

# Chapter 4b: Reducing emissions - opportunities and challenges across sectors

## *Transport, buildings and urban form*

*Emissions from transport, buildings and urban form currently contribute to total emissions from Aotearoa in a range of ways. Transport has been the most rapidly growing source of emissions for Aotearoa, with road transport emissions accounting for 90% of all transport emissions. Low-density residential developments are associated with higher emissions, while the way buildings are built and operated determines the emissions they produce.*

*This section outlines the opportunities and some of the key challenges for reducing emissions in transport, urban form and buildings.*

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## Transport, Buildings and Urban Form

This section outlines the opportunities and some of the key challenges for reducing emissions in:

- Transport
- Urban form
- Buildings

### 4b.1 Transport

Transport emissions have been a major and growing contributor to our total greenhouse gas emissions. Between 1990 and 2018, domestic transport emissions have increased by 90%. Transport currently contributes about 37% of long-lived gases.<sup>1</sup> Transport has been the most rapidly increasing source of emissions. Out of the 35.1 megatonnes (Mt) of gross carbon dioxide (CO<sub>2</sub>) emissions Aotearoa produced in 2018, approximately 16 Mt were from transport, and an additional approximately 2 Mt were from off-road vehicles and equipment used in agriculture, forestry, fishing and construction, such as tractors, fishing boats, and earthmovers. Off road vehicles and equipment are covered in this chapter as the options to reduce their emissions are similar to transport (such as electrification or use of low carbon fuels), however their emissions are categorised in Heat, Industry and Power.

Road transport is the main source of emissions from transport. Cars, utes, vans and SUVs are the predominant cause of these emissions, though emissions from trucks have doubled in the last 20 years. Table 4b.1 shows how the Commission categorises different types of vehicles in our report.

*Table 4b.1: Types of vehicles categorised in the Commission’s 2021 report*

<b>Internal Combustion Engine Vehicle</b>	includes <b>conventional hybrids</b> , such as the Toyota Prius. This is because even though conventional hybrid vehicles use batteries and electric motors to help propel the vehicle, the electricity is entirely produced on-board the vehicle by a generator driven by an internal combustion engine.
<b>Electric Vehicle</b>	An electric vehicle is a vehicle fully or partially powered by electricity from an external source. <b>Battery electric vehicles</b> are powered by batteries charged only from an external electricity source. <b>Plug-in hybrid</b> vehicles are powered by batteries charged either from an external electricity source or from electricity produced on-board the vehicle by a generator driven by an internal combustion engine.

<sup>1</sup> All gases excluding biogenic methane.

<b>Light Vehicle</b>	<p>This is a vehicle with a fully-loaded weight less than 3,500 kilograms (see ‘Vehicle Type Categorisation’ under <a href="https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/sheet/2018-annual-fleet-statistics">https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/sheet/2018-annual-fleet-statistics</a>).</p> <p>Light vehicles include <b>light passenger vehicles</b>, (most cars and SUVs) and <b>light commercial vehicles</b>, (most vans and utes). The distinction between light passenger vehicles and light commercial vehicles is based on the body type of the vehicle, not the use of the vehicle. Many light commercial vehicles are used as household vehicles.</p>
<b>Medium Truck</b>	<p>As used here, a medium truck has a fully loaded weight greater than or equal to 3,500 kilograms, but less than 30,000 kilograms. This category includes ‘straight trucks’, typically used for local deliveries, and some tractor-trailer ‘big rigs’.</p>
<b>Heavy Truck</b>	<p>As used here, a heavy truck has a fully loaded weight greater than or equal to 30,000kg. These are typically tractor-trailer ‘big rigs’. The Commission’s analysis draws the line between medium and heavy trucks at 30,000kg, since trucks over 30,000kg are approaching legal size and weight limits. This means that battery-powered versions may have to sacrifice payload for batteries. The economics of electrifying heavy trucks are therefore less attractive than they are for medium trucks.</p>

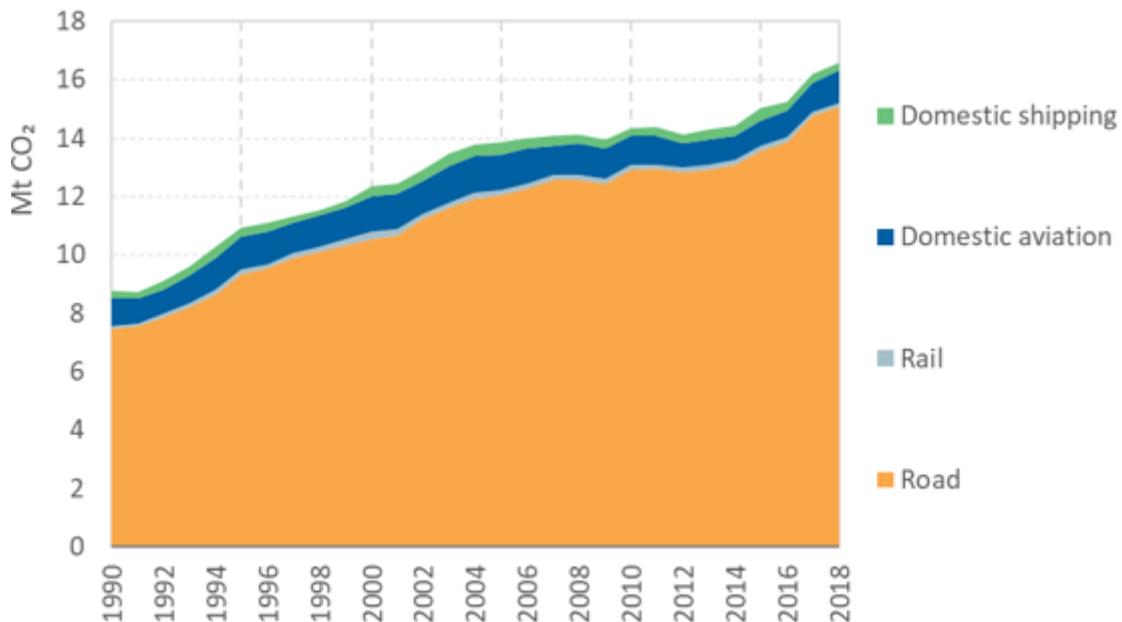


Figure 4b.1: Transport Emissions by Type in Aotearoa<sup>2</sup>

Figure 4b.1 above illustrates the dominance of road transport emissions – about 90% of all transport emissions. This has increased substantially since 1990. There are approximately 4.2 million vehicles

<sup>2</sup> (Ministry for the Environment, 2020a)

in Aotearoa. This is projected to rise to 5.2 million vehicles by 2042/43.<sup>3</sup> About 75% of this total is made of household vehicles.<sup>4</sup>

In 2018, light passenger vehicles (cars and SUVs) accounted for about 53% of emissions from road transport, while light commercial vehicles (vans and utes) accounted for about 18%. Much of the growth in light vehicle emissions has come from light commercial vehicles, which have increased 84% between 2000 and 2018. Motorcycles and scooters contribute only about 0.3% of road transport emissions. Figure 4b.2 below shows the split of emissions by type of vehicle.<sup>5</sup>

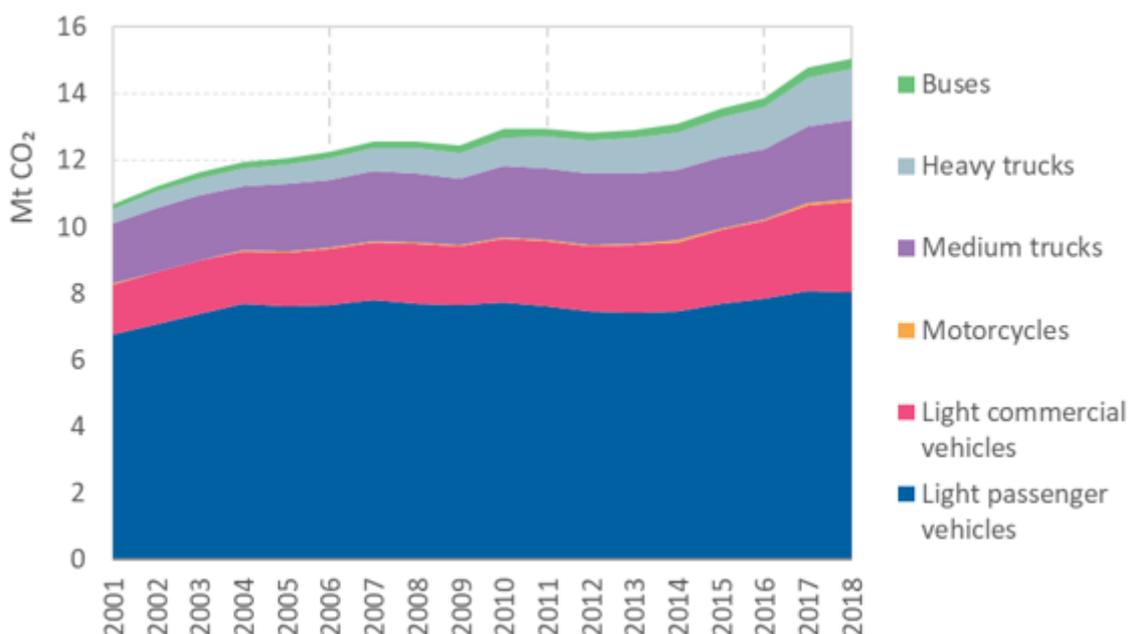


Figure 4b.2: Road Transport Emissions by Type of Vehicle in Aotearoa (Mt CO<sub>2</sub>)

Source: Commission analysis.

