

Ministry of Transport

The Green Freight Project

Background paper on reducing greenhouse gas emissions from road freight in New Zealand through the use of alternative fuels

September 2019



This background paper has been prepared by the Ministry of Transport. The paper includes feedback and input from a number of agencies. Particular thanks goes to the National Energy Research Institute (NERI), the Energy Efficiency and Conservation Authority (EECA), the Ministry of Business, Employment and Innovation (MBIE), and the New Zealand Transport Agency (NZTA). This paper does not represent Government policy.

Contents

| | |
|--|----|
| Introduction | 3 |
| Key terms used throughout this paper | 4 |
| Executive summary | 5 |
| Section one: New Zealand’s approach to climate change | 7 |
| What are some of Government’s current approaches to GHG emissions reduction? | 8 |
| Section two: Transport GHG emissions and road freight in New Zealand | 10 |
| The transport sector’s GHG emissions profile | 10 |
| The significance of road freight..... | 11 |
| Characteristics of road freight..... | 12 |
| Reducing GHG emissions from road freight..... | 15 |
| Key questions worth considering | 17 |
| Section three: Alternative fuel options – opportunities and challenges | 18 |
| A. Electricity | 18 |
| Opportunities and challenges..... | 18 |
| International Picture..... | 23 |
| NZ picture | 25 |
| Key questions worth considering around electricity..... | 26 |
| B. Hydrogen..... | 27 |
| Opportunities and Challenges | 27 |
| International Picture..... | 31 |
| NZ picture | 32 |
| Key questions worth considering around hydrogen | 34 |
| C. Biofuels..... | 35 |
| Opportunities and Challenges | 35 |
| International Picture..... | 37 |
| NZ picture | 39 |
| Key questions worth considering around biofuels | 42 |
| Section four: Summary themes and where to from here? | 43 |

Introduction

This background paper has been prepared by the Ministry of Transport (the Ministry) as part of the 'Green Freight' project. This project looks at opportunities to reduce greenhouse gas (GHG) emissions from road freight in New Zealand.

The Green Freight project fits within a wider programme of work across the Ministry to reduce GHG emissions from the transport sector. This project is focused on road freight because it accounts for nearly one quarter of all road transport GHG emissions, and is seen as one of the most challenging areas of transport to reduce emissions from. Road freight is also vital to New Zealand's economy and is predicted to grow substantially over the next 30 years.

The purpose of this paper is to help inform discussions across government, and with industry, on how to overcome the barriers in transitioning heavy trucks involved in road freight to alternative fuels. It is acknowledged that there are a number of mechanisms to reduce GHG emissions from road freight, but this paper has focused on alternative fuels as this is a growing area of interest and investment globally, and represents a gap in current thinking for transport in New Zealand. This paper explores three different alternative fuel options – electricity, green hydrogen and biofuels. It reflects thinking and research from domestic and international literature, and situates this in the context of the road freight industry in New Zealand, and New Zealand's wider approach to GHG emissions reduction.

This paper has not been developed as a technical paper. Detailed technical information can be found in the articles and websites referenced. Instead, this paper poses a series of questions where there may be knowledge gaps or areas of high uncertainty. These questions are intended to provoke thinking, discussion and further analysis. Finding answers to these questions will help inform policy approaches and investment decisions. Ultimately, the paper seeks to answer the question: *how could New Zealand best use alternative fuels to reduce GHG emissions from road freight?*

This background paper has been produced for the purposes of further engagement on this topic. It does not represent New Zealand Government policy.

Key terms used throughout this paper

Alternative fuels – a fuel other than conventional fossil fuels (like petrol or diesel), used for powering motor vehicles. This paper is focused on three alternative fuel options - electricity, hydrogen and biofuels.

Electric roads – roads that supply electricity to the vehicles travelling on them, through overhead catenary lines, or in-road conductive or inductive charging embedded in the road surface.

Freight – any goods or cargo, carried from one place to another, by air, land or sea.

Fuel efficiency - is the relationship between the amount of fuel a car uses and the distance it travels.

Greenhouse Gas (GHG) emissions – those gases that emit radiant energy, trapping heat in the atmosphere, and warming the planet above what it would be without these gasses.

Green hydrogen – hydrogen produced from renewable electricity sources such as hydro, solar or wind, through the process of electrolysis. Unless specifically mentioned otherwise, where hydrogen is referred to in this paper, it refers to green hydrogen.

Gross Vehicle Mass (GVM) - this is the maximum operating weight of a vehicle as specified by the manufacturer. It includes all components of the vehicle, fuel and the cargo.

Heavy trucks – those weighing in excess of 3.5 tonnes (3,500 kg) GVM.

Life-cycle analysis – evaluates the full life-cycle of GHG emissions from a good or service e.g. the emissions associated with raw material extraction, manufacturing or processing, transportation, use, and end-of-life management.

Long-haul road freight – long distance transport (>250km) performed mainly on motorways or main roads.

Original Equipment Manufacturer (OEM) - is a company that produces parts and equipment that may be used and marketed by another manufacturer, which then sells the finished item to users.

Road freight – is the transportation of commodities and goods by road between two or more points. It can be broken out into urban road freight (intra-regional) and long-haul road freight (inter-regional).

Tank-to-wheel – emissions that occur during the combustion of fuels by vehicles (otherwise known as tailpipe emissions).

Transport sector – organisations across industry and Government involved in providing services to move people and goods, or providing the infrastructure to do so.

Urban road freight – short to medium distance transport, primarily across in urban areas.

Well-to-tank – emissions that come from the production and distribution of transport fuels – from the extraction of primary food stocks to final delivery to the end user.

Well-to-wheel – both the emissions that come from well-to-tank, and tank-to-wheel.

Executive summary

New Zealand's approach to climate change

In 2016, New Zealand ratified the Paris Agreement to keep the global average temperature below 2°C, above pre-industrial levels. New Zealand has set a number of greenhouse gas (GHG) emissions targets to contribute to this goal. Currently, the Climate Change Response (Zero Carbon) Amendment Bill is going through the parliamentary process. Once enacted it will include a net zero target for GHG emissions by 2050. The Government has established a framework and an independent Climate Change Commission to support its targets. Changes have also been proposed to the Climate Change Response Act 2002 to strengthen the New Zealand Emissions Trading Scheme (ETS).

A number of funding mechanisms also exist to support initiatives that seek to reduce GHG emissions. This includes funding to support initiatives that improve energy efficiency, reduce carbon emissions, encourage innovation and investment in electric and low-emission vehicles, and support New Zealand's transition to a net-zero emissions economy.

Transport GHG emissions and road freight

The transport sector is a significant contributor to New Zealand's GHG emissions, with the majority coming from road transport. The Ministry has focussed on reducing GHG emissions from light vehicles, which account for 67% of all transport emissions. The heavy vehicle fleet accounted for 24.2% of all road transport GHG emissions in New Zealand in 2015, despite only making up 7% of total vehicle kilometres driven. Road is the dominant mode for moving freight domestically, accounting for 93% of all freight movements in 2017/18 (measured in tonnes). Its dominance is in large part due to the inherent advantages it provides customers, with fast, reliable, door-to-door service. It is also more cost efficient to deliver freight by road for shorter trips. Road freight also makes a vital contribution to the New Zealand economy, particularly around the movement of export goods. It carries the largest range of cargo and covers a multitude of routes. It also provides an essential inter-modal component for rail and coastal shipping.

The road freight industry is dominated by heavy trucks. Heavy trucks remains in the New Zealand fleet for a long time (24 years on average for a new truck), and there are limited low-emission vehicles available in New Zealand, particularly for long-haul road freight operations. Shifting road freight to rail and coastal shipping, and efficiency improvements to reduce fuel consumption, will have some impact on emissions. Existing government emissions reduction mechanisms (such as the Emissions Trading Scheme, minimum exhaust emission standards, and Road User Charge (RUC) exemptions for heavy electric vehicles) will also have some impact. Collectively these are still not seen as sufficient to achieve the reduction in GHG emissions from road freight required to meet the Government's GHG emission targets.

Alternative fuels – challenges and opportunities

This paper considers three alternative fuel options - electricity, hydrogen and biofuels. Each fuel presents opportunities and challenges to help reduce GHG emissions from road freight in New Zealand.

Battery electric technology is already well established across the light vehicle passenger fleet. Its application to heavy transport requires a number of technology and cost constraints to be overcome, particularly for very heavy trucks, including the cost and weight of electric batteries, the time it takes to charge them, and the limited range they currently provide. Swapping battery packs (as opposed to charging them in the vehicle), development of fast charging technology, and infrastructure to charge vehicles while in motion (electric roads) provide potential solutions. However, improvement in battery energy density and fast charging infrastructure are seen as essential for electric batteries to play a significant role in reducing GHG emissions from road freight in New Zealand. Electric battery trucks, however, have applicability now to shorter haul operations. A couple of key questions worth considering are:

- What freight tasks could be achieved in New Zealand using commercially available electric battery trucks?
- What would support the growth and deployment of high speed charging infrastructure?

Hydrogen fuel cell technology is likely to provide niche solutions for reducing GHG emissions from heavy trucks with long-range and high utilisation requirements, and is seen to complement other alternative fuel options. In New Zealand, challenges centre on achieving competitive domestic market prices for hydrogen from electrolysis, storage, and transportation costs and constraints, vehicle efficiency and availability, and the public's perception around safety for an unknown fuel type (although the risks are similar to LPG and other gases).

Improvements in the efficiency of both the electrolyzers to produce hydrogen, and the fuel cells to use it, and reductions in their capital cost would have a significant impact on the price of hydrogen and improve its competitiveness with other alternative fuel options. At this stage, it is estimated it could be 5-10 years until price parity with existing fossil fuels, but earlier if there are higher carbon costs and/or faster cost reductions for electrolyzers. A couple of key questions worth considering are:

- What level of infrastructure is needed to establish a hydrogen refuelling network, and what would it cost?
- What is required to keep the price of hydrogen low enough to compete with other alternative fuels?

Conventional biofuels are produced through well-understood technologies and processes. These can be used in existing internal combustion engines at low blends, usually around 5%-7%. Their impact on overall GHG emissions, increases as the percentage of biofuel increases. For much higher blends of conventional biofuels to be used (around 20%), vehicle engine modifications would be required. These can be expensive. Biofuels are also more costly to produce and scale up than fossil fuels, making them generally more expensive for the consumer. They require large amounts of feedstocks (the raw inputs into the production process), significant capital investment to begin production, and commercial scale production facilities. Advanced, or second-generation, biofuel production has increased steadily over recent years, with second-generation biofuels being commercially produced in some countries. These fuels do not need to be blended with fossil fuels, and have the potential to reduce GHG emissions by 85% to 90%. A couple of key questions worth considering are:

- Could existing biodiesel blends be a near term option for reducing GHG emissions? What would it take for greater uptake of higher blends of conventional biofuels?
- What would it take to fast-track the production of advanced (second-generation) biofuels in New Zealand?

Themes

Given the current state of technological development, none of the three alternative fuels being considered provide a clear solution to reduce GHG emissions from road freight, either in New Zealand or in any overseas jurisdiction. Identifying where alternative fuels can have the greatest impact on GHG emissions in the road freight industry requires an understanding around the barriers to uptake, including the significant up-front costs, and long lead times, in building and developing supporting infrastructure, and the commercial drivers for industry decisions around vehicle fleet replacements.

Good policy and investment decisions will need to ensure that the full life-cycle of each alternative fuel is considered to make a fair comparison of their impact on GHG emissions and the wider environment. Understanding that there are co-benefits to reducing GHG emissions from road freight, and how to reflect these in future policy development, will also be important to capitalise on the opportunities alternative fuels might bring.

Section one: New Zealand's approach to climate change

This section outlines New Zealand's climate change commitments and GHG emissions targets. It discusses some of the Government's key approaches to reducing GHG emissions in New Zealand, and also highlights some of the potential co-benefits of transitioning to a low emissions economy.

Climate change will impact New Zealand's economy, environment and the wellbeing of all New Zealanders

New Zealand's average temperature has already increased by 1°C since the early 1900s. As warming increases, New Zealand is projected to experience higher temperatures, rising sea levels, changes in rainfall patterns, and more frequent extreme weather events. These changes are likely to have widespread impacts, including increasing the risk of erosion and flooding on New Zealand's coastlines, the extinction of New Zealand's flora and fauna, and droughts and flooding disrupting the economy and communities. Substantial and sustained reductions in global GHG emissions are required to limit global warming and the impacts of climate change.¹

New Zealand has a responsibility to reduce its GHG emissions

New Zealand's contribution to global gross GHG emissions is small (0.17%) but per person it is amongst the highest in the world.² New Zealand's gross GHG emissions in 2017 were 80.9 million metric tons of carbon dioxide equivalent (Mt CO₂-e). Compared to 1990, this is a 23.1% increase in emissions. New Zealand's net emissions increased by 64.9% compared with 1990 due to underlying increase in gross emissions, and increased volume of timber harvested from New Zealand's forest estate in 2017. New Zealand's emissions have increased since 1990, whereas many other countries in the Organisation for Economic Co-operation and Development (OECD) now have emissions below 1990 levels.³ In 2016, New Zealand ratified the Paris Agreement. The Paris Agreement is a global agreement on climate change, with signatories agreeing to keep the global temperature rise this century well below 2°C above pre-industrial levels, while pursuing efforts to limit the temperature increase to 1.5°C. To achieve this target, a global, concerted effort is required. To meet its international commitment, New Zealand has a responsibility to join international efforts and reduce its GHG emissions.

New Zealand has set clear GHG emission reduction targets

New Zealand currently has three GHG emission reduction targets. In 2013, the Government announced an unconditional target to reach 5% below 1990 levels by 2020. As part of the Paris Agreement, New Zealand committed to reduce its GHG emissions by 30% below 2005 levels by 2030 (this is equivalent to 11% below 1990 levels by 2030). New Zealand also committed to reduce its emissions by 50% below 1990 levels by 2050, under the Climate Change Response Act 2002.⁴

In May 2019, the Government introduced the Climate Change Response (Zero Carbon) Amendment Bill (the Bill), setting a long-term vision for a transition towards a low-emissions, greener economy. The Bill provides a framework for reducing emissions by 2050 and achieving a climate resilient future. It proposes setting a 10% reduction in biological methane emissions by 2030, with a provisional reduction ranging from 24% to 47% by 2050. All other GHGs would have a net zero target by 2050. The Bill is currently going through the parliamentary process and is expected to be enacted by the end of 2019.⁵

¹ New Zealand Productivity Commission, 'Low-Emissions Economy', 2018; Ministry for the Environment and Statistics New Zealand, 'Our Atmosphere and Climate 2017: Data to 2016, 2017.

² New Zealand Productivity Commission, 'Low-Emissions Economy'; Ministry for the Environment and Statistics New Zealand, 'Our Atmosphere and Climate 2017'.

³ Ministry for the Environment, 'New Zealand's Greenhouse Gas Inventory 1990-2017', 2019.

⁴ Ministry for the Environment, 'About New Zealand's emissions reductions targets.' <https://www.mfe.govt.nz/climate-change/climate-change-and-government/emissions-reduction-targets/about-our-emissions> (retrieved 28 August 2019).

⁵ Ministry for the Environment, 'Establishing the Climate Change Commission.' <https://www.mfe.govt.nz/climate-change/climate-change-and-government/establishing-climate-change-commission> (retrieved 28 August 2019).

Callout box one: There are also significant co-benefits from transitioning to a low emissions economy

There are significant co-benefits from reducing GHG emissions, beyond reducing the risks of climate change. For example, road transport can have significant local, national and global effects on the environment, and in particular, on public health. Emissions from vehicle exhaust contributes to air pollution, which can cause serious health problems, including disease and premature death from cardiovascular and respiratory problems, such as heart attacks, stroke, or emphysema. It can also cause lung cancer and exacerbate asthma.⁶ New Zealand's air quality is generally good; however, there are times when air quality does not meet national or international standards. The 2012 Health and Air Pollution in New Zealand report found that harmful emissions from vehicles cause 256 premature deaths (with social costs of \$934 million) annually in New Zealand.⁷ Shifting to low emission transport can reduce air pollution, and therefore rates of illness and mortality caused by air pollution.

Further co-benefits from the transition could come from a cleaner environment, the creation of jobs, through fostering innovation and showing global leadership. While New Zealand has committed to reducing GHG emissions to mitigate the impact of climate change, it also has an opportunity to make the most of the co-benefits that could come from the transition.

What are some of Government's current approaches to GHG emissions reduction?

The Climate Change Commission and Just Transitions Unit

The New Zealand Cabinet has agreed to a framework for the whole of Government that will drive climate change policy towards low GHG emissions and improved climate resilience in New Zealand. This includes the establishment of an independent Climate Change Commission to provide advice to Government and carry out a national climate change risk assessment.⁸

The Government has also committed to making the transition to a low emissions economy a 'just transition' – one that is fair, equitable and inclusive. A just transition is about making sure that the Government manages the impacts and maximises the opportunities of the changes brought about by the transition to a low emissions economy. A Just Transitions Unit has been established within the Ministry of Business, Innovation and Employment (MBIE), to help share and coordinate the work of transitioning New Zealand to a low emissions economy. It will undertake an economic analysis of the opportunities and challenges of a new 2050 target, which will continue throughout 2018 and 2019 for a longer term assessment of the expected costs and benefits, and distributional impacts, of the transition.⁹

The Emissions Trading Scheme

The New Zealand Emissions Trading Scheme (ETS) is the Government's main tool for reducing GHG emissions. The ETS puts a price on GHG emissions, which is intended to create a financial incentive for businesses who emit GHGs to invest in technologies and practices that reduce emissions. It also encourages forest planting by allowing eligible foresters to earn New Zealand emission units as their trees grow and absorb carbon dioxide. The ETS requires all sectors of New Zealand's economy to report on their emissions and, with the exception of biological emissions from agriculture, to purchase and surrender emissions units to the Government for those emissions. There are proposed amendments to the Climate Change Response Act 2002 to strengthen the ETS. All these decisions will form an amendment bill to the Climate Change Response Act which is expected to be introduced to Parliament in late 2019. These do not however include changes to the emissions price component for fuel.¹⁰

⁶ Ministry for the Environment and Stats NZ, *Our Air 2018: Data to 2017, 2018*, <http://www.mfe.govt.nz/sites/default/files/media/Air/our-air-2018.pdf>.

