Chapter 8:
Reducing emissions from waste

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The majority of waste emissions are from biogenic methane, with smaller amounts of carbon dioxide and nitrous oxide also being generated from composting, incineration and wastewater treatment. There are practices and technologies available to reduce the amount of waste and associated emissions. While only emissions at the final destination point of waste are considered in New Zealand's Greenhouse Gas Inventory, there are also potential emissions reduction opportunities in other sectors that may result from tackling waste.

This chapter explores the sources of emissions from the waste sector and opportunities to reduce them – including waste avoidance, waste recovery, lower-emissions landfills and low global warming potential (GWP) refrigerants. Refrigerants are covered in this chapter, as resource recovery mechanisms, such as product stewardship, apply to both waste and refrigerants.

8.1 Introduction

New Zealanders create many forms of waste in their day to day lives. There are emissions associated with the creation, handling, processing and storage of this waste, particularly biogenic methane emissions from organic waste. There are a range of practices and technologies that can reduce the amounts of waste and associated emissions.

Our primary focus is on emissions from the management of organic waste. For this discussion, we view all waste with a decayable organic carbon (DOC) value as 'organic' – including waste with very low DOC such as construction and demolition (C&D) waste. However, greenhouse gases are emitted throughout the lifecycle of organic and inorganic resources until they turn to waste. These emissions can happen at a range of stages in a product/material lifecycle, for example when produced on farm, extracted from nature, manufactured, sold, used or transported, and ultimately, when disposed of in a landfill.

Opportunities to reduce non-disposal emissions may be accounted for in other sectors; for example, reducing emissions from the collection and movement of waste are accounted for in the transport sector. However, in the context of our discussion 'waste emissions' are only from the emissions at disposal – usually from organic waste decaying at landfill.

Nonetheless, we know that moving from a linear economy (on a 'take-make-use-throw' setting) to a more circular economy (where resources are repeatedly used), would result in less emissions from waste disposal, and from extraction, production, consumption and transport processes. The European Union has estimated that moving to a circular economy could cut emissions by nearly half compared to the status quo.[1]

Most waste disposal emissions are biogenic methane (92% of all waste emissions, expressed in CO_2e), with the remainder being small amounts of carbon dioxide (3%) and nitrous oxide (5%), which are generated from composting, incineration, and wastewater treatment. Overall, biogenic methane from waste makes up around 9% of total biogenic methane emissions with agriculture making up the other 91% in Aotearoa.[2] Our analysis is largely focused on how to reduce biogenic methane emissions from organic solid waste disposal because these make up most (81%) of the biogenic methane emissions from waste. A breakdown of waste volumes and emissions from solid waste are presented in Table 8.1

[1] (Ramboll et al., 2020)

[2] Modified from the national Greenhouse Gas Inventory (Ministry for the Environment, 2021)

Table 8.1: Waste disposal points and emissions from decay

Waste sites	Waste volumes (Kt) 2019	Emissions ($MtCH_4$) 2019
Municipal with landfill gas capture	3,350	0.0271
Municipal without landfill gas capture	279	0.0174
Non-municipal	5,622	0.0375
Farm fills[3]	479	0.025

Municipal sites with landfill gas capture (see Box 8.1) account for most of the waste volume from households. These are class 1 landfills servicing urban centres which receive a mixture of household and commercial waste. Municipal sites without landfill gas capture are a mixture of legacy sites which are now closed and a small number of active municipal landfills. These sites are not required to capture landfill gas as the tonnage of organic waste and/or total capacity of waste they receive falls below the legislative requirement. Municipal landfills receive high volumes of food, paper and wood waste.

Box 8.1: Landfill gas capture

Landfill gas capture systems typically comprise of vertical and/or horizontal extraction wells connected to a pipe network designed to extract biogenic methane gas from landfills. The instantaneous collection efficiency of a landfill gas capture system is the percentage of landfill gas collected when compared against the predicted generation rate. It is not only a function of the effectiveness of the collection system, but also considers factors such as the original landfilling methods, depth of waste, leachate saturation levels and cap permeability. Different landfills have different gas capture efficiencies, with newer landfills tending to have higher rates of gas capture due to more efficient design. There is also a 'lifetime' capture efficiency or a 'temporally weighted collection efficiency' which considers gas collection over a lifetime.[4] In Aotearoa approximately 87% of biogenic methane gas captured is used for energy generation with the other 13% flared (landfill gas burnt which converts it to a small amount of carbon dioxide emissions.[5]) Gas capture data from landfills in Aotearoa are not reported or audited which makes verification of actual gas capture rates difficult[6].

Non-municipal sites are class 2-5 landfills which receive commercial and industrial waste. The most common waste types across the aggregate category of municipal landfills were construction and demolition, garden and wood waste. However, we do know that there are differences in the different landfill classes with some such as class 2 Landfills accepting more waste with organic content and class 5 Landfills (Cleanfills) theoretically accepting no organic waste.

With farms in Aotearoa having no access to a kerbside waste collection system, farmers are responsible for managing their own waste. We estimate that around half is burnt and half is stored

[3] Farms send about half of their waste to be burnt, which produces roughly 0.152 $MtCO_2e$ of emissions meaning that the total volume of waste produced at farms is around 958 kt.
[4] (Barlaz et al., 2012)
[5] (Ministry for the Environment, 2020b)
[6] (Ministry for the Environment, 2021)

with the buried amounts producing biogenic methane emissions and the burnt waste producing smaller volumes (in CO_2e terms) of carbon dioxide,[7] nitrous oxide and methane emissions. Garden, paper and wood waste are the most common categories from farm sites. Neither farm sites nor non-municipal landfills are required to capture landfill gas as the volumes of organic waste they receive do not meet the threshold required under current regulations.

Box 8.2: Wastewater treatment emissions

Wastewater treatment contributes around 10% of waste emissions from operational emissions. In addition, the sludge produced gets sent to landfill and is accounted for in landfill emissions. However, we have not focused on this as the opportunity to reduce emissions is small and the level of data uncertainty too high. From analysis of evidence and discussions with stakeholders, we have identified some opportunities to reduce emissions from wastewater treatment. These include increasing water conservation,[8] better sludge management, and capturing fugitive emissions.[9] However, due to the poor data on wastewater treatment plants and the complexities of measuring baseline emissions and any reductions, it is difficult to quantify the emissions reduction potential of various actions. We agree with the Productivity Commission's conclusion about the need to establish "*an agreed measurement approach and to assess… costs of its use in any relevant scheme."*[10] With better data, we anticipate being able to do more analysis on this area.

