

Chapter 6: Reducing emissions from transport, buildings and urban form

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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. The interaction between where we live, learn and earn, and how we move between these places, also impacts on our emissions.

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

6.1 Transport

Transport emissions have been a major and growing contributor to our total greenhouse gas emissions. Between 1990 and 2019, domestic transport emissions have increased by about 90%. Transport currently contributes about 33% of long-lived greenhouse gases.¹

Transport has been the most rapidly increasing source of emissions. Out of the 48.6 MtCO₂e of gross long-lived greenhouse gases emissions Aotearoa produced in 2019, 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.²

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 6.1 shows how we categorise different types of vehicles in our report.

Table 6.1: Types of vehicles categorised in the Commission's 2021 report

Vehicle type	Description
Internal Combustion Engine Vehicle	Includes conventional hybrids , 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.
Electric Vehicle	An electric vehicle is a vehicle fully or partially powered by electricity from an external source. Battery electric vehicles are powered by batteries charged only from an external electricity source. Plug-in hybrid vehicles are powered by batteries charged from either an external electricity source or electricity produced on-board the vehicle by an internal combustion engine.
Light Vehicle	This is a vehicle with a fully-loaded weight less than 3,500kg. ³ Light vehicles include light passenger vehicles (most cars and SUVs), and light commercial vehicles (most vans and utes). The distinction between light passenger vehicles and light commercial vehicles is based on the body type of the

¹ All gases excluding biogenic methane.

² Off-road vehicles and equipment are covered in this chapter as the actions to reduce their emissions are like those for transport (such as electrification or use of low-carbon fuels); however, their emissions are categorised in Energy and Industry.

³ (Ministry of Transport, 2019a)

	vehicle, not the use of the vehicle. Many light commercial vehicles are used as household vehicles.
Medium Truck	As used here, a medium truck has a fully loaded weight greater than or equal to 3,500kg, but less than 30,000kg. This category includes ‘straight trucks’, typically used for local deliveries, and some tractor-trailer ‘big rigs’.
Heavy Truck	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’. Our 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 for medium trucks.

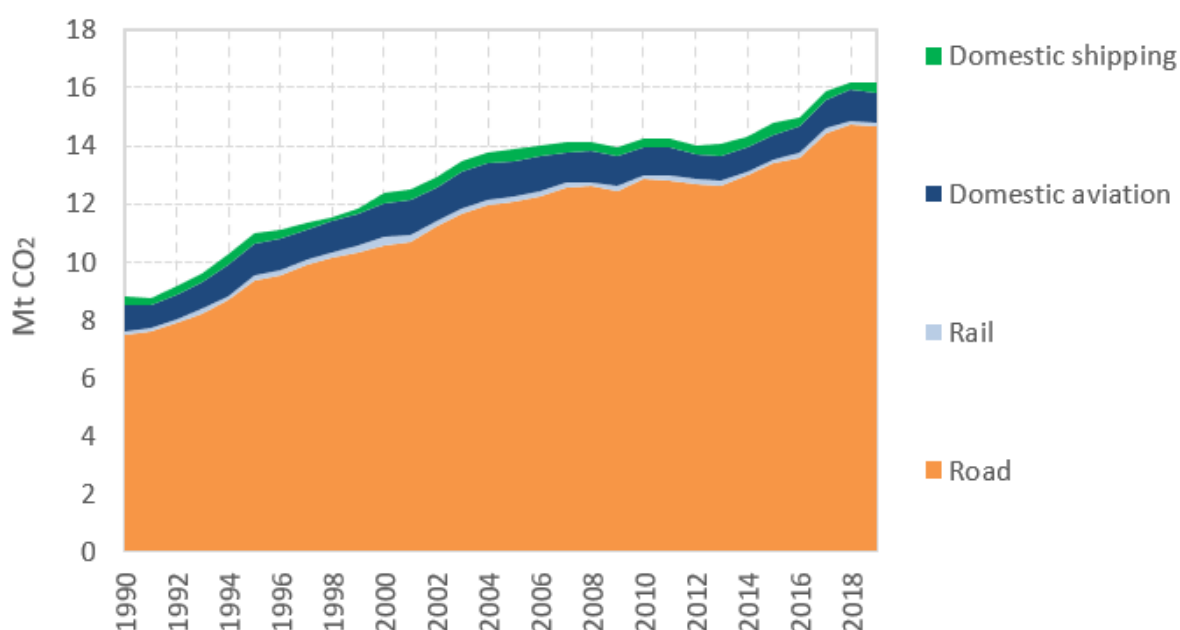


Figure 6.1: Transport Emissions by Type in Aotearoa⁴

Figure 6.1 above illustrates the dominance of road transport emissions – about 90% of all transport emissions. This has increased substantially since 1990. There are approximately 4.4 million vehicles in Aotearoa. This is projected to rise to 5.2 million vehicles by 2042/43.⁵ About 75% of this total is made of household vehicles.⁶

In 2019, 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 19%. Much of the growth in light vehicle emissions has come from light commercial vehicles, which have increased approximately 84% between 2000 and 2019. Motorcycles and scooters contribute only about 0.3% of road transport emissions. Figure 6.2 below shows the split of emissions by type of vehicle.⁷

⁴ (Ministry for the Environment, 2020a)

⁵ (Ministry of Transport, 2019c)

⁶ (Ministry of Transport, 2019c)

⁷ (Climate Change Commission ENZ Model results, 2020)

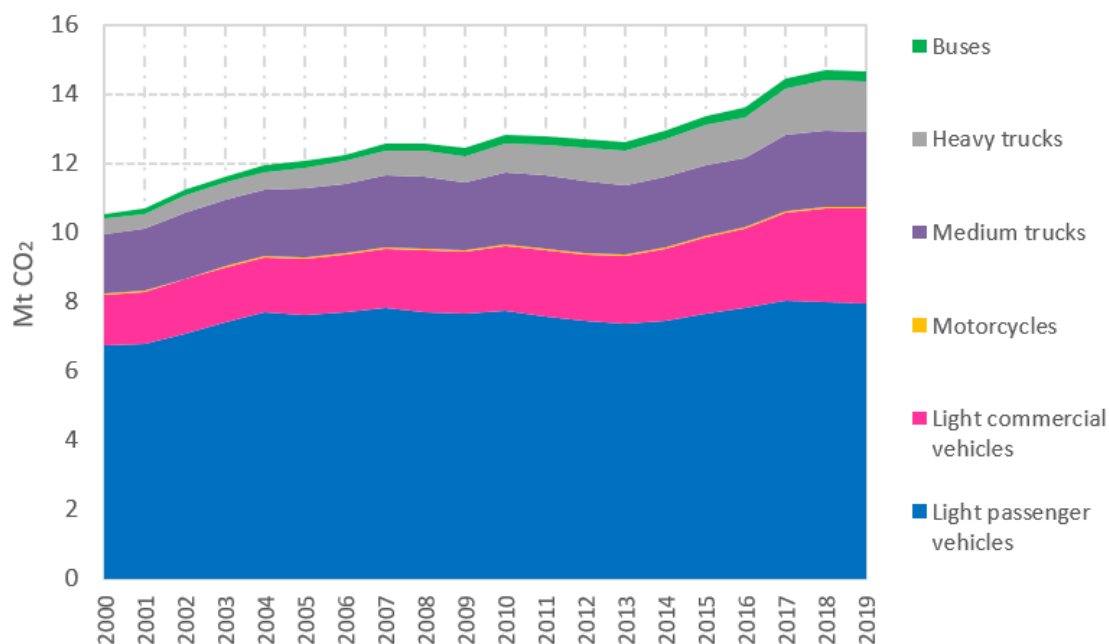


Figure 6.2: Road Transport Emissions by Type of Vehicle in Aotearoa (Mt CO₂)⁸

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 2019.⁹ The average truck age in Aotearoa increased significantly between 2005 and 2016 but has plateaued in recent years. In 2019, the average age was just under 18 years.¹⁰

Domestic aviation emissions make up 7% of transport emissions and have been relatively static since 1990.¹¹ 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. This means that the same number of passengers can be carried on fewer flights. It is anticipated that COVID-19 would have resulted in reductions of about 45% of aviation emissions in 2020, but Air New Zealand has predicted that air travel demand could return to 70% of its pre-COVID rate by August 2022.¹²

Rail and domestic shipping emissions together make up about 2% of transport emissions.¹³ Their low total emissions are partly because they account for a relatively small share of the freight that moves around Aotearoa,¹⁴ and partly because, on a per tonne/kilometre basis, they emit less than trucks.¹⁵

⁸ Source: Commission Analysis

⁹ (Climate Change Commission ENZ Model results, 2020)

¹⁰ (Ministry of Transport, 2019a)

¹¹ (Ministry for the Environment, 2020c)

¹² (Reuters, 2020)

¹³ (Ministry for the Environment, 2020c)

¹⁴ 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.

¹⁵ (Wang, 2019)

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 2018.¹⁶

Rates of vehicle ownership have also increased. There were 2.7 million vehicles in Aotearoa in 2001, by 2019 there were 4.4 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. For example, the average light passenger vehicle is driven until it is about 19 years old and this average is gradually increasing.¹⁷ 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 2018.¹⁸

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.¹⁹ 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 2,000cc or more increased from 35% in December 2001 to 46% in December 2018.²⁰ In 2019, eight of the top ten best-selling new vehicles in Aotearoa were utes or SUVs.²¹

While 84% 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 to access public transport.

6.1.1 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, public and 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 10-20 year horizon, including

¹⁶ (Ministry of Transport, 2020a)

¹⁷ (Ministry of Transport, 2019b)

¹⁸ (Ministry of Transport, 2019b, 2019c)

¹⁹ (TomTom, 2020)

²⁰ (Ministry of Transport, 2018)

²¹ (Automobile Association, 2020)

electrification. Where electrification is more difficult, for example with aviation, shipping and heavy transport, low-carbon fuels such as biofuel or hydrogen can play an important role.

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, is a simple way 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 that people find public transport, walking and cycling convenient, safe and enjoyable. There are also areas where 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 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 the most.

Table 6.2: Opportunities and challenges for reducing transport emissions

Option	Opportunities and challenges
Reducing travel	<p>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 CO₂ per year could be saved in commuter emissions if an additional 10% of people worked from home one day a week.²²</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.^{23,24}</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</p>

²² 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.

²³ 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.