⁷ Gerda Kuschel et al., 'Updated Health and Air Pollution in New Zealand Study, Volume 1: Summary Report', 2012.

⁸ Ministry for the Environment, 'The transition to a low-emissions and climate-resilient Aotearoa New Zealand.' <https://www.mfe.govt.nz/climate-change/climate-change-and-government/climate-change-programme> (retrieved 28 August 2019).

⁹ Ministry of Business, Innovation and Employment, 'Just Transition.' <https://www.mbie.govt.nz/business-and-employment/economic-development/just-transition/> (retrieved 28 August 2019).

¹⁰ Ministry for the Environment, 'About the New Zealand Emissions Trading Scheme.' <http://www.mfe.govt.nz/climate-change/new-zealand-emissions-trading-scheme/about-nz-ets> (retrieved 28 August 2019).

Government funding mechanisms to support GHG emissions reduction

Several funding mechanisms have been established to support initiatives that seek to reduce GHG emissions. Several of note have been described briefly below.

A *Technology Demonstration Fund* was established by the Energy Efficiency and Conservation Authority (EECA) in 2012/13 to contribute to the cost of demonstrating proven technology or an innovative process improvement opportunity that has yet to be widely adopted in New Zealand. The fund is aimed at improving energy efficiency and/or reducing carbon emissions and provides up to 40% of the costs of the early adopter. EECA has recently put out a request for proposals for projects to demonstrate the viability of electric passenger ferries in New Zealand in a one-off special funding round. A contestable pool of \$800,000 (GST exclusive) has been put aside to fund successful marine electrification proposals.¹¹

A *Low Emission Vehicles Contestable Fund* has been established through EECA to encourage innovation and investment to accelerate uptake of electric and other low-emission vehicles in New Zealand. The fund provides up to \$7 million per year to co-fund (up to 50% of project costs) with private and public sector partners, in areas where commercial returns are not yet strong enough or technology risks cannot justify full private investment. The fund has co-financed several e-bus and e-truck projects, including projects to convert and trial electric trucks in a number of sectors, and installation of charging infrastructure to support deployment of heavy e-vehicles.¹²

The *Provincial Growth Fund (PGF)* was primarily established to lift productivity in the provinces. One of the fund's objectives is to help meet New Zealand's climate change targets. It is a \$3 billion fund over three years. A Provincial Development Unit was established within MBIE in 2018 to evaluate applications and support the delivery of the fund. Applications can be for regional economic development projects, feasibility studies and capability building, regional infrastructure projects, and initiatives targeted at priority and/or high value sector opportunities. Individuals, non-government organisations, iwi, New Zealand companies, and charities can all apply to the PGF.¹³

The *Green Investment Fund* was established by Government as part of Budget 2018, specifically to address climate change and support New Zealand's transition towards a net-zero-emissions economy by 2050. It will provide \$100 million of funding for projects that will reduce New Zealand's GHG emissions, including transport projects. Unlike the Low Emission Vehicles Contestable Fund, projects must be able to demonstrate commercial viability to be eligible for funding. The fund is being established as a company, so that it can operate independently from Government and work in a market responsive and commercially focused way.¹⁴

The *Endeavour Fund* provides investment for researchers either wanting to rapidly test promising, innovative research ideas with high potential for benefit to New Zealand (Smart ideas), or to support ambitious, excellent, and well-defined research ideas which, collectively, have credible and high potential to positively transform New Zealand's future in areas of future value, growth or critical need (Research Programmes).¹⁵ Smart Ideas are funded at \$18 million per year, with Research Programmes at \$40 million per year. Applications for funding are invited annually. MBIE administers the fund, and has recently signalled a greater emphasis on emissions reduction.¹⁶

¹¹ Energy Efficiency and Conservation Authority, 'Technology demonstration projects.' <https://www.eecabusiness.govt.nz/funding-and-support/technology-demonstration-projects/> (retrieved 28 August 2019).

¹² Energy Efficiency and Conservation Authority, 'Low Emission Vehicles Contestable Fund.' <https://www.eeca.govt.nz/funding-and-support/low-emission-vehicles-contestable-fund/> (retrieved 28 August 2019).

¹³ Ministry of Business, Innovation and Employment, 'Provincial Development Unit.' <https://www.mbie.govt.nz/business-and-employment/economic-development/regional-economic-development/provincial-development-unit/> (retrieved 28 August 2019).

¹⁴ The Treasury, 'New Zealand Green Investment Finance Ltd.' <https://treasury.govt.nz/information-and-services/commercial-portfolio-and-advice/new-zealand-green-investment-finance> (retrieved 28 August 2019).

¹⁵ Ministry of Business, Innovation and Employment, 'Endeavour Fund.' <https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/> (retrieved 28 August 2019).

¹⁶ Ministry of Business, Innovation and Employment, 'Endeavour Fund Investment Plan 2019 to 2021.' 2018. See "S2. Supporting the transition to a low-emissions economy" p. 7.

Section two: Transport GHG emissions and road freight in New Zealand

This section outlines the transport sector's contribution to GHG emissions, including the growth in GHG emissions over the past 30 years, and the challenges facing transport to reduce emissions going forward. This section also describes the significance of road freight in New Zealand and the characteristics of the road freight fleet and industry. In addition, this section discusses what has been done to date to reduce road freight GHG emissions.

The transport sector's GHG emissions profile

Road transport as a key driver of GHG emissions

Transportation in New Zealand is dominated by private road transport. Compared to other developed countries, vehicle ownership rates are high, public transport use is low, and the vehicle fleet is old with poor fuel economy. The low cost of car ownership, rapid population growth and a decline in prices for fossil-fuel vehicles have caused the private vehicle fleet to greatly expand.

The transport sector is a major contributor to GHG emissions. After agriculture, the largest source of GHG emissions is transport.¹⁷ New Zealand's GHG Inventory 1990-2017, attributes 19.7% of New Zealand's total GHG emissions to the transport sector, the majority of these from road transport.¹⁸ Transport is also New Zealand's fastest growing source of GHG emissions, with emissions increasing by more than 70% between 1990 and 2016. Again, the majority of this increase comes from road transport.¹⁹ Between 2016 and 2017 alone, gross emissions increased by 2.2%, with road transport and fossil-fuel electricity production the biggest drivers of the increase.²⁰

The significant growth in GHG emissions from road transport means that, each year, the level of reduction must increase more steeply to keep on a trajectory towards net zero GHG emissions by 2050. At a strategic level, reducing GHG emissions from transport requires lowering the energy demand required to meet New Zealand's current and future transport needs. According to the Productivity Commission's 'low-emissions economy' report, this will require finding more energy efficient ways of transporting people and goods, including through the use of alternative energy sources.²¹

While there are no specific GHG emission targets for the transport sector, the Ministry has incorporated a focus on GHG emissions reduction into its Outcomes Framework. The Ministry's outcome of *Environmental Sustainability* reinforces the important role of the transport sector in responding to climate change, and the Ministry's commitment to transitioning to net zero carbon emissions.²² In addition, the Government Policy Statement on Land Transport (2018), highlights the need to reduce GHG emissions from the transport sector, as well as adverse effects on the local environment and public health.²³

¹⁷ New Zealand Productivity Commission, 'Low-Emissions Economy'.

¹⁸ Ministry for the Environment, 'New Zealand's Greenhouse Gas Inventory 1990-2017'.

¹⁹ Ministry of Transport, 'Transport Outlook: Future State.' 2017.

²⁰ Trans Tasman 18 April Issue 2019.

²¹ New Zealand Productivity Commission, 'Low-Emissions Economy'.

²² Ministry of Transport, 'Transport Outcomes Framework.' <https://www.transport.govt.nz/multi-modal/keystrategiesandplans/transport-outcomes-framework/> (retrieved 28 August 2019).

²³ Ministry of Transport, 'Government Policy Statement on Land Transport 2018/19 – 2027/28.' 2018.

Callout box two: More than tailpipe GHG emissions need to be considered

In some instances, GHG emission accounting considers “tailpipe” (or tank-to-wheel) GHG emissions, which occur during the combustion of fuel within the vehicle. A more comprehensive approach also considers “well-to-tank” emissions (or upstream or indirect emissions), which occur from the production, processing and supply of a fuel to a vehicle. In total, this is referred to as “well-to-wheel” emissions.²⁴ However, to understand the total impact of alternative fuels on New Zealand’s GHG emissions profile and the wider environment, we need to consider their full “life-cycle”. “Life-cycle analysis” considers the GHG emission (and other environmental impacts) throughout the life of an alternative fuel, including the extraction of primary feedstocks, production and distribution, and recycling and disposal. Life-cycle analysis is essential to ensure a fair comparison between different technologies and fuels.²⁵

A focus on the light vehicle fleet

The largest source of GHG emissions from road transport comes from light vehicles (under 3.5 tonnes). Within transport, light vehicles account for 67% of emissions. Compared to other developed countries, New Zealand’s light vehicle fleet is old with poor fuel economy. New Zealand is also one of only three developed countries that has no regulations, or meaningful incentives, to influence the fuel efficiency of light vehicles entering our country. As a result, the vehicles supplied into New Zealand are among the most fuel inefficient of any OECD country.

This is compounded by the size of the light vehicle fleet, and that light vehicles remain in the fleet, on average, for around 19 years in New Zealand. If current trends continue, about 1.3 to 1.5 million vehicles will enter the light fleet over the next five years. The GHG emissions from these vehicles will be locked-in until around 2043, unless there is a change in the vehicle fleet replacement rate.

On 9 July 2019, the Associate Minister of Transport released a paper seeking public consultation on introducing a vehicle fuel efficiency standard (the Clean Car Standard) and a vehicle purchase feebate scheme (the Clean Car Discount) for new and used light vehicles entering the fleet. The Clean Car Standard will encourage the supply of more low-emission vehicles, and the Clean Car Discount will provide a marketable discount on low-emission vehicles and put a fee on high emission vehicles. Both policies will make significant contributions to reducing light vehicle emissions and deliver significant fuel savings for households.²⁶

GHG emissions from road freight

Road freight accounted for 24.2% of all road transport GHG emissions in New Zealand in 2015, even though it only made up 7% of total vehicle kilometres driven.²⁷ Long-haul road freight generates most of road freight’s energy needs and GHG emissions, and is the most challenging area of road transport to reduce GHG emissions from.²⁸

The significance of road freight

Road transport is the dominant mode for domestic freight

In New Zealand, 93% of all freight is transported by road (measured in tonnes). Road freight also accounts for 75% of tonne-kilometres travelled for all freight delivery.²⁹ Table 1 shows the percentage of freight moved by rail and coastal

²⁴ International Energy Agency, ‘The Future of Trucks: Implications for Energy and the Environment’, 2017.

²⁵ Energy Efficiency and Conservation Authority, ‘Authority Life Cycle Assessment of Electric Vehicles: The environmental impact of electric vehicles, a New Zealand Perspective.’ 2015.

²⁶ Ministry of Transport, ‘Moving the light vehicle fleet to low-emissions: discussion paper on Clean Car Standard and Clean Car Discount.’ 2019.

²⁷ Ministry of Transport, ‘Transport Outlook: Future State.’ 2017.

²⁸ New Zealand Productivity Commission, ‘Low-Emissions Economy’.

²⁹ The Ministry of Transport, ‘The National Freight Demand Study: update 2019.’ 2019. This study outlines freight movements by commodity, mode and region.

shipping. Internationally, only 50% of tonne kilometres of freight moves by road in the European Union,³⁰ 42% in the United States,³¹ and 30% in Australia.³²

Table 1: Modal share of freight operations 2017/18³³

| Mode | Tonnes | | Tonne-kilometres | |
|------------------|----------------|------------------|-------------------|------------------|
| | Million tonnes | Percent of total | Billion tonne-kms | Percent of total |
| Rail | 15.9 | 5% | 3.5 | 12% |
| Coastal shipping | 4.6 | 2% | 4.0 | 13% |
| Road transport | 269.8 | 93% | 23.1 | 75% |
| Total | 290.3 | 100% | 30.6 | 100% |

Road freight provides advantages over other options

Road freight’s core advantage is the ability to offer faster, more reliable, and flexible freight services. Cargo can be delivered to most parts of the country by road within 24 hours, and to all parts of the country within 36 hours. It carries the largest range of cargo and covers a multitude of routes. It also provides an essential inter-modal component for rail and coastal shipping. It is currently the only freight mode that can provide a ‘door to door’ delivery service, and for shorter trips, it tends to be more cost efficient.

It is essential for the New Zealand economy

The movement of freight makes a vital contribution to the New Zealand economy. Efficient freight flows are critical to New Zealand’s productivity, economic strength and competitiveness. The equivalent of around 50 tonnes of freight is moved in New Zealand, per year, for each member of the population.³⁴

An important role of the domestic freight sector is to support the movements of international trade, particularly the movements of exports, which are vital to the New Zealand economy. Of the total freight volumes in 2012, it is estimated that about 30% of both tonnes and tonne-kilometres are associated with export products at some point along the supply chain.³⁵

Characteristics of road freight

Composition of the fleet

In 2017, there were just over 144,000 heavy trucks on New Zealand’s roads, travelling a combined total of nearly 3 billion kilometres. 50% of this travel was by trucks built from 2010 onwards (even though they only made up 23% of the fleet). Heavy trucks with a GVM over 20 tonnes (and most likely used for inter-regional transport) comprised only 36% of the truck fleet, but accounted for 64% of total truck vehicle kilometres travelled (the total kilometers traveled during a given period of time). Additionally, as the weight of the truck increased, the annual vehicle kilometres travelled also increased across all truck weights.³⁶

³⁰ Eurostat, ‘Freight transport statistics – modal split.’ http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split (retrieved 28 August 2019).

³¹ J. J. Brogan et al. ‘Freight Transportation Modal Shares: Scenarios for a low-carbon future.’ Prepared by Cambridge Systematics Inc. for the US Department of Energy. 2013.

³² National Transport Commission, ‘Who Moves What Where, Freight and Passenger Transport in Australia.’ August 2016. p 21.

³³ The Ministry of Transport, ‘The National Freight Demand Study: update 2019.’ 2019

³⁴ The Ministry of Transport, ‘The National Freight Demand Study: March 2014.’ 2014.

³⁵ The Ministry of Transport, ‘The National Freight Demand Study: March 2014.’

³⁶ Ministry of Transport, ‘Annual Fleet Statistics 2017.’ <https://www.transport.govt.nz/assets/Uploads/Research/Documents/Fleet-reports/1b33252a3d/The-NZ-Vehicle-Fleet-2017-Web.pdf> (retrieved 28 August 2019)

With a few exceptions, all new trucks that enter the New Zealand fleet are sourced from overseas. As the majority of new trucks are sourced from overseas, they comply with the fuel efficiency and environmental standards of the supplying country. Europe, Scandinavia, and Asia are the main sources of new trucks entering New Zealand. Some are also sourced from the United States, often via Australia. New trucks generally enter the country as a cab and chassis and have freight bodies and other equipment fitted locally. Traditionally, trailers were built in New Zealand, but because of local demand, there are some entering the fleet now that are built overseas; Australia and China are common sources.³⁷

The average age of the existing heavy truck fleet in New Zealand is 17.8 years.³⁸ On average, new heavy trucks that enter the New Zealand market remain in the fleet for about 24 years, with used heavy trucks remaining for around 16 years.³⁹ This locks in emissions and air pollution over that period. Even though the majority of mileage travelled is at the front of a truck's life, every additional hydrocarbon fuel-based heavy truck that enters the fleet now, increases the difficulty in meeting New Zealand's GHG emission targets.

Freight movements

In New Zealand, the average distance freight moves is 111 kms. Road freight movements tend to be localised with about 77% of freight tonnage remaining within the region from which it was sourced, with an additional 14% being transported to an adjacent region. There is also very little movement of freight between the North and South Islands (2.2% of tonnage in 2012/13) with most flowing from North to South.⁴⁰

The Auckland region has the largest tonnage of freight. This freight includes local products moving to local markets, additional freight coming into Auckland to cater for local needs, the movement of goods manufactured in Auckland or being shipped from Auckland distribution centres, and the movement of goods for export to the Ports of Auckland and Tauranga. Canterbury has a large amount of freight for similar reasons, as it is the main population and distribution centre for the South Island.⁴¹

The freight industry

A wide range of freight is moved on road, including moving stock between farms, home delivery of groceries and the movement of import and export goods. The national fleet of heavy freight vehicles in New Zealand is made up of both large fleets of vehicles and smaller owner-operated businesses.⁴² An owner-operator is someone who owns the transport business and drives a truck in that business as a contract driver. They may operate more than one truck and are essentially small business owners. Owner-operators may work for other fleet operators. Freight operators can either employ drivers or owner-operators.

The freight sector is highly competitive, containing a large number of freight operators.⁴³ The Ministry's Annual Fleet Statistics (2017), show that more than 55% of the heavy vehicles in the road freight industry operate as part of a small fleet, i.e. five or fewer vehicles.⁴⁴ The ease of entry and access to finance is one reason behind the large number of small fleet owner-operators within the industry. However, road freight is a highly price competitive market where the operating costs of a road freight transport business are comparatively high, (including road user charges, vehicle lease costs and fuel costs). This limits the potential for freight operators to invest in (often unproven) new technologies, particularly with uncertainty around pricing and supply.