Heavy vehicles—medium and large trucks as well as buses—are also a significant source of emissions. The heavier fleet accounts for only about 7% of annual travel but contributes about 28% of emissions from road transport. Truck emissions have been growing very rapidly, having increased 80% between 2000 and 2018.<sup>6</sup>

Domestic aviation emissions make up 7% of transport emissions and have been relatively static since 1990.<sup>7</sup> This is partly due to the introduction of larger and more fuel-efficient aircraft, and partly due to the increasingly sophisticated technological systems that airlines use to reduce the number of empty seats meaning the same number of passengers can be carried on fewer flights. It is anticipated that COVID-19 will have resulted in reductions of about 45% of aviation emissions in 2020, but Air New Zealand has predicted that air travel demand will return to 70% of its pre-COVID rate by August 2022.<sup>8</sup>

<sup>3</sup> (Ministry of Transport, 2019)

<sup>4</sup> (Ministry of Transport, 2019)

<sup>5</sup> (Climate Change Commission ENZ Model results, 2020)

<sup>6</sup> (Climate Change Commission ENZ Model results, 2020)

<sup>7</sup> (Ministry for the Environment, 2020c)

<sup>8</sup> (Reuters, 2020)

Rail and domestic shipping emissions together make up about 2% of transport emissions.<sup>9</sup> Their low total emissions are partly because they account for a relatively small share of the freight that moves around Aotearoa,<sup>10</sup> and partly because, on a per tonne/kilometre basis, they emit less than trucks.<sup>11</sup>

International aviation and shipping emissions are not included in this data, although they have historically been a significant and growing portion of global emissions.

Transport was largely responsible for the increase in our country's overall emissions over the last 30 years. The growing population – up 42% between 1990 and 2018 and 25% of that increase since 2001 – is a key contributor to increased transport emissions in Aotearoa.

Emissions growth from transport has also been driven by economic activity; a growing population consuming more products, increased exports and increased travel for business. Road freight tonne-kilometres increased 40% between 2001 and 2018.<sup>12</sup>

Rates of vehicle ownership have also increased. There were 2.7 million vehicles in Aotearoa in 2001, by 2018 there were 4.3 million and the fleet size increased faster than the population over the same period. In addition, Aotearoa has a predominance of used imports and slow fleet turn over. The average vehicle is driven until it's about 19 years old and this average is gradually increasing.<sup>13</sup>

There has been a modest increase in vehicle distance travelled per person for all vehicles: from about 9,400km per person in 2001 to about 10,000km per person in 2018.<sup>14</sup>

One consequence of our heavy dependence on private vehicles is traffic congestion. Aucklanders' travel time increased by 31% due to traffic congestion according to the TomTom Traffic Index.<sup>15</sup> Extra fuel use and increased emissions often come with congestion.

The engine size of vehicles is also increasing. The share of the light vehicle fleet with engines of 2,000 cc or more increased from 35% in December 2001 to 46% in December 2018.<sup>16</sup> In 2019, 8 of the top 10 best-selling new vehicles in Aotearoa were utes or SUVs.<sup>17</sup>

While 85% of our population live in urban areas, Aotearoa is a sparsely populated country. A household's transport choices often depend on where in the country they live, their proximity to economic and social activities and the services available. Some communities have a high dependence on vehicles for transport. For many rural communities public transport is often not practical and private transport is relied on, including for to access public transport.

Other groups, for example low income households and people with disabilities or limited mobility, children and older people often also have limited transport options. Public transport could be insufficient and low emissions cars too expensive. Policies which increase vehicle costs or driving costs may fall disproportionately on low income households, who may also not be able to afford fast

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<sup>9</sup> (Ministry for the Environment, 2020c)

<sup>10</sup> In 2017/18 the total amount of freight moved by domestic shipping was around 13.4% of total freight tonne/km, or 1.6% on a tonnage basis. For rail it was around 11.5% of total freight tonne/km, or 5.6% on a tonnage basis. Ministry of Transport, 2020a.

<sup>11</sup> (Wang, 2019)

<sup>12</sup> (Ministry of Transport, 2020a)

<sup>13</sup> (Ministry of Transport, 2019a)

<sup>14</sup> (Ministry of Transport, 2019a, 2019)

<sup>15</sup> (TomTom, 2020)

<sup>16</sup> (Ministry of Transport, 2018a)

<sup>17</sup> (Automobile Association, 2020)

broadband, also limiting virtual access allowing remote working or learning. Complimentary policies will be required to mitigate this inequality.

#### 4b.1.1 Focus on Auckland

In 2018, road transport emissions in Aotearoa were around 15 Mt of carbon dioxide.<sup>18</sup> Auckland accounted for 27% of those.<sup>19</sup>

The Auckland City Council's Climate Plan has set a goal to reduce net emissions by 50% by 2030,<sup>20</sup> and to zero emissions by 2050.<sup>21</sup> To achieve a net emission reduction of 50% by 2030, a 64% reduction in transport emissions would be required.

Achieving these goals would require fundamental shifts in how Aucklanders travel, how that travel is powered, how often they travel and how freight is transported. The plan to achieve these goals includes:

- increased uptake of public transport
- an increase in cycling and walking
- increases in remote working, and
- increased numbers of electric vehicles or other low emission vehicles on the roads.

All of these options are discussed in more depth below.

However, Auckland's population is expected to increase by another one million people by 2050, so achieving this plan will be very challenging,<sup>22</sup> unless specific policies are targeted at achieving outcomes such as higher density near transport hubs to decouple population growth from transport emissions.

#### 4b.1.2 Options for reducing emissions

Many options exist to reduce transport emissions. We have prioritised the options with the largest potential and ensured the analysis covered all types of transport. This section outlines the opportunities and challenges related to each option. All estimated emissions reduction potential has come from external sources of evidence, rather than from our modelling.

Overall, the evidence summarised here shows the technologies exist to decarbonise all types of transport, although some options are at very early stages and many options face barriers. Immediate savings are possible through behavioural change – that is finding ways for people to reduce their travel or switching to active travel and public or shared transport. Multiple lines of evidence show that over the next 15 years, the largest opportunity to reduce emissions comes from the electrification of the light vehicle fleet. Multiple options exist to decarbonise freight on a 10 to 20-year horizon, including electrification. Where electrification is more difficult, for example with heavy freight or aviation, low carbon fuels such as biofuel or hydrogen, can play an important role.

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<sup>18</sup> (Ministry for the Environment, 2020c)

<sup>19</sup> (Auckland Council, 2020)

<sup>20</sup> Against a 2016 base line

<sup>21</sup> (Auckland Council, 2020)

<sup>22</sup> (Ministry of Transport, 2019)

Electric vehicles are an important piece of the puzzle, but that does not take away how important it is to reduce emissions from other areas of transport and to give New Zealanders choices to reduce transport emissions.

Our transport system is dominated by private vehicles. Reducing the number of cars on the road and developing a more accessible transport system is an effective way to reduce emissions that has many co-benefits.

A successful outcome would be that transport emissions are reduced by cities and towns that are designed for liveability and ease of getting around. Active transport, such as walking or cycling are simple ways to reduce emissions. Where walking, cycling or working from home is not possible, public or shared transport are an attractive choice. A very important part of the move to a zero emissions transport system is to enable policies that work together well.

However, urban form and planning is a long term and evolving process and public transport systems take time to build up. Behaviour change also takes time. People will continue to rely on private transport until public transport services and infrastructure is provided so people find public transport, walking and cycling convenient, safe and enjoyable. There are also areas where using public transport is not practical and ultimately some people want and need to use their own cars. We see electric vehicles as an important part of the solution but they are not to be seen as a ‘silver bullet’.

It is important to address the real or perceived inequality associated with electric vehicles. Policies that support the transition to a low emissions future should operate by reducing social inequities rather than exacerbating them. Additional benefits of improved air quality and ongoing savings from the lower fuel and maintenance costs that electric vehicles provide can benefit low income households most.

One Māori community on the East Cape<sup>23</sup> has implemented shared mobility. Long established ways of sharing are underpinned by cultural principles such as manaakitanga (having a deep ethic of care for people that might be impacted), Mana Tauutuutu (community belonging and cohesion) and whanaungatanga (a relationship through shared experiences and working together which provides people with a sense of belonging). Shared mobility allows for social, cultural and economic benefits to the collective as well as environmental benefits.

Internationally there are many examples of schemes which provide substantial support for electric transport such as providing financial support to scrap old fossil fuelled cars, depending on income level and either provide funding for replacement low emissions vehicles, or public transport or car sharing services. Financial assistance to purchase an electric vehicle is just one way to assist people with limited resources. For example, electric vehicle sharing schemes could be targeted to address public transport gaps for low income earners, allowing them to get to their jobs. Increased support for rural charging stations will also be needed. These options are discussed more fully in the Impacts and Policy Direction of Emissions Reduction Plan sections.