Refrigerants are substances essential to the functioning of air conditioning, refrigeration, and freezing technologies. They absorb heat quickly, so are critical to heating and cooling cycles in these systems and appliances. The energy efficiency of many refrigerant-containing products like heat pumps means their use is increasing, as they provide both cost savings and environmental benefits.

Emissions from refrigerants, mostly hydrofluorocarbons (HFCs) are typically emitted during the lifetime of their product (e.g. air conditioners, fridges), or once that product is disposed of (if not disposed of correctly). While their volumes in Aotearoa are not large, they are often potent, long-lived greenhouse gases (see Box 8.3), with a Global Warming Potential (GWP) hundreds of times that of carbon dioxide. Preventing these emissions could have a measurable impact on our country's overall emissions profile.

While refrigerants are not part of the Waste Greenhouse Gas Inventory (refrigerant emissions are captured under industrial processes and product uses) of Aotearoa, they are in this section as the actions to reduce refrigerant emissions are similar to those necessary to reduce waste emissions. We have concentrated our analysis on HFCs as they are the only refrigerants with a phase down plan.

Box 8.3: What about refrigerants?

Refrigerants are chemicals used commonly across the economy in refrigeration and air conditioning equipment. Applications include refrigeration systems in homes, supermarkets, cool stores and industrial factories and air conditioning in cars and office buildings.

[7] Carbon dioxide from burning organic material is not accounted for as it returns sequestered carbon dioxide to the atmosphere.
[8] (Environment Agency, 2009)
[9] (Global Methane Initiative, 2013)
[10] (New Zealand Productivity Commission, 2018, p. 472)

HFCs are the most commonly used refrigerants and replaced chlorofluorocarbons (CFCs) after the ozone depleting properties of CFCs were identified. Roughly 500 tonnes are consumed annually in Aotearoa to charge new and service existing equipment. Additionally, about 400 tonnes are imported in vehicles and other finished products – for example in car air conditioning units. There is a large 'bank' of approximately 7,000 tonnes of refrigerants in existing equipment in Aotearoa.[11]

Many refrigerants are extremely potent greenhouse gases

Although we use relatively low volumes of refrigerants, they have very high GWPs. The most common refrigerant in Aotearoa, HFC-134a, has a GWP of 1,400 – this means 1 kg of HFC-134a has the same global warming impact of 1.4 tCO_2. Another common refrigerant, HFC-404A, has a GWP of 3,900.

We have been increasing our use of refrigeration and air conditioning equipment. The substances used in this equipment are potent greenhouse gases which can escape over time.

Increased economic activity, a growing population and increased demand for and movement of perishable goods has increased our use of refrigerants over time.

Prior to 1996, CFCs were the chemicals typically utilised as refrigerants. However, these were recognised to be destructive to the ozone layer and their use was prohibited under the Montreal Protocol and Ozone Layer Protection Act (1996). CFCs have been largely eliminated from use globally and were chiefly displaced by HFCs, which do not destroy ozone. Emissions from the leakage of HFC refrigerants from refrigeration and air conditioning equipment grew from zero in 1990 to about 1.7 $MtCO_2e$ in 2018, because of the displacement of CFCs by HFCs. As a result, HFC refrigerants are a significant source of emissions growth.

In 2019, Aotearoa ratified the Kigali Amendment to the Montreal Protocol, an international agreement to phase down global usage of HFCs. However, modelling carried out for the Ministry for the Environment shows that there is a gap between the emissions reductions that will be achieved under our Kigali Amendment phase down of bulk HFCs and our obligation to reach net zero emissions by 2050.

We are keen to understand the potential opportunities offered by increasing resource efficiency and moving to a circular economy in Aotearoa. We know that recovering and reusing inorganic material such as aluminium and glass will typically produce fewer emissions than producing new materials. Many of these emissions reductions are in non-waste sectors, such as building, manufacturing and transport. We also know that transitioning to a circular economy would generate substantial economic benefits.[12] However, more research and data is needed to quantify the extent to which a circular approach may reduce emissions. *Chapter 19: The direction of policy for Aotearoa* discusses the opportunities around the circular economy further.

The analysis here is tempered by an acknowledgement of the general unreliability and absence of waste data in Aotearoa. Where possible we have filled gaps in official data (which rely on projection, assumptions and expert opinion) with additional research and analysis.

[11] (Ministry for the Environment, 2018)

[12] (Auckland Tourism, Events and Economic Development & Sustainable Business Network Circular Economy Accelerator, 2018)

Box 8.4: Te ao Māori and waste

Based on input from interviews with Technical Reference Group members and insights from Iwi/Māori it is evident that a holistic approach to waste creation and management is essential, if we are to achieve intergenerational solutions for reducing emissions from the waste sector.

Throughout our evidence gathering and advice, we have drawn on the framework He Ara Waiora – A Pathway Towards Wellbeing (version 2)[13] to inform our understanding of a te ao Māori perspective on wellbeing, sourced in mātauranga Māori. He Ara Waiora underpins our analysis regarding impacts for Iwi/Māori and provides appropriate framing to assess impacts of emissions reductions and increased removals for Iwi and Māori.

He Ara Waiora provides a high-level interpretation of how Māori view the world holistically, which is consistent with the perspectives we heard through engagement with Māori with respect to waste creation and management.

As an example, we heard that Māori traditionally lived within a circular loop waste system, which returned all toenga (remains/leftovers) back to Papatūānuku, without detriment to the whenua, awa (waterways), or moana (ocean). Appropriate mechanisms to manage this system are preserved in tikanga e.g. human organic matter was not mixed with toenga kai and other compostable materials.[14] Drawing on He Ara Waiora, with a wairua and taiao centric approach to wellbeing, encourages us to consider mātauranga Māori and tikanga in a transition to a circular economy systems as one option to lower emissions in the waste sector.

8.2 Options for reducing emissions

As a country, Aotearoa is comparatively wasteful with municipal waste generation being among the highest per capita in the OECD.[15] We generated approximately 13.5 Mt of waste in 2019, of which 9.7 Mt was sent to landfill.[16] Around 44% of this waste has an organic portion which can decay at landfill.