²⁴ (Ministry of Transport, 2020b)

	<p>home environment. We estimate that about 10% more people would be able and willing to work from home.^{25,26}</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>In the longer term, land-use changes could mean that people live closer to places they need to go. This would contribute to travel reduction.</p>
<p>Transport mode shift to public transport</p>	<p>Shifting to public and shared travel modes has the potential to reduce carbon dioxide emissions from transport, particularly in urban areas. 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 include the design of our cities (characterised by low-density, dispersed and uncoordinated development), under investment in public transport and incentives to travel by car (where many of the true costs of car use, especially environmental effects and parking, are not considered).</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>Encouraging good quality, compact, mixed-use urban development would result in densities that can support rapid/frequent transit (and vice versa). Improving the quality, quantity and performance of public transport facilities and services would enable more people to use them. This can involve both optimising the existing system (for example, through reallocating road space), investment in new infrastructure and services, and providing better connections between travel modes.</p> <p>Additionally, as outlined in Part 4: What this could mean for New Zealanders, there are increasing examples of mobility as a service in smaller towns, as opposed to conventional public transport. ‘First and last kilometre transport solutions’²⁷ are also increasingly emerging, making it easier to access public transport.</p> <p>In lower-density suburban areas, demand responsive buses and shuttles (enabled by smart technology) may replace many scheduled bus services and routes. These could lead to better services for passengers, and a more efficient system. On-demand and shared services have the potential to increase public transport mode share by</p>

²⁵ 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.

²⁶ Climate Change Commission ENZ Model 2020 results based primarily on data from Ministry of Transport, Transport Outlook: Future State Vehicle Fleet Emissions Model

²⁷ 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 destination. This gap from public transit to destination is seen as a challenge to establishing a truly connected city.

	<p>providing a first/last leg connection to rapid and frequent public transport, and by replacing public transport routes where better access and value for money can be achieved by on-demand or shared services.²⁸</p> <p>The decarbonisation of public transport services, such as the electrification of buses, is addressed later in this chapter.</p>
<p>Transport mode shift to walking and cycling</p>	<p>Shifting to active travel modes, such as walking and cycling – and to a lesser extent micro-mobility, such as electric scooters or electric skateboards – has the potential to reduce carbon dioxide emissions from transport, particularly in urban areas. Active travel produces no carbon dioxide emissions (or close to zero for e-scooters and e-bikes).</p> <p>Cycling is a healthy way to travel medium-length distances. However, bikes mix poorly with pedestrians and vehicles, which means that specific infrastructure is needed to make cycling a high-quality option. Slower average speeds than motorised vehicles, exposure to the weather and required fitness levels limit cycling’s attractiveness for longer journeys.</p> <p>Electric bikes (e-bikes) can help overcome some of these challenges to traditional cycling as an alternative form of transport. They can increase the total distance and frequency of bicycle trips and promote longer individual cycle trips, compared to a conventional bicycle. Studies indicate that E-bikes can substitute for 23–72% of conventional bike journeys and 20%–86% of private cars journeys. However, the substitution effect of e-bikes (whether from cars to e-bikes or conventional bicycles to e-bikes) depends on multiple factors.²⁹</p> <p>Micro-mobility forms, such as e-scooters and e-skateboards, also provide opportunities to reduce emissions (and congestion) from short journeys. Given the recent advent of these technologies there are few studies that have quantified their emissions reduction potential.</p> <p>Walking is a healthy and congestion-free way of travelling shorter distances. It is free and does not require any specialist equipment or services. However, walking is slower than other transport modes, making it less attractive for longer journeys. Poorly designed streets and urban areas can also make walking unattractive or unsafe.</p>

²⁸ (Auckland Transport, 2019)

²⁹ (Bourne et al., 2020)

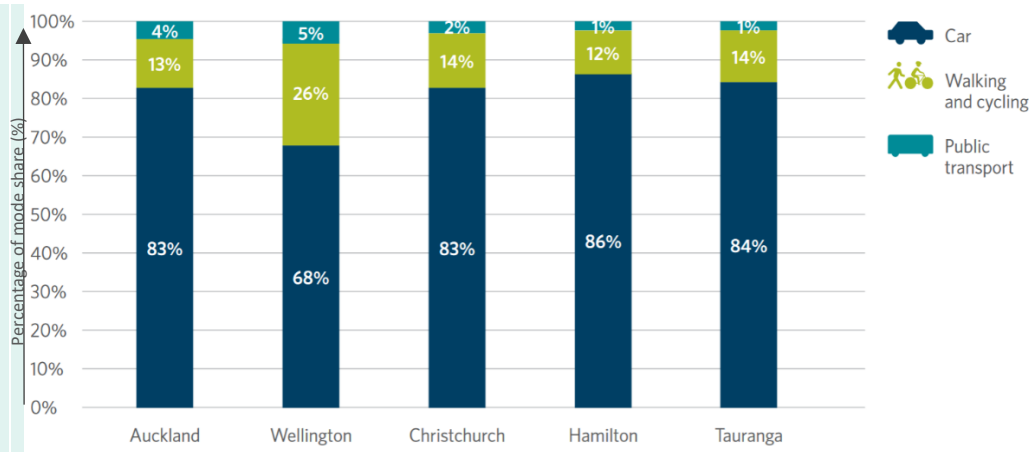


Figure 6.3: Mode share of total trip legs in Aotearoa (2014-2018)³⁰

Data from Waka Kotahi NZ Transport Agency indicates the cycling mode share in Aotearoa urban areas ranges between 1% (Auckland) and 3% (Christchurch).³¹ This is comparable to countries with a low cycling mode share.³² Walking and cycling together account for between 12% (Hamilton) and 26% (Wellington) of total trip legs as shown in figure 6.3 above.

Data from the Ministry of Transport indicates that walking in Wellington constitutes 24.5% of the overall number of trips, and 3.3% of travel by distance.³³ Some Aotearoa researchers have recommended a target to double the proportion of trips by walking to 25% of all trips by 2050.³⁴

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 2050.³⁵

The Auckland Transport business case for investment in cycling infrastructure estimates that providing 150km of cycleways would achieve a five-fold mode share increase from 1% to 5% of trips.³⁶ The mode share of cycling by distance is lower than the mode share by trips, with cycling accounting for approximately 0.6%³⁷ of kilometres travelled. If a five-fold increase in mode share by distance is assumed, cycling would account for around 2.8% of kilometres travelled.

If the current travel mode share in Wellington is assumed to be achievable in other urban areas of Aotearoa, a walking share of 3.3% of distance travelled is plausible.

The Institute for Transportation & Development Policy (ITDP) assessed the potential for urban mode shift to contribute to global CO2 emissions reduction targets in the Global High Shift Scenario report,³⁸ and the Global High Shift Cycling Scenario report.³⁹ The high cycling scenario is based on the assumption that the average city of the future can reach or at least approach the current cycling levels of the best performing cities within its own country or region. In the high cycling scenario it is estimated that cycling and e-bikes could account for 11% of urban passenger travel distance worldwide by 2030 and 14% by 2050 (ranging from about 25% in the Netherlands and China to about 11% in the United States in 2050).

Improve internal combustion engine (ICE) vehicles

Improving the efficiency of the ICE fleet could save 0.26 Mt CO₂ per year. The light vehicle fleet in Aotearoa is one of the most emissions-intensive in the OECD and evidence indicates that our performance is getting worse.⁴⁰ There are two key reasons for this:

- Although efficiency is generally improving within vehicle weight classes as manufacturers introduce fuel-saving technologies, New Zealanders are increasingly choosing to purchase larger, heavier vehicles.
- Manufacturers choose to provide less efficient model variants into the Aotearoa vehicle market than to markets where vehicle fuel efficiency standards apply.⁴¹

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 carbon dioxide emissions over the life of the vehicle.

More efficient conventional vehicles may cost more upfront but deliver significant fuel savings. The additional capital cost of a vehicle emitting 110 gCO₂/km, over one emitting 180 gCO₂/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's lifetime.⁴²

Efficiency can be improved by:

- Improvements in ICE 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).
- Moving to hybrid vehicles, including hybrid drive trains and stop start technology.

It is possible the fuel efficiency of ICE vehicles internationally may not improve further than it has over the last few decades. Several major automotive manufacturers including Volkswagen Group⁴³ and Daimler⁴⁴ have announced they will no longer be undertaking research and development activities and developing new light vehicle

³⁰ (NZTA based on data from the Household Travel Survey 2014-2018)

³¹ (Ministry of Transport, 2018c)

³² (Institute for Transportation & Development Policy, 2015)

³³ (Ministry of Transport, 2019b)

³⁴ (Institute for Transportation & Development Policy, 2015)

³⁵ (Mandic et al., 2019)

³⁶ (Auckland Transport, 2017)

³⁷ (Stats NZ, 2018)

³⁸ (Institute for Transportation & Development Policy, 2014)

³⁹ (Institute for Transportation & Development Policy, 2015)

⁴⁰ (Automobile Association, 2020a)

⁴¹ (New Zealand Productivity Commission, 2018, p. 356)

⁴² (Ministry of Transport, 2019b)

⁴³ (Reuters, 2018)

⁴⁴ (Electrek, 2019)

	<p>models based on internal combustion engine vehicles. Nissan⁴⁵ and Mitsubishi⁴⁶ have stopped research and development for diesel engines. Research and development focus has instead shifted to electric vehicles.</p> <p>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 a hybrid Hilux available by the end of 2021,⁴⁷ and Nissan have “<i>all but guaranteed</i>” the next Navara ute will have hybrid options.⁴⁸</p>
<p>Electrifying light vehicles – cars, SUVs, utes and vans</p>	<p>Light vehicles (cars, SUVs, utes and vans) emitted about 10.7 MtCO₂ in 2019.</p> <p>The electrification of light vehicles offers one of the most cost-effective ways to reduce emissions. Due to our highly renewable electricity system, Aotearoa has one of the better opportunities globally to reduce emissions through electrification. The Energy Efficiency and Conservation Authority has estimated that electric vehicles (EVs) could achieve a roughly 80% reduction in CO₂ emissions per km when in use in Aotearoa.⁴⁹</p> <p>When you take into account the full supply chain impact, including raw material extraction, battery manufacture, vehicle manufacture and shipping, an EV used in Aotearoa would emit about 60% fewer emissions over their full life cycle than an internal combustion engine vehicle.⁵⁰ These figures are expected to improve as Aotearoa phases out the use of fossil fuels for electricity generation and global efforts to reduce emissions from EV supply chains increase.</p> <p>The main challenge currently is the upfront cost of purchasing an EV. EVs are on average more expensive than their ICE equivalents. The upfront purchase price of new battery EVs 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 EVs is the expected decline in battery costs.</p> <p>Although currently more expensive to purchase, EVs 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 EV has a fuel cost roughly equivalent to buying \$0.54/litre petrol.⁵¹ Depending on annual distance driven, some new EVs are cost effective on a total cost of ownership basis today.⁵²</p>

⁴⁵ (Nikkei Asia, 2018)

⁴⁶ (The News Wheel, 2019)

⁴⁷ (Cars Guide, 2019)

⁴⁸ (Stuff, 2020)

⁴⁹ (Energy Efficiency and Conservation Authority, 2015)

⁵⁰ (Energy Efficiency and Conservation Authority, 2015)

⁵¹ Our model assumes battery electric vehicles require 16.2 kWh/100 km while petrol vehicles require 7.52 litres/100 km, so (16.2 kWh/100 km) / (7.52 litres/100 km) * \$0.25/kWh = \$0.54/litre.