³⁷ The Ministry of Transport, 'The National Freight Demand Study: March 2014.'

³⁸ Ministry of Transport, 'Annual Fleet Statistics 2017.'

³⁹ Ministry of Transport, annual fleet report found at: <https://www.transport.govt.nz/assets/Uploads/Research/Documents/Fleet-reports/b19d737497/NZ-Vehicle-Fleet-Graphs-2017-WEB.xlsx>

⁴⁰ The Ministry of Transport, 'The National Freight Demand Study: March 2014.'

⁴¹ Ministry of Transport, 'Transport Outlook: Future State.' 2017.

⁴² Energy Efficiency and Conservation Authority, 'About the Heavy Vehicle Fuel Efficiency Programme.' 2016. <https://www.mbie.govt.nz/search/SearchForm?Search=Heavy+Vehicle+Fuel+Efficiency> (retrieved 28 August 2019).

⁴³ The Ministry of Transport, 'The National Freight Demand Study: March 2014.'

⁴⁴ The Ministry of Transport, 'Annual Fleet Statistics 2017.'

Demand for road freight

Road transport is expected to remain the primary mode for freight in the foreseeable future, accounting for about 70% of tonne kilometres.⁴⁵ The demand for road freight is expected to increase over the next 20 years. In New Zealand, it is projected that the amount of freight in tonnes will increase by 58% (equivalent to about 67 tonnes of freight, per person, per year) by 2042 (from 236 million tonnes in 2012 to over 373 million tonnes).⁴⁶

Manufactured goods, retail, and other products are expected to have the greatest contribution to the absolute increase in road freight tonnage by 2042 (from 72 million tonnes in 2012/13 to 111 million tonnes in 2042/43).⁴⁷ Most of the demand for these products (81%) will remain within the region in which they are sourced or port in which they enter the country.⁴⁸

Currently, over 97% of freight demand is within regions, with around two thirds of freight tonne-kilometres involving inter-regional travel. It is anticipated that, by 2042, most freight movements will remain localised, with transportation to non-adjacent regions being driven by manufactured goods, retail and other products, primarily being driven out of Auckland and Canterbury distribution centres. Auckland's volume of road freight is forecast to increase by around 78% by 2042. By 2042, the Auckland, Hamilton and Tauranga "golden triangle" is also expected to account for 52% of total freight tonnage of manufactured goods, retail and other products.⁴⁹

There are however a number of assumptions underpinning these assessments. Changes to logistics operations, self-organising supply chains, autonomous vehicles and truck platooning, last mile delivery options, and 3D printing could change the landscape entirely. 2042 is a long way away in such a fast moving industry.⁵⁰

Callout box three: What drives road freight demand

Road freight demand is a derived demand, and depends on the demand for other goods and services.⁵¹ This demand is driven primarily by both the volume of economic activity (including our domestic consumption and the movement of our exports), and the changing structure of the economy. For example, New Zealand has a large forestry sector. Export revenue from China exceeded \$3.2bn in the year ending 2018, driven primarily by increased Chinese demand for New Zealand forestry products. This demand drives economic activity and the demand for road freight services for the logging industry.⁵²

It is important to note that the rates of economic and population growth by region are the largest uncertainties impacting the future demand for freight. Other factors include the growth rates of various industries and potential changes in their supply chains, as well as the competitive position of the various transport modes, which will depend on advances in technology and the direction of government policy.⁵³

⁴⁵ The Ministry of Transport, 'Government Policy Statement on Land Transport 2018/19 – 2027/28.' 2018.

⁴⁶ The Ministry of Transport, 'The National Freight Demand Study: March 2014.'

⁴⁷ The Ministry of Transport, 'Transport Outlook: Future State.'

⁴⁸ The Ministry of Transport, 'Transport Outlook: Future State.'

⁴⁹ The Ministry of Transport, 'The National Freight Demand Study: March 2014.'

⁵⁰ International Energy Agency, 'The Future of Trucks: Implications for Energy and the Environment'.

⁵¹ New Zealand Transport Agency, 'Drivers of demand for transport October 2013.' Research Report 534. 2013.

⁵² Beehive Media Release, 'NZ and China sign forestry cooperation arrangement.' <https://www.beehive.govt.nz/release/nz-and-china-sign-forestry-cooperation-arrangement>. 14 May 2019.

⁵³ Ministry of Transport, 'Transport Outlook: Future State.'

Reducing GHG emissions from road freight

There are several initiatives being progressed that impact GHG emissions from road freight. Some are outlined below.

Using alternative means of transporting freight

As part of the Ministry's wider emissions reduction work programme, work is underway to investigate the benefits of shifting road freight to lower emission modes, such as rail and coastal shipping. At the present level of rail electrification, rail produces less than one quarter of the emissions that road freight produces per tonne-kilometre (measured in grams of CO₂), and coastal shipping produces less than 10% per tonne-kilometre.⁵⁴ Both alternative modes have the additional benefits of relieving road traffic congestion and improving safety.

Where feasible, shifting road freight to rail or coastal shipping can provide a useful alternative for freight carried over longer distances (this is at above 300km).⁵⁵ It has been previously estimated that rail, and coastal shipping, could increase their share of freight tonne-kilometres to 20% each with deliberate measures to shift road freight where possible⁵⁶ (currently rail is around 12% and coastal shipping is around 13%).⁵⁷

However, much of New Zealand's freight moves over short distances, not all locations have access to rail/coastal shipping, and some cargo needs to be moved quickly (e.g. perishable goods). Many sectors are driven by "just-in-time", or "delivery on demand" business models. These models limit mode shift as they prioritise timeliness over other drivers.

Mode shift is primarily a commercial decision. That decision is driven by the market expectations that a business is responding to, such as timeliness and cost, the characteristics of their cargo, and the convenience of options available to them. The additional handling and cost of shifting freight from trucks to rail can be prohibitive. Rail and coastal shipping will need to offer freight operators faster and more reliable services than road to make a significant impact on road freight volumes.⁵⁸ An example of where mode shift is expected to have an impact is the reopening of the Napier-Wairoa rail line in Hawke's Bay (supported by \$6.2 million from the Provincial Growth Fund). It is expected to reduce the number of trucks on roads in the region by 5000 annually.⁵⁹

Efficiency measures

Reducing domestic transport costs improves the international competitiveness of our export goods. Practical approaches to reducing the fuel consumption of heavy transport, and better optimising the utilisation of fleets, can also have a material impact on emissions.⁶⁰

Research suggests that a SAFED (Safe and Fuel Efficient Driving) course can average a 9% fuel saving immediately after training and a 5% saving in the long-term. If it is assumed that 80% of the fuel use is by operators that have not already employed these measures and there is a 5% saving available, then there is potential for a 1.8 PJ saving today from SAFED alone. The equivalent GHG emissions savings is 140,442 Mt CO₂-e or 4.3% of total heavy vehicle emissions. Additionally, when drivers use fuel efficient practices, driver and other road user safety improves, as well as an estimated 2% reduction in annual repair and maintenance costs as a result of improved driving techniques (e.g. reduced harsh acceleration, braking and cornering, and fewer gear changes).

⁵⁴ The Ministry of Transport, 'The National Freight Demand Study: March 2014.'

⁵⁵ New Zealand Productivity Commission, 'Low-Emissions Economy'.

⁵⁶ H Mackie, P Baas, and J de Pont, 'Prediction of freight growth by 2020 and rail's ability to share the load.' IPENZ Transport Group Conference 2007. Coastal Shipping and Modal Freight Choice, Rockpoint, July 2009.

⁵⁷ The Ministry of Transport, 'The National Freight Demand Study: update 2019.' 2019

⁵⁸ Ralph D. Samuelson, 'What We Know and Don't Know About Freight Emissions by Mode in New Zealand (DRAFT)', Ministry of Transport, 14 February 2019.

⁵⁹ Laura Wiltshire, 'Napier-Wairoa rail line reopening heralds a new era in Hawke's Bay.' NZ Herald.

https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=12238733 (retrieved 28 August 2019).

⁶⁰ New Zealand Productivity Commission, 'Low-Emissions Economy'.

In 2012, the EECA launched a programme for improving heavy vehicle fuel efficiency. The programme aimed to improve heavy vehicle fuel efficiency by building on the existing SAFED driver development course. The programme provided short courses to train industry professionals around a range of strategies for improving fuel efficiency.⁶¹ These professionals would then assist freight companies to reduce fuel costs, aiming for a 7.5% improvement in efficiency. A review of the programme suggested the costs far outweighed the small number of benefits from reducing emissions, largely due to small participation, difficulties in measuring savings, and the high costs of training (MBIE, 2016c).⁶² The programme did confirm that there is a role for the Government to intervene in the heavy transport market to help realise the significant public benefits of reduced carbon emissions and improved air quality.

The Sustainable Business Council (SBC) and EECA have also made efforts to improve operational efficiency in the road freight sector (e.g. demand management and load-sharing). The SBC freight procurement guidelines also commit members to use their influence as either procurers, or sellers, of freight services to reduce emissions. For example, the guidelines help freight providers collaborate with cargo owners to reduce the amount of just-in-time deliveries, and to reduce under-utilised freight movements i.e. half empty trucks.

The Emissions Trading Scheme

As discussed previously, the Emissions Trading Scheme (ETS) is the Government's main tool for reducing GHG emissions. However, the Productivity Commission's report 'Low-emissions economy' argues that the ETS has a limited ability to reduce transport emissions because the current emissions price is a small component of fuel prices. A rise in the emissions price could drive behaviour change and make the production and use of alternative fuels more viable. However, even with a significant increase to the emissions price, additional measures will be needed to achieve large emission reductions in the transport sector.⁶³

Minimum standards applied to the entire vehicle fleet

New Zealand has age restrictions on used imports, including heavy vehicles, as there is a clear relationship between vehicle age, its related engine technology, and more stringent emissions standards in the manufacturing or source country. These restrictions enable the efficient transfer of improved vehicle technology from other jurisdictions into the New Zealand fleet.

New Zealand also has a land transport rule around vehicle exhaust emissions that sets emissions standards for vehicles entering the New Zealand fleet.⁶⁴ It also sets out controls on emissions that apply to vehicles already in the New Zealand fleet. Since the introduction of the rule, the percentage of imported used trucks has reduced.⁶⁵ A number of minor and technical changes have been made to the emissions rule through the amendment rules in 2009, 2010, 2011 and 2012. The Rule establishes progressively lower (more stringent) vehicle emissions standards depending on the date of entry into service, the date of manufacture, the type of fuel used (petrol or diesel), weight (less than or greater than 3.5 tonnes) and whether the vehicle is imported as a new or used vehicle.⁶⁶

Exemptions

The Government has also introduced Road User Charge (RUC) exemptions for heavy electric vehicles until they make up 2% of the heavy vehicle fleet. The Road User Charges Act 2012 (the RUC Act) imposes charges on vehicles, for their use of the road in proportion to the costs that the vehicles generate. Road user charges are applied to all vehicles that do not use a fuel that is taxed at source (e.g. petrol). The exemption appears to have encouraged the uptake of electric buses but has had limited impact on the uptake of electric trucks (potentially as a result of supply issues of up front

⁶¹ These included maintenance, tyres, aerodynamics, truck selection, route planning as well as driver training.

⁶² Energy Efficiency and Conservation Authority, 'About the Heavy Vehicle Fuel Efficiency Programme.' 2016. <https://www.mbie.govt.nz/search/SearchForm?Search=Heavy+Vehicle+Fuel+Efficiency> (retrieved 28 August 2019).

⁶³ New Zealand Productivity Commission, 'Low-Emissions Economy'. p. 345.

⁶⁴ The rule, and subsequent amendments, can be found at: <https://www.nzta.govt.nz/resources/rules/vehicle-exhaust-emissions-2007-index.html>.

⁶⁵ The Ministry of Transport, 'Annual Fleet Statistics 2017.'

⁶⁶ The Ministry of Transport, 'Vehicle Emissions.' <https://www.transport.govt.nz/multi-modal/vehicleemissions/> (retrieved 28 August 2019).

costs). The Productivity Commission recommends that a simpler form of price support (e.g. upfront grants for heavy electric vehicles) may be more effective than a RUC exemption.⁶⁷

Key questions worth considering

How effective are minimum fuel efficiency standards in reducing GHG emissions? Would strengthening these over time provide part of the solution to reducing GHG emissions from road freight?

How could we reduce GHG emissions by changing the composition of the heavy truck fleet (e.g. size and weight of trucks entering NZ)?

What other mechanisms might support GHG emissions reduction from road freight?

How do we better understand the life-cycle emissions generated by each alternative fuel option?

What influence does the end consumer have in driving changes to the way freight is delivered?

⁶⁷ New Zealand Productivity Commission. (2018). Low-emissions economy: Final report. Available from www.productivity.govt.nz/low-emissions.

Section three: Alternative fuel options – opportunities and challenges

“In the long term, alternative fuels will provide the only means for deep decarbonisation of the road freight sector.”⁶⁸

International Energy Agency

This section explores three alternative fuels that we have identified as having the most potential to reduce GHG emissions from road freight – electricity, hydrogen and biofuels. While we think these fuels have the most potential, there are likely to be other fuel or technology breakthroughs in the future which cannot be ruled out. This section discusses the opportunities and challenges of each of these fuels to help reduce GHG emissions from heavy trucks, as well as approaches internationally, and in New Zealand, to transition to them.

A. Electricity

The term “electric vehicle” refers to a wide range of vehicle types, including hybrid-electric, plug-in electric, battery electric vehicles, as well as fuel cell technologies. Battery Electric Vehicles, (BEVs), use electricity stored in a battery pack within the vehicle to power an electric motor and turn the wheels. When depleted, the batteries are recharged using the electricity grid, either from a wall socket or by using a dedicated charging unit. Since they do not use an additional fuel source, (such as petrol, diesel or hydrogen) BEVs are considered “all-electric” vehicles.⁶⁹

Electric battery technology is already well established as a viable option to reduce GHG emissions from the light passenger vehicle fleet in New Zealand. Electric batteries, however, have limitations that mean transitioning the heavy truck fleet to electric battery powertrains is more challenging than for light vehicles.

Opportunities and challenges

The sustainability of battery electric trucks and their potential to reduce GHG emissions

GHG emissions and air pollution

Battery electric trucks produce zero tailpipe GHG emissions (or other harmful gases). While GHG emissions can arise from the generation of electricity to charge batteries, New Zealand is well-placed to achieve substantial emission reductions by adopting electric vehicles, because most of its electricity is generated using renewable sources.⁷⁰ The challenge lies in being able to reduce GHG emissions over the full life-cycle of electric trucks (including GHG emissions associated with raw material extraction, battery manufacture, vehicle manufacture and shipping) and how these emissions compare to the life-cycle for fossil fuels, hydrogen and biofuels. While there is good understanding around what to include in these assessments, the ability to measure each step in the process is challenging.⁷¹

Battery production and disposal

We also need to consider the environmental impacts associated with battery production and disposal. Every stage of the battery life-cycle, from mineral extraction to disposal has environmental risks. For example, the demand for minerals such as cobalt and manganese has led to renewed interest in deep-sea mining, which could have serious and irreversible impacts on biodiversity. Battery waste also contains various hazardous materials, which can contaminate soil, water and air quality.⁷²

⁶⁸ International Energy Agency, ‘The Future of Trucks: Implications for Energy and the Environment’.

⁶⁹ Union of Concerned Scientists, ‘How do battery electric cars work.’ <https://www.ucsusa.org/clean-vehicles/electric-vehicles/how-do-battery-electric-cars-work> (retrieved 28 August 2019).

⁷⁰ New Zealand Productivity Commission, ‘Low-Emissions Economy’.

⁷¹ European Environment Agency, ‘Electric vehicles from life cycle and circular economy perspectives.’ Transport and Environment Reporting Mechanism (TERM) report. 2018.

⁷² Amnesty International, ‘Amnesty challenges industry leaders to clean up their batteries.’

<https://www.amnesty.org/en/latest/news/2019/03/amnesty-challenges-industry-leaders-to-clean-up-their-batteries/> (retrieved 28 August 2019).

Lithium-ion batteries, particularly those in electric vehicles, are a priority product for New Zealand to recycle or repurpose, avoiding the waste of valuable resources and minimising the embodied environmental and social impacts of the materials from which the batteries are made. As New Zealand moves to a more productive, sustainable, low emissions economy, the linear 'throw-away culture' (take-make-dispose) will need to change to a circular economy (make-use-return). The Government is therefore working to find ways to increase the reuse of batteries. Longer term, the disposal of lithium-ion batteries, once any "second life" has been achieved, could become an issue as the number of electric vehicles in New Zealand increases.

Technology developments are also seeing the growth in alternative battery chemistry which is cheaper than Lithium-ion batteries, less exploitive and uses lower emission materials such as zinc or aluminium. These technologies purport higher energy density and energy mass, and their cost is dropping faster than lithium-ion batteries. These technologies could dominate battery development over the next 10-15 years.

Life-cycle analysis

Life-cycle analysis for heavy electric trucks in New Zealand has not been undertaken. In 2015, EECA commissioned a full life-cycle analysis of the environmental impact of electric cars compared to internal combustion cars. The report concluded that when you take into account raw material extraction, battery manufacture, vehicle manufacture and shipping, BEVs still emit 60% fewer GHG emissions over their full life-cycle than petrol vehicles.⁷³ Similarly for trucks, we need to understand the full life-cycle environmental impacts (including GHG emissions and other adverse impacts on the environment) of electric trucks and how this compares to fossil fuels, hydrogen and biofuels.

