Household food waste: Diversion to where?

10 December 2022

This note explores household food waste management solutions in the context of the Ministry for the Environment (MfE) proposal to mandate kerbside collection of household food waste, as part of their *Transforming recycling* workstream. The note focuses on a narrow piece of the broader food waste challenge, which involves actors throughout the food supply chain and requires solutions at all levels of the food recovery hierarchy, as described in the first report in the OPMCSA food waste series, *Food waste: A global and local problem*.

Key messages

1. The majority of New Zealand's landfilled food waste comes from households. This contributes to climate change and wastes valuable resources.
2. While preventing food waste in the first instance is the preferred intervention, there will always be some household food waste that isn't prevented. MfE has proposed that every household should have a kerbside food waste bin to divert unprevented food waste from landfill. They haven't specified what should be done with the collected waste.
3. Territorial Authorities (TAs) will need to decide how to collect and process food waste. This will require them to decide which processes to use and the extent to which to involve different kinds of enterprises, which can be broadly described as community enterprises (e.g. community composting initiatives) and commercial enterprises.
4. Working with commercial food waste enterprises is likely to be seen as the easiest and most cost-effective option for councils. Supporting the scaling out of community enterprises can also be part of the solution to household food waste, particularly given the social value they deliver.
5. While composting is the most prominent and well-known food waste processing technique in Aotearoa, many other approaches exist, such as vermicomposting (i.e. worm farming), anaerobic digestion, animal feed production, and thermochemical processing (e.g. pyrolysis, gasification). Each processing technique has its own advantages and disadvantages.
6. OPMCSA is undertaking an evidence synthesis exploring how each food waste processing option works, the utility and quality of the processing products, key environmental considerations, key social and cultural considerations, and other factors for consideration such as lock-in risks. Provisional findings, not yet fully peer reviewed and with further research to come, are included as annex 2.
7. It is likely that no single method of food waste processing option will be appropriate for all situations, and TAs and other users will have to weigh up the environmental, social, cultural, and financial impacts of collection and processing options before proceeding. Therefore, we don't intend to recommend a 'best' approach.
8. When completed, this work be published as a public-facing web explainer, which may be useful for local and central government decision makers, likely in Q1 of 2023.
9. This work will also be included in the third report in the OPMCSA food waste series, which will cover upcycling, animal feed, and material, nutrient, and energy recovery options for food waste throughout the food system.
10. While this note is narrowly focused on household food waste, there is a lot of overlap with other food waste streams and wastewater treatment in terms of the available processing options and challenges. These overlaps will be drawn out in the third report in the OPMCSA food waste series.

Landfilling food waste contributes to climate change and undermines our shift to a circular economy

Over 330,000 tonnes of food waste were sent to municipal landfills in Aotearoa in 2020,[1] mostly from household general waste bins.[2] This is a problem for two key reasons:

- Food waste contributes 22% of New Zealand's total greenhouse gas emissions from municipal landfills.[3] When landfilled food waste breaks down without oxygen, it produces methane (CH_4), a potent greenhouse gas with substantially greater short-term warming potential than carbon dioxide (CO_2). Even when methane is captured (as is the case for most levied landfills in Aotearoa), imperfect gas capture means about 0.6 tonnes of CO_2 equivalent (CO_2e) is released for each tonne of food waste.[4,5]
- If food waste is landfilled, its nutrient value can't be captured, and energy capture opportunities are limited. Landfilling food waste drives resource extraction when we could be recovering what we already have as part of a circular bioeconomy.[6] Embracing the circular bioeconomy also creates new economic opportunities, including new jobs.

Reducing the volume of food waste that is landfilled can therefore contribute to New Zealand's climate change mitigation targets and be part of the country's ambition to move from a linear economy to an increasingly circular one.[7]

Box 1: What is a circular economy?

A circular economy framework calls for a shift away from the linear take-make-use-waste approach to resource use towards an approach where waste is designed out, products and materials are kept in use. This approach to resource use designs waste and pollution out of the economy where possible, and keeps products and materials in use, slowing, narrowing, and closing material resource loops and regenerating te taiao.[8-12] Definitions vary,[13] but MfE describes the core principles as follows:

> "Design out waste and pollution – View waste as a design flaw. Loss of materials and energy through the production process is minimised.
>
> "Keep products and materials in use – Think in systems. Products are designed to be reused, repaired and recycled, and waste materials for one process become an input for another.
>
> "Regenerate natural systems – Shift perspectives from minimising environmental harm to doing good. Valuable nutrients are returned to the soil and ecosystems are enhanced."[14]

For more details, see report one in the OPMCSA food waste series, *Food waste: A global and local problem*.

The problem is big enough for multiple solutions

There are four ways to reduce the volume of household food waste going to landfills in Aotearoa.