Comparing our waste statistics to other countries shows there are opportunities to reuse much of the waste generated and reduce emissions across the economy including those directly generated from waste itself. Our recycling (excluding incineration) rate of 28% is relatively low, compared to Australia's 62%[17] or the European Union's recycling rate of 47%.[18]

The low recycling rate is partly due to a lack of on-shore processing in Aotearoa for recycled products, as well as a lack of end-markets. Other reasons for the low recycling rate include a fragmented waste system, lack of economies of scale due to our low population density and the 'governance gap' between central and local government and other actors in the waste sector.[19] The Infrastructure Commission's report on resource recovery infrastructure highlighted the potential

[13] (McMeeking et al., 2019)
[14] (Auckland Council, 2017)
[15] (OECD, 2018)

[16] Assumption from Eunomia figure of 28% recovery rate holds steady.
[17] (Department of the Environment and Energy (AU) & Blue Environment Pty Ltd., 2018)
[18] (European Environment Agency, 2019)
[19] (Blumhardt, 2018)

need for further investment in the sector[20]. Not only do these challenges contribute to the country's low recovery rates, they also leave Aotearoa vulnerable to shocks in international resource recovery markets.[21] When China implemented Operation National Sword in 2018, many councils and recyclers were forced to stockpile or landfill recyclable material as there was no processing options available for the waste. Improving domestic capacity for on-shore processing, standardising kerbside collection and developing end markets for recovered products were some of the proposals to address the implications of National Sword and improve the resource recovery rate.[22]

Table 8.2 outlines the opportunities to reduce waste from emissions that would have been generated at landfill. However, there are other potential actions not assessed here because the potential for emissions reductions are difficult to quantify. These encompass interventions that we know would enable or greatly enhance some of the opportunities. For example, product stewardship schemes would help reduce waste at source and increase recovery rates[23] and ultimately reduce emissions. We also know that the type of collection system has an impact on contamination rates and ultimately the value of the recovered waste product[24] but collection systems, in isolation do not lead to recovery but could enhance and enable it.

Figure 8.1: Waste sector and potential interventions

We have assessed the opportunities and challenges for reducing waste emissions from the perspective of preventing emissions that would have occurred at disposal, with Figure 8.1 showing some of the potential interventions. This 'production-based emissions accounting approach' is consistent with the international approach. A 'consumption-based' accounting approach that quantifies the emissions associated with the manufacturing, importation and transport of goods across the economy could be a useful tool to analyse resource/waste flows along the economy. While Stats NZ have started releasing consumption-based accounting statistics,[25] they are not yet at a precise enough level to inform decision making or judgement.

[20] (New Zealand Infrastructure Commission Te Waihanga, 2020)
[21] (Eunomia, 2018)
[22] (MRA Consulting Group, 2018)
[23] (WasteMINZ Product Stewardship Group, 2019)
[24] (WasteMINZ, 2020)
[25](Stats NZ, 2020)

This section has indicative costs based on our analysis of work done by different stakeholders. The actual costs included in the modelling for the emissions budgets are outlined in *Chapter 12: Long-term scenarios to meet the 2050 target*. Overall, there is a lack of quality data in the waste sector in Aotearoa which makes forecasting costs challenging. Improving the frequency of collection and quality of waste data would significantly help to identify and realise emissions reduction opportunities.

There are three broad opportunities to reduce emissions in the waste sector. These opportunities are a mixture of practices and technologies and are aligned with the waste hierarchy[26] (see Figure 8.2) and international best practice.[27]

1. Avoiding waste: avoiding the generation of waste at source
2. Waste recovery: recovering waste through reuse, recycling and recovery
3. Landfill gas capture: improving the efficiency of landfill gas collection systems and increasing the proportion of waste going to landfills that capture that gas

[26] (*Waste Minimisation Act*, 2008)

[27] (Bogner et al., 2007) and (Fischedick et al., 2014, pp. 785–792)