The cost of battery electric trucks and supporting infrastructure

Battery electric trucks offer reduced fuel and maintenance costs, and increased engine efficiency in comparison to conventional vehicles.⁷⁴ Concept Consulting has modelled the cost effectiveness of diesel, battery electric and hydrogen trucks in New Zealand. With respect to fuel costs, electric trucks are significantly more fuel efficient and will continue to have lower fuel prices as long as renewable electricity infrastructure continues to be developed. A study from the EU in 2018 identified that cost competitiveness is highly sensitive to electricity price.⁷⁵

Electric trucks are more costly to purchase than conventional trucks, and there is uncertainty around the return on investment.⁷⁶ Concept Consulting recently estimated that those heavy electric trucks currently available, cost 45% more than diesel trucks to purchase.⁷⁷ This may change as more production line electric heavy vehicles begin to be manufactured.

The main incremental cost of battery electric trucks is the cost of the battery.⁷⁸ As battery prices decrease and stack life improves, the life-cycle costs of heavy electric trucks are expected to become lower than those of heavy diesel trucks.⁷⁹ Technology advances are delivering substantial cost reductions for batteries. The International Energy Agency (IEA) highlights that continued cost reductions in batteries are likely. The IEA expects that by 2025, batteries will increasingly use cathode chemistries that are less dependent on cobalt. This will lead to an increase in energy density and a decrease in battery costs, in combination with other developments. Technology is also progressing for fast chargers, in

⁷³ Energy Efficiency and Conservation Authority, 'Life Cycle Assessment of Electric Vehicles: The Environmental impact of electric vehicles, a New Zealand Perspective, Final Executive Summary.' 2015. Retrieved from: <https://www.eeca.govt.nz/assets/Resources-EECA/ev-lca-exec-summary-nov-2015.pdf>.

⁷⁴ Marissa Moultaq, Nic Lutsey, and Dale Hall, 'Transitioning to Zero-Emission Heavy-Duty Freight Vehicles', White Paper (International Council on Clean Transportation, September 2017).

⁷⁵ Thomas Earl et al. 'Analysis of long haul battery electric trucks in EU, Marketplace and technology, economic, environmental, and policy perspectives.' European Federation for Transport and Environment. 2018.

⁷⁶ New Zealand Productivity Commission, 'Low-Emissions Economy'.

⁷⁷ Concept Consulting Group, 'Hydrogen in New Zealand: Report 1 - Summary', 2019.

⁷⁸ International Energy Agency, 'The Future of Trucks: Implications for Energy and the Environment'.

⁷⁹ Liimatainen et al., 'The potential of electric trucks – An international commodity-level analysis.' Applied Energy 236 (2019) 804-814; Mareev et al., 'Battery Dimensioning and Life Cycle Costs Analysis for a Heavy-Duty Truck Considering the Requirements of Long-Haul Transportation', Energies 11: 55. 2018.

part to support heavy-duty applications such as buses, trucks, shipping and aviation, but charging is primarily still aimed at overnight depot charging.⁸⁰ New Zealand is a world leader in this space, particularly around applications of superconductors in power systems equipment.⁸¹

The cost associated with deploying suitable charging infrastructure for electric trucks is also seen as a significant barrier for near-term battery electric truck adoption.⁸² The rapid uptake of light electric vehicles is likely to benefit heavy-vehicles by driving electricity cost reductions, but additional specialist charging infrastructure will still be required to support heavy electric trucks.⁸³

The weight of batteries, charging time and range

The weight of batteries, the time it takes to charge them, and the limited range they can provide heavy trucks are major barriers facing the adoption of long-haul electric trucks.⁸⁴ The greater the size and weight of trucks, and the further they need to travel, the more barriers there are for batteries to serve as a substitute for diesel.⁸⁵

Weight

Heavy electric trucks require a large number of electric batteries to undertake road freight operations similar to diesel trucks. Rough estimates are that an electric fleet size would need to be 18% greater to move the same amount of freight as a diesel fleet. The weight of the batteries required is currently prohibitive for the majority of long-haul road freight operations. This is because the watt-hours per kilogram (Wh/kg) is still too low.⁸⁶ This is often referred to as the “storable charge per weight”, or energy density of the battery. Improving battery energy density (and therefore reducing the weight of batteries) requires storing larger amounts of lithium in the anode, which is costly.⁸⁷

Charging time

Heavy-duty commercial fleets have some unique characteristics that can make charging challenges even more formidable, including power requirements, and scale and operational demands. For example, a Chanje V8100 medium-duty panel van has a 100-kWh battery, and Freightliner’s eCascadia semi-truck has a 550-kWh battery. While charging these larger batteries overnight (for fleets with one or two shift operations) may be feasible, larger fleets with less time to charge may require more bespoke options (e.g. inductive charging options and pantographs deployed in depots).

This challenge is amplified when multiple electric trucks need to be charged at the same facility, at the same time. A fleet manager responsible for ensuring that 10, 20, or even 100 trucks are charged and ready to go for their first shift may struggle with how best to plan the necessary charging infrastructure to minimize capital and installation costs as well as operating expenses. Contributing to this is the business requirement to meet the customer’s expectations, including fast delivery times. This creates constraints around when large fleet operators can charge trucks, making it harder to avoid high energy prices due to unfavorable peak rates.⁸⁸ This challenge could potentially be addressed through software solutions that optimise charging across (and between) vehicles and fleets.

⁸⁰ International Energy Agency, ‘Global EV Outlook 2019.’ <https://www.iea.org/publications/reports/globalevoutlook2019/> (retrieved 28 August 2019).

⁸¹ National Energy Research Institute, ‘Superconductivity.’ <https://www.neri.org.nz/superconductivity> (retrieved 28 August 2019).

⁸² Jessie Lund, ‘One Size doesn’t fit all: How commercial EVs present unique challenges for charging infrastructure.’ GreenBiz. April 11 2019. <https://www.greenbiz.com/article/one-size-doesnt-fit-all-how-commercial-evs-present-unique-challenges-charging-infrastructure> (retrieved 28 August 2019).

⁸³ Concept Consulting Group, ‘Hydrogen in New Zealand, Report 3 – Research.’ 2019.

⁸⁴ New Zealand Productivity Commission, ‘Low-Emissions Economy’.

⁸⁵ International Energy Agency, ‘The Future of Trucks: Implications for Energy and the Environment’.

⁸⁶ The watt-hour per kilogram is a unit of specific energy commonly used to measure the density of energy in batteries and capacitors.

⁸⁷ Mark Lapedus, ‘Electric Cars Gain Traction, But Challenges Remain.’ Semiconductor Engineering. April 22 2019. <https://semiengineering.com/electric-cars-gain-traction-but-challenges-remain/> (retrieved 28 August 2019).

⁸⁸ Jessie Lund, ‘One Size doesn’t fit all: How commercial EVs present unique challenges for charging infrastructure.’ GreenBiz. April 11 2019.

Some of these issues could be addressed through the use of more powerful (higher voltage and current) charging stations. With multiple such stations however, a further consideration is the need to ensure the local electricity network can handle the increased load, or the cost to ensure it can, over and above the cost of the EV infrastructure.

Range

Electric batteries are rated in kilowatt hours (kWh).⁸⁹ The greater the kWh capacity the battery has, the longer the potential range the vehicle can travel. For example, a 2019 Nissan Leaf has a 40kWh battery and an average range of 270km, whereas a 2018 Hyundai Kona has a range of around 400km thanks to its 64kWh battery. Battery range is also dependent on environmental factors and load, including the terrain, outside temperature, driving behaviour and the drain from electrical devices within the car. Brake regeneration systems are designed to continuously recharge the battery to counter this. Over time electric batteries degrade, reducing their ability to store charge. The duty-cycle of the vehicle (how much a vehicle is used) will have a significant impact on this degradation. This means as high use vehicles age, a full battery charge will not travel as far, resulting in gradual reduction in range between charges.⁹⁰

Callout box four: Human rights concerns with battery development

Amnesty International has highlighted that lithium-ion batteries, which power most electric vehicles, are linked to human rights abuses, including child labour, in the Democratic Republic of Congo (DRC). One of the key ingredients in lithium-ion batteries is cobalt. As demand for batteries grows, so does the demand for cobalt. More than half of the world's cobalt originates in the Democratic Republic of Congo (DRC). In 2016, Amnesty International published a report that linked serious human rights violations in cobalt mines in DRC to the supply chains of many of the world's leading electric vehicle companies. Amnesty International has challenged companies to ensure that their products do not contribute to or perpetuate human rights abuses.⁹³

The UN Guiding Principles on Business and Human Rights outlines the responsibility of companies to respect international human rights in their global processes, including in their supply chains. This requires that companies carry out human rights due diligence "to identify, prevent, mitigate and account for how they address their impacts on human rights."⁹⁴ Some manufacturers are already acting to improve their supply chains to address this issue.

Electric roads and battery-swapping could help overcome some of the limitations of batteries

While issues over battery density are being resolved, electric roads have been proposed as a long-term solution for long-haul road freight, as they reduce battery needs through the supply of electricity to vehicles while in motion.⁹⁵ If heavy vehicles can access electricity directly from the grid as they travel along the road, then it is possible for them to travel for longer distances than if they were relying on battery storage alone. The vehicles would still require rechargeable batteries, but in smaller quantities, as they can be recharged en-route (resulting in lighter and cheaper vehicles). Trucks can connect with the overhead lines via retractable pantographs, and with the in-road rail via a moveable arm under the vehicle. Inductive charging requires installing coils that generate an electromagnetic field in

⁸⁹ kWh measures the amount of energy expended in 60 minutes by 1kWh of power

⁹⁰ 'Electric vehicle batteries explained.' Driven. 16 June 2019. <https://www.driven.co.nz/advice/advice/electric-vehicle-batteries-explained/> (retrieved 28 August 2019).

⁹¹ Daniel Myall et al. 'Accelerated Reported Battery Capacity Loss in 30 kWh Variants of Nissan Leaf. PrePrints. 15 March 2018. <https://www.preprints.org/manuscript/201803.0122/v1> (retrieved 28 August 2019).

⁹² Fred Lambert, 'Tesla battery degradation at less than 10% after over 160,000 miles, according to latest data'. Electrek. 14 April 2018. <https://electrek.co/2018/04/14/tesla-battery-degradation-data/> (retrieved 28 August 2019).

⁹³ Amnesty International, 'Amnesty challenges industry leaders to clean up their batteries.' <https://www.amnesty.org/en/latest/news/2019/03/amnesty-challenges-industry-leaders-to-clean-up-their-batteries/> (retrieved 28 August 2019).

⁹⁴ UN, 'Guiding Principles on Business and Human Rights.' https://www.ohchr.org/Documents/Publications/GuidingPrinciplesBusinessHR_EN.pdf (retrieved 28 August 2018).

⁹⁵ International Energy Agency, 'The Future of Trucks: Implications for Energy and the Environment'.

the road as well as receiving coils for electricity generation in the vehicle.⁹⁶ Either option does impact on flexibility and resilience due to the need for fixed routes and infrastructure.

The initial investment in installing electric roads is costly. Given the high costs and long-term nature of investment in electric roads, they are most suited to high volume routes (e.g. between major distribution centres, ports, and terminals).⁹⁷ For example, high duty-cycle trucks on medium-distance routes with high freight use.⁹⁸ Infrastructure investment would need to be modelled against the predicted patterns of use, availability of electricity and rate of electric truck uptake. It is understood that electric roads should be shared between passenger and commercial vehicles to provide a much greater return on investment.⁹⁹

There are concerns in New Zealand around the location of electric roads on earthquake fault lines and in earthquake prone cities. Electric roads will require stringent controls around disruption of the road surface in road corridors to ensure integrity of the electric connections. They may also prove difficult to maintain effectively in areas subject to natural damage by weather or earthquakes.

Battery-swapping could help overcome the barrier caused by battery recharging time, but would be very expensive. Battery-swapping requires vehicles to be designed to accommodate multiple daily battery pack swaps, battery swapping stations on key routes, and a larger stock of battery packs. If batteries were cheap, and robust enough, the time to replace the battery could potentially overcome charging time issues.¹⁰⁰ A degree of battery standardisation across heavy truck electric vehicle fleets would be required for it to be effective at a nationwide level.

Impact on the electricity network

As heavy freight vehicles tend to be driven a lot further per vehicle than light vehicles, and consume significantly more energy per km than light vehicles, converting the heavy vehicle fleet to electric (either battery or via electric roads) could have a significant impact on the electricity network.

In 2018, Concept Consulting estimated that the electrification of the commercial fleet (light and heavy) in New Zealand would have almost as much impact on the electricity system as the electrification of the light passenger fleet. If all vehicles, including trucks, were changed overnight to electric, this would increase total New Zealand electricity consumption by approximately 16 TWh – a 41% increase.¹⁰¹ Interestingly, the generation of an adequate quantity of electricity, even with the rapid uptake of BEVs, is seen to be manageable given consented capacity additions of wind generation.

However, if large numbers of vehicles travel long distances, and recharge quickly, there could be significant loads on the electricity grid in localised areas during peak times.¹⁰² Options to support peak charging requirements might include distributed power to local storage systems (e.g. lithium-ion battery banks or flywheels¹⁰³), that are trickle charged from the grid. These can be accessed as required, but may require significant battery storage capacity, and are most effective for short storage periods.

⁹⁶ ITF, 'Towards Road Freight Decarbonisation: Trends, Measures and Policies', ITF Policy Papers (Paris, 2018); International Energy Agency, 'The Future of Trucks: Implications for Energy and the Environment'.

⁹⁷ ITF, 'Towards Road Freight Decarbonisation: Trends, Measures and Policies'.

⁹⁸ Moultaq, Lutsey, and Hall, 'Transitioning to Zero-Emission Heavy-Duty Freight Vehicles'.

⁹⁹ Demonstrated as part of the OLEV project in Electric Roads: Analyzing the Societal Cost of Electrifying All Danish Road Transport, World Electric Vehicle Journal. 2018, 9, 9.

¹⁰⁰ Moultaq, Lutsey, and Hall, 'Transitioning to Zero-Emission Heavy-Duty Freight Vehicles'.

¹⁰¹ Concept Consulting Group, 'Driving Change - Issues and Options to Maximise the Opportunities from Large-Scale Electric Vehicle Uptake in New Zealand', 2018.

¹⁰² L. Landon-Lanea; A. Millerb P; Gaynorc and A.T. Marshalla., 'Electric Vehicles Storage Technologies and Range.' University of Canterbury. 2017.

¹⁰³ This is a mechanical device specifically designed to efficiently store rotational energy as kinetic energy, and convert it back to electrical energy as required.

Applications for transport

Battery electric trucks are currently best suited for urban areas, due to the smaller vehicle size requirements, shorter travelling distances, and the ability to incorporate charging times for urban freight.¹⁰⁴ This includes light commercial urban delivery freight, medium-duty regional delivery trucks, and rubbish trucks.¹⁰⁵ Commercial trucks operating in urban environments, especially those belonging to large, well co-ordinated fleets and logistics services, have the greatest potential to electrify.¹⁰⁶

Electric batteries are highly efficient. Lithium-ion has 99% charge efficiency, and the discharge loss is small. In comparison, the energy efficiency of a hydrogen fuel cell is 20% to 60%, and the Internal Combustion Engine (ICE) is 25% to 30%.¹⁰⁷ Concept Consulting suggests that electric vehicles are likely to be the least-cost option to reduce GHG emissions for the majority of New Zealand's road transport requirements, in the future.¹⁰⁸

Electrifying long-haul road freight is likely going to depend on continuing energy density and charging time improvements and cost reductions in lithium-ion batteries. The IEA has indicated that advanced solid state chemistries may be able to achieve energy densities of 300-400 Wh/kg, and even more advanced chemistries (such as Lithium-Air) may have the potential to reach densities as high as 1000 Wh/kg or more.¹⁰⁹ Realistically, these batteries are unlikely to be available before 2030.

International Picture

Policy development

United Kingdom

In July 2018, the UK Government released The Road to Zero strategy. The Strategy sets out plans to enable a massive expansion of green infrastructure across the country, reduce emissions from the vehicles already on the UK's roads, and drive the uptake of zero emission cars, vans and trucks. Current regulation has been successful at significantly reducing emissions from new diesel vehicles, so while work is underway to progress zero emission and other low emission options, diesel is still viewed as a viable fuel choice. The UK Government is also working with industry on low-emission standards for trucks and emissions testing on natural gas options as a near term lower emission fuel.¹¹⁰

Germany

Germany has been working on a number of policies to reduce heavy vehicle emissions. One policy implemented in January 2019 was the waiving of truck tolls for electric trucks. The change is estimated to result in net savings of around €5,000 per vehicle, depending on the routes used. The German government is hoping that this initiative will help provide an extra incentive for fleet managers looking to justify an early push into electric trucks.¹¹¹

Investment in infrastructure

Several countries are piloting electric road technology, including Sweden, which plans to build a network of electric roads throughout the country to help meet its target to reduce GHG emissions by 70% by 2030. Sweden has already funded two electric road pilot projects. The first project in 2016, installed 2km of overhead power lines at truck level.

¹⁰⁴ ITF, 'Towards Road Freight Decarbonisation: Trends, Measures and Policies'.

¹⁰⁵ Moultaq, Lutsey, and Hall, 'Transitioning to Zero-Emission Heavy-Duty Freight Vehicles'.

¹⁰⁶ Jacob Teter, 'Trucks & Buses (heavy-Duty Vehicles): Tracking Clean Energy Progress', 27 May 2019, <https://www.iea.org/tcep/transport/trucks/>.

¹⁰⁷ Battery University, "Comparing the Battery with Other Power Sources", https://batteryuniversity.com/learn/article/comparing_the_battery_with_other_power_sources

¹⁰⁸ Concept Consulting Group, 'Hydrogen in New Zealand: Report 1 - Summary'.

¹⁰⁹ International Energy Agency, 'Trucks & buses (heavy-duty vehicles.' <https://www.iea.org/tcep/transport/trucks/> (retrieved 28 August 2019).