1. Prevention

   Preventing food waste is the priority action in the food recovery hierarchy, keeping food in the human supply chain and thereby avoiding wasted emissions and resource use throughout the food system.[6] Household food waste can be prevented through changes in people's practices and modification of the structural drivers of food waste.[15,16] Households can also upcycle food at risk of going to waste and share surplus with their communities.[6]

2. Processing food waste at home

   Unprevented food waste can be managed at home through composting, worm farming, bokashi fermentation, and feeding to animals. About 55% of New Zealanders have some form of home composting system.[17] By managing food waste at home, emissions associated with transporting food waste are avoided, and individuals become part of the waste management solution, which can motivate broader sustainability behaviours.[18-20]

3. Community enterprises

   Community composting and worm farming initiatives play a role in capturing value from household food waste. Community enterprises comprise a mixture of not-for-profits, social enterprises, incorporated societies, and volunteer-run initiatives that are often place-based and of a smaller scale than commercial enterprises. Community gardens with drop-off compost bins and local collection services operate in communities throughout the country and contribute to broader environmental and community benefits such as facilitating food resilience and sovereignty through urban farming initiatives, teaching people in the community new skills, providing sustainability education, and fostering social cohesion.[21-23]

4. Commercial enterprises

   Household food waste can be processed by commercial enterprises. In Aotearoa, composting predominates, with all 12 TAs that currently collect separated household food waste from the kerbside processing those waste using commercial composting facilities[21] (see annex 1 for maps showing the current state of kerbside food waste collection services and processing in Aotearoa). However, a range of other processing options exist, including worm farming, anaerobic digestion, thermochemical processing, and production of animal feed (see annex 2 for details). Some of these alternatives to composting are starting to gain traction in Aotearoa. For example, Auckland Council is set to send its food waste to an anaerobic digestion plant in Reporoa from 2023,[24] while a worm farming trial for business food waste is ongoing in Hamilton.[25]

Prevention and home-based solutions can't go it alone

Even if efforts are made to boost food waste prevention and increase the number of households managing their food waste at home, these solutions alone won't be able to maximise diversion of household food waste from landfill.

- Preventing food waste is crucial but challenging. Shifting embedded practices takes time, and perfect prevention is an unrealistic ideal. In addition, about half of household food waste is made up of components of food that are considered inedible by some or most people, so there will always be some food waste remaining.[2]
- Home-based solutions aren't feasible for everyone, and even those who manage food waste at home very rarely process all types of food waste.[17] Some of the barriers to greater uptake of home-based solutions are surmountable (e.g. cost can be overcome with free or subsidised equipment, lack of knowledge can be overcome with courses and information) while others are harder to overcome (e.g. time paucity, lack of space).

Community and commercial solutions have a role to play

Household food waste prevention interventions and home-based solutions therefore need to be supplemented with community and/or commercial solutions. For community and commercial solutions to operate, food waste needs to be separated from general waste and delivered to a processing site (see box 2 for options available if food waste isn't separated).

Box 2: Managing food waste without source separation: A fifth option?

When food waste is mixed with other municipal solid waste, downstream processing options are constrained to energy recovery and disposal. The waste can either be landfilled (the status quo throughout most of the country) or processed thermochemically for energy recovery (not widely practiced in Aotearoa, see annex 2 for details). Alternatively, general waste could be machine-sorted to separate organic and inorganic components.[21,26] However, this practice is imperfect: the separated organic stream can still contains at least 5% inorganic material at the end of the process, and it is highly likely that not all organic material is recovered from the inorganic stream either.

MfE is therefore proposing to mandate nationwide rollout of kerbside food waste bins as part of its *Transforming Recycling* proposal.[3] While food waste could be delivered to transfer stations or community drop-off sites by households themselves, MfE assesses that kerbside collection is the easiest and most accessible solution for households, likely to achieve the greatest food waste diversion rate. They also assess that relying on voluntary rollout of kerbside food waste collection services would lead to patchy coverage.[27] Alongside this work, MfE has other food waste initiatives underway, including a household and business food waste prevention workstream.[16,28]

More processing capacity will be needed to handle the anticipated increased volume of separated food waste.[3] This capacity can be found through both commercial enterprises and community enterprises. See box 3 for details about community composting, and annex 1 for maps showing the current state of kerbside food waste collections and current processing sites.

Box 3: Putting community solutions on the map

Kerbside collection and management of general waste in Aotearoa is currently undertaken by commercial enterprises, making it easy to assume that a commercial model with large-scale, centralised processing is the approach needed for kerbside food waste too.[21] The simplicity of engaging with one company with the capacity to handle all the food waste from a TA and the cost savings that can be achieved with economies of scale are appealing.

While community enterprises may struggle to compete with commercial processors on price, they often deliver broader environmental and social benefits, which could be factored into decision making through a social procurement or progressive procurement approach.[29,30] For example, transport emissions are drastically reduced, and community connection, mental and physical wellbeing, food sovereignty, community resilience, and learning and intergenerational knowledge exchange are among the social benefits. Community enterprises can also flex to serve the unique needs in their area.[18,21-23] There is also a link between community composting and Māori soil and kai sovereignty.[31] Māori have long managed organic waste through composting and have used ash, charcoal, and kelp as soil amendments.[18,32,33] In addition, sustainable and regenerative place-based relationships with the environment are a core part of Te Ao Māori.[34]

The full extent of community composting in Aotearoa is unknown. We aren't aware of any maps showing the location and processing capacity of all community composting initiatives throughout the country, although a good start has been made (see annex 1). We aren't aware of any studies that seek to systematically detail or quantify the social benefit of community composting in Aotearoa, but a French study found an urban farm and composting school delivered a community economy return on investment of about 2:1 over a one-year period, forecast to reach 27:1 over a ten-year period.[22]

Putting community composters on the map, calculating their aggregate processing capacity and growth potential, and articulating the environmental and social benefits of their work will help highlight the role they can play in the food waste processing equation. Supporting the scaling out of community composting solutions can be part of the solution to household food waste.[18,21]

What has MfE proposed?