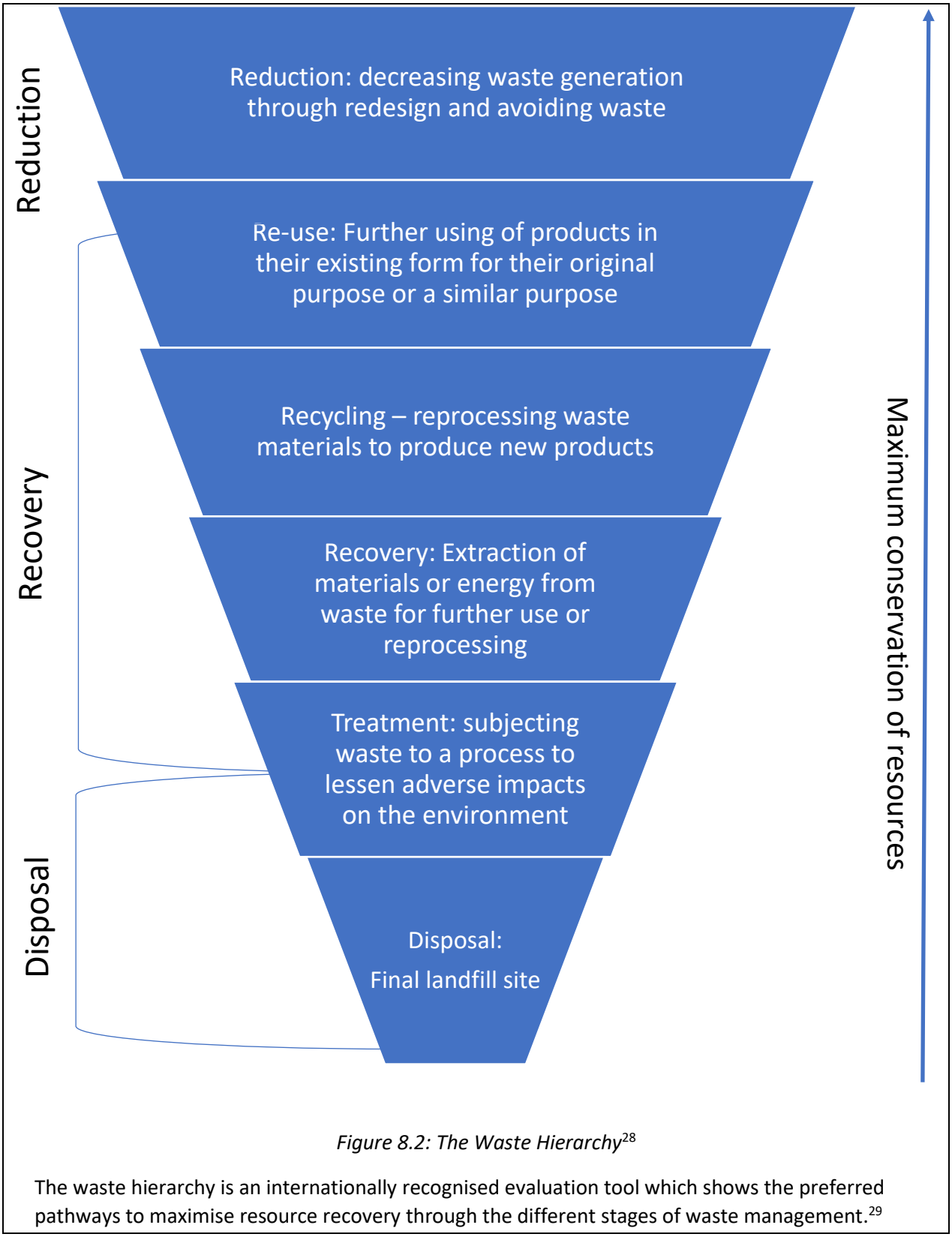

Figure 8.2: The Waste Hierarchy[28]

The waste hierarchy is an internationally recognised evaluation tool which shows the preferred pathways to maximise resource recovery through the different stages of waste management.[29]

[28] (Eunomia et al., 2017)

[29] (Department for Environment, Food and Rural Affairs (UK), 2011)

Table 8.2: Opportunities for reducing emissions

Option	Opportunities and challenges
Avoiding Waste	Preventing waste from being created in the first place provides a big potential opportunity to reduce emissions. There are two broad ways to make less waste: 1) Production processes can be improved to generate less waste. For example, houses can be built in a way that minimises the number of timber offcuts that are produced and/or goods can be designed to create less waste, for example through reducing the packaging. 2) Changes in consumption patterns can reduce production of waste and waste emissions. There are a range of actions which can lead to changes in consumption patterns, for example, helping consumers buy more durable products. Potentially, almost all waste sources and their emissions could be avoided or eliminated. However, this goal is unlikely to be achieved in the near-term given that our country's systems and infrastructure which could support widespread behaviour change are underdeveloped. It is difficult to quantify the exact size and cost of the opportunity of avoidance as it is reliant on significant behaviour change and widespread changes to product design and production systems. Because many of our goods are manufactured overseas, Aotearoa has little direct control over how much waste these goods can potentially generate. Nevertheless, international examples suggest the potential here is great. For example, over the decade from 2006 to 2016, Ireland reduced its waste generation by nearly 50% primarily due to European Union directives such as those to prevent food waste and promote resource efficiency.[30] It is also important to note there is a lag between action and emissions reductions because it takes time for organic waste already landfilled to decay. Even if no new waste was generated from 2030, waste emissions would fall 53% by 2035 and 76% by 2050. Work has not been done to assess the full range of opportunities and costs for waste reduction in Aotearoa. However, in many circumstances, reducing waste also increases efficiencies and would be low or no cost. For example, restricting junk mail could reduce the paper waste stream by up to 30%, and also reduce costs for businesses.[31] Businesses and industries need to be supported and upskilled to help them understand the cost of their inputs and waste, and how to reduce this. Reducing waste going to landfills provides wider benefits. Landfills can have disruptive effects on environmental quality and poorly managed landfills can contaminate surrounding land and waterways. Many current and old landfills are close to rivers and the coast and will be increasingly at risk as climate

[30] (Eurostat, 2020)
[31] (Ministry for the Environment, Unpublished)

Option	Opportunities and challenges
	change raises sea levels and increases the frequency of storms and floods.[32] The flooding of the Fox River on the West Coast in 2019 destroyed an old landfill, spreading an estimated 135 tonnes of rubbish over more than 60 km of river and coastline.[33] In terms of cultural impacts, some old landfills are located on land taken from Māori but returned through Settlement or other means. Māori collectives responsible for managing the land are actively seeking to understand how to restore their whenua.
Waste Recovery	Recovering organic material away from disposal in landfills to other uses can reduce direct waste emissions. It could also reduce emissions in other sectors and increase overall efficiency of resource use.[34] Organic waste can generally be reused, composted/recycled, or converted to energy. Reuse and recycling of materials such as paper and wood could be increased, from the reuse of wood waste in new builds to the reprocessing of paper waste to cardboard. Textiles can be reused, for example through sending used clothing to op-shops instead of landfill or repurposing them into other textiles. Food that would have otherwise gone to landfill can be donated to food banks. Composting food and garden waste converts organic waste into fertiliser in a process that generates small amounts of greenhouse gas emissions such as nitrous oxide, biogenic methane and carbon dioxide. Home composting of food scraps has been a familiar ritual for generations of New Zealanders and there is increasing community-level composting as well as commercial-scale composting of waste from commercial and industrial sites. For example, the Living Earth facility in Christchurch composts 50-100,000 tonnes of food and garden waste each year,[35] directly reducing biogenic methane emissions.[36] The resulting compost can be used in the agricultural sector, potentially displacing synthetic fertilisers and sequestering soil carbon.[37] However, there are no robust figures on the potential of this to reduce emissions across the agricultural sector in Aotearoa. Further analysis would be welcomed in this space. The Productivity Commission cited waste to energy as *"one key avenue"* for a low-emissions economy.[38] The Ministry for the Environment has also published

[32] (New Zealand Government, 2019a)
[33] (Westland District Council, 2019)
[34] (Ramboll et al., 2020)
[35] (Living Earth, 2020)
[36] The exact amount of emissions reductions is challenging to estimate, as it depends on whether the food waste would have otherwise gone to landfill with high biogenic methane capture rates or unmanaged landfill with no gas capture.
[37] (NSW Government: Environment, Climate Change and Water & The Organic Force, 2011)
[38] (Ministry for the Environment, 2020a)