¹¹⁰ Department of Transport, 'The Road to Zero: Next steps towards cleaner road transport and delivering our Industrial Strategy.' 2018. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739460/road-to-zero.pdf.

¹¹¹ Kyle Field, 'Germany looks to electric trucks in battle against urban emissions.' CleanTechnica. 30 April 2018.

<https://cleantechnica.com/2018/04/30/germany-looks-to-electric-trucks-in-battle-against-urban-emissions/> (retrieved 28 August 2019).

This made it unusable for electric cars. The second project in 2018, installed 2km of electric rail in the road that can recharge the batteries of cars and trucks driving on it.¹¹² These pilot projects are testing how well the system works under normal traffic conditions and in various weather conditions. In addition to the Swedish trials, there are trials being undertaken in Germany, Italy and the United States.¹¹³

Investment in fast charging infrastructure for heavy vehicles is continuing to develop. Heavy trucks have higher power demands, and require faster charging to limit time off the road and meet business requirements. Tesla launched its third generation Supercharger charging stations in March 2019, capable of charging its Model 3 electric vehicle at a rate of 250kW, which Tesla says is fast enough to add 75 miles of range in 5 minutes. Fast charging networks require cooling systems to stop them overheating, with tailored vehicle batteries required to use the networks.¹¹⁴ Other major vehicle manufacturers are investing in charging infrastructure in parallel with vehicle development.

Vehicle development

Globally, there were 5.1 million electric cars in 2018, up by 2 million since 2017, and more than 300 million electric two and three-wheelers. There were also more than 460,000 electric buses in the world in 2018, almost 100,000 more than in 2017. In road freight, electric vehicles have mostly been deployed as light commercial vehicles, which reached 250,000 in 2018, up from 80,000 from 2017. Heavy electric truck sales were in the range of 1000-2000 in 2018, mostly concentrated in China.¹¹⁵ There is an increasing selection of electric trucks, weighing less than 16 tonnes, reaching the market, and major postal and package delivery companies, including DHL, UPS, and FedEx, are expanding their fleets of electric vehicles.¹¹⁶

For the most part, long-haul electric trucks are in the pilot or development stage, but smaller, urban road freight electric trucks are becoming available on the market. Australia electric truck maker, SEA Electric, has several models that have a 350km range delivering “back-to-base” operations for operators who can charge the trucks overnight at the end of a working day. Sea Electric have stated that operators can expect a payback period of less than four years (without incentives) on their SEA-Drive powered trucks or vans, with a battery life-cycle of up to 10 years.¹¹⁷

Manufacturers, such as Tesla and Daimler, are trialling battery electric very heavy-duty trucks. Tesla is developing the ‘Tesla Semi’ – a heavy-duty all-electric truck. Elon Musk has claimed that the truck has a range of 500 miles, and a recharge time of 30 minutes.¹¹⁸ Daimler is also developing a big rig, the ‘Freightliner eCascadia’ which claims to have a range of up to 250 miles, and can be recharged within 90 minutes.¹¹⁹

Innolith, a Swiss start-up, claims to have developed the world’s first 1,000 Wh/kg high-density lithium-ion rechargeable battery. A battery with that density would be capable of powering a light electric car for 1,000 kms on a single charge. By comparison, the batteries that Tesla uses in its Model 3 are an estimated 250 Wh/kg. The US Department of Energy is funding a programme to create 500 Wh/kg battery cells. Others, like electric car manufacturer Henrik Fisker, are

¹¹² ‘World’s first electrified public road opens in Sweden.’ The Local. 13 April 2018. <https://www.thelocal.se/20180413/worlds-first-electric-road-opens-in-sweden> (retrieved 28 August 2019).

¹¹³ Siemens, ‘eHighway – Solutions for electrified road freight transport.’ 8 November 2017. <https://www.siemens.com/press/en/feature/2015/mobility/2015-06-ehighway.php> (retrieved 28 August 2019).

¹¹⁴ Sean O’Kane, ‘Tesla launches faster third generation Supercharger.’ The Verge. 6 March 2019. <https://www.theverge.com/2019/3/6/18253618/tesla-supercharger-250kw-v3-specs-location> (retrieved 28 August 2019).

¹¹⁵ International Energy Agency, ‘Global EV Outlook 2019.’ <https://www.iea.org/publications/reports/globalevoutlook2019/> (retrieved 28 August 2019).

¹¹⁶ International Energy Agency, ‘Trucks & buses (heavy-duty vehicles.’ <https://www.iea.org/tcep/transport/trucks/> (retrieved 28 August 2019).

¹¹⁷ Bridie Schmidt, ‘Australia electric truckmaker SEA Electric gets multiple orders from US.’ The Driven. 15 April 2019. <https://thedriven.io/2019/04/15/australia-electric-truckmaker-sea-electric-gets-multiple-orders-from-us/> (retrieved 28 August 2019).

¹¹⁸ Zac Estrada, ‘This is the Tesla Semi Truck.’ The Verge. 16 November 2017. <https://www.theverge.com/2017/11/16/16667366/tesla-semi-truck-announced-price-release-date-electric-self-driving> (retrieved 28 August 2019).

¹¹⁹ Fred Lambert, ‘Daimler unveils electric eCascadia semi truck to compete with Tesla Semi, launches electric truck group.’ Electrek. 7 June 2018. <https://electrek.co/2018/06/07/daimler-electric-semi-truck-ecascadia-tesla-semi/> (retrieved 28 August 2019).

pursuing solid-state battery technology¹²⁰, which they claim can achieve around 800 kms of range. If Innolith's claims turn out to be true, its high-density battery will resolve weight and range challenges faced by heavy trucks.¹²¹

NZ picture

As mentioned in section two on page 16, the Government has introduced Road User Charge (RUC) exemptions for heavy electric vehicles until they make up 2% of the heavy vehicle fleet. As at 18 August 2019, there were 146 registered all electric heavy vehicles in New Zealand.

Reuse of lithium-ion batteries

Members of the Motor Industry Association of New Zealand (MIA) have committed to a code of practice to have suitable systems in place for the use, refurbishment, recycling and disposal of batteries to minimise their environmental impact.¹²² Vector has also been collaborating with a number of businesses who have large lithium-ion batteries in their value chain. This *Battery Leaders Group* are contributing to research on circular economy opportunities for lithium-ion batteries, with a view to responsibly managing their end-of-life. Members include Audi, BMW, Toyota, Waste Management, Sims Pacific Metals and the Scrap Metals Recycling Association of NZ.¹²³ The Ministry for the Environment are leading work to design a scheme that will increase our recovery and re-use of materials that go into making lithium-ion batteries. The proposed scheme is open for public consultation until October 2019.¹²⁴

EECA's Low Emission Vehicle Contestable Fund has recently been extended to include projects looking at repurposing and recycling batteries.¹²⁵

Inductive Power Transfer technology project at Auckland University

The Faculty of Engineering at Auckland University, led by John Boys and Grant Covic, has pioneered work in the field of wireless power transfer.¹²⁶ Inductive Power Transfer enables power to be transmitted via large air gaps efficiently, making applications such as wireless electrical vehicle charging a possibility. The research, spanning over a decade, expanded into a University of Auckland start-up *PowerbyProxi* in 2007.

Government has invested \$11 million from the Endeavour Fund into a five year research project at the university on in-road wireless charging pads. The research aims to develop new charging pads that could survive being put into the roadway, and create new charging materials made of soft composites. Charging pads could be located at intersections, or on slopes, to support power transfer for vehicles travelling uphill. The research also aims to solve the issue of achieving this cost-effectively, without degrading the performance of the road, and with a 10 to 30 year lifetime.¹²⁷

¹²⁰ Most current electric cars are powered by "wet" lithium-ion batteries, which use liquid electrolytes to move energy around. Solid-state batteries have cells that are made of solid and "dry" conductive material. The technology is still in development.

¹²¹ Andrew J. Hawkins, 'Electric car battery with 600 miles of range? This startup claims to have done it.' *The Verge*. 4 April 2019. <https://www.theverge.com/2019/4/4/18293989/innolith-ev-battery-breakthrough-lithium-ion> (retrieved 28 August 2019).

¹²² Motor Industry Association, 'Code of Practice.' <https://www.mia.org.nz/Portals/0/MIA-CodesAndPractice/Code%20of%20Practice%20for%20Recycling%20of%20Traction%20Batteries.pdf> (retrieved 28 August 2019).

¹²³ 'Lithium-Ion Battery Industry Group.' *WasteMINZ*. <https://www.wasteminz.org.nz/2019/04/lithium-ion-battery-industry-group/> (retrieved 28 August 2019).

¹²⁴ Ministry for the Environment, 'Regulated product stewardship.' <https://www.mfe.govt.nz/waste/we-all-have-role-play/responsible-product-management/regulated-product-stewardship> (retrieved 28 August 2019).

¹²⁵ Energy Efficiency and Conservation Authority, 'Apply for co-funding.' <https://www.eeca.govt.nz/funding-and-support/low-emission-vehicles-contestable-fund/apply-for-co-funding/> (retrieved 28 August 2019).

¹²⁶ The University of Auckland, 'Wireless power transfers from our University to the world'. 25 October 2017. <http://www.engineering.auckland.ac.nz/en/about/news/news-2017/wireless-power-transfers-from-our-university-to-the-world.html> (retrieved 28 August 2019).

¹²⁷ Jamie Morton, '\$11m project could see EVs charged by in-road wireless pads.' *NZ Herald*. 13 April 2017. https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11921905 (retrieved 28 August 2019).

Summary of opportunities and challenges for electricity

| Opportunities | Challenges* |
|--|---|
| <ul style="list-style-type: none"> • Battery electric trucks produce zero tailpipe GHG emissions and provide co-benefits, including reduced noise pollution and improved air quality • Battery electric trucks have reduced fuel and maintenance costs, and increased engine efficiency (compared to conventional vehicles) • Electric batteries are more energy efficient than hydrogen fuel cells or ICE vehicles • Trucks involved in urban freight could be electrified for certain freight tasks, immediately • New Zealand’s pioneering work in the field of wireless power transfer, could pave the way for induction electric roads • New Zealand has a high penetration of renewable electricity resources to support renewable vehicle charging infrastructure | <ul style="list-style-type: none"> • Understanding GHG emissions over the full life-cycle of electric trucks • Environmental impacts associated with battery production and disposal • Cost of electric batteries, and subsequently electric trucks • Weight of batteries resulting in range and payload limitations for long-haul freight operations • Lengthy charge times for electric trucks • Deploying specialist fast charging infrastructure • Managing the load on the electricity grid |

* Potential solutions to some current challenges have been identified, (e.g. swapping battery packs, fast charging technology, trickle charging storage systems, electric roads). These require further scrutiny.

Key questions worth considering around electricity

Are there any other opportunities or challenges around electricity that the paper needs to highlight?

What freight tasks could be achieved in New Zealand using commercially available electric battery trucks?

What would support the growth and deployment of high speed charging infrastructure?

If selectively deployed, where could induction electric roads help mitigate battery range issues in New Zealand?

How many of the current issues limiting battery electric technology do we expect to be resolved over the next 10 years?

What are the implications for investment decisions across all three fuel options?

B. Hydrogen

Hydrogen is a gaseous element that is both odourless and colourless. While it does not occur naturally on Earth, it is found in combination with other elements such as water. It is also found in many organic compounds, notably the "hydrocarbons" that make up fuels such as gasoline, natural gas, methanol, and propane. The hydrogen can be separated through the application of heat - a process known as steam reforming.¹²⁸

Around three quarters of hydrogen produced globally is from natural gas (equating to 70 million tonnes). Natural gas is followed by coal, due to its dominant role in China, and from oil.¹²⁹ Hydrogen produced from these fossil fuels is called "brown" hydrogen. This process generates significant GHG emissions. If these emissions are released into the atmosphere then the hydrogen is termed 'grey'. At present, around 95% of all hydrogen manufactured worldwide is 'grey'.

There are two other types of hydrogen. "Blue" hydrogen generates fewer GHG emissions than grey hydrogen, as the emissions are captured and stored, or reused. "Green" hydrogen is generated using renewable electricity sources such as hydro, solar or wind, and produces no GHG emissions from its production. The electricity is used to separate water into its components of oxygen and hydrogen. This process is known as electrolysis. Only a tiny percentage of global hydrogen is produced from electricity.¹³⁰

Grey hydrogen is the cheapest to produce, and is the process used today for manufacturing New Zealand's supply of industrial hydrogen. The price of blue hydrogen is driven by the cost of capturing and reusing or storing the carbon emissions, a technology that is not yet completely mature and requires suitable CO₂ neutral uses or storage. The drivers influencing the price of green hydrogen will be discussed later in this section.

Fuel Cell Electric Vehicles

Fuel Cell Electric Vehicles (FCEVs) convert hydrogen into electricity by combining hydrogen stored in the vehicle's tank, with oxygen from the air.¹³¹ The electricity is then used to continuously drive an electric motor and recharge the car's electric battery. The fuel cell generates electric energy as long as fuel is fed. Refuelling a FCEV is comparable to refuelling a conventional fossil fuel vehicle, with pressurized hydrogen replacing petrol or diesel at refuelling stations.

The driving range, and pattern of refuelling for FCEVs is similar to internal combustion engine vehicles yielding some advantages over EV's. Nevertheless FCEV's have been slow to take off, as technical challenges and high prices have delayed their market introduction. The IEA however, suggests that long-haul freight offers strong prospects for hydrogen fuel cell vehicles, especially at ranges above 600kms, depending on the cost of hydrogen.¹³²

Opportunities and Challenges

The sustainability of green hydrogen and its potential to reduce GHG emissions

Hydrogen fuel cell technology is one option to facilitate a reduction in GHG emissions from the road freight sector, as hydrogen fuel cell vehicles (using green hydrogen) produce zero GHG tailpipe emissions, and only water vapour as a by-product.¹³³ As New Zealand possesses large, and as yet undeveloped renewable electricity resources, this puts New Zealand in the position of being able to produce predominantly green hydrogen if it wishes to do so. As well as having

¹²⁸ International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.' <https://www.iea.org/hydrogen2019/> (retrieved 28 August 2019).

¹²⁹ International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.'

¹³⁰ International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.'

¹³¹ Concept Consulting Group, 'Hydrogen in New Zealand: Report 3 - Research', 2019.

¹³² International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.'

¹³³ ITF, 'Towards Road Freight Decarbonisation: Trends, Measures and Policies'.

the potential to reduce GHG emissions, green hydrogen-powered FCEVs (as well as BEVs) help reduce local air pollution.¹³⁴

In considering any zero carbon technology the life-cycle emissions of the technology, outside of the operation of the vehicle needs to be considered as well. This applies to EV's as well as FCEVs. Factors to consider for FCEV's include, the GHG emissions generated from the storage and distribution of hydrogen, and manufacture and distribution of hydrogen vehicles including the fuel cells contained within them. The impact on overall GHG emissions will also be reduced if grey or blue hydrogen is used in fuel cells. However, we note the Government's just released vision for hydrogen, is for the adoption of 'green' hydrogen as a path to assist in decarbonisation.

As with lithium-ion batteries, hydrogen fuel cells, and hydrogen fuel tanks, are also both limited-life components that will require disposal and/or recycling. However, hydrogen fuel cells generally use less rare earths or metals than lithium-ion batteries, and the experience from trials of hydrogen buses in Europe is that the fuel cells last considerably longer than the batteries of equivalent electric buses operating on similar routes.

The cost of producing green hydrogen and scaling up production

The current cost of green hydrogen production is high, both compared to fossil fuels and to more direct uses of electricity. This is due to the capital costs of supporting infrastructure and process inefficiencies involved in producing hydrogen from electricity.¹³⁵ Some research suggests that these constraints may mean the price of hydrogen may not come down until the 2030s, despite production costs expected to reduce over this period.¹³⁶

Capital costs

The cost of supporting infrastructure is a notable barrier to establishing a green hydrogen refuelling network, with FCEVs, production facilities, storage, transportation and refuelling stations all needing significant up-front investment.¹³⁷

- Less than 0.1% of global dedicated hydrogen production today comes from electrolysis. To produce sufficient volumes of hydrogen by electrolysis is currently costly. A significant capital cost is the electrolyser required to separate out the hydrogen from water. This is partly why the majority of hydrogen plants globally are still producing grey hydrogen from natural gas and coal. To reduce the cost of electrolysis, there is a need to reduce the energy consumption, cost, and maintenance of electrolysers, and increase their efficiency, durability, and safety.¹³⁸
- FCEVs, like existing petrol and diesel vehicles, require dedicated refuelling stations, supported by a reliable supply of hydrogen fuel. With sufficient renewable energy, hydrogen can be made on site, as it is at present in many of the more remote refuelling stations in California. The IEA (2017b) considers the cost of developing these stations to be the greatest barrier to the development of a hydrogen market.¹³⁹ In New Zealand this could be achieved with 20-30 "hubs" at places like truck depots and ports, to capture most of the long-haul fleet.
- The competitiveness of FCEVs depends on several factors, including up-front vehicle costs. These costs are currently very high compared to BEVs due to the lesser numbers of FCEV's made. However, fundamentally a FCEV's is internally an electric vehicle with a different fuel source. As much of the componentry is similar,

¹³⁴ Moultaq, Lutsey, and Hall, 'Transitioning to Zero-Emission Heavy-Duty Freight Vehicles'.

¹³⁵ Concept Consulting (2019) *Hydrogen in New Zealand*.

¹³⁶ International Energy Agency, 'Commentary: The clean hydrogen future has already begun.' <https://www.iea.org/newsroom/news/2019/april/the-clean-hydrogen-future-has-already-begun.html> (retrieved 29 August 2019).