*Table 4b.2: Opportunities and challenges for reducing transport emissions*

Option	Opportunities and challenges
<b>Reducing travel</b>	Using transport less, or not at all – such as use of technology to work from home and attend appointments – can reduce emissions at little cost. About 0.5 Mt per

<sup>23</sup> (Haerewa, 2018)

	<p>year could be saved in commuter emissions if an additional 10% of people worked from home one day a week.<sup>24</sup></p> <p>Around 13% of total current transport emissions are from people travelling to and from work. Although not an experience we would want to see repeated, restrictions on travel during the COVID-19 pandemic demonstrated on a broad scale the potential of working from home and video conferencing to reduce travel.<sup>25,26</sup></p> <p>Normally, whether it is possible for someone to avoid travel to and from work would depend on their occupation, access to a digital connection and suitability of their home environment. We estimate that about 10% more people would be able and willing to work from home.<sup>27,28</sup></p> <p>The digital technology to support increased levels of working from home is well-developed but is not universally accessible in remote and rural regions. The potential is also limited for some occupations, such as services, construction and manufacturing where workers need to be on site.</p> <p>Land use changes over the longer term so that people live closer to places they need to go, will contribute to travel reduction.</p>
<p><b>Transport type shift to walking, cycling, public transport</b></p>	<p>Shifting to active and shared travel types has the potential to reduce carbon dioxide emissions from transport, particularly in urban areas. Active travel has no carbon dioxide emissions (or close to zero for electric scooters and e-bikes). Shared travel, including public transport, typically has significantly lower carbon dioxide emissions per passenger km compared with single occupancy vehicles.</p> <p>Challenges for increasing public transport use and active travel include the design of our cities, underinvestment in public transport and walking and cycling and incentives encouraging travel by car. The Auckland Climate Plan has indicative targets for cycling to achieve 7% travel share by 2030 and 9% travel share of kilometres travelled by 2050 in Auckland. At a national level, public health researchers have recommended a target of 15% of all trips by bicycle by 2050.<sup>29</sup></p>

<sup>24</sup> We have not attempted an assessment of the emissions reduction potential of increased online shopping, although it is likely to offer some net reduction in emissions.

<sup>25</sup> The impact of COVID-19 saw a significant decrease in the number of people commuting to work in Aotearoa, dropping from 58% of people pre-COVID to only 15% under level 1. This would have included people working from home and people no longer able to work during this period.

<sup>26</sup> (Ministry of Transport, 2020b)

<sup>27</sup> An estimated 30% of workers in Aotearoa are in roles allowing them to work from home. However, around half of these people are already doing so at least part time, and some people who have jobs allowing them to work from home still may not be able to, if, for example, if there are young children or flatmates in the house. We estimate that around 10% more people could be able and willing to work from.

<sup>28</sup> Climate Change Commission ENZ Model 2020 results based primarily on data from Ministry of Transport, Transport Outlook: Future State Vehicle Fleet Emissions Model

<sup>29</sup> (Mandic et al., 2019)

	<p>Some Aotearoa researchers have recommended a target to double the proportion of trips by walking to 25% of all trips by 2050.<sup>30</sup> This would be about the same as the current proportion of trips by walking in Wellington, which is 24.5% of trips and 3.3% of travel by distance.<sup>31</sup> If we assume that the current travel type share in Wellington is achievable in other urban areas of Aotearoa, a walking share of 3.3% of distance travelled is plausible.</p> <p>Low population density also means rural communities have a high dependence on vehicles for transport. It is likely that for many rural communities public transport is not practical. Electrifying or improving the fuel efficiency of private vehicles may be the best options for rural areas.</p> <p>Cycling, micro-mobility, walking and car sharing could have a big role in smaller cities and towns, where distances are usually short. Additionally, as outlined in <i>Part 4: What this could mean for New Zealanders</i>, there are increasing examples of mobility as a service in smaller towns, as opposed to conventional public transport. First and last kilometre transport solutions<sup>32</sup> are also increasingly emerging making it easier to access public transport.</p>
<p><b>Conventional vehicle improvements</b></p>	<p>Improving the efficiency of the conventional vehicle fleet could save 0.26 Mt CO<sub>2</sub> per year. The efficiency of new and used conventional vehicles has improved in recent years, despite vehicles tending to increase in both engine and overall size.<sup>33</sup></p> <p>However, the light vehicle fleet is emissions-intensive compared to most developed countries and evidence indicates that our performance is getting worse.<sup>34</sup> There are two key reasons for this:</p> <ul style="list-style-type: none"> <li>• Although efficiency is generally improving within vehicle weight classes as manufacturers introduce fuel-saving technologies, New Zealanders are increasing choosing to purchase larger, heavier vehicles.</li> <li>• Manufacturers choose to provide less efficient model variants into the Aotearoa vehicle market than to markets where vehicle fuel efficiency standards apply.<sup>35</sup></li> </ul> <p>If Aotearoa were to match the average fuel efficiency of new vehicles today in other jurisdictions (without any further technology improvements from today's internal combustion engine vehicles), this could see around a 33% reduction in CO<sub>2</sub> emissions over the life of the vehicle.</p>

<sup>30</sup> (Ibid)

<sup>31</sup> (Ministry of Transport, 2019a)

<sup>32</sup> The 'first and last-kilometre' is a term that describes the beginning and end of an individual's public transport journey. Usually, after traveling on public transport, we need to walk, or take a second type of travel to reach our final destination. This gap from public transit to destination is seen as counterintuitive to establishing a truly connected city.

<sup>33</sup> (Ministry of Transport, 2018b)

<sup>34</sup> (Automobile Association, 2020a)

<sup>35</sup> (New Zealand Productivity Commission, 2018, p. 356)

	<p>More efficient conventional vehicles may cost more upfront but deliver significant fuel savings. The additional capital cost of a vehicle emitting 110 gCO<sub>2</sub>/km, over one emitting 180 gCO<sub>2</sub>/km in 2021, is estimated to be an average of \$750 per vehicle. In 2025 this additional vehicle cost is estimated to be \$1,580 per vehicle. However, the fuel savings are estimated to average \$6,800 per vehicle over the vehicle lifetime.<sup>36</sup> Efficiency can be improved by:</p> <ul style="list-style-type: none"> <li>• improvements in internal combustion engine vehicles (for example through engine stop functions when the vehicle is stationary, less friction in the engine and better engine management, low resistance tyres, improved aerodynamics)</li> <li>• moving to hybrid vehicles – including hybrid drive trains and stop start technology.</li> </ul> <p>It is possible that the fuel efficiency of internal combustion engine vehicles internationally may not improve further than it has done over the last few decades. Several major automotive manufacturers including Volkswagen Group<sup>37</sup> and Daimler<sup>38</sup> have announced they will no longer be undertaking research and development activities and developing new light vehicle models based on internal combustion engine vehicles, with Nissan<sup>39</sup> and Mitsubishi<sup>40</sup> stopping research and development for diesel engines. The focus of research and development has instead shifted to electric vehicles.</p> <p>However, Aotearoa has the potential to reduce the average emissions of new internal combustion engine vehicle entrants to its fleet to match those of other countries. Hybrid vehicles have the potential to improve fuel efficiency by between 40 and 50% compared to a non-hybrid equivalent and new models are increasingly entering the market. Toyota have announced they expect to have hybrid Hiluxes available by the end of 2021,<sup>41</sup> and Nissan have “<i>all but guaranteed</i>” the next Navara ute will have hybrid options.<sup>42</sup></p>
<p><b>Electrification of light vehicles - cars, SUVs, utes and vans</b></p>	<p>Light vehicles (cars, SUVs, utes and vans) emitted about 10.6 Mt CO<sub>2</sub> in 2018. EECA<sup>43</sup> has estimated that battery electric vehicles could achieve a roughly 80% reduction in CO<sub>2</sub> emissions per km when in use in Aotearoa. Since most of the emissions of battery electric vehicles are from electricity generation, this figure could be improved as the Aotearoa electricity grid is further decarbonised.</p> <p>The main challenge currently is the upfront cost of purchasing an electric vehicle, which is more expensive than the internal combustion engine equivalents. For example, the cheapest new electric vehicles on the market in Aotearoa cost around \$50,000. Owning an electric vehicle today is challenging for those living</p>

<sup>36</sup> (Ministry of Transport, 2019a)

<sup>37</sup> (Reuters, 2018)

<sup>38</sup> (Electrek, 2019)

<sup>39</sup> (Nikkei Asia, 2018)

<sup>40</sup> (The News Wheel, 2019)

<sup>41</sup> (Cars Guide, 2019)

<sup>42</sup> (Stuff, 2020)

<sup>43</sup> (Energy Efficiency and Conservation Authority, 2015)

in areas of high social deprivation and those on a lower incomes. Lower socioeconomic groups may not prioritise such a purchase.<sup>44</sup>

For people for whom access to electric vehicles will be challenging, good access to public transport is particularly important. New Zealanders living in areas rated high on the deprivation index would benefit from investment to improved public transport, particularly in areas such as West and South Auckland.

The cost of reducing emissions with electric vehicles is shrinking rapidly as the cost of them declines. Our projections suggest that EVs will drop below the cost of conventional vehicles on a lifetime cost of ownership basis by 2024 for new light passenger vehicles (cars and SUVs) and by 2025 for new light commercial vehicles (vans and utes).<sup>45</sup>

Further, the upfront purchase price of new battery electric vehicles is expected to drop below those of conventional vehicles by 2029 for light passenger vehicles and by 2032 for light commercial vehicles. The main reason for the declining cost of battery electric vehicles is the expected decline in battery costs.