Option	Opportunities and challenges
	a guide for waste to energy which emphasises that projects must move up the waste hierarchy.[39] The approach includes a range of actions: • Wood waste can be burnt for heating or as fuel in industrial boilers, as is planned for Christchurch Hospital[40] and already implemented in a high temperature incinerator for treated wood at Golden Bay Cement.[41] • Organic (and inert) waste can also be incinerated in large-scale plants to generate electricity. However, the process is expensive to develop and requires a large and high calorific waste stream to run. On current volumes, only Auckland is large enough to support what would be considered a large waste to energy plant by international standards.[42] Additionally, burning inorganic materials such as plastics could further increase emissions over landfill disposal and incentivise sending waste to incinerators, which would decrease reuse and recycling, and result in more fossil fuel emissions.[43] • Biogenic methane from anaerobic digesters can also be used to generate biogas, a key renewable energy source. In this context, anaerobic digesters refer to dedicated plants which help induce microorganismal biological processes that break down biodegradable material in oxygen-free environments to generate bioenergy sources.[44] A large-scale plant is currently being built in Reporoa to process a range of feedstocks including Auckland's food waste.[45] Small-scale anaerobic digestors are also used across Aotearoa, such as wastewater treatment plants.[46] • Biogenic methane captured from landfills can also be captured to generate electricity. However, this is generally considered to sit within the 'disposal' tier of the waste hierarchy as opposed to the 'recovery' tier. Redvale, the country's largest municipal landfill, generates enough energy to power 14,000 homes.[47] While increasing organic waste recovery from landfills can reduce biogenic methane emissions, the total emissions involved in diverting waste from landfill need to be considered. For example, recovering and transporting large waste volumes for processing using diesel trucks may generate more emissions than it saves.[48] In general, we do not expect increasing resource recovery to increase overall transport emissions as the transport emissions to resource

[39] (Ministry for the Environment, 2020c)
[40] (New Zealand Government, 2019b)
[41] (BERL, 2019, pp. 38–39)
[42] (BERL, 2019, p. 31)
[43] (Hoffart, 2019)
[44] (Science Direct, 2020)
[45] (Auckland Council, 2020)
[46] (Boušková & Thiele, 2018)
[47] (Office of the Prime Minister's Chief Science Advisor, 2019)
[48] (Waste Management NZ Ltd, 2018)

Option	Opportunities and challenges
	recovery would substitute for transport emissions to landfill. There may be a small number of cases where transport emissions from sending waste to resource recovery could create more transport emissions than it saves in landfill emissions – particularly for waste with low proportions of decayable content such as construction and demolition (C&D) waste.[49] But investing in local resource recovery would reduce additional transport emissions and ultimately, decarbonisation of the transport fleet would resolve the issue. If all organic waste was recovered from landfills, waste emissions could reduce by nearly 50% by 2035 and up to 75% by 2050 in Aotearoa. This depends on the mix of recovery options as composting, waste to energy, and anaerobic digestion will have their own emissions factors.[50] However, the resource recovery sector would need to be scaled up, new bioenergy facilities constructed and behavioural changes embedded in society. End uses for the diverted waste (such as compost or recycled products) would also need to be developed. Our analysis suggests between 5% to 65% (depending on waste type) of the organic waste stream could be recovered by 2030, and 40-93% (depending on waste type) of the organic waste stream could be recovered by 2050.[51] We anticipate that some waste streams will be able to achieve more ambitious levels of reduction and recovery than others. For some waste streams such as food waste where there are existing recovery options and roadmaps, these would be easier to recover with higher potential.[52] For other waste streams, recovery can be more complicated. For example, a limited number of recovery options and end-markets for treated wood makes wood waste more difficult to recover.[53] States across Australia have set targets for resource recovery comparable to the high end of the possible range[54], but their resource recovery sector is better developed than Aotearoa. Ministry for the Environment analysis shows that the marginal cost of abatement might range from a cost saving of $34 to a cost of $618 per tonne of CO_2e.[55] Increasing resource recovery rates would also generate employment

[49] Staff calculations

[50] The delay in emissions reductions is because it takes time for existing organic matter in landfills to decompose.

[51] Analysis of options, discussions with stakeholders.

[52] (Mirosa & Environment Select Committee, 2020)

[53] (Environment Canterbury, 2013)

[54] (Collins et al., 2020)

[55] Costs based on MfE MACC work. For that exercise, mitigation costs were calculated as dollars per tonne of abatement in CO_2e.

Option	Opportunities and challenges
	opportunities. The Ministry for the Environment has estimated that up to five times as many jobs could be created in recycling as in disposal.[56]
Modern, low-emissions landfills	Any organic waste which is not emissions or resource efficient to recover should be sent to landfills which have efficient biogenic methane capture systems. While some municipal landfills already have high-efficiency gas capture systems, most landfills do not have capture systems at all and over 75% of solid waste emissions come from disposal sites without gas capture. These landfills without gas capture include municipal landfills which receive low volumes of waste, legacy landfills as well as non-municipal and farm fills[57] While modern, low-emissions landfills are at the bottom of the waste hierarchy, ensuring high performance systems are installed is still important to manage the existing waste at landfills, which will take decades to decay, and to reduce emissions from the remainder of organic waste that does go to landfill. Even in areas with separate Food Organics, Garden Organics (FOGO) collection such as some localities in New South Wales, substantial volumes of residual organic waste still get deposited in municipal landfills with residual organic residues of around 25%.[58] Analysis of the Australian Emissions Reduction Fund project register shows substantial levels of methane emissions from converted C&D fills such as the Kimbriki Resource Recovery Centre which operates a class II landfill that receives about 70,000 tonnes pa of 'inert'[59] C&D waste.[60] This landfill generated enough methane to be awarded 17,211 carbon units in the last financial year.[61] This is evidence of substantial methane generation at this landfill, despite the theoretically lower organic composition at New South Wales C&D landfills [62] compared to some non-municipal landfills in Aotearoa.[63] While this is only a snapshot, this indicates the potential for gas capture at non-municipal fills and raises the possibility that emissions from these sites in Aotearoa may be underestimated. Mandating gas capture for all landfills (except farm fills) could have three key effects on the waste sector: • An increase in the number of non-municipal and municipal landfills with gas capture, as gas capture systems are installed on those sites. • An increase in waste recovery from landfill, as recovery options become cheaper than landfill as non-municipal landfills pass on costs of gas capture.