¹³⁷ Moultaq, Lutsey, and Hall, 'Transitioning to Zero-Emission Heavy-Duty Freight Vehicles'.

¹³⁸ Diogo M. F. Santos, Cesar A. C. Sequiera and Jose L. Figueiredo, 'Hydrogen production by alkaline water electrolysis.' *Quimica Nova*. 2013. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-40422013000800017 (retrieved 29 August 2019).

¹³⁹ New Zealand Productivity Commission, 'Low-Emissions Economy'.

companies that produce both electric and hydrogen vehicles should be able to shift production focus relatively easily between the two as demand necessitates.

- Like fossil fuels, hydrogen is flammable in the right oxygen mix and conditions. Its lighter nature, and the need to store it under high compression, requires specialist equipment, vehicles and expertise in all aspects of its management and utilisation, further contributing to costs. Standardised and proven processes for storage and management will be required (e.g. Chyoda's SPERA process).

Hydrogen capital costs are likely to fall in the future, if worldwide equipment production scales up, and the capital cost of the electrolyser unit (in particular) falls. IEA analysis finds that that an increase in global electrolysis capacity¹⁴⁰ will reduce the cost of producing hydrogen from renewable electricity by up to 30% by 2030 as a result of declining costs of renewables and the scaling up of hydrogen production.¹⁴¹

Locating hydrogen manufacturing plants near renewable electricity resources and transport hubs, has also been suggested to reduce capital costs by minimising distribution networks and reducing the number of re-fueling outlets required. Research is also underway around operating electrolysers at higher pressures. This would integrate the compression of hydrogen into the electrolyser, and avoid the cost of a separate hydrogen compressor needed to pressurise hydrogen for storage.

Process costs

One drawback of hydrogen as a transport fuel is the loss of energy during the production process converting electricity to hydrogen, and then storing that hydrogen, and then converting hydrogen back into electricity in the vehicle. While hydrogen uses the same primary fuel (renewable electricity) there are material energy losses associated with converting electricity into hydrogen, (up to 2.5 times more electricity is required for hydrogen fuel cells).¹⁴²

With current technology, the conversion of electricity into hydrogen results in an energy loss of around 30 to 35% (using existing low temperature electrolysis), with an additional energy loss of up to 50% to convert hydrogen back to electricity. Overall the total conversion and re-conversion process can result in energy losses as high as 60 to 70%.¹⁴³

This is significant, as electricity as an input can be the largest cost component for hydrogen production, accounting for between 45% and 75% of total production costs.¹⁴⁴ It also means that the amount of electricity required could be 2.5 times that required to directly charge electric vehicles, increasing the additional demand for renewable electricity from 16 TWh (a 41% increase), to potentially, 28 TWh (a 72% increase). This could result in the need for high cost options like offshore wind farms.

Nicola Motors, a manufacturer of electric and hydrogen-powered heavy trucks, states it takes 55kWh to make one kilogram of hydrogen, and each truck "is anticipated to consume around 50-75kgs per day." That suggests that at the high end, it would require a little over 4MWh of renewable energy to refuel a single Nikola truck.¹⁴⁵ This means for green hydrogen production, the efficiency of the conversion process, and wholesale electricity and electricity network prices, will be major drivers of the price of green hydrogen.¹⁴⁶

It is generally understood that, to be commercially viable, high utilisation, large-scale hydrogen production and sustainable demand for hydrogen would be required. It may be possible to reduce hydrogen production costs by targeting periods of low electricity prices (such as surplus overnight renewable electricity). However, this lower-cost

¹⁴⁰ Electrolysis capacity refers to the total volume of hydrogen that is able to be produced using water electrolysis technology.

¹⁴¹ International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.'

¹⁴² Concept Consulting Group, 'Hydrogen in New Zealand: Report 1 - Summary'.

¹⁴³ Energy Storage Association, 'Hydrogen Energy Storage.' <http://energystorage.org/energy-storage/technologies/hydrogen-energy-storage> (retrieved 29 August 2019).

¹⁴⁴ International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.'

¹⁴⁵ Megan Geuss, 'Anheuser-Busch just bought 800 fuel cell Nikola trucks.' ArsTechnica. 5 June 2018. <https://arstechnica.com/cars/2018/05/anheuser-busch-just-bought-800-fuel-cell-nikola-trucks/> (retrieved 29 August 2019).

¹⁴⁶ International Energy Agency, 'Commentary: The clean hydrogen future has already begun.'

'opportunistic' hydrogen production results in a low utilisation of the electrolyser, and high hydrogen costs that reflect CAPEX costs.¹⁴⁷ Low utilisation is also expected to only satisfy a relatively small amount of New Zealand's demand for energy.¹⁴⁸ Higher utilisation of the electrolyser, and paying a higher price for electricity, can actually be cheaper than just running it when there is surplus electricity, as this leads to an overall decline in the cost of producing a unit of hydrogen.¹⁴⁹

Technology developments will improve the efficiency of converting electricity to hydrogen. It is understood that operating electrolysers at higher temperatures is more efficient than low temperature electrolysis.¹⁵⁰ Higher temperature electrolysers are under development, with aspirations to improve the electricity conversion efficiency from 65-70%, up to 90% and potentially beyond.

The cost of generating solar and wind energy has also come down in the past decade. In countries and regions with abundant sunshine and wind power – such as the Middle East, North Africa and Latin America – green electricity prices have come down to around 2 euro cents per kWh (approx. \$35 NZD/MWh).¹⁵¹ New Zealand would need to see a significant reduction in electricity generation prices before hydrogen prices would reach parity with alternative fuel options. The price of wind generation is already below \$60 NZD/MWh and declining. Taking these trends into account and depending on the assumptions adopted, the cost of hydrogen fuel could achieve parity with diesel sometime in the next 10 years. Building electrolysers at locations with renewable resources could become a low-cost supply option for hydrogen, even after taking into account the transmission and distribution costs of transporting hydrogen from (often remote) renewables locations to the end users.¹⁵²

Niche applications for transport

While there are challenges to establishing a hydrogen refuelling network, and reaching price parity for hydrogen with existing fossil fuel options, hydrogen could deliver benefits in niche parts of the road freight sector, particularly in areas where current battery technology alone cannot provide viable solutions. It is also seen to complement other alternative fuel options, as a number of solutions will be required to reach GHG emissions targets.

When compared to BEVs, FCEVs can offer greater travel range and a faster rate of fuelling, given current technologies.¹⁵³ The continuous recharge extends the driving range of the vehicle, and means that only a relatively small battery is required, saving weight. This also eliminates the long recharge times as the battery never has to be plugged in to recharge.¹⁵⁴ For these reasons FCEVs could provide distinct advantages over their battery electric counterparts for operations, where BEVs are not suitable due to range limitations and charging down-time. In line with this, Concept Consulting suggests that hydrogen may be better suited to certain niche return-to-base or never-leave-base operations, like ports and logistics hubs, where the usage demands are high for forklifts, port crane operations and drayage trucks (used to transport goods over a short distance in the shipping and logistics industries).¹⁵⁵

Ports and certain rail sites are freight hubs, so have a key role to play in the overall freight supply chain. They may be early adopters of alternative fuels as they are relatively more fixed and have more scale than the road freight fleet. They are also often the originator or end point of a freight trip they could also be considered as hubs to support changes in the road fleet, and used as fuelling stations for the road freight industry.

Heavy duty-cycle tractor-trailer trucks, involved in long-haul operations, could be particularly well-suited to hydrogen, which would overcome the range, charging time and payload issues faced by BEVs. There may, however, be long lead

¹⁴⁷ International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.'

¹⁴⁸ Concept Consulting Group, 'Hydrogen in New Zealand: Report 1 - Summary'.

¹⁴⁹ International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.'

¹⁵⁰ Rachael Elder, Denis Cumming and Mogens Bjerg Mogensen, 'High Temperature Electrolysis.' Carbon Dioxide Utilisation. 2015. p. 183-209. Retrieved from: <https://www.sciencedirect.com/science/article/pii/B9780444627469000116>.

¹⁵¹ International Energy Agency, 'Commentary: The clean hydrogen future has already begun.'

¹⁵² International Energy Agency, 'The Future of Hydrogen: Seizing today's opportunities.'

¹⁵³ New Zealand Productivity Commission, 'Low-Emissions Economy'.

¹⁵⁴ Concept Consulting Group, 'Hydrogen in New Zealand: Report 3 - Research'.

¹⁵⁵ Concept Consulting Group, 'Hydrogen in New Zealand: Report 1 - Summary'.

times to develop a green hydrogen transport infrastructure and refuelling network to support them. Even if comparatively cheap hydrogen was available today, there would be a significant transition period as cost equivalent hydrogen fuel cell vehicles enter the New Zealand vehicle fleet. The requisite production, storage and refuelling infrastructure will also take a long time to establish. The challenge would be generating enough demand to drive supply, and vice versa. There are also challenges around public acceptance of hydrogen vehicles, due to the perceived volatility of hydrogen. This would need to be carefully managed through education and successful demonstration cases.

International Picture

Policy development

Energy policy can make a significant difference to the uptake of FCEVs. There are a number of examples of where countries have begun implementing hydrogen-focused strategies and policies. The majority of these have been around grey and blue hydrogen production. Their intention has been to inform the next series of investment decisions amongst various stakeholder groups (e.g. industry, government and research) so that the industry can continue to scale-up in a coordinated manner. Japan, Australia, France and Korea all have national hydrogen roadmaps targeting things like:

- hydrogen technology costs and research and development investment (Japan),
- identifying the key priorities and areas for investment needed to make hydrogen competitive (Australia),
- green hydrogen production targets for industry and a reduction in electrolysis cost (France), and
- FCEV production capacity and hydrogen refuelling station infrastructure targets (Korea).

The Netherlands has also expanded its existing subsidies around renewable energy production to include all possible cost-effective ways to reduce CO₂.¹⁵⁶ Other important policy instruments that are being considered internationally include the doubling of Research and Development (R&D) in green hydrogen; removing fossil fuel subsidies; blending clean gas (including hydrogen) into the gas grids (noting the most advanced gas turbines can only take a 50:50 mix); guarantees of origin for blue and green hydrogen; common quality and safety standards; and aligned regulatory approaches on what roles different market participants can play in this new market.¹⁵⁷

Investment in infrastructure

Globally, there has been consensus around the need for supporting infrastructure to make green hydrogen a viable alternative fuel source. Countries like Germany, Norway, Denmark, the United States, Korea, China and Japan have set targets for establishing hydrogen refuelling stations over the next few years. In a number of cases, private industry is partnering with government and private investors to share the cost, and the risk, of large scale investment. In the United States (US) for example, the California Fuel Cell Partnership, an industry-government collaboration, issued a vision report in July 2018 targeting 1 million FCEVs and 1 000 hydrogen fuelling stations by 2030.

In 2017, a group of 11 Japanese firms signed a Memorandum of Understanding to expand the fuel cell market by building 320 refuelling stations across Tokyo, Nagoya, Fukuoka, and Osaka by 2025. The firms include: Toyota, Nissan, Honda, XTO Energy, Idemitsu Kosan, Iwatani Corporation, Tokyo Gas, Toho Gas, Air Liquide Japan, Toyota Tsusho Corporation, and the Development Bank of Japan Inc.

Nikola Motors plans to build more than 700 hydrogen refuelling stations across the US and Canada by 2028. Each station will be capable of 2,000 to 8,000 kgs of daily hydrogen production. Nikola is seeking \$1.55 bn from private investors to fund it, including suppliers, partners, future customers and carmakers.¹⁵⁸ Nikola are taking a similar

¹⁵⁶ International Energy Agency, 'Commentary: The clean hydrogen future has already begun.'

¹⁵⁷ International Energy Agency, 'Commentary: The clean hydrogen future has already begun.'

¹⁵⁸ Alan Ohnsman, 'Startup Nikola bets hydrogen will finally break through with big rigs.' Forbes. 14 April 2019.

<https://www.forbes.com/sites/alanohnsman/2019/04/14/can-a-15-billion-bet-on-fuel-cell-big-rigs-be-a-game-changer-for-hydrogen/#6dffca31fe4c> (retrieved 29 August 2019).

approach in Europe, with refuelling stations are planned to come online around 2022 and are projected to cover most of the European market by 2030.¹⁵⁹

Vehicle development

A wide variety of hydrogen-powered vehicles are being trialled, and are in use globally (e.g. buses, ferries, forklifts), and a number of countries are already selling FCEVs commercially. As this paper is focused on road freight, we are primarily interested in approaches from other countries around hydrogen-powered heavy trucks that could be used in the road freight industry.

The last five years has seen significant growth in the types and volumes of hydrogen-powered heavy trucks being tested and trialled globally. This is looking to shift into commercial production over the next five years. Of note is Nikola Motors, which has been developing hydrogen-powered Class 8 heavy trucks since 2016. The trucks have an estimated range of between 500-750 miles, (with the latest offering up to 1200 miles).¹⁶⁰ They are now receiving pre-orders for the trucks which will go into mass production in 2022.¹⁶¹ Hyundai Motors, is similarly set to provide 1,000 fuel cell electric trucks (18 tonne, 34 with trailer), and an adequate supply chain for renewable hydrogen, to the Swiss commercial vehicle market, beginning 2019 through to 2023. The fuel cell electric truck features a new 190kWh hydrogen fuel cell system with an expected travel range of approximately 400km in real-life driving conditions.¹⁶²

China based Horizon Fuel Cell Technologies is a global company specialising in hydrogen fuel cells and related products. It recently signed MOUs with global customers to supply 1,000 units of 100kWh and higher automotive fuel cell systems for heavy duty trucks over the next three years, with the first units to be delivered in the second half of 2019. This represents one of the largest deployments of fuel cell heavy vehicles globally.¹⁶³

NZ picture

A vision for green hydrogen in New Zealand

MBIE has commissioned consultants Arup to prepare a vision paper, with a focus on the current and future economic opportunities of green hydrogen in New Zealand. Stakeholders provided input into the development of the paper through a series of workshops in March 2019; in Wellington, Auckland, Christchurch and New Plymouth. These views have been incorporated into a draft hydrogen green paper that will be released for feedback from the public and wider stakeholders in the latter half of 2019.¹⁶⁴

This paper outlines the role that hydrogen could play in assisting New Zealand to decarbonise some areas of the economy that will be hard to electrify, and explores some of the opportunities and challenges that will be faced utilising hydrogen in this manner. Following consultation on this paper, the Government will develop a roadmap for hydrogen use as part of its Renewable Energy Strategy.

There is also interest in the potential for hydrogen to become an export commodity to countries like Japan and the Republic of Korea, which lack domestic renewable energy sources. In October 2018, New Zealand signed a

¹⁵⁹ Ben Straight, 'Hydrogen stations to be built alongside truck deployments.' Freightwaves. 18 April 2019.

<https://www.freightwaves.com/news/fuel/hydrogen-station-installations-to-start-by-2021> (retrieved 29 August 2019).

¹⁶⁰ Nikola, 'Products.' <https://nikolamotor.com/motor> (retrieved 29 August 2019).

¹⁶¹ Nick Carey, 'Factbox: Manufacturers' plans for electric big rig trucks.' Reuters. 22 October 2018. <https://www.reuters.com/article/us-autos-electric-trucks-factbox/factbox-manufacturers-plans-for-electric-big-rig-trucks-idUSKCN1MW0NM> (retrieved 29 August 2019).

¹⁶² Hyundai, 'Hyundai Motor and H2 Energy to bring the world's first fleet of fuel cell electric trucks into commercial operation.'

<https://www.hyundai.co.nz/hyundai-motor-and-h2-energy-to-bring-the-world-s-first-fleet-of-fuel-cell-electric-trucks-into-commercial-operation-> (retrieved 29 August 2019).

¹⁶³ 'Horizon Fuel Cell Technologies Signs Agreement to supply 1,000 fuel cell electric heavy vehicles or cleaner port operations.' FuellCellsWorks. 10 July 2019. <https://fuelcellworks.com/news/horizon-fuel-cell-technologies-signs-agreement-to-supply-1000-fuel-cell-electric-heavy-vehicles-for-cleaner-port-operations/> (retrieved 29 August 2019).

¹⁶⁴ Ministry of Business, Innovation and Employment, 'Energy strategies for New Zealand.' <https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-strategies-for-new-zealand/> (retrieved 29 August 2019).

Memorandum of Cooperation with Japan to work in partnership to develop hydrogen technology, and New Zealand joined the Clean Energy Ministerial Hydrogen Initiative in June 2019.¹⁶⁵

There are challenges for New Zealand to become a competitive market player in the area of hydrogen, primarily due to our cost disadvantage on renewable electricity relative to other potential hydrogen producer/exporters. While New Zealand can produce some wind and geothermal for around \$60/MWh, larger sunny countries (like Australia) can already produce solar for \$20/MWh.

The New Zealand Hydrogen Association (NZHA)

The NZHA was formed in September 2018 by private and public sector organisations with seed funding from the Ministry of Business, Innovation and Employment (MBIE) to support the progress and uptake of low-emission hydrogen in New Zealand.

The organisation aims to assist the transition to a low emissions future using renewable green hydrogen as an integral part of New Zealand's evolving energy needs. It facilitates cooperation between industry, government and academic stakeholders and promotes the development and adoption of effective hydrogen policy. Members include transport and infrastructure industry operators H.W Richardson Group and Fulton Hogan, Hyundai, Toyota, Siemens (NZ), Green Cabs, Venture Southland, Real Journeys, Southern Hemisphere Proving Grounds, Contact Energy and Genesis Energy.¹⁶⁶

Green hydrogen in Taranaki

In March 2019, the Government announced the "**H2 Taranaki**" regional initiative. The H2 Taranaki Roadmap looks at the potential for Taranaki to leverage its existing skills and infrastructure to become a global leader in hydrogen production and utilisation.¹⁶⁷

A joint venture by Hiringa Energy (Hiringa) and Balance Agri-nutrients to develop a green hydrogen manufacturing plant in Taranaki is part of the Roadmap. This plant will initially supply the Balance Kapuni plant to produce green ammonia. Hiringa Energy has also accessed funding from the Government's Provincial Growth Fund to scope out hydrogen's potential as a zero emissions energy source for the heavy transport industry, to develop a heavy vehicle hydrogen transport network in the Taranaki.