Although currently more expensive to purchase, electric vehicles offer considerable savings in both energy and maintenance costs compared to conventional vehicles. Based on a typical delivered electricity price of \$0.25/kWh and typical car/SUV fuel efficiencies, a battery electric vehicle has a fuel cost roughly equivalent to buying \$0.54/litre petrol.<sup>46</sup> Depending on annual distance driven, some new electric vehicles are cost effective on a total cost of ownership basis today.<sup>47</sup>

The range of electric vehicles has also been a constraint.<sup>48</sup> However, with improvements in battery technology, this concern is rapidly diminishing. The first electric vehicles had ranges of around 100km on a full charge. In comparison, new electric vehicles on the market today have ranges of over 400km on a full charge.

Currently there is a lack of choice of electric vehicles in Aotearoa, particularly for utes and SUVs – which New Zealanders often favour over smaller vehicles, although choices are expanding. Aotearoa accounts for a very small proportion of global sales and electric vehicle models available in other countries are not offered here. Some models are offered at a significant price premium over the same model in other countries.<sup>49</sup>

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<sup>44</sup> (Haerewa, 2018)

<sup>45</sup> Climate Change Commission ENZ Model results

<sup>46</sup> Our model assumes battery electric vehicles require 16.2 kWh/100 km while petrol vehicles require 7.52 litres/100 km, so  $(16.2 \text{ kWh}/100 \text{ km}) / (7.52 \text{ litres}/100 \text{ km}) * \$0.25/\text{kWh} = \$0.54/\text{litre}$ .

<sup>47</sup> Using EECA's TCO tool you can see how some new electric vehicles doing 35-40,000 km per year are cheaper on a TCO basis than equivalent petrol vehicles (Gen Less, 2020)

<sup>48</sup> (Stevenson et al., 2018)

<sup>49</sup> (New Zealand Productivity Commission, 2018)

There is also a lack of supply volume from second-hand markets. Most of the electric vehicles brought into the Aotearoa fleet are used cars, predominantly from Japan and Aotearoa increasingly competes with other countries for low emission used Japanese vehicles. Second hand electric vehicles are older technology and may have smaller battery range than newer models. The batteries in second hand electric vehicles may also have already degraded to some degree.

Electric vehicles require charging infrastructure and network up-grades or new power lines may also be needed, especially for high capacity rapid chargers. These costs are relatively small and most drivers will use a mix of home chargers and public charging stations. Overall the impact on the electricity system is likely to be modest. The Interim Climate Change Committee estimated that converting half of the vehicle fleet, including heavy vehicles, to electricity would increase electricity demand by 10%.<sup>50</sup>

However, the coordination of electric vehicle charging times is a potential challenge for some local lines' networks. There is the risk that people coming home and plugging their electric vehicles in after work at the same time may lead to greater evening peak demand, putting local lines under pressure and pushing up network costs.<sup>51</sup> Conversely, pricing encouraging overnight charging could potentially improve network utilisation, reducing overall network costs and improve the economics of wind generation, as well as further reduce costs for electric vehicle owners.

Many low- and middle-income households and those in rental housing or apartments, may find it much harder to access and use electric vehicles compared to those owning their own homes. If there is no suitable three pin plug access (or wall charger) at a rental property, there is little benefit for the landlord to put one in and no security for the renter to make it worthwhile installing one at their own cost. This is particularly relevant for households who are disproportionately represented in low income and rental housing. Similarly, many apartment buildings have not been designed with electric vehicles in mind and therefore there is inadequate charging infrastructure.

Through Māori-collectives, iwi/Māori and hapū there is an opportunity for collaboration to create a network of electric vehicle charging stations throughout Aotearoa that would encourage tourist and tourism operators in the regions, although the cost could be a barrier.<sup>52</sup> There is potential for Government and Māori to partner to utilise Marae as rural and regional charging stations. In times of emergency Marae are often well positioned to support local communities. The potential of charging stations will need to be negotiated with each Marae Trust.

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<sup>50</sup> (Interim Climate Change Committee, 2019)

<sup>51</sup> (Energy News, 2020)

<sup>52</sup> Evidence Report, Chapter 6: Māori sector

	<p>There are unexplored opportunities for the electrification of taxis and light vans, which are high mileage vehicles and can therefore deliver high rates of emissions reductions. These may require additional public charging infrastructure in city centres to encourage transition. For example, dedicated electric vehicle charging infrastructure for electric vehicle taxis is being rolled out in London.<sup>53</sup></p> <p>There are also challenges of relying on electrification. Prioritising electric vehicle uptake continues to encourage car dependency and contributes to demand for low density development.</p>
<p><b>Electrification of trucks and buses</b></p>	<p>Trucks and buses accounted for approximately 4 Mt of emissions in 2018 and there is significant potential for electrification.</p> <p>The actual emissions reduction for both trucks and buses will depend on the rate at which older diesel vehicles are replaced with battery electric vehicles or retrofitted to battery electric operation.</p> <p>There are challenges associated with battery electric heavy trucks due to the size, weight and cost of the batteries and time required to recharge them. These challenges are less of an issue for medium trucks typically used for local deliveries and other short-haul duties with lighter loads.</p> <p>Given this, the Commission estimates that emissions reduction potential of between 2 and 2.5 Mt each year.</p> <p>The economics of electrification for medium trucks are be similar to light vehicles, perhaps better, due to their higher utilisation. As battery technology continues to improve, further reducing battery costs and charging times, the challenges would be increasingly be limited to only the heaviest of trucks (greater than 30t gross vehicle mass) in long-haul service. These trucks typically operate near their legal load or size limits, and may need to reduce payload to accommodate batteries, making the economics of electrification less attractive.</p> <p>Cost projections suggest that by around the early 2020s, new medium battery electric trucks would be cheaper on a lifetime total cost basis than diesel trucks. By about 2030 even new heavy trucks would typically be cheaper on a lifetime total cost of ownership basis than diesel trucks.<sup>54</sup></p> <p>Battery electric buses are already beginning to roll out in Aotearoa. There are over 30 electric buses currently in service, with another 50 entering the fleet over the next year.<sup>55, 56, 57, 58</sup> New battery electric buses are expected to have a lifetime total cost of ownership lower than diesel buses by the late 2020s.</p>

<sup>53</sup> (LEVC, UK, 2018)

<sup>54</sup> Climate Change Commission, ENZ model

<sup>55</sup> (Auckland Transport, 2018)

<sup>56</sup> (Bay of Plenty Regional Council, 2019)

<sup>57</sup> (Greater Wellington Regional Council, 2019)

<sup>58</sup> (Environment Canterbury Regional Council, 2018)

	<p>Carbon dioxide emissions from public transport buses were estimated at approximately 0.12 Mt in 2017/18.<sup>59</sup> Lifecycle analysis undertaken for Auckland Transport estimated that battery electric buses deliver 72% fewer greenhouse gas emissions compared to conventional buses.<sup>60</sup></p> <p>Electrifying public transport buses has significant co-benefits in urban areas because diesel fuelled public transport contributes significantly to air quality problems where many people are exposed to this pollution.</p>
<p><b>Biofuels for trucks and buses</b></p>	<p>Biofuels offer the opportunity to reduce emissions in our current heavy vehicle fleet or for transport options that are hard to electrify. Biofuels can be blended with conventional petrol and diesel or be a 100% substitute, potentially reducing all emissions.</p> <p>The emissions reductions that can be achieved with the use of biofuels are highly specific to the feedstock, how its grown/recovered (for example whether irrigation is needed, whether it is a waste or by-product), how it is transported and processed, how much carbon dioxide is associated with the energy used in these stages and any impacts on land use changes to grow feedstocks. The “carbon intensity” (the combination of the things listed above) varies from 20% to 80%.</p> <p>In reality the emissions reduction potential in trucks and buses is likely to be split between electrification, biofuels and hydrogen. There are limitations with regards to biofuels, such as limits on the current engine technology to accept high biofuel blends, and the available supply of bioenergy and competing uses in the energy sector. The potential emissions reductions from biofuel are therefore likely to be in the range of between 20 and 50%.</p> <p>There are three main types of liquid biofuels used in the transport sector as a partial or full substitute for fossil fuels:</p> <ul style="list-style-type: none"> <li>• Conventional or “first generation” biofuels made with well-established technologies from a limited range of wastes and crops: biodiesel made from animal fats and vegetable oils, which is typically blended with diesel fuel; and ethanol from sugars and starches, which is typically blended with petrol.</li> <li>• “Second generation” biofuels made from non-conventional, but potentially more widely available feedstocks: ethanol from cellulose found in wood and grasses; and biodiesel from algae. First- and second-generation biofuels can be used in vehicles that are designed to handle them and may be suitable for use in many other vehicles when blended with fossil fuel.</li> <li>• Synthetic renewable fuels include synthetic jet fuel, diesel, and petrol made using advanced processing techniques from a variety of feedstocks including wood, other crops and waste. Unlike the first- and second-</li> </ul>

<sup>59</sup> (Waka Kotahi (NZ Transport Agency), 2020)

<sup>60</sup> (Auckland Transport, 2018)

generation biofuels, these fuels are chemically identical to their fossil fuel equivalents. They are, therefore, often referred to as 'drop-in' fuels, since they can be freely used in any conventional vehicle.

