country/ Source	Targets by Year			
	2022	2025	2030	2050
Japan	n/a		3% Passenger vehicle sales FCV 30% BEV's	
South Korea	65,000 FCV, 0.3% of fleet			
China		100,000 fuel cell stacks produced. Fuel cells in commercial vehicles, introduction to passenger private use	500,000 fuel cell systems produced, total cost of ownership parity for internal combustion	
Hydrogen Council			3% Global vehicle sales FCV's	35% global vehicle sales FCV's
Honda			67% electrified (plug-in hybrid, FCV and BEV's). Breakdown not provided	
Hyundai	Production capacity 40,000 FCV's per annum		500,000 FCV's	
Toyota	30,000 FCV sales per annum		5.5m electrified drivetrains, of which 4.4m are PHEV's and 1m are FCV's / BEV's	FCV and BEV 10% of sales

Source: Bloomberg NEF. FCV = fuel cell vehicle (hydrogen fuelled). BEV = battery electric vehicle

In addition, customers are expected to need time to familiarise and gain confidence before committing to total fleet conversion.

"At the end of 2018, there were about 10,000 fuel cell vehicles (FCVs) on the road globally. We do not expect fuel cell vehicles to gain any significant share of the passenger vehicle fleet over the next two decades. We see a growing role for fuel cells in long-haul, heavy-duty trucking but scaling up the required infrastructure and bringing down the cost of clean hydrogen production will mean that progress is slow." BNEF, Electric Vehicle Outlook 2019

Z's view is that:

- For the light vehicle market, hydrogen fuel cell vehicles are likely to be niche, require dedicated and specialist infrastructure and likely to be supported by limited manufacturers.
- Heavy transport manufacturers are significantly behind light vehicle manufacturers in prototyping and deployment.
- Heavy vehicle transport operators may invest in fuel cell vehicles where there are limited other options to decarbonise. Shorter asset turnover rates present the ability to adopt fuel cell vehicles much more quickly than the light passenger fleet, but it will take time for fuel cell options to reach the market.

Enabling hydrogen to fuel part of the heavy transport market is likely to be achievable with a small number of dedicated refuelling sites – limiting the need for producing a full national scale infrastructure – and may enable the transition to a low carbon fuel more quickly.

A number of large-scale transport related asset replacement decisions (ferries, trains and buses) present opportunities to transition away from fossil fuels.

In many cases battery storage and electric drives will service the shorter range/lower utilisation ferry, train and bus transport segments.
For example, the East by West electric ferry in Wellington, and investment in electric buses across New Zealand.

However, based on Z's understanding of operator requirements, electrification will not be universal for other longer range or higher utilisation segments of heavy transport, given the current cost and performance (energy stored per kg) of battery technology. Overseas pilots show that hydrogen can be a viable technology for these segments especially where they have back-to-base or back-to-port routes, resulting in a centralised refuelling facility.

As these vehicles and vessels reach full replacement or half-life replacement, Z expects that consideration of hydrogen and fuel cells will be considered and may be retrofit options.

Z also expects that technology developments might result in "hybrid" solutions servicing the heavy transport market, similar to what is occurring in the passenger market where hybrid drivetrains bridge between pure fossil fuel and fully electric drivetrains.

For example, smaller, and more efficient "range extended" diesel engines might be coupled with onboard batteries and electric motors to provide a balance between efficiency, acceleration and torque without sacrificing payload.

Z's view is that:

- All major asset replacement decisions should explicitly seek to replace vehicles and vessels with lower carbon solutions, as opposed to replacing like for like.

Conclusion: It is too soon to commit to hydrogen as a decarbonisation option, but neither should we dismiss it.

Z believes that there is no single "silver bullet", and that we should continue to investigate multiple options to meet our emissions reduction goals, and that urgency is required.

While we will be reliant on large scale manufacturing capacity of FCEV's to ramp up across all transportation segments, we can actively learn and experiment now, so that we are ready to adopt when the timing is right. New Zealand is also a superb test bed of technologies with early adopters often establishing projects in our market, which presents opportunities to work with international suppliers.

Z is all about solving what matters for a moving world, and we believe that the future of transportation will involve different fuels for different uses amongst our customer base. We want to actively partner with our customers and suppliers to be at the forefront of decarbonising and reducing harmful emissions from New Zealand's transport sector.