The Government has also committed \$27 million to build a National New Energy Development Centre in Taranaki to help meet its GHG emissions targets. The centre will focus on working with stakeholders to demonstrate and deploy near commercial new energy technologies. Government has also committed \$20 million over four years to establish a Strategic Science Investment Fund for cutting edge energy technology projects.¹⁶⁸

Green hydrogen pilot project in Taupo

A project to pilot the commercial production of green hydrogen using renewable geothermal energy was established in December 2017 between the Taupō-based Tuaropaki Trust and Japanese construction company Obayashi Corporation. The Mokai geothermal power station, near Taupō, would be used to produce green hydrogen. Timings for the construction of the plant are still pending.¹⁶⁹

¹⁶⁵ Clean Energy Ministerial, 'Hydrogen Initiative: An initiative of the Clean Energy Ministerial.' <http://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/hydrogen-initiative> (retrieved 29 August 2019).

¹⁶⁶ Hydrogen New Zealand, 'Supporting the progression and uptake of low emission hydrogen in New Zealand.' <https://www.nzhydrogen.org/> (retrieved 29 August 2019).

¹⁶⁷ Jamie Morton, 'Is this what the clean, green future of NZ energy looks like?' NZ Herald. 23 April 2019. https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12224222 (retrieved 29 August 2019).

¹⁶⁸ Beehive release, 'Government invests in clean energy centre to help power New Zealand's economy.' 9 May 2019. <https://www.beehive.govt.nz/release/government-invests-clean-energy-centre-help-power-new-zealand%E2%80%99s-economy> (retrieved 29 August 2019).

¹⁶⁹ Daniel Hutchinson, 'Joint Maori and Japanese hydrogen pilot project for Taupo.' Stuff. 9 February 2018. <https://www.stuff.co.nz/business/101292443/joint-iwi-and-japan-hydrogen-pilot-project-for-taupo> (retrieved 29 August 2019).

Ports of Auckland

Ports of Auckland has also committed to building a hydrogen production and refuelling facility at its Waitemata port in 2020. The project partners with Auckland Council, Auckland Transport and KiwiRail, and is supported by Arup consulting through the development, design and delivery phases. The hydrogen produced will initially be used for hydrogen-powered forklifts and cars, with the possibility of a hydrogen bus trial on Auckland routes. EECA has provided funding towards the procurement of one bus and up to three cars that will be used and tested as part of the wider hydrogen demonstration project in Auckland.¹⁷⁰ Ports of Auckland has acknowledged that trucks and ferries could also run on hydrogen from the plant, and are working with KiwiRail on potential hydrogen demonstration projects for rail.¹⁷¹

Summary of opportunities and challenges for hydrogen

| Opportunities | Challenges* |
|--|--|
| <ul style="list-style-type: none"> Hydrogen fuel cell trucks produce zero tailpipe GHG emissions and provide co-benefits, including reduced noise pollution and improved air quality Reduced fuel and maintenance costs, and increased engine efficiency (compared to conventional vehicles) FCEVs offer greater range and faster refuelling than electric battery trucks Potentially best option for long-haul operations and high utilisation requirements (if challenges can be overcome) New Zealand has a high penetration of renewable electricity resources to support green hydrogen production | <ul style="list-style-type: none"> Understanding GHG emissions over the full life-cycle of hydrogen fuel cell trucks Environmental impacts associated with hydrogen production, fuel cell and fuel tank disposal Cost of green hydrogen production from electrolysis is high (capital plant costs and supporting infrastructure) and electrolysis is inefficient Achieving competitive domestic market prices for hydrogen relies on low electricity prices Storage and transportation costs Vehicle efficiency, cost and availability Public perception around safety for an unknown fuel type |

* Potential solutions to some current challenges have been identified, (e.g. improvements in the efficiency of electrolyzers and fuel cells, reduction in capitals costs, equipment production scales up, co-location of plants near transport hubs, and sustained demand). These require further scrutiny.

Key questions worth considering around hydrogen

Are there any other opportunities or challenges around hydrogen that the paper needs to highlight?

What level of infrastructure is needed to establish a hydrogen refuelling network, and what would it cost?

What is required to keep the price of hydrogen low enough to compete with other alternative fuels?

Which parts of the New Zealand road freight sector could shift to hydrogen fuel cells relatively quickly?

How can public perceptions around the safety of hydrogen be managed? Whose role is this?

¹⁷⁰ Energy Efficiency and Conservation Authority, 'Summaries of projects approved for co-funding.' <https://www.eeca.govt.nz/funding-and-support/low-emission-vehicles-contestable-fund/summaries-of-all-projects-approved-for-co-funding/> (29 August 2019).

¹⁷¹ Ports of Auckland, 'Ports of Auckland to build Auckland's first hydrogen production and refuelling facility.' 4 December 2018. <http://www.poal.co.nz/media/ports-of-auckland-to-build-auckland%E2%80%99s-first-hydrogen-production-and-refuelling-facility> (retrieved 29 August 2019).

C. Biofuels

The term 'biofuel' typically refers to liquid fuels that are produced from renewable biological materials or organic waste. Biofuels can be produced from a range of different feedstocks (the materials used to make biofuels), with different processes used to make them. Biofuels can be divided into two categories: 'conventional' and 'advanced' biofuels.

Conventional, or first generation, biofuels are produced through well-understood technologies and processes, and include biodiesel, bioethanol and bio jet fuel. Biodiesel can be produced from a range of feedstocks, including oil crops (such as canola), used cooking oils, and tallow (and inedible meat by-product from meat processors). Biodiesel is generally blended with fossil diesel to make it more compatible with existing vehicle fleets and fuelling infrastructure.¹⁷² Bioethanol is produced from sugar or starch, through a process of fermentation and distilling. Bioethanol is most commonly blended with petrol in low blends, such as 10% bioethanol. Higher blends of bioethanol, such as 95% bioethanol, require vehicle modifications to use.¹⁷³

Advanced, or second generation, biofuels are known as "drop-in" biofuels and are defined as liquid bio-hydrocarbons that are functionally equivalent to petroleum fuels and are fully compatible with existing petroleum infrastructure.¹⁷⁴ Drop-in biofuels can be produced from oilseeds via trans-esterification, lignocellulosic biomass via thermochemical process, sugars and alcohol via biochemical conversion or by hybrids of the above methods. Drop-in fuels encompass high hydrogen to carbon ratio with no/low sulfur and oxygen content, low water solubility and high carbon bond saturation. In short drop-in fuel is a modified fuel with close functional resemblance to fossil fuel.

Advanced biofuels have the potential to reduce GHG emissions by 85% to 90%.¹⁷⁵ There are two main technology pathways – one based on cellulosic based biomass (such as agricultural and forest residues, forest and non-food energy crops, municipal solid wastes and algae)¹⁷⁶ which is still in the pilot or demonstration phase, and the other utilising fats and oils, which is proven at commercial scale, and in the market now, (particularly in Singapore, the United States and Europe).

The Scion Biofuels Roadmap scenarios show that biofuel volumes, of the scale required to competitively service New Zealand's 2050 heavy freight industry, could be achieved. Scion's roadmap also makes the point that the economics for advanced biofuels favour situations where the liquid biofuel is a co-product from an integrated bio refinery that also produces other products, like by-products from forestry.

In addition, biogas, particularly Biomethane, is a drop-in replacement for natural gas that can be either compressed or used in liquid form. Biomethane typically comes from waste via anaerobic digestion and upgrading, but ultimately the supply of feedstock is limited. Biomethane is also possible from energy crops (e.g. willow) using pyrolysis, but this is currently expensive.

Opportunities and Challenges

The sustainability of biofuels and their potential to reduce GHG emissions

Biofuels are made from plants that absorb carbon dioxide as they grow, which balances the emissions that biofuels create when they are combusted as a fuel. The production of biofuels, has received greater scrutiny over the past decade, including the sustainability of feedstocks and the conversion process into biofuel.

¹⁷² International Energy Agency, 'The Future of Trucks: Implications for Energy and the Environment'.

¹⁷³, 'The Future of Trucks: Implications for Energy and the Environment'.

¹⁷⁴ Sergios Karatzos, James D. McMillan and Jack N. Saddler, 'The potential and challenges of drop-in biofuels.' IEA Bioenergy. 2014. Retrieved from: <http://task39.sites.olt.ubc.ca/files/2014/01/Task-39-drop-in-biofuels-report-summary-FINAL-14-July-2014-ecopy.pdf>.

¹⁷⁵ 'Advanced biofuels: what future do they have in transportation.' 15 July 2019. <https://www.ifpenergiesnouvelles.com/article/advanced-biofuels-what-future-do-they-have-transportation-summary> (retrieved 29 August 2019).

¹⁷⁶ Scion, 'New Zealand Biofuels Roadmap Summary Report: Growing a Biofuelled New Zealand', 2018.

Poorly developed biofuel supply chains can pose risks to food production, water and soil quality. For example, the use of fertilisers to support the growth of biofuel crops can increase GHG emissions (the process of making nitrogenous fertilisers, such as urea, can use fossil fuels, and when these fertilisers are applied to soil, a proportion of the nitrogen content is released as nitrous oxide).¹⁷⁷ Sustainable certification schemes have been developed, so that users and stakeholders can be assured that a qualifying biofuel is produced sustainably. Additionally, where governments provide incentives to biofuels there are qualification criteria to assure that any biofuel receiving that support avoids any negative outcomes.

We need to consider whether biofuels emit less GHG emissions over their full life-cycle than fossil fuels. This includes biofuels that are imported or produced in New Zealand. A 2009 report on life-cycle greenhouse gas emission for New Zealand biodiesels, commissioned by EECA, indicated this is the case for the three feedstocks evaluated.¹⁷⁸ We also need to consider the wider environmental sustainability of any biofuel that is imported or produced in New Zealand. The production of biofuels can result in the degradation of land, forests, water resources and ecosystems. Internationally, the growing demand for biofuels has led to the deforestation and use of land with high biodiversity value, as well as negative consequences associated with the use of freshwater, fertilisers and pesticides.¹⁷⁹

The cost of producing biofuels and scaling up production

For biofuels to make a significant difference to New Zealand's GHG emissions, they have to substitute a large volume of fossil fuels in New Zealand. However, at this stage there is very limited supply of biofuels. Biofuels are currently more costly to produce than fossil fuels, with competing markets for some feedstocks driving up the price.¹⁸⁰ Biofuel production also requires large quantities of these feedstocks, significant capital investment to begin production, and commercial scale production facilities.¹⁸¹ Even so, advanced biofuels could still be cheaper than green hydrogen in New Zealand, before 2030.

While woody biomass is an abundant and relatively low-cost type of feedstock for biofuels production, it has relatively low energy density and the current refining processes for woody biomass are relatively high-cost. For production of algal-based biofuels, it is difficult to find land with suitable characteristics for algal growth, the costs and energy requirements of algal production and conversion of algae into biofuels are high, and there are technical challenges of scaling up the production.¹⁸²

Building biofuel production facilities is challenging for several reasons, including difficulties obtaining capital investment given an uncertain regulatory environment, securing long term demand and supply chains, and meeting technical specifications.¹⁸³ Biofuel production may also compete with existing industries/sectors for resources, such as land, capital and feedstocks that already have existing uses.¹⁸⁴

The compatibility of biofuels with existing vehicles and infrastructure

Almost all diesel vehicles can use a 5% biodiesel blend (B5), without any engine or fuel system modifications, and many diesel vehicles have also been approved to use 7% (B7) biodiesel blend (B7). Higher blends, such as B20, can be used in

¹⁷⁷ Parliamentary Commissioner for the Environment, 'Some Biofuels Are Better than Others: Thinking Strategically about Biofuels', 2010.

¹⁷⁸ Energy Efficiency and Conservation Authority, 'Life cycle greenhouse gas emission model for New Zealand biodiesels.' 2009. Retrieved from: https://www.eeca.govt.nz/assets/Resources-EECA/biodiesel_report_ghg_emissions-models.pdf.

¹⁷⁹ Royal Academy of Engineering, 'Sustainability of Liquid Biofuels', 2017.

¹⁸⁰ Susan van Dyk et al. "Drop-in' biofuels: The key role that co-processing will play in production.' IEA Bioenergy. 2019. Retrieved from: <http://task39.sites.olt.ubc.ca/files/2019/02/IEA-Bioenergy-Task-39-Drop-in-Update-Executive-Summary-February-2019.pdf>.

¹⁸¹ Scion, 'New Zealand Biofuels Roadmap Summary Report'.

¹⁸² European Commission Joint Research Centre, 'Biofuels from algae: a budding technology yet to become viable.' PhysOrg. 29 February 2016. <https://phys.org/news/2016-02-biofuels-algae-budding-technology-viable.html> (retrieved 29 August 2019).

¹⁸³ Parliamentary Commissioner for the Environment, 'Some Biofuels Are Better than Others: Thinking Strategically about Biofuels'.

¹⁸⁴ Scion, 'New Zealand Biofuels Roadmap Summary Report'.

some large commercial vehicles such as trucks and buses as well as machinery.¹⁸⁵ Blends higher than this generally require vehicle modifications.

Advanced drop-in biofuels are attractive from both an infrastructure and a fuel market perspective. Current commercial drop-in biofuel production represents a small percentage (<4%) of total global biofuel markets, with the vast majority of drop-in biofuels derived from feedstocks such as used cooking oil and tallow.¹⁸⁶ However, advanced drop-in biofuels do not require vehicle modifications and completely substitute fossil fuels. This represents a significant advantage when compared with either electricity or hydrogen, particularly when considering infrastructure investment costs, and the size of the existing heavy truck fleet (circa 144,000).

Co-benefits of biofuels

Biomass supply chains can also generate additional co-benefits. Diverting wastes to biofuels can avoid pollution or land-use capacity issues. Some of the emerging technologies not only use biomass feedstocks but can process waste plastics and tyres, thus providing wider benefits and economies of scale. In New Zealand, there is considerable potential to develop large-scale supplies of biofuel sustainably, while also providing these co-benefits. In particular, concerns around diverting arable land to biofuel production can be avoided by focusing on wastes, and energy crops grown on non-arable land.

Biofuels offer opportunities for regional economic development. Regional supply chains can support isolated communities with job growth and economic development. For example, regional areas could grow the feedstocks required for biofuels, as well as have the processing plants.¹⁸⁷ Further potential economic benefits could come from reducing New Zealand's reliance on imported fuels, better management of by-products, and supporting the transition of the aviation and maritime industries to reduce GHG emissions.

International Picture

Policy development

United States

The US Congress created the federal Renewable Fuel Standard (RFS) programme to reduce greenhouse gas emissions and expand the nation's renewable fuels sector while reducing reliance on imported oil. Under the RFS programme, refiners are required to blend biofuels into the nation's gasoline and diesel pool. Renewable fuel percentage standards are reviewed and reissued each year by the Environmental Protection Agency (EPA).¹⁸⁸

France

The French Energy and Climate Strategy was published in early 2019. Its goal is to achieve carbon neutrality by 2050 and acknowledges that the transport sector is a fundamental challenge for achieving carbon neutrality. The approach is to reduce fuel consumption, electrify transport where possible, and, when internal combustion engines are unavoidable, develop advanced biofuels and bio-Natural Gas for Vehicles (bio-NGV).¹⁸⁹

Two bills have been passed to support this. The bill for the French framework law on mobility and transport makes provision for public funding and support for bio-NGV production units. The goal is not to have any light vehicles

¹⁸⁵ Energy Efficiency and Conservation Authority, 'Biofuels.'

¹⁸⁶ Sergios Karatzos, James D. McMillan and Jack N. Saddler, 'The potential and challenges of drop-in biofuels.'

¹⁸⁷ Scion, 'New Zealand Biofuels Roadmap Summary Report'.

¹⁸⁸ United States Environmental Protection Agency, 'Regulations and Volume Standards for Renewable Fuel Standards.'

<https://www.epa.gov/renewable-fuel-standard-program/regulations-and-volume-standards-renewable-fuel-standards> (retrieved 29 August 2019).

¹⁸⁹ 'Advanced biofuels: what future do they have in transportation.' 15 July 2019. <https://www.ifpenergiesnouvelles.com/article/advanced-biofuels-what-future-do-they-have-transportation-summary> (retrieved 29 August 2019).

powered by fossil energies on the road by 2040. The French law on energy and climate will set targets for decarbonisation, and in particular for achieving carbon neutrality by 2050. In regards to incorporating biofuels, incentive tools exist (in the form of an incentive tax credit every year in the French budget law) for land transport.¹⁹⁰

Canada

Incentives (or "mandates" in Quebec) promote biofuels, by requiring a certain percentage of advanced biofuels in fossil fuels. This creates the market and puts all producers on an equal footing.¹⁹¹

Investment in infrastructure

To enable the immediate increase in production of drop-in biofuels, current petroleum/diesel refinery infrastructure can be reconfigured to enable the co-processing of feedstocks. In France and Italy, underperforming plants are beginning to be repurposed to enable the co-processing of biofuel.