⁵² 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)

Due to these lower operating costs, our projections suggest that EVs would 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).⁵³

Those who already own an EV or who purchase an EV in the next few years could be classified as early adopters. International studies have shown that early adopters of EVs are mainly high-income consumers with a distinct set of attitudes, including environmental concerns, willingness to adopt new technologies and who are looking to save money (lower fuel costs).⁵⁴

Owning an EV in the coming years could be challenging for those on a lower income due to the high upfront cost.⁵⁵ This is an equity challenge that warrants policy consideration. Those who would benefit the most from the lower fuel costs offered by EVs are lower-income households. This is especially relevant if the cost of running an ICE increases due to the New Zealand Emission Trading Scheme (NZ ETS) or other mechanisms.

The range of EVs has also been a constraint.⁵⁶ With improvements in battery technology this concern is rapidly diminishing; however, it may persist as a challenge for used EV imports. The first EVs had ranges of around 100km on a full charge. In comparison, new EVs on the market today have ranges of over 400km on a full charge.

Currently there is a lack of choice of EVs 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 many EV models available in other countries are not offered here. Some models are offered at a price premium over the same model in other countries.⁵⁷ The historical lack of emissions policy for transport in Aotearoa could be contributing to this (see Transport section in *Chapter 19: The direction of policy for Aotearoa*).⁵⁸

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

EVs require charging infrastructure and network upgrades or new power lines may also be needed, especially for high capacity rapid chargers. These costs are relatively low, and most drivers would 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

⁵³ Climate Change Commission ENZ Model results

⁵⁴ (Amsterdam Roundtable Foundation and McKinsey & Company, 2014)

⁵⁵ (Haerewa, 2018)

⁵⁶ (Stevenson et al., 2018)

⁵⁷ (New Zealand Productivity Commission, 2018)

⁵⁸ (Ministry of Transport, 2020a)

	<p>Change Committee estimated that converting half of the vehicle fleet, including heavy vehicles, to electricity would increase electricity demand by 10%.⁵⁹</p> <p>However, the coordination of EV charging times is a potential challenge for some local lines' networks. There is the risk that people coming home and plugging their EVs in after work at the same time may lead to greater evening peak demand, putting local lines under pressure and pushing up network costs.⁶⁰ Conversely, pricing that encourages overnight charging could potentially improve network utilisation. This would reduce overall network costs and could further reduce electricity costs for EV owners.</p> <p>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 EVs in mind and therefore there is inadequate charging infrastructure.</p> <p>Through Māori-collectives, Iwi/Māori and hapū there is an opportunity for collaboration to create a network of EV charging stations throughout Aotearoa that would encourage tourist and tourism operators in the regions, although the cost could be a barrier.⁶¹ 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 would need to be negotiated with each marae trust.</p> <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 EV charging infrastructure for EV taxis is being rolled out in London.⁶²</p> <p>There are also challenges that can emerge from relying too heavily on electrification. Prioritising EV uptake could continue to encourage car dependency and contributes to demand for low-density development.</p>
<p>Electrifying trucks and buses</p>	<p>Trucks and buses accounted for approximately 3.7 Mt of emissions in 2019 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 EV or retrofitted to battery electric operation.</p>

⁵⁹ (Interim Climate Change Committee, 2019)

⁶⁰ (Energy News, 2020)

⁶¹ See *Chapter 10: Perspective from Tangata Whenua: considering emissions reductions and removals from a Te Ao Māori view*

⁶² (LEVC, UK, 2018)

	<p>There are challenges associated with battery electric heavy trucks due to the size, weight and cost of the batteries, range and the time required to recharge them. However, innovations that are reducing the size and recharge time of the batteries are developing quickly. In early 2021, four major truck manufacturers indicated they would be reorientating their production to an all-electric future.⁶³</p> <p>The challenges of battery weight and recharge time are less of an issue for medium trucks typically used for local deliveries and other short-haul duties with lighter loads.</p> <p>The economics of electrification for medium trucks are 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 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 battery electric medium trucks would be cheaper on a lifetime total cost basis than diesel trucks. By about 2030 even new battery electric heavy trucks would typically be cheaper on a lifetime total cost of ownership basis than diesel trucks.⁶⁴</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.^{65,66,67,68} New battery electric buses are expected to have a lifetime total cost of ownership lower than diesel buses by the late 2020s.</p> <p>Carbon dioxide emissions from public transport buses were estimated at approximately 0.12Mt in 2017/18.⁶⁹ Lifecycle analysis undertaken for Auckland Transport estimated that battery electric buses deliver 72% fewer greenhouse gas emissions compared to conventional buses.⁷⁰</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>Biofuels for trucks and buses</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. This includes how its grown/recovered (for example whether irrigation is needed, whether it is a waste or by-product), how it is transported and</p>

⁶³ (International Energy Agency, 2021)

⁶⁴ Climate Change Commission, ENZ model

⁶⁵ (Auckland Transport, 2018)

⁶⁶ (Bay of Plenty Regional Council, 2019)

⁶⁷ (Greater Wellington Regional Council, 2019)

⁶⁸ (Environment Canterbury Regional Council, 2018)

⁶⁹ (Waka Kotahi (NZ Transport Agency), 2020)

⁷⁰ (Auckland Transport, 2018)

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 of biofuels varies widely due to the combination of the things listed above.

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%.

There are three main types of liquid biofuels used in the transport sector as a partial or full substitute for fossil fuels:

- 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.
- ‘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.
- 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-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 emissions reductions.

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 would 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.⁷¹ 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 CO₂e.

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

⁷¹ (Concept Consulting, 2020)

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.⁷²

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. Scion has estimated that 4 Mt of forestry waste could be extracted from existing Aotearoa forests for use in biofuels production while still maintaining forest and soil health. It estimates that this could be converted in 700 million litres of biofuels. Scion also considered that up to 140 million litres of biofuels could be produced each year from domestically produced tallow. Aotearoa produces 140,000 tonnes of tallow each year, which is currently exported.⁷³ Scion's Roadmap 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 NZ ETS 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 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.⁷⁴

Hydrogen trucks and buses

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.

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 CO₂e of the roughly 3.7 Mt CO₂e 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).

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.⁷⁵ Blue hydrogen could be used in the transition to a zero carbon economy. However, its reliance on carbon intensive gas

⁷² (Ministry of Transport, 2020a)

⁷³ (SCION, 2020)

⁷⁴ (New Zealand Productivity Commission, 2018)

⁷⁵ (Venture Taranaki, 2018)

	<p>supplies and carbon capture and storage 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.⁷⁶ One Māori business is leading the charge when it comes to hydrogen energy in Aotearoa.⁷⁷ 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 EVs, 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 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 large trucks that 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.⁷⁸</p> <p>Green hydrogen would need to become more cost competitive with both fossil fuels and battery EVs. Costs are uncertain, but recent analysis suggests the marginal cost of emissions reduction of green hydrogen in 2030 as \$425 tCO₂-e. For comparison, the marginal cost of emissions reduction of other heavy truck emissions reduction options were estimated as \$109tCO₂-e for battery electric trucks⁷⁹ and \$190 tCO₂-e for drop-in biofuels.^{80,81}</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.⁸²</p>
Aviation	<p>Domestic air travel made 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</p>

⁷⁶ (Ministry for the Environment & Ministry for the Environment, 2007)

⁷⁷ (Tuaropaki Trust, 2017)

⁷⁸ (Ministry of Transport, 2020a)

⁷⁹ 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 CO₂-e

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

⁸¹ (Ministry for the Environment, 2020b)

⁸² (Pflugmann & De Blasio, 2020)

and air traffic management.⁸³ These initiatives have the potential to achieve up to 10% improvement in fuel efficiency.⁸⁴

Low-emissions options for air travel are emerging, with some adoption possible in the next 10 years, but widespread deployment is likely to be at least 15 years away.

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.

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, 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.⁸⁵ Based on feedback from sector stakeholders on the *2021 Draft Advice for Consultation*, about 30% of domestic flights could be electric by 2035. As the shortest distance flights are likely to be electrified first this equates to about 10% of total distance travelled by domestic aviation.

For example, 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 2026.⁸⁶

For long haul flights (both domestic and international) sustainable aviation fuel (SAF) is likely to provide the biggest opportunity to reduce emissions, or Electrofuels (e-Fuels). 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.⁸⁷ The process for producing SAF is also likely to produce sustainable biofuel to be used in the wider transport system.

E-fuels are liquid fuels which could be made from hydrogen and captured carbon dioxide. They can be used in can be used in internal combustion engine vehicles and are another possibility in the future.

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.⁸⁸

However, business initiatives have begun in Aotearoa. Air New Zealand, Z Energy, SCION and Auckland International Airport have set up a joint initiative to investigate how they could transition aviation fuel into domestically produced biofuels.⁸⁹

⁸³ (Kharina, Rutherford, Zeinali, 2016)

⁸⁴ (Federal Ministry of Transport and Digital Infrastructure, 2018)

⁸⁵ (Daswani, Armitage, Boscarol, et al, 2019)

⁸⁶ 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).