[56] (Ministry for the Environment, 2019)
[57] (New Zealand Productivity Commission, 2018)
[58] (Rawtec, 2020)
[59] (Shore Regional Organisation of Councils, 2014)
[60] The recovery center also accepts municipal waste but only landfills C+D waste with the municipal waste subject to alternative waste treatment (NSW Government: Planning & Infrastructure, 2012)
[61] (Australian Government, 2021)
[62] (Department of Environment and Climate Change NSW, 2007)
[63] (Tonkin and Taylor, 2014)

Option	Opportunities and challenges
	• A shift in waste volumes from sites without gas capture to sites with gas capture. Our analysis of non-municipal landfills shows that around 63% of the overall tonnage of waste with some portion of organic content ends up across twelve different landfill sites across Aotearoa with nine of those sites receiving waste volumes above 50,000 per year. Gas capture could be more viable on those sites and would have the added benefit of capturing methane from historic waste. Installing landfill gas capture systems at all farm fills is likely to be prohibitively expensive and impractical with many thousands of farm sites across the country. However, farms and rural communities could be supported to reduce waste through increasing access to drop off points and other measures proposed in the Rural Waste Minimisation Project.[64] Closed or legacy landfills continue to produce biogenic methane, as the organic waste in them breaks down. Fitting gas capture systems is technically feasible and could further reduce emissions. Even without capture systems, biogenic methane emissions at legacy landfills will reduce over time as the organic waste decays, eventually reaching zero as all the waste decays. However, this process may take decades depending on a number of factors including the waste composition of the legacy landfill. There are risks to relying on landfill gas capture as a method of reducing emissions. While modern, low-emissions landfills produce less methane and have lower impacts on the wider environment, they still produce methane. The efficiency of gas capture systems plays a key role in how much methane escapes. The effectiveness of landfill gas capture is also contested as landfill gas collection efficiencies vary depending on practice.[65] This makes regular monitoring and audits of landfill gas capture systems important, as increasing the average efficiency of existing gas capture systems would help reduce overall emissions. Other concerns with incentivising landfill gas capture include the potential to divert resources away from waste reduction and recovery, as well as the potential for some landfill gas management practices to increase fugitive emissions.[66] Nonetheless, these potential risks can be mitigated in whole or in part and the potential benefits – in emissions reductions, in decreasing local air pollution and in energy generation can be realised.[67] Installing landfill gas capture at sites without gas capture, and that have received substantial volumes of organic waste, could be highly effective to reduce emissions from historic deposits as well as any future waste.

[64] (Scott & Curtis, 2018)
[65] (Oonk, 2012)
[66] (Sierra Club LFGTE Task Force, 2010)
[67] (Chen & Green, 2003)

Option	Opportunities and challenges
	It is important to note however that the potential for emissions reductions for modern, low-emissions landfills decreases as the amount of waste is reduced and recovery increases. This is because with less waste at landfill, there would be fewer emissions to reduce. Analysis indicates the cost of abatement for different landfill gas options might range from around $20 - $450 per tonne of CO_2e.[68] The large variance in abatement cost is due to the different potential assumptions around operational lifespan, gas capture efficiency, running costs and revenue from gas generation.
Reduce refrigerant emissions	HFCs are subject to the New Zealand Emissions Trading Scheme (NZ ETS), via the synthetic greenhouse gas levy. As NZ ETS prices rise, so would the price of importing goods containing refrigerants. 2020 is the first year of phasedown of HFCs in Aotearoa under the Kigali Amendment to the Montreal Protocol. The phasedown of HFCs imported in bulk (i.e. for insertion into equipment in Aotearoa) would reduce our use of HFCs imported in bulk by 81% in 2036 from the average consumption over 2011-2015. HFCs 'pre-charged' into products overseas (like heat pumps) are not included in our Kigali Amendment phasedown, as they were anticipated to reduce in line with other countries' phasedowns, and are subject to the synthetic greenhouse gas levy. The Ministry for the Environment is examining possible further interventions at different stages of the refrigerant lifecycle,[69] including: **Incentivising or requiring usage of alternatives**. Alternative refrigerants with low GWP such as ammonia and hydrofluoroolefins (HFOs) and HFC blends can be used in place of HFCs. HFO-HFC blends offer intermediate emissions reductions and can be used in existing equipment, however other blends are not compatible and require new equipment. **Prohibition on import of high-GWP HFCs**. Internationally, import prohibitions reflect the availability of more environmentally friendly technology options, and are designed to prevent import of high-GWP refrigerants when lower GWP alternatives are available. A rapid phase out of powerful refrigerants could mean there may be insufficient refrigerant to service the existing fleet of equipment which may result in 'stranded assets.' There may also be an increased safety burden and cost of housing a flammable and toxic substance on site. This is particularly relevant for organisations with medium sized systems who have enough charge for fire to be a serious risk but because of their scale do not have the systems and processes to manage it.

[68] Costs based on MfE Guidelines on Landfill Gas Accounting (Ministry for the Environment, 2004, pp. 13–20) and confirmed with stakeholders.
[69] (Verum Group, 2020)

Option	Opportunities and challenges
	Regulated Product Stewardship. Refrigerants were declared a priority product under the Waste Minimisation Act in 2020. This means the introduction of a refrigerant stewardship scheme could significantly increase our ability to reduce HFC emissions. By addressing leakage and poor end of life disposal, emissions that would otherwise be emitted to the atmosphere at the end of a product's life could be reduced. Currently, a voluntary program is in place in Aotearoa, but the overall recovery rate is low. Regulated product stewardship would assess a range of policy options to reduce refrigerant emissions by addressing improper disposal and installation practices and bringing equipment leakage to attention. **Integrating refrigerant management across building and infrastructure policy.** Encouraging use of carbon footprint and benchmarking tools such as carboNZERO, CEMARs and GREENSTAR. Government procurement activities could require selection of low-emissions refrigerants. Government could also reduce the need for HFCs through good building design.

8.3 References

Auckland Council. (2017). *Auckland Waste Management and Minimisation Plan 2018*.