The cost of first- and second-generation biofuels can vary greatly depending on the feedstock used, however are generally more expensive than fossil fuel. The cheapest feedstocks, such as various waste products, tend to be available in limited quantities. Biofuels are internationally traded, much like petroleum products, so their price will fluctuate with supply and demand shifts in other parts of the world. There is potential for biofuels to be an export product as well as a domestic emission reduction

Since synthetic renewable fuels are a chemically identical substitute for fossil fuels in any vehicle, they provide a solution that could work for types of transport that will be difficult to electrify or otherwise reduce in the foreseeable future. The synthetic renewable fuels tend to be expensive, with estimates of their wholesale, pre-tax cost in 2030 at about \$1.20 per litre.<sup>61</sup> This compares to about \$0.70 per litre for fossil fuel at US\$50 per barrel, which would work out to a cost of emissions reduction of over \$400/tonne CO<sub>2</sub>e.

For the consumer and the supplier, the additional cost of biofuels acts as a disincentive for increased use. For the producer, the profitability of making biofuel depends primarily on the price difference between the international price of biofuel feedstocks and the international oil price. Introducing biofuels at a commercial scale would require all parts of the value chain, from feedstock production to blending and distribution, to act in a coordinated way, and be profitable at each stage.

Increasing domestic production of biofuels (either conventional or advanced) would require large quantities of feedstock and increased commercial scale production facilities. Work is ongoing across government to confirm what feedstocks are feasible and where they could be grown to achieve this without displacing food production.<sup>62</sup>

A 2018 Scion report, '*New Zealand Biofuels Roadmap Summary Report*', concluded that credible large-scale biofuel production and use routes exist for Aotearoa based on sustainably produced feedstocks. The report also concluded that biofuels could provide transport fuel independence for Aotearoa. However, it found that the market alone would not bring about a biofueled future for Aotearoa.

Unlike many countries, such as in Europe or the UK, Aotearoa does not have any specific policies requiring or supporting the use of biofuels. An emissions price under the Emissions Trading Scheme would need to be very high since the current emissions price is a small component of fuel prices (compared to the total costs of importing and distributing fuel and the total taxes on fuel). The

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<sup>61</sup> (Concept Consulting, 2020)

<sup>62</sup> (Ministry of Transport, 2020a)

	<p>Productivity Commission has suggested that even with a significant increase to the emissions price, additional measures would be needed to achieve large emissions reductions from transport. This is because transport fuel is a relatively inelastic product, which means that changes in price have little influence on demand.<sup>63</sup></p>
<p><b>Hydrogen trucks and buses</b></p>	<p>Hydrogen can be used to power a wide range of vehicles and may be particularly valuable for areas of transport that would be hard to electrify, such as large, long distance trucks and inter-city buses. Green hydrogen used in trucks and buses, in particular, is an emerging solution.</p> <p>Trucks over 30 tonnes gross vehicle mass, which are the ones that are typically close to legal weight or size limits, accounted for approximately 1.4 Mt CO<sub>2</sub>e of the roughly 3.7 Mt CO<sub>2</sub>e of medium and large truck emissions in 2018. These are the vehicles that could be replaced by hydrogen trucks (or other alternatives such as shifting more freight to rail, biodiesel, a battery-swapping system, or more advanced battery technology).</p> <p>We have focused on green hydrogen because Aotearoa has the potential for a long-term green hydrogen economy through its abundance of renewable energy, water, infrastructure potential, and highly skilled workforce.<sup>64</sup> Blue hydrogen could be used in the transition to a zero carbon economy. However, its reliance on carbon intensive gas supplies and carbon capture and storage (CCS) technology mean it may not be an appropriate long-term solution for climate change action in Aotearoa.</p> <p>Māori have indicated they would like opportunities, build capacity, and develop people through education.<sup>65</sup> One Māori business is leading the charge when it comes to hydrogen energy in Aotearoa.<sup>66</sup> In a world-first with Japan, the Aotearoa government in cooperation with the government of Japan in October aims to foster the development of hydrogen technology between the two countries. Tuaropaki Trust in conjunction with Obayashi Corporation of Japan is contributing to a global quest to remove a reliance upon fossil fuels and creating a lower carbon economy.</p> <p>In fuel cell electric vehicles, hydrogen is stored in fuel tanks under pressure. Hydrogen is converted to electricity in the fuel cell, then the electricity is used to drive an electric motor. Due to the conversion losses involved in making hydrogen from electricity, and then converting the hydrogen back to electricity on the vehicle, nearly three times the amount of energy is required to power a truck with green hydrogen compared to a battery electric truck.</p> <p>Therefore, batteries are usually more efficient at powering vehicles except in cases where the use of batteries is not practical. The most likely road vehicles</p>

<sup>63</sup> (New Zealand Productivity Commission, 2018)

<sup>64</sup> (Venture Taranaki, 2018)

<sup>65</sup> (Ministry for the Environment, 2007)

<sup>66</sup> (Tuaropaki Trust, 2017)

	<p>where use of batteries may not be practical are generally trucks that travel long-distances with heavy loads, or off-road machinery or vehicles, which would be difficult to power with existing battery technology. The limitations of battery trucks are especially critical for trucks that are so large that they are near the legal weight or size limits, which means any additional batteries carried would reduce the amount of payload the truck can carry.</p> <p>The supply of green hydrogen is current limited, though Aotearoa has abundant renewable electricity available to make it. Work is underway across the private sector to build hydrogen plants and develop a refuelling network.<sup>67</sup></p> <p>Green hydrogen would need to become more cost competitive with both fossil fuels and battery electric vehicles. Costs are uncertain, but recent analysis suggests the marginal cost of emissions reduction of green hydrogen in 2030 as \$425 per tonne CO<sub>2</sub>-e. For comparison, the marginal cost of emissions reduction of other heavy truck emissions reduction options were estimated as \$109tCO<sub>2</sub>-e for battery electric trucks<sup>68</sup> and \$190 tCO<sub>2</sub>-e for drop-in biofuels.<sup>69,70</sup></p> <p>Adopting hydrogen at scale would require innovation along the value chain, scaling technologies, significantly reducing costs, deploying enabling infrastructure and defining appropriate national and international policies and market structures.<sup>71</sup></p>
<b>Aviation</b>	<p>Domestic air travel makes up approximately 1.1 Mt of transport emissions in 2018.</p> <p>Early actions to help reducing emissions in air travel includes improvement on airspace operations and infrastructure efficiency with collaborations between airlines, airports and air traffic management.<sup>72</sup> These initiatives have the potential to achieve up to 10% improvement in fuel efficiency.<sup>73</sup></p> <p>Low emissions options for air travel are emerging, with some adoption possible in the next 10 years, but widespread deployment likely to be at least 15 years away.</p> <p>Small electric aircraft are currently in experimental operation, but the limiting factors preventing more widescale electrification of the sector are the weight and energy storage capacity of the batteries. Electric aircraft are, therefore, likely to be limited to short-haul flights for the foreseeable future.</p> <p>Regional air services operated by battery electric aircraft are anticipated to be operating by 2030. Such services would be able to cover routes up to 650 km,</p>

<sup>67</sup> (Ministry of Transport, 2020a)

<sup>68</sup> Assuming that battery electric trucks: 50% top-up charge during the day, for trucks that charge fully overnight the abatement cost is -\$40 per tonne CO<sub>2</sub>-e

<sup>69</sup> Assuming delivered costs of logs to biorefinery = NZ\$80 per tonne. Resulting cost of fuel = \$30.4/GJ.

<sup>70</sup> (Ministry for the Environment, 2020b)

<sup>71</sup> (Pflugmann & De Blasio, 2020)

<sup>72</sup> (Kharina, Rutherford, Zeinali, 2016)

<sup>73</sup> (ICAO State Action Plan for CO<sub>2</sub> Emissions Reduction - Germany, 2018)

	<p>which would allow some commercial domestic flights to be electrified. By 2040, electric aircraft could be able to service routes up to 1,200 km. This would allow a greater amount of domestic aviation to be electric.<sup>74</sup></p> <p>Sounds Air, a small regional airline focused on short flights across the Cook Strait, recently signed a letter of intent to purchase electric aircraft with the Swedish company Heart Aerospace. Heart is aiming to manufacture 19-seat aircraft for commercial flights in 2026.<sup>75</sup></p> <p>For long haul flights (both domestic and international) sustainable aviation fuel (SAF) is likely to provide the biggest opportunity to reduce emissions, or e-Fuel. Sustainable aviation fuels use feedstocks such as agricultural residues, woody biomass, municipal waste and waste gases that can be continually and repeatedly resourced in a manner by avoiding depletion of natural resources.<sup>76</sup> The process for producing SAF is also likely to produce sustainable biofuel to be used in the wider transport system.</p> <p>Electrofuels, or e-fuels, are liquid fuels which could be made from hydrogen and captured carbon dioxide. They can be used in internal combustion engine vehicles and are another possibility in the future.</p> <p>The use of sustainable aviation fuels is currently minimal. Currently, there is no commercially viable SAF supply in Aotearoa. In offshore ports where SAF is being produced, it has been supported to market by public funding and policy.<sup>77</sup></p> <p>However, business initiatives have begun in Aotearoa. Air New Zealand, Z Energy, Refining NZ, SCION and Auckland International Airport have set up a joint initiative to investigate how they could transition aviation fuel into domestically produced biofuels.<sup>78</sup></p> <p>There may also be a reduction in business travel as a result of increased use of digital meetings, however the extent of this is currently unknown.</p>
<b>Shipping</b>	<p>In 2018, emissions from coastal shipping contributes to 230 kt CO<sub>2</sub>e. Domestic shipping moved about 13% of the total freight tonne per kilometre.<sup>79</sup></p> <p>A study by Waka Kotahi on comparative costs, fuel consumption and carbon emissions for freight transporting shows both shipping and rail were lower carbon dioxide emissions than road transport.<sup>80</sup> This suggests there is the potential to further reduce emissions by shifting freight from roads to shipping.</p>

<sup>74</sup> (Daswani, Armitage, Boscarol, et al, 2019)

<sup>75</sup> The airline's board chair and director, Rhyan Wardman, states that the electric planes will not cost a lot more than the usual ones for the airline. They have a 400 nautical mile range, and take only about 20-40 minutes to recharge (RNZ, 2020).