⁸⁷ (Air Transport Action Group, 2020)

⁸⁸ (Smit & Stevenson, 2020)

⁸⁹ (Air New Zealand, 2019)

	<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. Additionally, the impacts of COVID-19 on future demand for aviation travel are still unknown. There may also be a reduction of demand for domestic aviation if there is a greater switch to alternative passenger services such as train or bus.</p>
<p>Shipping</p>	<p>In 2019, emissions from coastal shipping contributes to 0.3 Mt CO₂e. Domestic shipping moved about 13% of the total freight tonne per kilometre.⁹⁰</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.⁹¹ This suggests there is the potential to further reduce emissions by shifting freight from roads to shipping.</p> <p>The primary options to reduce emissions from coastal shipping itself are:</p> <ul style="list-style-type: none"> • Managing the performance of existing vessels • Improving the fuel efficiency of new vessels entering the fleet • Switching from bunker fuel to lower-emissions fuels, such as biofuels, ammonia, hybrid or battery electricity <p>According to the International Energy Agency (IEA), ship efficiency, in terms of energy per t/km, has been improving globally at around 1.6% per year over the period between 2000 and 2017.⁹² 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 are currently being sought to be used for the Interislander’s Cook Strait service. Kiwirail has stated the vessels will have <i>“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.”</i>⁹³</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.⁹⁴</p> <p>Aotearoa does not have a large dry-dock facility so the opportunity for retrofit technologies on coastal ships, including relatively simple greenhouse gas emissions</p>

⁹⁰ (Ministry of Transport, 2014)

⁹¹ (Cenek, Kean, Kvatch, Jamieson, 2012)

⁹² (International Energy Agency, 2020)

⁹³ (KiwiRail, 2020)

⁹⁴ (Ministry of Transport, 2019d)

	reduction activities such as hull cleaning and application of hull coatings, requires vessels to make a voyage to suitable facilities in Singapore or Sydney. This adds expense, vessel downtime and emissions from fuel consumption for the international voyage. ⁹⁵
Rail	<p>Rail accounted for about 0.1 Mt of transport emissions in 2019. 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 carbon dioxide emissions from rail. The 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).⁹⁶ 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 conservatively estimates a cost of \$2.5 million per km to electrify track.^{97,98} Given this, electrifying rail can generally only be justified on high volume routes.⁹⁹</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.)¹⁰⁰ 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>
Improved freight efficiency, including shifting from road to rail	<p>As with other emissions from energy consumption, improved energy efficiency is one of the easiest ways to immediately reduce emissions from freight in Aotearoa. In this context that broadly means a combination of freight optimisation and modal shift.</p> <p>Specific opportunities for road freight include vehicle efficiency upgrades, optimising routes with software, driver training to assist in making good low fuel use decisions, anti-idling technology and training. The Sustainable Business Council estimates that by</p>

⁹⁵ (New Zealand Shipping Federation, 2020)

⁹⁶ The North Island Main Trunk is the main railway line in the North Island connecting Wellington and Auckland and is 682 kilometres long.

⁹⁷ (The Treasury, 2016)

⁹⁸ (International Energy Agency, 2019)

⁹⁹ 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.

¹⁰⁰ (BNSF, 2019)

<p>and coastal shipping</p>	<p>2030, 28% of emissions can be abated from the freight sector by these readily available technologies and behavioural changes.¹⁰¹</p> <p>Integrating different freight networks – by road, rail or coastal shipping – can also reduce emissions by shifting less-time-constrained freight to lower emissions forms of transport. 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.¹⁰² 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 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 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. As an alternative, widening delivery windows can also enable energy savings by allowing vehicles to avoid congestion.</p> <p>The additional handling and cost of shifting freight from trucks to rail can be expensive if distances are short. Rail and coastal shipping would need to offer freight operators more reliable services than road to significantly impact on road freight volumes.</p>
<p>Use of low-carbon fuels for off-road vehicles and heavy machinery</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 2018.¹⁰³ Electrification would generally be an applicable low-emissions 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 would 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, and fully electric utes from other manufacturers are expected to be available in Aotearoa within the coming years. Similarly, there are electric 2- and 4-wheeled</p>

¹⁰¹ (Sustainable Business Council, 2021)

¹⁰² (Ministry of Transport, 2014)

¹⁰³ (Ministry for the Environment, 2020c)

motorbikes available in Aotearoa now, including the locally designed and manufactured UBCO farm bike.

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.¹⁰⁴ Electric mining trucks have further advantages in underground mining operations from reducing required energy for ventilation.

6.1.2 Focus on Auckland

In 2018, road transport emissions in Aotearoa were around 15 Mt CO₂e.¹⁰⁵ Auckland accounted for 27% of those.¹⁰⁶ The transport sector is also the largest source of emissions in Auckland with road transport accounting for 35% of the region's greenhouse gas emissions. Decarbonising transport in Auckland will, therefore, contribute significantly to decarbonising Auckland and decarbonising transport in Aotearoa. Given its size and density, it also offers some of the best opportunities for integrated low-emissions transport solutions at scale.

The Auckland City Council's Climate Plan has set a goal to reduce net emissions by 50% by 2030,¹⁰⁷ and to zero emissions by 2050.¹⁰⁸ To achieve a net emission reduction of 50% by 2030, a 64% reduction in transport emissions would be required.

Auckland's population is expected to increase by another one million people by 2050. As a result, achieving this plan will be very challenging¹⁰⁹ unless specific policies are targeted at achieving outcomes that decouple population growth from transport emissions.

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 EVs or other low-emissions vehicles on the roads.

The Auckland City Council has undertaken modelling to develop indicative transport targets aligned to a decarbonisation pathway. Mode share targets are expressed as mode share by distance.

Table 6.3: Auckland City Council's targets for decarbonising transport

2030 (relative to 2016)	2050 (relative to 2016)
Avoided motorised travel through actions such as remote working and reduced trip lengths reduces vehicle kilometres travelled by 12%	

¹⁰⁴ (Boilden Aitik, 2020)

¹⁰⁵ (Ministry for the Environment, 2020c)

¹⁰⁶ (Auckland Council, 2020)

¹⁰⁷ Against a 2016 base line

¹⁰⁸ (Auckland Council, 2020)

¹⁰⁹ (Ministry of Transport, 2019c)

Public transport mode share increases from 7.8% to 24.5%	Public transport mode share increases from 7.8% to 35.0%
Cycling mode share increases from 0.9% to 7.0%	Cycling mode share increases from 0.9% to 9.0%
Walking mode share increases from 4.1% to 6.0%	
100% of Auckland's bus fleet is zero emissions	
40% of passenger and light commercial vehicles to be electric or zero emissions	80% of passenger and light commercial vehicles to be electric or zero emissions
18% increase in fuel efficiency of the light vehicle fleet (internal combustion engine)	25% increase in fuel efficiency of the light vehicle fleet (internal combustion engine)
8% of road freight shift to rail	20% of road freight shift to rail
40% of road freight to be electric or zero emissions	80% of road freight to be electric or zero emissions
15% increase in fuel efficiency of the freight vehicle fleet (internal combustion engine)	25% increase in fuel efficiency of the freight vehicle fleet (internal combustion engine)

The Auckland Transport Alignment project (ATAP) is a non-statutory process to improve alignment between Auckland Council and government. ATAP sets out a long-term strategic approach to developing Auckland's transport system that is agreed between central government and Auckland Council. ATAP was first developed in 2015 and was updated in April 2018.

The agreed approach is converted into action through the Auckland Regional Land Transport Plan. This is a 10-year investment programme for Auckland, which is reviewed every three years. ATAP 2018 sets out a recommended package for transport investment in Auckland between 2018 and 2028, including \$8.4 billion for rapid transit, \$700 million for bus and ferries and \$900 million for walking, cycling and local board priorities.¹¹⁰ Overall, around 60% of ATAP's investment is directed to rapid transit, public transport, walking and cycling.

Transport modelling of the ATAP package predicts that public transport ridership will increase from 93 million annual boardings to around 170 million by 2028.¹¹¹

Auckland Transport have modelled the overall effect of expected investment in the transport network between 2016 and 2028. Modelling predicts that the mode share of public transport, walking and cycling will grow to 22% of trips, resulting in a 4% decrease in per capita VKT. Over the same period, the fuel efficiency of the fleet is expected to improve by 18%, primarily due to the uptake of electric vehicles. These changes result in a 15% reduction in per capita road transport emissions between 2016 and 2028. However, over the same period, the population is expected to grow by 24% resulting in a 19% increase in total vehicle kilometres travelled and an overall 5% increase in carbon dioxide emissions.¹¹²

¹¹⁰ Auckland Transport Alignment Project (2018)

¹¹¹ Ibid

¹¹² Auckland Transport (2019a)

The ATAP 2021-2031 was announced in March 2021, investing \$31 billion into transport infrastructure and services. It continues the focus on “encouraging the shift from private cars to public transport, walking and cycling and addressing Auckland’s longer-term challenges of climate change and housing development.”¹¹³

6.1.3 Focus on the global production of Electric Vehicles

There were 10 million electric vehicles (EVs) on the world’s roads at the end of 2020, following a decade of rapid growth. EVs registrations increased by 41% in 2020, despite the pandemic-related worldwide downturn in car sales in which global car sales dropped 6%.¹¹⁴

EV sales in the first quarter of 2021 again reached record highs, achieving almost 6% of global car sales, as shown in the graph below.

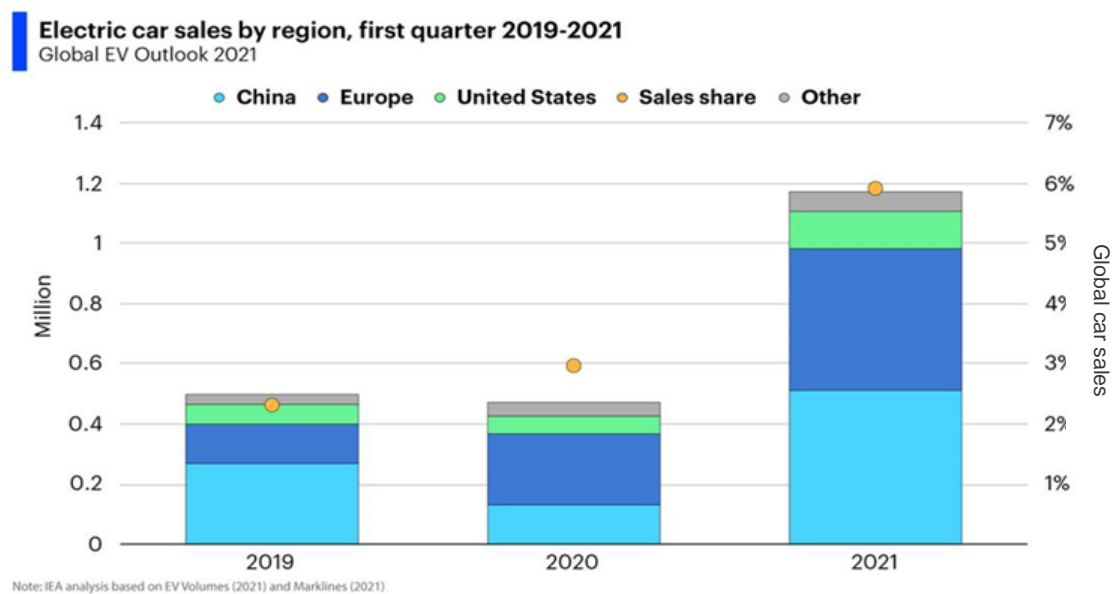


Figure 6.4: EV sales by region, first quarter 2019-2021¹¹⁵

In 2020 and early 2021, vehicle manufacturers have announced increasingly ambitious electrification plans.¹¹⁶ Out of the world’s top 20 vehicle manufacturers, which represented around 90% of new car registrations in 2020, 18 have stated plans to widen their portfolio of models and to rapidly scale up the production of light-duty electric vehicles. This is shown in the graph below.