Auckland Council. (2020). Breaking New Ground on Zero Waste. *Our Auckland*.

https://ourauckland.aucklandcouncil.govt.nz/articles/news/2020/08/breaking-new-ground-on-zero-waste/

Auckland Tourism, Events and Economic Development, & Sustainable Business Network Circular Economy Accelerator. (2018). *Circular Economy: A new dynamic for Auckland Businesses* [Auckland Economic Insight Series]. Auckland Tourism, Events and Economic Development and Sustainable Business Network Circular Economy Accelerator. https://www.aucklandnz.com/sites/build_auckland/files/media-library/documents/ATEED-economic-insight-paper-Circular-economy-final.pdf

Australian Government. (2021). *Kimbriki LFG flare project*. http://www.cleanenergyregulator.gov.au/ERF/Pages/Emissions%20Reduction%20Fund%20project%20and%20contract%20registers/Project%20register/ERF-Project-Detailed-View.aspx?ListId={7F242924-BF02-45EE-A289-1ABCC954E9CE}&ItemID=483

Barlaz, M. A., Chanton, J. P., & Green, R. B. (2012). Controls on Landfill Gas Collection Efficiency: Instantaneous and Lifetime Performance. *Journal of the Air & Waste Management Association*, *29*(12), 1399–1404. https://doi.org/10.3155/1047-3289.59.12.1399

BERL. (2019). *Waste to energy: The incineration option*. BERL. https://berl.co.nz/sites/default/files/2020-07/BERL%20Report%20WtE%20final%20July.pdf

Blumhardt, H. (2018). Trashing Waste: Unlocking the wasted potential of New Zealand's Waste Minimisation Act. *Policy Quarterly*, *14*(4). https://doi.org/10.26686/pq.v14i4.6545

Bogner, J., Abdelrafie Ahmed, M., Diaz, C., Faaij, A., Gao, Q., Hashimoto, S., Hashimoto, S., Mareckova, Pipatti, R., & Zhang, T. (2007). Waste Management. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)]* (pp. 585–618). Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter10-1.pdf

Bouškova, A., & Thiele, J. (2018). *Assessment of potential for energy generation from expanding industrial wastewater treatment facilities* (Bioenergy Association of New Zealand Energy from expanding WWT facilities, Project No: 4162). BPO. https://www.bioenergy.org.nz/documents/resource/Reports/Industrial-Waste-Treatment_rev1.pdf

Chen, C., & Green, N. (2003). *Is Landfill Gas Green Energy?* National Resources Defence Council.

Collins, R., Hazell, L., & Niakolas, A. (2020). *Analysis of State & Territory Waste Strategy Targets*. Australian Council of Recycling. http://www.acor.org.au/uploads/2/1/5/4/21549240/acor_-_final_report_v02__1_.pdf

Department for Environment, Food and Rural Affairs (UK). (2011). *Guidance on applying the Waste Hierarchy*.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69403/pb13530-waste-hierarchy-guidance.pdf

Department of Environment and Climate Change NSW. (2007). *Report into the Construction and Demolition Waste Stream Audit 2000-2005*. Department of Environment and Climate Change New South Wales.

Department of the Environment and Energy (AU), B. E., & Blue Environment Pty Ltd. (2018). *National Waste Report 2018*. Department of the Environment and Energy, Blue Environment Pty Ltd. https://www.environment.gov.au/system/files/resources/7381c1de-31d0-429b-912c-91a6dbc83af7/files/national-waste-report-2018.pdf

Environment Agency. (2009). *Evidence: A Low Carbon Water Industry in 2050* (SC070010/R3; p. 41). Environment Agency (UK). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291635/scho1209brob-e-e.pdf

Environment Canterbury. (2013). *Treated Timber Waste Minimisation Project Milestone 1: Industry Overview*.

Eunomia. (2018). *National Resource Recovery Project—Situational Analysis Report*. Ministry for the Environment. https://environment.govt.nz/assets/Publications/Files/national-resource-recovery-project-redacted.pdf

Eunomia, Chowdhury, T., Elliott, T., Elliott, L., & Hogg, D. (2017). *The New Zealand Waste Disposal Levy: Potential Impacts of Adjustments to the Current Levy Rate and Structure.* [Final Report]. Eunomia. https://www.eunomia.co.uk/reports-tools/the-new-zealand-waste-disposal-levy-potential-impacts-of-adjustments-to-the-current-levy-rate-and-structure/

European Environment Agency. (2019). *Indicator Assessment: Waste Recycling*. https://www.eea.europa.eu/data-and-maps/indicators/waste-recycling-1/assessment-1

Eurostat. (2020). *Generation of waste by waste category, hazardousness and NACE Rev. 2 activity*. https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wasgen&lang=en

Fischedick, M., Roy, J., Abdel-Aziz, A., Acquaye, A., Allwood, J. M., Ceron, J. P., Geng, Y., Kheshgi, H., Lanza, A., Perczyk, D., Price, L., Santalla, E., Sheinbaum, C., & Tanaka, K. (2014). Industry. In *In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]* (pp. 739–810). Cambridge University Press. https://www.ipcc.ch/report/ar5/wg3/

Global Methane Initiative. (2013). *Municipal Wastewater Methane: Reducing Emissions, Advancing Recovery and Use Opportunities*. Global Methane Initiative. https://www.globalmethane.org/documents/ww_fs_eng.pdf

Hoffart, M. (2019). What's wrong with burning rubbish? Waste to energy incineration. *LG NZ Local Government Magazine*. https://localgovernmentmag.co.nz/waste-to-energy-incineration/

Living Earth. (2020). *Living Earth: Our Story*. https://www.livingearth.co.nz/our-story

McMeeking, S., Kahi, H., & Kururangi, G. (2019). *He Ara Waiora: Background paper on the development and content of He Ara Waiora*. The Treasury.

https://ir.canterbury.ac.nz/bitstream/handle/10092/17576/FNL%20%20He%20Ara%20Waiora%20Background%20Paper.pdf?sequence=2&isAllowed=y

Ministry for the Environment. (2004). *Landfill Full Cost Accounting Guide for New Zealand*. Ministry for the Environment. https://www.mfe.govt.nz/sites/default/files/media/Waste/Landfill%20Full%20Cost%20Accounting%20Guide.pdf

Ministry for the Environment. (2018). *Hydroflourocarbon Consumption in New Zealand* [Prepared by Expert Group]. Ministry for the Environment. https://www.mfe.govt.nz/publications/climate-change/hydrofluorocarbon-consumption-new-zealand

Ministry for the Environment. (2019). *Reducing waste: A more effective landfill levy—Consultation document*. Ministry for the Environment. https://www.mfe.govt.nz/publications/waste/reducing-waste-more-effective-landfill-levy-consultation-document

Ministry for the Environment. (2020a). *Marginal abatement cost curves analysis for New Zealand: Potential greenhouse gas mitigation options and their costs* (p. 102). Ministry for the Environment. https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/marginal-abatement-cost-curves-analysis_0.pdf

Ministry for the Environment. (2020b). *New Zealand's greenhouse gas inventory: 1990—2018*. Ministry for the Environment. https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/new-zealands-greenhouse-gas-inventory-1990-2018-vol-1.pdf

Ministry for the Environment. (2020c). *Waste to Energy Guide for New Zealand*. Ministry for the Environment. https://www.mfe.govt.nz/publications/waste/waste-energy-guide-new-zealand

Ministry for the Environment. (2021). *New Zealand's greenhouse gas inventory: 1990—2019. Volume 1*. Ministry for the Environment. https://environment.govt.nz/assets/Publications/New-Zealands-Greenhouse-Gas-Inventory-1990-2019-Volume-1-Chapters-1-15.pdf

Ministry for the Environment. (Unpublished). *National Resource Recovery Fibre Long List Options*.