<sup>76</sup> (Air Transport Action Group, 2020)

<sup>77</sup> (Smit & Stevenson, 2020)

<sup>78</sup> (*Sustainability Report*, 2019)

<sup>79</sup> (Ministry of Transport, 2014)

<sup>80</sup> (Cenek, Kean, Kvatch, Jamieson, 2012)

	<p>The primary options to reduce emissions from coastal shipping itself are:</p> <ul style="list-style-type: none"> <li>• Manage the performance of existing vessels</li> <li>• Improve the fuel efficiency of new vessels entering the fleet</li> <li>• Switch from bunker fuel to lower carbon emission fuels, such as biofuels, ammonia, hybrid or battery electricity.</li> </ul> <p>According to the International Energy Agency (IEA), ship efficiency, in terms of energy tonne/km, has been improving globally at around 1.6% per year over the period between 2000 and 2017.<sup>81</sup> This improvement can be used as a proxy for global improvement in coastal shipping. In Aotearoa, where there are currently only 12 vessels providing a domestic shipping service, and the entire fleet typically sees a single vessel replacement only every few years, the rate of improvement will be uneven. In addition, there have been some recent additions to the domestic fleet which have had poorer than global average emissions ratings.</p> <p>Two replacement vessels to be used for the Interislander’s Cook Strait service are currently being sought. Kiwirail has stated the vessels will have “the latest propulsion systems, and able to run on battery power at times. KiwiRail is also future proofing the design so new fuel sources can be adopted as they become available.”<sup>82</sup></p> <p>The new vessels are expected to be in service from 2024 and 2025 and will replace the three existing ferries and will be able to carry three times as many rail wagons and almost double the number of trucks.</p> <p>Aotearoa has recently announced it will sign up to the International Maritime Organisation MARPOL Annex VI from late 2021, which could lead to several positive benefits including reducing carbon dioxide emissions and improving air quality around ports and harbours.<sup>83</sup></p> <p>Aotearoa does not have a large dry-dock facility so the opportunity for retrofit technologies on coastal ships, including relatively simple GHG emission reduction activities such as hull cleaning and application of hull coatings, requires vessels to make a voyage to suitable facilities in Singapore or Sydney. There is additional expense, vessel downtime and emissions from fuel consumption for the international voyage.<sup>84</sup></p>
<b>Rail</b>	<p>Rail accounted for 0.12 Mt of transport emissions in 2018. Large parts of our rail network already run on electricity via overhead wires. Electrification of additional freight lines, in combination with battery electric or green hydrogen trains on other lines today would eliminate direct CO<sub>2</sub> emissions from rail and</p>

<sup>81</sup> (International Energy Agency, 2020)

<sup>82</sup> (KiwiRail, 2020)

<sup>83</sup> (Ministry of Transport, 2019b)

<sup>84</sup> (New Zealand Shipping Federation, 2020)

	<p>reduce emissions by 0.1 Mt CO<sub>2</sub>. A shift of freight from road to rail could provide further emissions reduction potential.</p> <p>The majority of the North Island Main Trunk (NIMT), between Te Rapa (north of Hamilton) and Palmerston North is already electrified (412 km).<sup>85</sup> The main trunk lines on the North Island could be fully electrified by filling the remaining non-electrified gaps between Auckland and Wellington, as well as electrifying the East Coast Main Trunk (ECMT) between Mount Maunganui (Bay of Plenty) and Hamilton.</p> <p>Kiwirail estimates a cost of \$2.5 million per km to electrify track.<sup>86 87</sup> Due to the cost involved, railway electrification can generally only be justified on high volume routes.<sup>88</sup></p> <p>For non-electrified lines, battery electric locomotives could be an option in our second and third Budget periods as this is at the early deployment and demonstration technology stage. One hundred percent battery-electric road locomotive prototypes are being developed that work with conventional diesel locomotives to make a battery-electric hybrid consist. (Consist refers to when two or more locomotives are coupled together.)<sup>89</sup> The Ministry for the Environment Marginal Abatement Cost Curve (MACC) analysis estimated that battery electric locomotives, with batteries sized to enable recharging overnight, are likely to have a negative carbon cost by 2030 (i.e. they would cost less than diesel) based on a battery cost of US\$140/kWh.</p> <p>In addition to the potential for emissions reduction, there are wider benefits to rail electrification. These include improved freight logistics (eliminating the need to swap between diesel and electric locomotives), reduced fuel costs, higher speeds, and better acceleration.</p>
<p><b>Shift freight from road to rail and coastal shipping</b></p>	<p>Shifting freight from roads and onto rail or coastal shipping could provide further emission reductions. In 2019, approximately 16% of the total amount of freight moved around Aotearoa was hauled by rail, and accounts for about 21% of freight shifted between regions.<sup>90</sup> Every tonne of freight moved by rail produces around 70% less carbon dioxide emissions compared with current long-haul trucks, although the exact emissions reduction potential and costs will vary.</p> <p>However, there are also some challenges, including that a lot of freight in Aotearoa moves over short distances, and not all locations have access to rail/coastal shipping. Many sectors are driven by “just-in-time”, or “delivery on</p>

<sup>85</sup> The North Island Main Trunk is the main railway line in the North Island connecting Wellington and Auckland and is 682 kilometres long.

<sup>86</sup> (The Treasury, 2016)

<sup>87</sup> (International Energy Agency, 2019)

<sup>88</sup> In addition to the potential for emissions reduction, there are wider benefits to rail electrification. These include improved freight logistics (eliminating the need to swap between diesel and electric locomotives), reduced fuel costs, higher speeds, and better acceleration.

<sup>89</sup> (BNSF, 2019)

<sup>90</sup> (Ministry of Transport, 2014)

	<p>demand” business models, so goods need to be delivered quickly and very reliably (such as perishable goods). These models limit the ability to shift travel type as they prioritise timeliness and reliability over other objectives and are most likely to be carried by electric trucks in the future.</p> <p>The additional handling and cost of shifting freight from trucks to rail can be also prohibitive where distances are short. Rail and coastal shipping would need to offer freight operators more reliable services than road to make a significant impact on road freight volumes.</p>
<p><b>Use of low carbon fuels for off-road vehicles and heavy machinery</b></p>	<p>Gross emissions from the combustion of fossil fuel for the agricultural, mining and construction sectors who typically use diesel fuel for trucks, diggers, tractors, loaders, and other heavy vehicles used for earthworks, off-road transport and transportation totalled about 2 Mt in 2018.<sup>91</sup> Electrification will generally be an applicable low emission alternative for this activity however there may be some particular use for which it is not suited, and low carbon fuels may be more appropriate.</p> <p>Available electric versions of off-road vehicles are considerably more expensive than internal combustion engine versions currently. Vehicle production costs need to fall considerably in order to be cost competitive to produce and own. However, energy and maintenance costs may mean that electrified options can compete on a total cost of ownership basis.</p> <p>Farmers, contractors and others in rural communities need vehicles that can carry heavy loads or access rugged or remote locations, such as a single or double-cab ute. Farm bikes and quad bikes are also an essential part of farming and rural landscapes. For these needs, there are cost-effective solutions available now, or will be in the next few years.</p> <p>Ford have scheduled fully electric versions of their F-150 pick-up and Transit van by 2022,<sup>90</sup> and fully electric utes from other manufacturers are expected to be available in the Aotearoa within the decade. Similarly, there are electric 2- and 4-wheeled motorbikes available in Aotearoa now, including the locally designed and manufactured UBCO farm bike.</p> <p>The mining, construction and agriculture sectors encompass a broad range of activities and currently there is generally not a commercially available vehicle alternative. However, there are niche examples of electrified heavy trucks which are already in use internationally<sup>92</sup>. Electric mining trucks have further advantages in underground mining operations as they reduce the requirement for energy for ventilation.</p>

<sup>91</sup> (Ministry for the Environment, 2020c)

<sup>92</sup> (Boilden Aitik, 2020)

## 4b.2 Urban form

Transport emissions and urban form are closely inter-linked. In particular, low-density residential development – urban sprawl – is associated with higher transport emissions. Cities with a low average population density are more spread out and their economic hubs (employment, education facilities, residences, shopping centres) are located farther from each other. The resulting longer travel distances make walking and cycling less attractive, and the follow-on less concentrated travel demand is difficult to serve with convenient public transport. Hence, transport demand in such cities is likely to be met by privately-owned passenger cars. This results in relatively high per capita vehicle kilometres and emissions.