¹¹³ Auckland Transport Alignment Project (2021)

¹¹⁴ (International Energy Agency, 2021)

¹¹⁵ IEA Global EV Outlook 2021

¹¹⁶ (BloombergNEF, 2021)

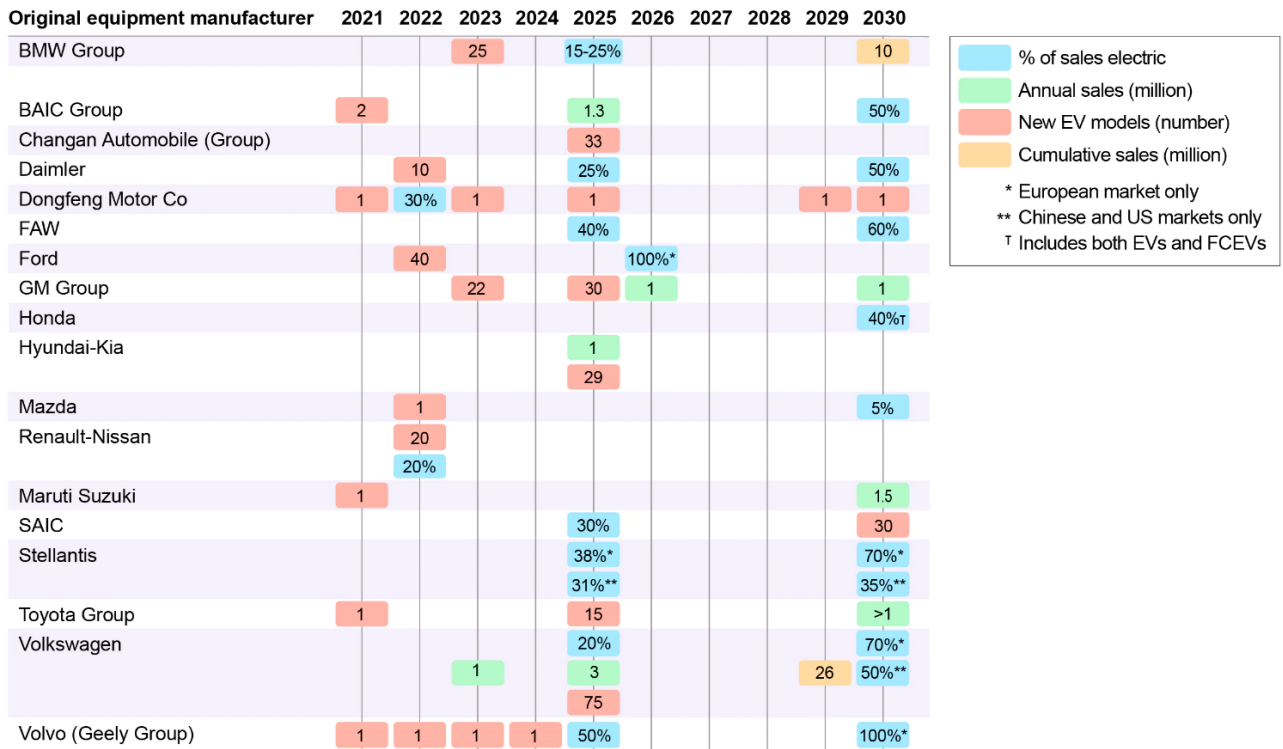


Figure 6.5: Electrification plans of the world's top 20 vehicles manufacturers¹¹⁷

This is a rapidly developing area. In the first quarter of 2021, several vehicle manufacturers announced plans to refigure their production lines to produce only EVs. This included that: Volvo will only sell EVs from 2030; Ford will only sell EVs in Europe from 2030; General Motors plans to offer only EVs from 2035; Volkswagen aims for 70% electric sales in Europe, and 50% in China and the United States by 2030; and Stellantis aims for 70% electric sales in Europe and 35% in the United States.¹¹⁸

The International Energy Agency (IEA) has projected two scenarios of global EV uptake out to 2030. In 2020 there were about 4.3 million EVs sold. The Stated Policies Scenario, based on existing policies, the IEA projects that global EV sales will reach about 11.5 million in 2025 and 22.4 million in 2030. In the Sustainable Development Scenario, the IEA projects that global EV sales will reach about 18.3 million in 2025 and 41 million in 2030. In the short term (2021-2022), the estimated cumulative sales based on manufacturers' announcements aligns closely with the projections in the IEA's Stated Policies Scenario. By 2025, the estimated cumulative sales based on manufacturers' announcements are aligned with the trajectories of IEA Sustainable Development Scenario.

In consultation on our *2021 Draft Advice for Consultation*, some submissions from the vehicle industry and some members of the public argued that there is limited production capacity of EVs globally. Because Aotearoa is a technology taker for EVs and is a small, distant, and right-hand-drive market they argued that a rapid uptake of EVs in the coming years may be challenging due to supply constraints.

¹¹⁷ IEA Global EV Outlook 2021

¹¹⁸ The stronger sales shares in Europe likely reflect more stringent emissions policies on vehicles and broader support for the adoption of EVs.

With the rapid developments in the global EV market and strong commitments from vehicle manufacturers to go electric, it is likely that any supply constraints on new EVs that Aotearoa may face would be minor and short lived. Because we only import a small number of vehicles annually, we would only need a small percentage of the global EV stock. Internationally it has been shown that strong EV policy can have a material impact in overcoming supply constraints (see *Chapter 19: The direction of policy for Aotearoa*). To date the supply of EVs to Aotearoa has not been constrained, though demand has been low. The range of EV models offered in Aotearoa may be limited while the global EV market scales up production. However, this is not an issue that is unique to EVs, new products and supply to Aotearoa is usually delayed by several months in comparison to the major markets.

The supply of used EV imports

At present, Aotearoa is heavily reliant on used vehicle imports from Japan –almost half of annual imports.¹¹⁹ Used vehicle imports help in keeping private vehicle use affordable for low-and middle-income households.

To date, most of the EVs brought into Aotearoa have been used imports from Japan. This dependence also makes Aotearoa consumer's choice for used EVs dependent on what Japanese manufacturers, governments and consumers choose three to seven years prior to entering our market. Aotearoa increasingly competes with other countries for low-emissions used Japanese vehicles, as countries including Australia look for affordable ways to reduce their emissions.¹²⁰

Historically, Japan has had a low uptake of EVs with consumers tending to favour traditional hybrids as a low-emissions option. However, in December 2020, the Japanese Government only announced the target of new domestic passenger vehicle sales to be 100% low-emissions vehicles by 2035.¹²¹ To stimulate the uptake of low-emissions vehicles, Japan has expanded its existing subsidy schemes.

It is likely that Aotearoa will face supply constraints on the quantity of used EVs it can source from Japan through to the late 20s. The severity of this constraint is uncertain as it depends on a multitude of factors including the share of new vs used EV imports in Aotearoa, the uptake and rotation of EVs in Japan, and our ability to enter emerging markets, such as China's EV market.

¹¹⁹ (Ministry of Transport, 2020a)

¹²⁰ (Concept & Retyna, 2021)

¹²¹ (Ministry of Economy, Trade and Industry, 2021) This includes battery electric vehicles, plug-in hybrids, fuel cell electric vehicles, and clean diesel vehicles. Note, the inclusion of clean diesel vehicles is out of line with low-emissions vehicle targets set by other countries.

6.2 Buildings

Buildings are associated with two sources of emissions:

- On-site combustion of fossil fuels and electricity use to operate the building¹²² and
- The emissions associated with the materials and energy involved in construction activities.

Emissions from the on-site combustion of fossil fuels accounted for 1.8 MtCO₂ as seen in figure 6.6 below, or about 4% of long-lived greenhouse gas emissions in 2019.¹²³ 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, increasingly renewable electricity, increased consumer awareness and higher building standards.

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.

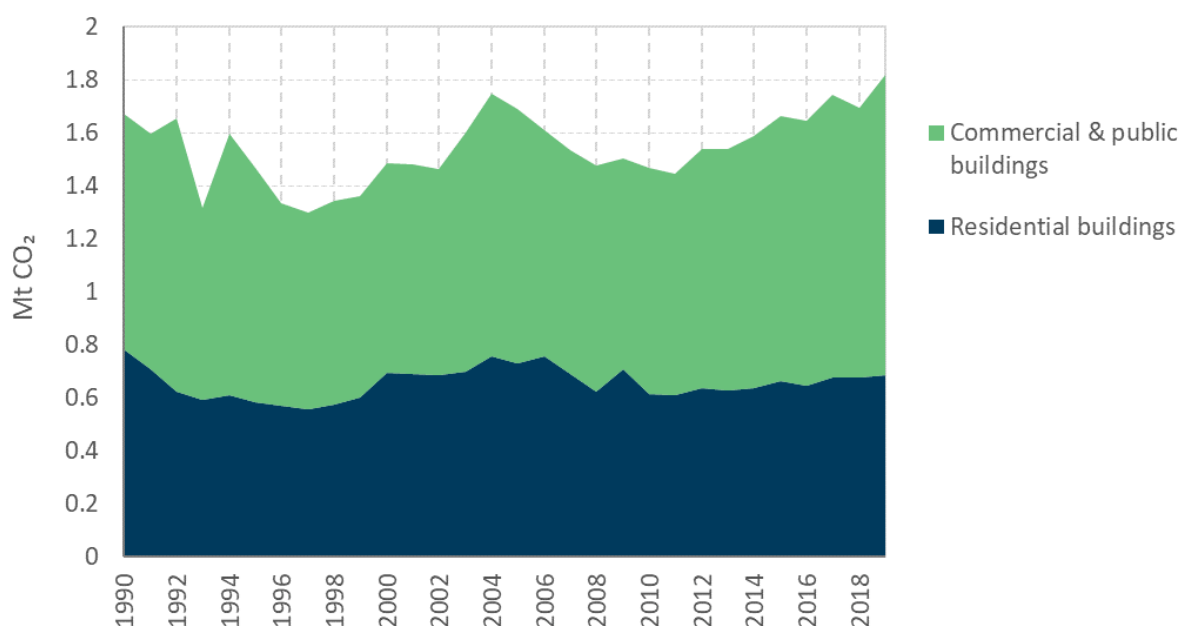


Figure 6.6: Emissions from on-site fossil fuel use in buildings, 1990-2019¹²⁴

There are also emissions associated with the production of construction materials, construction and renovation, and demolition over the lifecycle of a building. Together with operational energy use

¹²² 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. Our analysis addresses electricity emissions at the point of generation rather than at the end user.