Mirosa, M., & Environment Select Committee. (2020). *Briefing to investigate food waste in New Zealand: Appendix B*. https://www.parliament.nz/resource/en-NZ/SCR_96164/cebeaf7cf20b40245fdf5c60601d83a2ac5b105f

MRA Consulting Group. (2018). *Proposals for Short to Medium Term Responses to National Sword*. Ministry for the Environment. https://environment.govt.nz/assets/Publications/Files/proposals-for-short-to-medium-term-responses-to-national-sword.pdf

New Zealand Government. (2019a). *Minister announces multi-agency response to identify risks from legacy landfills*. https://www.beehive.govt.nz/release/minister-announces-multi-agency-response-identify-risks-legacy-landfills

New Zealand Government. (2019b). *Renewable energy for Christchurch hospital*. https://www.beehive.govt.nz/release/renewable-energy-christchurch-hospital

New Zealand Infrastructure Commission Te Waihanga. (2020). *Sector State of Play: Resource Recovery and Waste. Discussion document* (p. 50). New Zealand Infrastructure Commission Te Waihanga. https://infracom.govt.nz/assets/Uploads/State-of-Play-Resource-Recovery-and-Waste.pdf

Waste Minimisation Act, (2008) (testimony of New Zealand Parliament). http://www.legislation.govt.nz/act/public/2008/0089/latest/DLM999802.html

New Zealand Productivity Commission. (2018). *Low-emissions economy: Final report*. New Zealand Productivity Commission. https://www.productivity.govt.nz/assets/Documents/lowemissions/4e01d69a83/Productivity-Commission_Low-emissions-economy_Final-Report_FINAL_2.pdf

NSW Government: Environment, Climate Change and Water, & The Organic Force. (2011). *The benefits of using compost for mitigating climate change*. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/waste/110171-compost-climate-change.pdf?la=en&hash=7ADC0B32600A8EE49E72187E4A027FA1C809AEAE

NSW Government: Planning & Infrastructure. (2012). *Major Project Assessment: Kimbriki Resource Recovery Project*. NSW Government: Planning & Infrastructure. https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=MP10_0065%2120190808T020007.883%20GMT

OECD. (2018). *Municipal Waste Generation in the OECD*. https://data.oecd.org/waste/municipal-waste.htm

Office of the Prime Minister's Chief Science Advisor. (2019). *Modern landfill: A waste-to-energy innovation*. https://www.pmcsa.ac.nz/2019/11/05/modern-landfill-a-waste-to-energy-innovation/

Oonk, H. (2012). Efficiency of landfill gas collection for methane emission reduction. *Greenhouse Gas Measurement and Management*, *2*(2–3), 129–145. https://doi.org/10.1080/20430779.2012.730798

Ramboll, Fraunhofer ISI, & Ecological Institute. (2020). *The Decarbonisation Benefits of Sectoral Circular Economy Actions: Quantification methodology for, and analysis of, the decarbonisation benefits of sectoral circular economy action* (Final Report Framework Service Contract EEA/ACC/18/001/LOT 1). European Environment Agency. https://ramboll.com/-/media/files/rm/rapporter/methodology-and-analysis-of-decarbonization-benefits-of-sectoral-circular-economy-actions-17032020-f.pdf?la=en

Rawtec. (2020). *Analysis of NSW Kerbside Green Lid bin Audit Data Report*. New South Wales Government.

Science Direct. (2020). *Anaerobic Digesters*. https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/anaerobic-digesters

Scott, F., & Curtis, J. (2018). *New Zealand Rural Waste Minimisation Project: Project Completion Report*. Ministry for the Environment. https://www.ecan.govt.nz/your-region/your-environment/waste-and-hazardous-substances/new-zealand-rural-waste-minimisation-project/

Shore Regional Organisation of Councils. (2014). *Too Good To Waste: A Waste Avoidance and Resource Recovery Strategy for Manly, Mosman, Pittwater and Warringah* (p. 17). https://www.renewnsw.com.au/content/uploads/2017/02/CONFIDENTIAL-SHOROC-Final-detailed-strategy-31-October-2014JS.pdf

Sierra Club LFGTE Task Force. (2010). *Sierra Club Report on Landfill-Gas-To-Energy*. https://www.sierraclub.org/sites/www.sierraclub.org/files/landfill-gas-report.pdf

Stats NZ. (2020, August 27). *Greenhouse gas emissions (consumption-based): Year ended 2017*. https://www.stats.govt.nz/information-releases/greenhouse-gas-emissions-consumption-based-year-ended-2017

Tonkin and Taylor. (2014). *New Zealand Non-Municipal Landfill Database*. Ministry for the Environment.

Verum Group. (2020). *Projections of HFC stocks and emissions to 2050 in relation to key factors influencing HFC consumption* [Prepared for Ministry for the Environment]. Verum Group.

Waste Management NZ Ltd. (2018). *Submission of Waste Management NZ Limited to the NZ Productivity Commission on Low-Emissions Economy*. New Zealand Productivity Commission. https://www.productivity.govt.nz/assets/Submission-Documents/633e4c513a/DR-332-Waste-Management-New-Zealand.pdf

WasteMINZ. (2020). *Recommendations for standardisation of kerbside collections in Aotearoa*. Prepared for MfE. https://www.mfe.govt.nz/sites/default/files/media/Waste/recommendations-for-standardisation-of-kerbside-collections-in-Aotearoa.pdf

WasteMINZ Product Stewardship Group. (2019). *A Plain English Guide to Product Stewardship in New Zealand*. Waste Management Institute of New Zealand. https://www.wasteminz.org.nz/wp-content/uploads/2019/09/Plain-English-Guide-to-Product-Stewardship-in-Aotearoa.pdf

Westland District Council. (2019). *Fox Landfill Clean-Up*. https://www.westlanddc.govt.nz/fox-landfill-clean