Around 85% of New Zealanders live in urban areas with populations greater than 50,000.<sup>93</sup> As a result, much of the country's transport emissions occur within these urban areas. Cities can 'grow up' or 'grow out'. Historically, cities in Aotearoa have had a tendency to grow out, resulting in growth at the urban boundary rather than the urban centre.<sup>94</sup> The result has been sprawling car-oriented cities in the style typical of Australia or North America, rather than the more compact transit-, cycling-, and pedestrian-oriented cities typical of Europe and many parts of Asia. Outward growth can also have other effects, such as the loss of agricultural land, and push up the price of food.<sup>95</sup>

Shifting toward more compact urban design could therefore, be a key long-term goal of urban planning. According to a report by the Intergovernmental Panel on Climate Change (IPCC)<sup>96</sup>:

*“Urban planning that decreases the need for carbon-intensive transportation in the long term – such as compact, pedestrianised cities and towns – plays an important role in limiting future emissions. Such planning, coupled with policies that encourage improve fuel efficiency; zero emission vehicles; and model shifts toward walking, cycling, public transport, and shorter commute distances, is key to decarbonisation.”*

As the quotation highlights, higher density is not the only aspect of urban planning that influences emissions. Density needs to be coupled with quality infrastructure for walking, cycling, and public transport, as well as street designs that make walking and cycling safe and pleasant.

There are numerous studies examining the emissions reduction potential from compact urban planning and design. For example, the Productivity Commission notes that higher density urban centres can reduce vehicle kilometres travelled per capita by between 5 and 12%.<sup>97</sup> A study by the Stockholm Environment Institute highlights that urban planning for compact urban form can reduce emissions by 5% by 2030 and 6% by 2050.<sup>98</sup> However, the potential to achieve emissions from land use change is slow, buildings typically last between 50-100 years and infrastructure lasts for at least 100 years. Therefore, we need to ensure a stronger and more deliberate relationship between urban planning, design and transport immediately. Ensuring this happens at planning stage is more effective than retrofitting transport needs.

Evidence from both the New Zealand Census and Household Travel Survey demonstrates that residents of higher density, centrally located areas have significantly lower emissions from transport

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<sup>93</sup> (New Zealand Productivity Commission, 2018, p. 493)

<sup>94</sup> (Productivity Commission, 2017, p. 80)

<sup>95</sup> (Deloitte, 2018)

<sup>96</sup> (IPCC, 2018)

<sup>97</sup> (New Zealand Productivity Commission, 2018, p. 493)

<sup>98</sup> (Stockholm Environment Institute, 2014)

than residents of lower density, less central areas. Census data shows that residents of higher density areas have lower car ownership rates, have shorter commutes (in research examining Wellington), and are less likely to commute via car. New Zealand Household Travel Survey data also shows that residents of denser areas have lower overall vehicle kilometres, and thus lower carbon dioxide emissions.<sup>99</sup>

Reducing emissions is just one of the reasons Aotearoa could be moving toward the compact urban design principles outlined here. A report by the Public Health Advisory Committee of the Ministry of Health pointed out that:

*“If designed appropriately, urban form and transport can increase physical activity, improve air quality, reduce road traffic injuries, increase social cohesion, and achieve maximum health benefits from services and facilities. Urban form can also help create a sense of place. This is important for the health and wellbeing of all populations living in urban areas, especially Maori”.*<sup>100</sup>

Many parts of Tāmaki Makaurau and other major urban centres, where largely lower socio-economic groups live, have been under invested in for decades in terms of transport amenity. To prioritise investment into public transport in areas of high social deprivation would benefit low emission economy targets. Prioritising areas such as South Auckland and West Auckland would reduce carbon and be beneficial for social and health purposes.

In short, a shift toward compact urban design can offer both lower emissions and a higher quality of life.

### 4b.3 Buildings

Buildings are associated with two different sources of emissions: 1) on-site combustion of fossil fuels and electricity use to operate the building<sup>101</sup> and 2) the emissions associated with the materials and energy involved in construction.

Emissions from the on-site combustion of fossil fuels accounted for 1.5 Mt CO<sub>2</sub>, or 2% of our gross emissions in 2018.<sup>102</sup> These emissions stem primarily from fossil fuel use to heat spaces, provide hot water and to cook. In non-residential buildings, such as hospitals, cleaning and sterilising equipment are additional uses of energy.

Buildings range in size and purpose, including single detached homes to warehouses to high-rise commercial towers to health care facilities. Direct emissions associated with on-site fossil fuel use from buildings are linked to the total number of buildings in Aotearoa. The number of buildings in Aotearoa has been slowly increasing as our population size grows and economic activity increases. However, these direct emissions have remained stable over time due to increasing energy efficiency, an increasingly renewable electricity system, increased consumer awareness, and higher building standards.

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<sup>99</sup> (Chapman & Dodge, 2016)

<sup>100</sup> (Public Health Advisory Committee, 2010)

<sup>101</sup> Lighting is powered from electricity which contributes to indirect electricity emissions rather than direct on-site fuel combustion emissions. Electricity emissions are not attributed to buildings in the inventory. The Commission’s analysis addresses electricity emissions at the point of generation rather than at the end user.

<sup>102</sup> When indirect electricity generation emissions are attributed to buildings based on energy demand and energy end use data from the Ministry of Business, Innovation and Employment (MBIE), this increases to 5%.

Buildings are also significant electricity users and at times influence the amount of fossil fuel generation in the electricity system. For example, residential buildings are often a driver of periods of peak demand (cold winter nights) and this peak is often met by coal or gas generation.

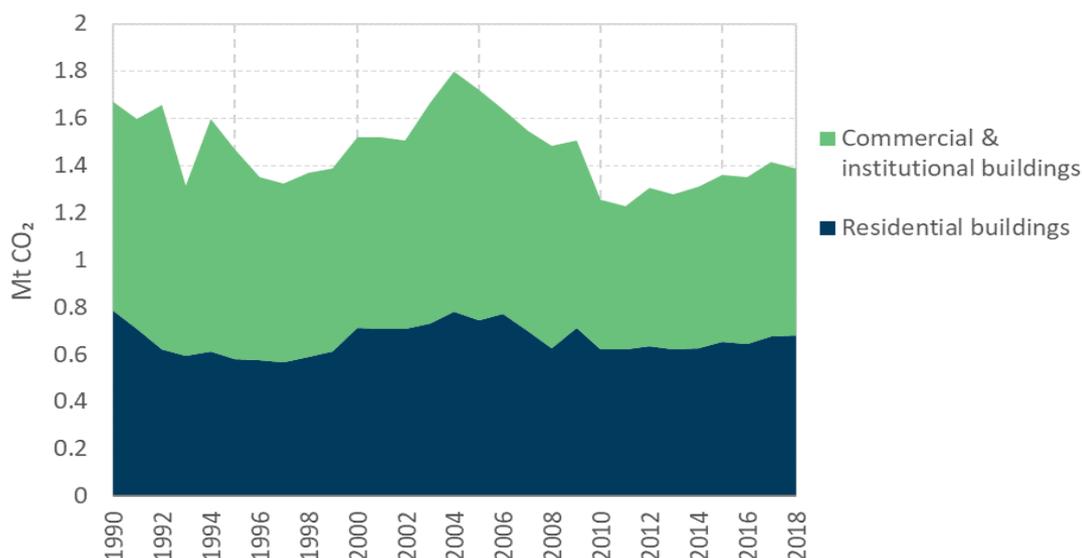


Figure 4b.3: Emissions from on-site fossil fuel use in buildings, 1990-2018<sup>103</sup>

There are also emissions associated with the production of construction materials, construction and renovation, and demolition over the lifecycle of a building. The emissions associated with building materials are partially accounted for under *Chapter 4a: Reducing emissions – opportunities and challenges across sectors: Heat, Industry and power*, for example, in the manufacture of steel, cement and wood products. Industrial production activity and related emissions from the manufacture of materials is influenced by domestic and international demand for them in the construction sector. Note that the construction sector encompasses other infrastructure such as roads and bridges and is not exclusive to buildings.

While emissions from operational energy use in buildings account for a relatively small proportion of gross emissions, they are long-lived assets so the type of fuel we use and when we use it are important factors when considering emissions from buildings. For example, many of the residential buildings that exist today will exist in 2035 and 2050. Consideration of materials and functionality during building design can contribute to emissions reduction as well as other benefits such as building warmth, safety and occupant well-being.

#### 4b.3.1 Options for reducing emissions

This section outlines the opportunities and challenges related to options for emissions reduction in buildings. Overall, the evidence summarised below shows that continued efforts to improve energy efficiency are important to reduce emissions while providing co-benefits related to occupant health and well-being. While energy efficiency measures are commercially mature and widely available, further opportunities exist and have not been adopted for a myriad of reasons.

<sup>103</sup> (Climate Change Commission ENZ Model results, 2020)

The greatest opportunity for emissions reduction across our building inventory is fuel switching from coal or natural gas boiler systems to low emissions alternatives like biomass and electricity. Deterring investment in fossil fuel fired assets and new connections to the natural gas grid during new build design are important opportunities to prevent emissions lock-in from long-lived assets. In existing buildings, stronger government direction and support along with strengthened requirements under the Building Code would be needed to transition away from fossil fuels for space and water heating, and to improve the thermal envelope.

Emissions reduction opportunities related to improved energy efficiency and a transition away from fossil fuel heating can potentially also support iwi/Māori aspirations for affordable, warm and dry housing. This would have health co-benefits including reduced time away from school due to illness and lower heating costs. These health co-benefits could be realized across Aotearoa. Some whānau are collaborating in papakāinga housing developments<sup>104</sup> which can serve as a model for community housing.