¹²³ 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%.

¹²⁴ (Climate Change Commission ENZ Model results, 2020)

emissions, this is often referred to as the whole-of-life emissions of a building and accounts for the carbon embodied in the materials used. The emissions associated with building materials that are manufactured and used domestically are partially accounted for under *Chapter 5: Reducing emissions from energy and industry*, 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. 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 long-lived greenhouse gas emissions, buildings are long-lived assets, so the type of fuel used and when it is used 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 wellbeing.

Box 6.1: Embodied carbon in the built environment

What is embodied carbon?

A consumption-based accounting approach accounts for emissions ‘embodied’ in a good or service that result from the entire supply chain required to produce that good or service for final use. This includes the carbon emissions from raw material extraction to manufacture and use in construction to processing and disposal. Certain goods, like steel and cement, are high in embodied carbon because of the processes used in their manufacture. These process emissions are hard to abate because there are no or limited technically and economically feasible alternatives.

For more detailed discussion on emissions accounting approaches, refer to *Chapter 3: How to measure progress*

Embodied carbon is a significant proportion of the building sector’s whole-of-life emissions.

According to the International Energy Agency, building operational emissions accounted for 28% of global energy related carbon emissions in 2018, and embodied emissions accounted for 11%.¹²⁵

Consumption-based emissions estimates for Aotearoa are at an early stage of development but provide a useful complement to New Zealand’s Greenhouse Gas Inventory (the GHG inventory). In 2020, StatsNZ produced consumption-based emissions estimates for the first time. These estimates indicate that residential buildings were the asset type with the highest contribution to emissions embodied in gross fixed capital (28%) with the third highest contribution coming from non-residential buildings (16%).¹²⁶ As such, buildings represent a key driver of and emissions reduction opportunity for embodied carbon in Aotearoa.

In our proposed emissions budgets, emissions associated with the built environment are partially accounted for under stationary energy (process heat) and industrial processes (chemical reactions), provided the materials are domestically manufactured. These emissions are calculated from a production-based accounting approach which is the standard method used by countries for setting and tracking emissions reduction targets, and it is used to compile the GHG inventory. For more information, refer to *Chapter 3: How to measure progress* and *Chapter 4: Reducing emissions – opportunities and challenges across sectors*.

¹²⁵ (United Nations Environment Programme, 2020)

¹²⁶ (Stats NZ, 2020b)

The built environment is a key driver of demand for emissions intensive materials.

The total volume of building work in Aotearoa has varied in the past year due in part to COVID-19 restrictions but remains at the high levels seen over the past few years. Population and economic growth are expected to continue to drive the upward trend in new building consents seen since the early 2010s.¹²⁷

While timber is widely used for structural framing and infill and partition wall framing, a significant amount of steel and concrete is also used, especially in non-residential buildings.¹²⁸ Steel and concrete provide durability and structural strength and stiffness to buildings, particularly in high-rise buildings for seismic strengthening.

Consumer education, awareness and demand can drive the uptake of different building designs and materials and influence the industry to build capability around design and constructing low-emissions, climate-resilient infrastructure. Central and local governments can also drive demand through different measures including procurement directives and codes and standards.

Moving towards low-emissions, resilient and healthy buildings

The Ministry of Business, Innovation and Employment (MBIE) is undertaking two significant work programmes related to the building and construction sector. According to MBIE:

- The Building Law Reform work programme seeks to support the sector to shift to new, more effective ways of working, help support productivity improvements, lift the efficiency and quality of building work and improve trust and confidence in the building regulatory system.
- The Building for Climate Change (BfCC) work programme aims to reduce greenhouse gas emissions and improve resilience to climate change from buildings. Key action areas include reducing whole-of-life embodied emissions, improving operational efficiency and improving the ability of buildings to withstand future climate change events. While the programme is currently focused on new buildings, extending this work programme to cover existing buildings would be an important step in moving towards low-emissions, resilient and healthy buildings.

Continued development and implementation of these complementary work programmes will be critical to reducing emissions from the building and construction sector and meeting climate change goals.

6.2.1 Options for reducing emissions

This section outlines the opportunities and challenges related to options for emissions reductions 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 wellbeing. While energy efficiency measures are commercially mature and widely available, further opportunities exist and have not been adopted for a myriad of reasons.

The greatest opportunity for emissions reductions across buildings is fuel switching from coal or natural gas heating systems to low-emissions heating systems fuelled by bioenergy, such as biogas, bio-liquefied petroleum gas (bioLPG) or wood pellets, or electricity. Redirecting investment from

¹²⁷ (Stats NZ, 2021) Includes standalone houses, townhouses, flats and units, apartments and retirement village units.

¹²⁸ (BRANZ, 2020c, 2020d)

new fossil fuel fired assets during natural replacement cycles in existing buildings and deterring new connections to the natural gas grid during development of new buildings is an important opportunity to prevent emissions lock-in from long-lived assets. Directing capital investments to low-emissions fuels and heating systems today can prevent stranded assets and unnecessary costs in the future.

In existing buildings, stronger government direction and support along with continued improvements to 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. Increasing consumer and building operator awareness and knowledge on energy and emissions performance of all buildings through better information disclosure and reporting can support more informed low-emissions choices.

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 realised across Aotearoa.

Some whānau are collaborating in papakāinga housing developments.¹²⁹ From a land development perspective, papakāinga is generally considered to be communal housing and facilities on ancestral land owned by Māori. 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 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.¹³⁰ Central and local government procurement policies can also support adoption of low-emissions design and construction practices and materials.

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

Table 6.4: Opportunities and challenges for reducing building emissions

¹²⁹ (Te Puni Kōkiri, 2017a)

¹³⁰ MBIE has a significant work programme with the goal of reforming the building regulatory system, lifting the productivity of the building and construction sector, and ensuring all buildings are low-emissions, healthy and durable.

Option	Opportunities and Challenges
Design, materials and construction	<p>Embodied carbon refers to 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>There are significant opportunities during building design to reduce emissions, improve climate resilience and ensure occupant health and safety. Design and construction choices can influence the environmental impact of a building for its serviceable life, generally 50 years or more. Building design and material choice should factor in material availability and cost of transport, climate zone, land size and orientation, and durability. There may be trade-offs across these and other factors in terms of embodied carbon, durability, overall construction costs and heating and cooling demands.</p> <p>Design choices that can reduce emissions from buildings includes selecting lower-emissions-intensity materials, optimising material manufacturing, off-site or prefabricated construction and building layout and siting. 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 reduce emissions and waste over the lifecycle of a building through improved resource efficiency. Maximising construction and demolition waste recycling and recovery can reduce 20-30% of the embodied emissions associated with refurbishing existing buildings.¹³¹</p> <p>Local development requirements for a minimum house size on a given plot of land and restrictions on building height may be barriers to optimising building size against land availability and more compact urban development. Land amalgamation and land plot size and shape may also limit design choices.</p> <p>In some cases, using wood-based products could remove carbon dioxide from the atmosphere and store it for the life of the building, potentially reducing the associated embodied emissions. 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 2.85kg CO₂e per kg compared to -1kg CO₂e per kg for glued laminated or cross laminated timber from sustainably managed forests.¹³² Increased use of analytical tools and databases, including environmental product declaration (EPDs), when designing a building can support identification of emissions reduction opportunities associated with material choice.</p> <p>While increasing the use of wood products in the built environment¹³³ can reduce emissions and provide long-term storage of carbon dioxide, material</p>

¹³¹ (Ghose et al., 2020)

¹³² (BRANZ, 2020a)

¹³³ 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.

Option	Opportunities and Challenges
	<p>substitution needs to be considered against structural resilience and durability. Increased resilience to natural hazards, through the use of higher emissions intensive materials such as steel at the design and construction stage of a building, could provide a reduction in potential life cycle embodied carbon in high hazard areas by avoiding wide scale but periodic demolition and replacement impacts.¹³⁴</p> <p>One of the barriers to the adoption of better design choices and lower-emissions materials is the behavioural change required across the value chain. There is an industry and consumer 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 for familiar technologies and materials, and limitations in the Building Code and standards.</p> <p>Strengthening the Building Code and raising the minimum requirements is a critical opportunity to reduce emissions and ensure 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.^{135,136}</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> <p><i>See also Chapter 5: Reducing emissions from energy and industry; Chapter 8: Reducing emissions from waste; and Chapter 9: Removing carbon from our atmosphere.</i></p>
Operating (on-site use of fossil fuels and electricity use)	Emissions from fossil fuels used for heating of commercial and public buildings totalled 1.1 Mt CO ₂ in 2019 of which 60% was from boiler systems. ¹³⁷ In residential buildings, emissions from the combustion of gas for space and water heating was approximately 0.7 Mt CO ₂ . ¹³⁸

¹³⁴ (Earthquake Commission Kōmihana Rūwhenua, 2021)

¹³⁵ (Bealing, 2020)

¹³⁶ (Sense Partners, 2018)

¹³⁷ (Energy Efficiency and Conservation Authority, 2020)

¹³⁸ (Energy Efficiency and Conservation Authority, 2020)