Second-generation biofuels began to be produced at full commercial scale in 2015. By January 2017, 67 second-generation biofuel facilities were in operation around the world, with over one-third of these operating at commercial scale. As of 2015, 35% of the commercial installed capacity for production of second generation ethanol worldwide was located in the US.¹⁹²

Canada

The aim of the Bioénergies La Tuque (BELT) project is to build the first bio-refinery in Canada for refining residue from forest logging. It represents an 800 million euro investment, and aims to replace between 5% and 7% of the fossil fuels used for transportation in Quebec with advanced biofuels. The goal is to produce fuels of the "drop-in" type. BELT is working with the First Nations Community, who have very good knowledge of the local logging industry. Key to success has been securing procurement of the refining residue for at least 25 years, with the objective of running the plant for 40 to 50 years.¹⁹³

India

In 2009, the Indian government announced its National Policy on Biofuels. The policy states that the setting up of processing units for production of bio-diesel and creation of any new infrastructure for storage and distribution would be declared as a priority sector for the purposes of lending by financial institutions and banks. In 2018, this policy was further strengthened with the Indian government investing 100 billion rupees (approximately US\$ 1.3 billion) to develop the countries biofuel capacity. The investment will go toward building 12 new bio refineries.¹⁹⁴

Neste

Neste is a Finnish company that produces renewable diesel from 100% renewable raw materials, claiming it outperforms both conventional biodiesel and even conventional fossil diesel in terms of engine performance. Renewable diesel is chemically similar to hydrocarbons, so it is a true drop-in fuel that does not need to be blended with mineral diesel, does not require vehicle engine modifications, and can use existing diesel fuel distribution infrastructure.¹⁹⁵ Neste has a production plant based in Singapore that produces the renewable diesel and has installed

¹⁹⁰ 'Advanced biofuels: what future do they have in transportation.' 15 July 2019.

¹⁹¹ 'Advanced biofuels: what future do they have in transportation.' 15 July 2019.

¹⁹² Que Nguyen et al. 'Global production of second generation biofuels: trends and influences.' Dovetail. 2017. Retrieved from: http://www.dovetailinc.org/report_pdfs/2017/dovetailbiofuels0117.pdf.

¹⁹³ 'Advanced biofuels: what future do they have in transportation.' 15 July 2019.

¹⁹⁴ Ministry of New & Renewable Energy, 'National Policy on Biofuels.' Retrieved from: https://mnre.gov.in/file-manager/UserFiles/biofuel_policy.pdf.

¹⁹⁵ Neste, 'Neste MY Renewable Diesel™ -high- performing low-carbon biofuel.' <https://www.neste.com/companies/products/renewable-fuels/neste-my-renewable-diesel> (retrieved 29 August 2019).

multi-fuel stations in Finland. During operations it has found that the public are ready to accept a higher price for advanced biofuels.

Production development

Biofuels production technology continues to improve, both for mature processes, such as corn-based ethanol and vegetable oil-based biodiesel, and for new processes, such as renewable diesel, renewable jet fuel, and cellulosic biofuels.¹⁹⁶

Global second generation liquid biofuel production has increased steadily over recent years. Biofuel accounted for about 4% of fuel for transport in 2015. The main biofuels produced are bioethanol (74% of global production), biodiesel (22%) and renewable diesel (4%).¹⁹⁷ There is strong policy interest in advanced biofuels because they offer more significant GHG emission reduction potential than conventional biofuels, as they do not compete with food crops for prime agricultural land.¹⁹⁸

To support biofuel production, the EU have an Updated Renewable Energy Directive (RED) with a 3.5% target for novel advanced biofuels by 2030. There are mandates for this policy in Denmark, Finland, France, Germany, Italy, Norway and the United Kingdom. In the US, the producer incentive for bio-based diesels has boosted the production of diesel biofuels for road transport in California and British Columbia.¹⁹⁹

France

Conventional biofuels are already an industrial reality in France. They are incorporated at 7% to 8% in fuels and they account for 25,000 jobs. However, they come from raw materials that can be in competition with food use (beet sugar, corn starch, wheat starch, or rapeseed oil). That is why, as of the 2000s, major R&D work was launched for developing new technologies for producing advanced biofuels using lignocellulosic resources. Two projects of note are: Futurol (demonstrating production of advanced bioethanol, using technology validated over more than 10 different types of biomass); and BioTfuel (demonstrating production of synthetic biodiesel and of synthetic biokerosene approved by ASTM for being incorporated up to 50% in aircraft tanks). These technologies will make it possible to produce fuels with greenhouse gas emissions reduced by 85% to 90% compared with the fossil fuel reference.²⁰⁰

Both of these projects have been jointly developed with manufacturers in order to fully understand their issues and their goals, and to ensure commitment to the end products. Also seen as critical to success are tax incentives that support manufacturers, and vehicle emission regulations that take into account the full life-cycle analysis of the vehicles and not merely the CO₂ emissions at the exhaust pipe.

NZ picture

Lower blends of conventional biofuel are already used in New Zealand in existing vehicles and fuel distribution infrastructure at a 5% to 7% biodiesel blend.²⁰¹ This means that the emissions reductions from these fuels are relatively small.²⁰² Current biofuel production in New Zealand makes up less than 0.1% of the total liquid fuel sales.

Bioenergy Association of New Zealand

The Bioenergy Association represents the main New Zealand companies and researchers involved in the biofuels industry and has special interest groups for biogas and liquid fuels. Key members involved in road transport include

¹⁹⁶U.S. Energy Information Administration, 'Biofuels markets face blending constraints and other challenges.' 18 October 2012. <https://www.eia.gov/todayinenergy/detail.php?id=8430> (retrieved 29 August 2019).

¹⁹⁷ Scion, 'New Zealand Biofuels Roadmap Summary Report'.

¹⁹⁸ International Energy Agency, 'Renewables 2018.' <https://www.iea.org/renewables2018/transport/> (retrieved 29 August 2019).

¹⁹⁹ Susan van Dyk et al. "Drop-in' biofuels: The key role that co-processing will play in production.'

²⁰⁰ 'Advanced biofuels: what future do they have in transportation.' 15 July 2019.

²⁰¹ Energy Efficiency and Conservation Authority, 'Biofuels.' <https://www.eecabusiness.govt.nz/technologies/renewable-energy/biofuels/#Biofuelsandvehicle> (retrieved 29 August 2019).

²⁰² New Zealand Productivity Commission, 'Low-Emissions Economy'.

liquid fuel producers and distributors, potential major users (including Fonterra), biofuels researchers, and key companies in the forestry and wood processing sector. The Association has an active programme in liquid and gaseous biofuels and is about to release an Information Sheet on “Greenhouse gas emissions reduction from transport biofuels”.

New Zealand Companies

Green Fuels NZ produce their own biodiesel from used cooking oil, and Gull New Zealand purchase biodiesel off Fonterra’s Anchor Ethanol plant. Both offer a 5% biodiesel blend for diesel vehicles, resulting in a 4% reduction in life-cycle GHG emissions.²⁰³ KiwiRail is also actively exploring ways to use biofuels.²⁰⁴ Fonterra’s Anchor Ethanol plant also produces bioethanol from whey, a by-product of cheese. If used, 100% bioethanol can lead to a 20% reduction in life-cycle GHG emissions compared to petrol alone. Whey can also be used as a fertiliser due to the valuable nutrient components, nitrogen, potassium and phosphorus, and as a food ingredient, including as an additive to increase nutritional value and as a cooking liquid. This provides a competing alternative for whey as a feedstock for bioethanol.

Z Energy biodiesel plant

Z Energy currently produces biodiesel from tallow at its Wiri large-scale biodiesel production facility. The facility has so far produced 1 million litres of high quality, pure biodiesel, which is blended with mineral diesel and sold to customers at a 5% blend rate. The plant has a current run rate of 6-8million litres per annum, with potential for maximum production of 20 million litres per annum (which is still relatively low).

Z Energy has previously worked with Norske Skog to investigate using second generation biofuels technology to process wood waste from the forestry sector into biofuels (referred to as the Stump to Pump programme). This wood waste is otherwise discarded after trees have been removed from the forest and processed in the mill. While technically and economically challenging, it is possible to convert this waste into a form of ‘green crude’ that can be refined into petrol, diesel, and potentially even jet fuel.²⁰⁵

Z Energy, Refining NZ, Scion and Air New Zealand are currently in a consortium exploring the potential of an aviation biofuels industry in New Zealand, and a plant that would produce second generation renewable diesel and petrol as well as renewable jet fuel. At this time the potential to build a renewable fuels plant is technically feasible but economically unfeasible, without a higher carbon price, high oil prices, policy support, government investment or a combination of some of these conditions.

Government approaches to supporting biofuels

In 2007, the Government passed the Biofuel Bill 2007, which aimed to create a biofuel sales obligation in New Zealand, under which every fuel supplier’s sales would have to include at least 5% biofuels. Signed into law in September 2008, it was repealed by the incoming Government in December 2008. In 2009, the Green Party introduced the Sustainable Biofuel Bill to Parliament. The Bill aimed to ensure that biofuels supplied or sold in New Zealand were sustainable. It was defeated in its second reading in April 2012.

The Biodiesel Grants scheme, introduced in 2009, provided a 42.5c per litre sales credit for one particular kind of biofuel made in New Zealand from methanol and either vegetable oil or animal fat. The scheme was discontinued in 2012, because the Government’s focus shifted from subsidising first generation biofuels to research and development into more advanced biofuels. Z Energy states that they would have begun construction of a biofuels plant sooner had the scheme remained in place.

Crown research institutes, such as Scion and NIWA, are actively involved in bioenergy-related research. Beyond research and development, other government policies, such as zero-rating of biofuels under the New Zealand Emissions

²⁰³ Energy Efficiency and Conservation Authority, ‘Biofuels.’

²⁰⁴ Scion, ‘New Zealand Biofuels Roadmap Summary Report’.

²⁰⁵ Z Energy, ‘Biofuels.’ 1 July 2014. <https://z.co.nz/about-z/news/sustainability-news/biofuels/> (retrieved 29 August 2019).

Trading Scheme and exemption of bioethanol from excise tax, are also beneficial to the continuing development of some biofuels.

Parliamentary Commissioner for the Environment report

In 2010, the Parliamentary Commissioner for the Environment published the report ‘Some Biofuels are Better than Others: Thinking Strategically about Biofuels’, which explored the role biofuels could play in reducing New Zealand’s GHG emissions. The report found that to reduce GHG emissions in New Zealand, biofuel feedstocks must be grown on land that does not require felling forests or draining wetlands. Biofuel feedstocks must also be grown without using large quantities of nitrogenous fertilisers, with minimal diesel used in harvesting and haulage, and using only small amounts (if any) of coal and natural gas in the production process.²⁰⁶

Scion Biofuel Roadmap

Scion, the lead Crown Research Institute for research into bioenergy production for New Zealand, developed a Biofuels Roadmap to inform and stimulate debate on large-scale production and use of liquid biofuels in New Zealand. The study focuses on the production of liquid biofuels from sustainable feedstocks, large-scale deployment and use, and narrowing down a broad range of options to find the best solutions for New Zealand.²⁰⁷ The study identified drop-in fuels from non-food feedstocks, particularly forestry grown on non-arable land, as the most attractive option. It identified that the investment required is large, and stakeholder industries would need a degree of certainty when committing to feedstock and processing options, as well as taking ownership of delivering their parts of the value chain.²⁰⁸

Summary of opportunities and challenges for biofuels

| Opportunities | Challenges* |
|--|--|
| <ul style="list-style-type: none"> • Current conventional biofuels can be used in most trucks now (at 5% blend) • Conventional biofuel volumes could be produced at the scale required to competitively service New Zealand’s road freight industry • Advanced (second generation) “drop-in” liquid biofuels will not need to be blended with existing fossil fuels and can be used in existing diesel trucks • Biomass supply chains can generate additional co-benefits (e.g. using waste and existing industrial by-products and providing job growth and economic development) | <ul style="list-style-type: none"> • Understanding GHG emissions over the full life-cycle of producing biofuels (including feedstocks) • Avoiding impacts on food production, water and soil quality • Biofuels are more costly to produce and scale up than fossil fuels, making them generally more expensive for the consumer • Require large amounts of feedstocks • Commercial scale production facilities required, and significant up-front investment to begin production • Vehicle engine modifications are currently required for higher blends of conventional biofuels |

* Potential solutions to some current challenges have been identified, (e.g. advanced biofuels, higher conventional biofuel blends can be used in some large commercial vehicles already, existing conventional biofuel production in New Zealand). These require further scrutiny.

²⁰⁶ Parliamentary Commissioner for the Environment, ‘Some Biofuels Are Better than Others: Thinking Strategically about Biofuels’.

²⁰⁷ Scion, ‘New Zealand Biofuels Roadmap Summary Report’.

²⁰⁸ Scion, ‘New Zealand Biofuels Roadmap Summary Report’.

Key questions worth considering around biofuels

Are there any other opportunities or challenges around biofuels that the paper needs to highlight?

Could existing biodiesel blends be a near term option for reducing GHG emissions? What would it take for greater uptake of higher blends of conventional biofuels?

What would it take to fast-track the production of advanced (second-generation) biofuels in New Zealand?

What feedstock(s) would be suitable for biofuels production in New Zealand? Which region(s) would be best for producing those feedstocks?

What do you consider to be the Government's role in biofuels development?

Section four: Summary themes and where to from here?

This section brings together several themes that are consistent across the challenges identified in the previous section. It stops short of proposing solutions to resolve these challenges, and instead, raises some pivotal questions in relation to them. It concludes by looking at where to from here.

No single alternative fuel can address GHG emissions for the road freight sector

Given the current state of technological development, none of the three alternative fuels being considered provide a universal solution to reduce GHG emissions from road freight, either in New Zealand or in any overseas jurisdiction. Careful consideration needs to be given to each alternative fuel option to understand where they can have the greatest impact across the road freight industry, if we are to maximize the opportunities (and minimise the risk) to investors and government.

This includes considering how technological developments will mitigate current challenges through to 2030 and beyond. New Zealand will have a role to play in this because our high penetration of renewable electricity means we have the potential to transition more quickly than other nations. We might also have a role to play in technology development (e.g. induction roads), but what should our level of investment be, and in what technologies and when? How do we understand where our investment would have the greatest impact on speeding up alternative fuel uptake and reducing the demand for fossil fuels? What are the barriers to increased research and demonstration projects? What are the social impacts of these changes? Are there potential national and international economic opportunities that arise? And what are the commercial drivers for industry decision around replacing vehicle fleets?

More research and demonstration projects may be required to test technology boundaries and diversify investment across alternatives until the appropriate technologies emerge as dominant. Keeping abreast of future breakthroughs in logistics, advanced biofuels, battery energy density, and electrolyser efficiency will help inform these investment decisions. What might this timeframe look like though, and how do we get greater certainty around this in the New Zealand context?

The cost of infrastructure poses a significant barrier

There are significant up-front costs, and long lead times, in building and developing supporting infrastructure for each of the fuel options discussed. This goes beyond just the fuels themselves and includes equipment, vehicles, feedstocks and distribution networks. The level of investment required in supporting infrastructure suggests that the widespread adoption of both hydrogen fuel-cell technology, and electric battery technology is unlikely in New Zealand. With limited funding, the Government will need to prioritise its investment in supply infrastructure. This raises questions around what options to consider, what infrastructure to invest in and when to invest, given the exponential increase in technology developments, and the emission reduction targets that need to be met. Then there are questions around who is best placed to own and maintain the infrastructure required to support alternative fuels, and what role does Government have in this? Could a private/public partnership be considered to co-fund the development of infrastructure and procurement of equipment and vehicles?

New Zealand is also reliant on international markets for vehicles, but also for some specialised equipment to support infrastructure development. How do we get a full evaluation of costs and impact of infrastructure development for electric battery and hydrogen vehicles in New Zealand? And how do we ensure security of vehicle supply through Original Equipment Manufacturers (OEMs), given New Zealand's market share and distance from international markets? For hydrogen, some of this may rely on assuring OEMs that there is a guaranteed, reliable fuel supply in New Zealand for their vehicles.

Life-cycle analysis is essential for good policy and investment decisions

There are high levels of uncertainty around the impact of alternative fuels on GHG emissions over their full life-cycles. Understanding the full life-cycle of environmental impacts (including GHG emissions and other adverse impacts on the environment) of alternative fuels is essential for good policy and investment decisions. Exactly how to obtain the data and insight to understand life-cycle emissions, in a New Zealand context, will be a challenge in itself.

This is not just a GHG emissions issue

The co-benefits of transitioning New Zealand's vehicle fleet to low GHG emission options is also a strong argument for taking decisive action. Cleaner air in our cities, job creation, innovation and global leadership should be viewed as outcomes worth pursuing themselves. Understanding the significance of these goals, and articulating the interdependence across them, will be essential to building momentum for change.

Where to from here?

The Ministry of Transport would like to hear your views on the information provided in this paper. Does the paper highlight new information or raise questions that are useful? Does it challenge your current thinking or reinforce what you already knew? Or do the ideas presented run contrary to your experience or understanding. Please get in touch with the authors of this paper to share your thoughts.

The next step for the Ministry is to arrange a series of targeted conversations with groups and organisations who can contribute further to the discussion around reducing GHG emissions from road freight and heavy trucks. This will include those involved in the road freight industry directly, but also private sector organisations working in the energy sector, and those organisations and universities generating research and thinking in this area.

This next round of conversations will be focussed on the specific challenges and barriers around transitioning to alternative fuels for heavy trucks in the New Zealand context. It will also be an opportunity to discuss the advantages we have in this space in New Zealand. Identifying and exploiting these will be important to shape good policy and identify a clear way forward for industry and government.

Input from these conversations will be used to inform the development of a strategic working paper. The working paper is not intended to provide specific policy recommendations. Rather, it is intended to provide insights that could inform future policy development. This paper will be published in early 2020.

If you would like to contribute answers to some of the questions posed in the paper, or have additional questions or thoughts and ideas you would like to provide, we would love to hear from you. Please email us @ greenfreight@transport.govt.nz.

Thank-you for taking the time to read the paper, we look forward to discussing this topic with you further.