For example, some papakāinga designs incorporate communal kitchen and washing facilities and are built using local natural materials. This can reduce the energy and emissions associated with the manufacture and transport of building materials to site. Whare uku<sup>105</sup> are a cement, earth and fibre mix that might be an emissions reduction opportunity for buildings. Whare uku utilise mostly locally available materials. These materials provide additional benefits related to building insulation, durability, ease of construction, and cost-effectiveness. It draws on traditional iwi/Māori knowledge, with similarities to maioro (fortifications) in pā construction.

In addition to consumer choices regarding energy and technology use, the construction sector has a role to play during the design and construction of a building. Designing resilient, high-performance buildings and choosing materials that are lower emissions and/or produced with waste minimisation principles can help reduce emissions over the life of the building. This can be supported through ongoing and planned improvements to the Building Code and New Zealand Standards.<sup>106</sup>

As our country’s population continues to grow, the choices around how buildings are designed, built, and used, and where they are located, will influence overall emissions.

*Table 4b.3: Opportunities and challenges for reducing building emissions*

Option	Opportunities and Challenges
<b>Materials &amp; construction</b>	<p>Embodied carbon accounts for greenhouse gas emissions that are generated throughout the supply chain of a material, generally from raw material extraction to demolition (cradle to grave).</p> <p>Reducing demand for emissions intensive construction materials can be achieved through design choices, selecting lower carbon dioxide alternatives or optimising material manufacturing. For example, precision design and manufacturing to optimise steel framing can add strength where required and remove material or thin it out where additional strength is not required. Precision manufacturing and prefabricated building components may help</p>

<sup>104</sup> (Te Puni Kōkiri, 2017)

<sup>105</sup> (Morgan, 2012)

<sup>106</sup> MBIE has a significant programme of work to reform the buildings and regulatory system and building and construction sector, and ensuring all buildings are safe, healthy and durable.

	<p>reduce emissions and waste over the lifecycle of a building through improved resource efficiency.</p> <p>In some cases, using wood-based products could remove CO<sub>2</sub> from the atmosphere and store it for the life of the building. Negative embodied carbon means that carbon dioxide sequestered during the growth of trees for building materials may be greater than the emissions produced during their manufacture. For example, the embodied carbon for structural steel columns and beams is 2.85 kg CO<sub>2</sub>e per kg compared to -1kg CO<sub>2</sub>e per kg for glued laminated or cross laminated timber from sustainably managed forests.<sup>107</sup> As such, increasing the use of wood products in the built environment<sup>108</sup> can reduce emissions and provide long-term storage of carbon dioxide.</p> <p>Green construction capital cost estimates vary widely. One of the barriers to the adoption of better design choices and lower emissions materials is industry perception of a cost premium on the construction of high-performance, sustainable buildings built beyond the minimum Building Code requirements. There are also perceptions of risk towards using new materials and practices, individual preferences towards familiar technologies and materials, and limitations in the Building Code. Strengthening the Building Code and raising the minimum requirements is a critical opportunity to ensuring that buildings are resilient and durable to withstand current and future climatic conditions. However, there can be mismatches between those bearing the cost of low emissions technologies, materials and practices and those accruing the benefits. These costs may be passed on to building occupants or buyers which may impact affordability.</p> <p>For residential buildings, one study estimates additional capital costs ranging from less than 2% to nearly 20% for building beyond the minimum requirements under the Building Code, depending on the energy efficiency achieved and location. However, savings during the operation of the building usually offset the additional capital costs, resulting in net benefits for the occupants over time.<sup>109,110</sup></p> <p>The difference in construction costs also depends on whether the materials are produced domestically or imported, location, and whether the building was part of a volume build or a bespoke project. Costs will also be influenced by the extent to which prefabricated or modular components are used. Given the range of applications, it is difficult to determine the cost and emissions reduction potential of transitioning towards a more resource and materials efficient building stock.</p>
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<sup>107</sup> (BRANZ, 2020)

<sup>108</sup> The substitution of materials, for example, structural engineered wood products in place of steel, and resulting operational performance would be dependent on building design and use. The extent to which materials can be substituted would in part be determined by compliance with the Building Code and New Zealand Standards.

<sup>109</sup> (Bealing, 2020)

<sup>110</sup> (Sense Partners, 2018)

	<p><i>See also Chapter 4a: Reducing emissions – options and challenges across sectors: Heat, industry and power; Chapter 4d: Reducing emissions – options and challenges across sectors: Waste; and Chapter 5: Removing carbon from our atmosphere (Forestry section).</i></p>
<p><b>Operating (on-site use of fossil fuels and electricity use)</b></p>	<p>Emissions from fossil fuels used for heating of commercial and public buildings totalled 0.7 Mt CO<sub>2</sub> in 2018 of which 60% was from boiler systems.<sup>111</sup> In residential buildings, emissions from the combustion of gas for space and water heating was approximately 0.7 Mt CO<sub>2</sub><sup>112</sup>.</p> <p>Emissions from on-site fossil fuel use can be reduced through increased energy efficiency and fuel switching. For example, switching a building’s coal or natural gas heating system to biomass or electricity. The high energy efficiency that electric heat pumps provide, when properly sized and installed, is ideally suited for space heating applications where temperature requirements do not typically exceed 25°C. The energy efficiency of a heat pump will also be influenced by location, for example, whether the building is located in Christchurch or Hastings. Replacing a centralised boiler system with heat pumps can also enable separate buildings within a complex, such as a hospital, to operate individually and adjust heat outputs in response to seasonal variations, building occupancy, and changes in daily use. However, heat pump systems may not be compatible with some existing heat distribution systems in large buildings and retrofitting could increase project costs.</p> <p>Other options include heat recovery systems and improvements to the thermal envelope.<sup>113</sup> Improvements to the thermal envelope includes optimising insulation and window glazing, achieving passive heating and cooling, natural ventilation, and updating the building’s thermal control systems. Because buildings have a long operational life, efficiency gains can achieve significant long-term energy and emissions savings.</p> <p>There are significant remaining opportunities for energy efficiency and fuel switching in public buildings. These buildings include schools, health care facilities and other public sector buildings, many of which use coal fired boiler systems. In 2018, public buildings used approximately 0.3 petajoules (PJ) of coal, diesel or fuel oil in boiler systems to provide space and water heating.<sup>114</sup> A \$200 million Clean Powered Public Service Fund is supporting the transition of public buildings to low emissions alternatives. As of October 2020, 26 schools, seven hospitals, and four universities have been allocated a total of \$60 million to replace coal boilers, increase energy efficiency and improve the building</p>

<sup>111</sup> (Energy Efficiency and Conservation Authority, 2020)

<sup>112</sup> (Energy Efficiency and Conservation Authority, 2020)

<sup>113</sup> A building’s thermal envelope include the walls, windows, ceiling/roof and floor of a building. They are the critical components that separate the interior environment from the exterior environment, retain heat, and prevent the ingress of air, water, and moisture.

<sup>114</sup> (Energy Efficiency and Conservation Authority, 2020)

	<p>thermal envelope.<sup>115,116</sup> Recent Government commitment to a carbon neutral public service by 2025<sup>117</sup> is anticipated to accelerate action and will include, among other things, the phase out of all coal boilers, conversion of the government fleet to electric vehicles, and implementation of an energy efficiency building standard.</p> <p>Additionally, there are over 60,000 state homes in Aotearoa that will benefit from an announced \$500 million investment in upgrades and renewals. Improvements will include full insulation of the homes with wall, ceiling and floor insulation, double glazing, improved airtightness, ventilation and new heating to ensure a healthy indoor living environment.<sup>118</sup> A further 600,000 households who rent are expected to benefit from thermal envelope and energy efficiency improvements through the Healthy Homes Standard.</p> <p>While measures to reduce energy demand and emissions are commercially mature and widely available, further opportunities remain that have not been adopted. Tradespeople, property managers and building occupants can lack the capacity or expertise to obtain, understand and analyse the information and options available for their respective circumstances. For example, building developers or property managers may not be incentivised to reduce energy demand because they bear the costs of implementing technologies, but the tenant receives the benefits of lower energy costs and improved building comfort and safety. Additionally, the capital cost of the technology is often prioritised over its whole-of-life costs. The requirement for rapid payback periods on the upfront capital cost limits uptake of energy efficient technologies. Conversely, cost-benefit analysis and calculation of payback periods are not always undertaken.</p> <p>The emissions reduction cost of energy efficiency and fuel switching measures in buildings is highly variable. Costs would depend on the building's condition or age, layout, infrastructure (metering and cabling), and size of the equipment required. The rate of transition and transformation of energy use in buildings would also be dependent on availability of skilled expertise to undertake the work, alignment with natural capital replacement cycles to minimize risk of stranded assets, and availability and ability of low emissions technologies to meet the technical requirements of heating and cooling, particularly in high-rise commercial buildings.</p> <p><i>See also Chapter 4a: Reducing emissions – opportunities and challenges across sectors: Heat, industry and power (Electricity System section)</i></p>
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<sup>115</sup> (New Zealand Government, 2020b)

<sup>116</sup> (New Zealand Government, 2020c)

<sup>117</sup> (New Zealand Government, 2020d)

<sup>118</sup> (New Zealand Government, 2020a)

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