Option	Opportunities and Challenges
	<p>Emissions from on-site fossil fuel use can be reduced through increased energy efficiency and fuel switching. For example, switching from halogen and incandescent lightbulbs to light emitting diode (LED) bulbs and switching a building's coal or natural gas heating system to bioenergy 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.</p> <p>The energy efficiency of a heat pump will also be influenced by location, for example, whether the building is 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. Retrofitting could increase project costs as infrastructure and electricity network upgrades may be needed.</p> <p>The cost of space and water heating using electricity is comparable with natural gas, although rising carbon prices and gas network costs may lead to electricity being more favourable over time.</p> <p>In the medium to long term, there may be opportunities to transition away from natural gas heating to low-emissions alternatives like biogas, bioLPG and hydrogen. These low-emissions gases could be blended into the existing gas network. BioLPG could replace existing uses in bulk LPG facilities and networks or mobile applications.</p> <p>While there may be opportunities in the future to deliver low-emissions gases like biogas and hydrogen through the existing gas network, it would be important that their deployment is based on demonstrated substantial emissions reductions while minimising costs to consumers. Furthermore, depending on the volume of hydrogen blended into the network, a transition to hydrogen could require replacing existing heating appliances plus associated installation costs. Hydrogen heating appliances are not currently widely available.</p> <p>The cost of the gas network is recovered through a consumers' bills as gas pipeline businesses are a regulated monopoly. Expanding the natural gas connections that serve residential, commercial or public buildings would mean that the cost of expansion would be recovered through consumers regardless of the number of users on the network.</p> <p>Consumers generally face an information asymmetry regarding the future supply, demand and cost of natural gas and low-emissions gases. For example, hydrogen as a heating fuel is not currently cost-competitive against electricity or bioenergy and, if green hydrogen is used, it would require a substantial increase in renewable electricity generation and infrastructure. There are significant conversion losses associated with using electrolysis of water to produce hydrogen and then combustion of hydrogen to produce heat. Blue</p>

Option	Opportunities and Challenges
	<p>hydrogen would require substantial effort and investment to develop carbon capture and storage capabilities. Biogas would require investment to establish supply chains to collect, transport and process the feedstock. Direct electrification or biomass are more cost-effective and efficient options.</p> <p>Other emissions reduction options include heat recovery systems and improvements to the thermal envelope.¹³⁹ 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 local and central government sector buildings, many of which use coal fired boiler systems. In 2019, public buildings used approximately 0.4 PJ of coal, diesel or fuel oil in boiler systems to provide space and water heating.¹⁴⁰</p> <p>A \$200 million State Sector Decarbonisation Fund¹⁴¹ is supporting the transition of public buildings to low-emissions alternatives. Recent Government commitment to a carbon neutral public service by 2025¹⁴² is anticipated to accelerate action and will include, among other actions, the phase out of all coal boilers, conversion of the government fleet to electric vehicles, and implementation of an energy efficiency building rating standard. As of April 2021, 36 schools, ten hospitals, and seven universities have been allocated roughly \$83 million to replace coal boilers, increase energy efficiency and improve the building thermal envelope.¹⁴³</p> <p>Additionally, there are over 60,000 state homes in Aotearoa that are expected to benefit from an announced \$500 million investment in upgrades and renewals. Improvements would 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.¹⁴⁴ 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</p>

¹³⁹ 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.

¹⁴⁰ (Energy Efficiency and Conservation Authority, 2020)

¹⁴¹ Also referred to as the Clean Powered Public Service Fund. The Fund is administered by EECA

¹⁴² (New Zealand Government, 2020d)

¹⁴³ (New Zealand Government, 2020b, 2020c)

¹⁴⁴ (New Zealand Government, 2020a)

Option	Opportunities and Challenges
	<p>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.</p> <p>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 minimise risk of stranded assets, and availability and ability of low-emissions technologies to meet the technical requirements of heating and cooling.</p> <p>There may be occasions where low-emissions alternatives, like electricity or biomass, may not be feasible. For example, to meet the specific heating and cooling demands of a mixed-use high-rise commercial tower in a central business district. In rural and remote communities with either no or tenuous electricity infrastructure, the transition to bioLPG could displace use of existing conventional fossil fuel LPG.</p> <p>There are also co-benefits associated with switching to low-emissions fuel in homes and businesses. Switching to low-emissions fuels such as electricity or biomass can result in improved indoor air quality, particularly for households that use portable LPG appliances or unflued gas appliances. The use of gas cooking appliances, especially without an exhaust hood¹⁴⁵ or if not well maintained,^{146,147} can also contribute to lower indoor air quality. While cooking releases certain pollutants regardless of the type of stove used, the combustion of natural gas for cooking emits nitrogen dioxide, carbon monoxide and formaldehyde, each of which can exacerbate various respiratory symptoms and other health issues.¹⁴⁸</p> <p><i>See also Chapter 5: Reducing emissions from energy and industry.</i></p>

¹⁴⁵ The Government's Healthy Homes Standard requires an appropriately sized extraction fan or rangehood for rooms with an indoor cooktop in rental properties.

¹⁴⁶ (Nicole, 2014)

¹⁴⁷ (Seals & Krasner, 2020)

¹⁴⁸ (Zhu et al., 2020)

6.3 Urban form

Urban form has a critical role in the response to climate change – both in mitigation and adaptation – and represents a pivotal intersection between land use, transport, buildings, energy and waste. Urban form is an important consideration for achieving long-term emissions reduction targets.

Box 6.2: What is urban form?

Urban form is the physical characteristics that make up urban areas, including the shape, size, density, activities and configuration of settlements. It is determined by urban planning and design:

- Urban planning is the planning of city structures such as policies, zones, neighbourhoods, infrastructure, standards and building codes. The focus is more on the way a city functions at the political, strategy, structure, and policy level.
- Urban design is the creation of city features including public space, infrastructure, transport, landscapes and community facilities. It is focused on design and user experience.

Urban planning and design look across a system of multiple interconnected and interdependent layers. For example, land use, movement (e.g., transport, cycling), built form (e.g., buildings), social and environmental aspects.

Urban areas are a major driver of economic growth, contain most of the built assets, and support wellbeing by providing a sense of place, community and connection. However, urban areas also concentrate environmental impacts and emissions resulting from heating and cooling, transport, industry and disposal of waste and wastewater.

Historically, urban expansion has been greater than the rate of population increase.¹⁴⁹ Auckland is projected to account for more than half of the population growth in Aotearoa out to 2043.¹⁵⁰ Additionally, the population aged 65 years or more is likely to make up a greater proportion of the total population over time,¹⁵¹ which may affect the services and infrastructure needed to serve New Zealanders in the future.

Urban development and expansion have resulted in significant demographic, social and cultural change for Māori. Most places in Aotearoa were built around or on top of existing Māori settlements. In addition to involuntary land acquisitions and seizures, many rural Māori environments were gradually subsumed within an expanded urban boundary as settlements and towns evolved into cities.¹⁵²

The Māori ethnic population currently represents a significant proportion of the urban population. Between the 1960s and 2010s, the percentage of Māori living in urban areas increased by more than 20%, driven by manufacturing booms and higher wages in cities, population pressures on sparse rural resources and targeted government relocation programmes. Approximately 84% of the Māori ethnic population live in urban areas, with a quarter living in the Auckland region. Urbanisation can result in cultural dislocation with impacts on important aspects of Māori culture including whakapapa and whanaungatanga. It will be important for urban planning and design to fulfil obligations under Te Tiriti o Waitangi/The Treaty of Waitangi and to weave mātauranga Māori into

¹⁴⁹ (The Royal Society of New Zealand, 2011)

¹⁵⁰ (Te Puni Kōkiri, 2017b)

¹⁵¹ (Stats NZ, 2020a)

¹⁵² (Ryks et al., 2014; Te Puni Kōkiri, 2017b, p. 21)

the decision-making framework to increase understanding of the impacts of urban form on taonga Māori, communities and values.

6.3.1 Relationship with transport emissions

Transport emissions and urban form are closely interlinked.¹⁵³ 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 and shopping centres) are located further 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. Equally so, high density cities that are not well designed and are congested can also lead to higher transport emissions and impacts on local air quality.

Around 85% of New Zealanders live in urban areas with populations greater than 50,000.¹⁵⁴ 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 tended to grow out, resulting in growth at the urban boundary rather than the urban centre.¹⁵⁵ 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.¹⁵⁶

Transport accounts for approximately one third of total urban emissions. In Auckland, transport accounts for nearly 36% of total transport emissions.¹⁵⁷ Figure 6.7 shows a comparison of the gross per capita emissions for various geographic regions and cities. While the data includes studies at different timeframes and geographic levels (e.g. Wellington is regional rather than Wellington City), the key finding is that transport contributes a significant part of the emissions profile in urban areas.

There are numerous factors that can reduce travel distance including regional accessibility, population density, mixed land use, parking supply, interconnectivity of transport routes, and quality and quantity of alternative transport modes. For example, transit-oriented development (TOD) prioritises pedestrian-friendly, mixed use, medium to high density development that is located within a short distance to a public transport station and other services and amenities. When designed well, TOD creates opportunities to connect the surrounding community to the public transport station and other cycling and pedestrian networks. Enabling New Zealanders to more easily use alternative transport can also reduce the need for private vehicle ownership which can reduce the need for parking space and other car-orientated infrastructure.

Reducing transport emissions through changes to urban form depends on decisions made today. More compact, well-designed urban form can reduce operational emissions from transport and, over time, can reduce embodied emissions by minimising the overall number of zero- or low-emissions vehicles needed. For example, decisions under the COVID-19 Recovery (Fast-Track

¹⁵³ The current relationship between transport emissions and urban form is premised on the use of internal combustion engine vehicles. In our modelling, by 2035, a majority of the vehicle fleet is still based on ICE technology. By 2050, the transport fleet is largely decarbonised through electrification or other low-carbon fuels.

¹⁵⁴ (New Zealand Productivity Commission, 2018, p. 493)

¹⁵⁵ (Productivity Commission, 2017, p. 80)

¹⁵⁶ (Deloitte, 2018)

¹⁵⁷ (Auckland Council, 2017)

Consenting) Act 2020 can result in significant shifts in transport funding to meet climate, social and economic outcomes. These decisions will have short- and long-term impacts as they have the potential to lock in development pathways such as where buildings are built and how much land-use changes occurs at the urban-rural fringe. Long-term decisions should be combined with other complementary policy measures, such as petrol taxes (e.g. Auckland regional fuel tax) and subsidies for public transport, that have a more immediate impact and may be more effective and less costly.¹⁵⁸

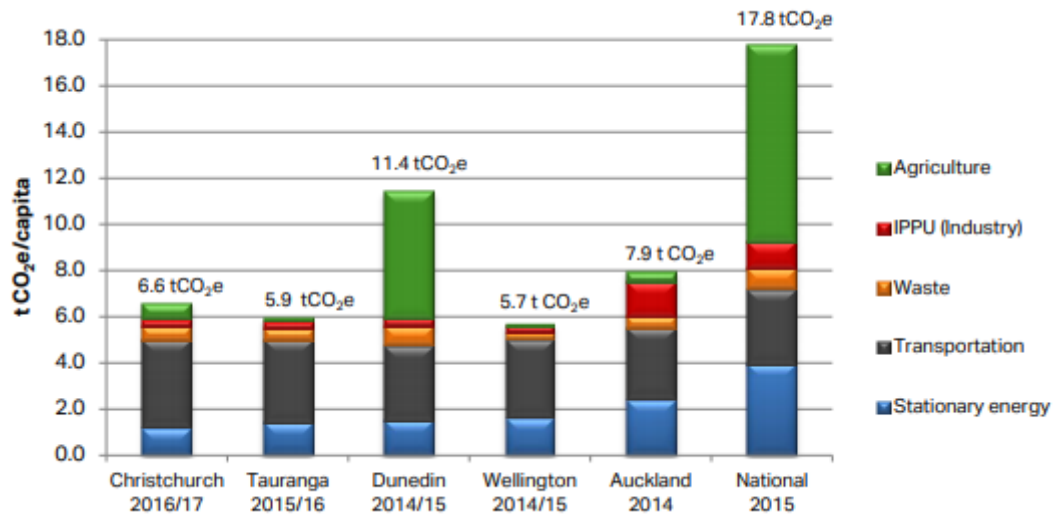


Figure 6.7 Comparison of gross per capita emissions in Aotearoa¹⁵⁹

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):¹⁶⁰

“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 emissions 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 enjoyable.

Box 6.3: What if the transport fleet was decarbonised?

Regardless of whether transport emissions are fully mitigated or not, well-designed urban form is the foundation of a well-functioning and affordable lowemissions transport system. It facilitates emissions reduction today and over time by reducing vehicle kilometres travelled and making active and public transport more attractive. Urban form and function would continue to influence the viability and economics of active and public transport which can reduce the number of zero- or low-emissions vehicles needed. In turn, this would reduce the investment needed for

¹⁵⁸ (Productivity Commission, 2017, p. 277)

¹⁵⁹ (Martin & Lindberg, 2018)

¹⁶⁰ (IPCC, 2018)

infrastructure such as renewable electricity generation and civil infrastructure such as roads, three waters, fibre and energy. This could lower the overall cost of the transition. It also minimises the embodied emissions associated with infrastructure and zero- or low-emissions vehicles, reducing the 'carbon footprint' of urban spaces over time.

An integrated approach to transport and land-use planning is vital. Well integrated land use and transport policies and planning for urban form can support well-connected multi-modal access to local services, jobs and amenities while reducing travel distance and improving accessibility. This is critical for long-term emissions reduction at a system level; and brings many other transport, public health and environmental benefits, through reduced air and noise pollution, increased levels of physical activity, reduced congestion, better connected communities and improved safety.

The best mix of interventions for shifts in mode of transport will depend on the size and characteristics of the area. While larger urban areas are generally prioritised in national planning and strategies, in smaller urban areas, public transport might be provided by on-demand shuttle services instead of a fixed rapid transit network. Active transport could also be a more significant contribution to travel in smaller urban areas where trip lengths are shorter.

Developing connectivity across communities is vital to facilitate shifting to different types of transport and to ensure accessibility for all New Zealanders today and in the future. 24% of New Zealanders have a disability. Accessibility and mobility are dictated by urban form; the design and layout of buildings and transport networks must accommodate the needs of a diverse population to provide more equitable and universal access to city spaces and services, buildings, infrastructure and transport systems. Accessible urban spaces can also support people to 'age in place' which supports mental and physical health, along with providing other co-benefits.

Land use and planning for housing developments and future infrastructure needs to be accounted for. One of the main ways to increase the share of clean public, shared and active types of transport is to develop and implement compact urban design policies. This requires a stronger and more deliberate relationship between urban planning, design, transport but also land use. Where possible, this should happen at the planning stage rather than trying to retrofit the system.

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%.¹⁶¹ 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 2050.¹⁶² 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 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

¹⁶¹ (New Zealand Productivity Commission, 2018, p. 493)

¹⁶² (Stockholm Environment Institute, 2014)

shows that residents of denser areas have lower overall vehicle kilometres, and thus lower carbon dioxide emissions.¹⁶³

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 Māori”.*¹⁶⁴

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.

6.3.2 Relationship with building and energy emissions

The evolution of towns into major urban centres is a resource and energy intensive process. Emissions from these activities and the resulting urban form are enduring and often referred to as embodied carbon (see section 6.3 and Box 6.1) or the ‘carbon footprint’ of a city.

The relationship between urban design, buildings and energy use is not straightforward. However, buildings are a key component of any response to climate change due to their long lives. Due in part to building code requirements, the common design life of a building in Aotearoa is 50 years but can range from 90-130 years.¹⁶⁵ Buildings are also key because they drive demand for emissions-intensive materials such as cement and steel, and are a key driver of peak electricity demand.

Urban form and building design are influenced by local government policies, including zoning and land use, building regulations or ordinances, covenants and procurement policies. Building and site design decisions would in turn determine construction methods and materials (embodied emissions) and thermal performance (operational emissions). Design can also influence the amount of waste that is generated during construction, renovation and building end of life. As the operational emissions of a building decline through increasingly energy efficient technologies and consumer appliances, switching to lower emissions energy sources and more stringent building code requirements, it is the embodied emissions that would remain. Deep energy retrofits, refurbishment or repurposing of existing buildings can be a way to significantly reduce the embodied emissions that would be incurred through demolition and rebuild.

While operational emissions from buildings are relatively small, buildings are a significant driver of peak demand in the electricity system. Reducing electricity demand through improvements in the thermal performance of buildings can be viewed as an alternative to building new generation assets and network infrastructure. Transpower estimates peak demand could increase from 7.3 GW in 2020 to 8.9 GW by 2035 and 10 GW by 2050¹⁶⁶ (see *Chapter 5: Reducing emissions from energy and industry* for more information).

¹⁶³ (Chapman & Dodge, 2016)

¹⁶⁴ (Public Health Advisory Committee, 2010)

¹⁶⁵ (Alcorn, 2010; Ministry of Business, Innovation and Employment, 2021, pt. B2)

¹⁶⁶ (Transpower, 2020)

Urban areas with high resource demand have a higher degree of resilience built into its energy infrastructure. For example, power supplies to the Auckland region are built and operated to withstand the two largest transmission assets and the largest generation unit all failing at the same time. In contrast, power supplies to medium-sized cities are built and operated to withstand only the failure from the largest transmission asset.¹⁶⁷ As transport and heat electrify in medium to high population growth areas, managing demand would be important to support grid resiliency, minimise electricity system emissions and avoid high electricity prices. In turn, this would support electrification in other sectors of the economy.

Urban form can also support an inclusive and equitable transition by enabling better access, participation and inclusion in society. It is generally feasible to meet accessibility requirements at 1% of the total cost of building. Retrofitting for accessibility is more expensive – up to 20% of the original cost – than integrating accessibility and universal design principles into new buildings.¹⁶⁸ Applying MBIE’s Buildings for Everyone design guide¹⁶⁹ and emphasis on related building standards can support a more inclusive built environment that accommodates the a diverse population.

6.3.3 Relationship with waste emissions

Urban densification or the development of more compact, pedestrianised cities and towns can also result in concentrated waste and wastewater generation due to increased population density. Waste is a by-product of increased economic activity, population growth and increased consumption.

New Zealanders dispose of about 15 Mt of waste per year with 90% coming from urban sources and the remaining 10% from rural sources.¹⁷⁰ Resource recovery facilities are predominantly located in larger urban areas, meaning that in many parts of the country it is not cost-effective to recycle waste because of additional transport costs. Approximately 70% of the total national municipal waste volume is managed by two facilities in Auckland and Christchurch.

Development activities, including new construction, refurbishment or demolition, can generate a substantial amount of waste that is often not reused or repurposed. Waste emissions may be exacerbated by shifts in urban form in the absence of robust waste management infrastructure, measures to reduce waste at source and to maximise waste recovery, or incentives to ‘design out’ waste during the development process.

There is uncertainty and lack of data around the quantities of construction and demolition (C&D) waste generated and related emissions. It is estimated that C&D waste makes up 40-50% of the total waste generated in Aotearoa,¹⁷¹ with current recovery estimated at around 28%. One Auckland study estimates that construction waste composition by weight is 20% timber and 5% metal. A significant factor in waste generation is thought to be the fragmented nature of the construction industry, given it is largely made up of many small to medium sized businesses. In Aotearoa, there were over 51,000 companies operating in the construction sector as of 2014.¹⁷² As C&D waste is a source of commercial waste, local government has had limited influence over the construction sector’s behaviour in managing it.

¹⁶⁷ (New Zealand Infrastructure Commission Te Waihanga, 2021)

¹⁶⁸ (World Health Organization & The World Bank, 2011, p. 197)

¹⁶⁹ (Ministry of Business, Innovation and Employment, 2019)

¹⁷⁰ (Eunomia, 2017; New Zealand Infrastructure Commission Te Waihanga, 2020)

¹⁷¹ (New Zealand Infrastructure Commission Te Waihanga, 2020)

¹⁷² (BRANZ, 2018)

When developing new housing supply, there are significant opportunities to design out waste to save time, money, resources and energy while reducing emissions. Each new home generates an average of 4 t of waste.¹⁷³ There is insufficient data on how much demolition takes place each year in Aotearoa, but studies estimate between 2,000 to 8,000 houses per year are demolished. Kāinga Ora estimates that demolishing one state house generates around 3 t of waste. Roughly three-quarters of the 65,000 state houses under Kāinga Ora are past their end of life. These houses can be renovated or demolished and replaced with higher density housing built using modern methods of construction (see Box 6.4).¹⁷⁴ When constructing a new building, designing for deconstruction rather than demolition can include increased use of prefabricated materials and non-composite materials to simplify the disassembly and sorting process.¹⁷⁵

Box 6.4: Modern methods of construction (MMC)

Modern methods of construction include prefabrication and off-site manufacturing of modular building components. Innovation in manufacturing technology, assembly and processes can increase sector productivity, save time and costs and reduce the generation of on-site waste. MMC leverages automation, technology and assembly line methodologies to produce building work. For example, off-site manufacturing of panels and other building components, or use of 3D printing on-site. The resulting cost and time savings can in turn drive innovation to remain competitive in an evolving market.

MBIE's Building Law Reform programme aims to streamline the consenting process for projects seeking to use MMC. Current consenting processes are best suited to traditional construction methods, making it difficult to receive approval for MMC and new or innovative building components. Lack of client and developer awareness can also impede the uptake of MMC.

¹⁷³ (BRANZ, 2020b)

¹⁷⁴ Personal communications with Kāinga Ora (2020)

¹⁷⁵ (Rohani et al., 2019)

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