In the *Transforming Recycling* consultation document, MfE has proposed that:

- Household food waste should be collected from the kerbside in urban areas (defined as a town with a population of 1,000 or more residents) and in areas where there are already existing kerbside collections.[3] See box 4 for information about multi-unit dwellings.
- TAs should collect food waste at a minimum. It's up to them if they want to collect garden waste as well. For those TAs that decide to collect garden waste, MfE doesn't specify whether it should be combined with food waste (known as food organics and garden organics, or FOGO) or collected separately, but notes that FOGO collection limits downstream processing options and reduces food waste diversion rates (see box 5).[3]
- For TAs within 150 km of existing commercial food waste processing facilities, MfE suggests that kerbside food waste collection could be rolled out by 2025, and by 2030 for those that are further away and might require new processing infrastructure.[3]
- There should be a consistent approach to what is accepted in food waste and garden waste bins so that resources and messaging can be shared between TAs and to improve the quality and consistency of food waste processing products. MfE suggests excluding all potentially biodegradable materials except for food and garden waste. They argue that paper and cardboard products, compostable packaging, compostable bin liners, tea bags, hair, vacuum cleaner dust, and animal waste should be ruled out, as these can be sources of contamination and/or potentially limit the culturally and socially acceptable uses of products.[3] The exclusion of biodegradable plastics reflects the fact that they aren't desirable inputs to the vast majority of food waste processing options and are a source of confusion for households.[17,35-37]
- MfE has also proposed that businesses should be required to separate their food waste from other waste.[3]

Box 4: What about multi-unit dwellings?

As Aotearoa densifies in urban areas,[38] waste management solutions for multi-unit dwellings will become increasingly important, including for food waste.[39] Multi-unit dwellings often don't have kerbside collection services for each unit: waste is aggregated and collected in bulk for offsite management.[40] This approach can be applied for separated organics too.[39]

On-site processing (e.g. in-vessel composting) and partnerships with community composting enterprises may be part of the mix of solutions too, and home-based solutions (e.g. bokashi bins) could also play a role, although space for processing and product use may be constraints.

In-sink disposal is another option. The environmental impacts of in-sink disposal depend on how sewage sludge is managed. In some parts of the country, sewage sludge undergoes anaerobic digestion (in parts of Auckland, Hamilton, Palmerston North, and Christchurch), meaning methane is captured and used to generate electricity, while in other parts of the country sewage sludge may be landfilled.[41] Other sewage sludge destinations include composting and vermicomposting, land reclamation, land application, and pond storage.[41,42]

Where does this leave Territorial Authorities?

The *Transforming Recycling* kerbside food waste proposal leaves a lot of flexibility for TAs, who are responsible for waste minimisation and management.[43] While it means that solutions can be tailored to the local context, it also gives rise to many questions for TAs to work through. If MfE's kerbside food waste proposal goes ahead, TAs without kerbside services will have to make two key decisions:

- Whether to collect just food waste or include garden waste too (in a FOGO bin, or separately).
- How to collect and process the separated food waste (and possibly garden waste), given that new processing capacity will be necessary if kerbside organics collection is mandated.

TAs, along with central government, will also need to consider:

- How to avoid compromising source prevention efforts and at-home solutions for food waste management when kerbside collections are rolled out, and how to ensure that community initiatives can be part of the solution (see boxes 3 and 5 for further details).
- How to ensure that the end products of food waste processing are utilised so that the twin goals of reduced landfill emissions and contribution to the circular bioeconomy are achieved (see boxes 1 and 6 for further details). This could include ensuring the regulatory landscape is sufficiently enabling while also making sure it promotes the safe operation of food waste processors and use of their products.
- How to ensure that households use their bins appropriately, maximising landfill diversion and minimising contamination of food waste bins (see box 5 for further details).

For TAs with existing kerbside collection services or advanced plans, the outcome of *Transforming Recycling* may impact what they are already doing, particularly around acceptable inputs.

Box 5: Ensuring that people use their bins properly without undermining prevention

A separate bin for food waste will only be effective at diverting household food waste from general waste if people use it – and properly. A Miramar-based trial found that households given a trial food waste bin still put over 60% of their food waste in the general waste.[44] There is also a risk that food waste bins get contaminated with unwanted materials.[45]

Evidence from the UK suggests that more household food waste is separated if: food waste bins are collected weekly (especially when coupled with fortnightly general waste collection) and food waste are collected separately from green waste. Clear communication, good execution of the service (including reliability), and bin design are also crucial to high engagement.[46]

MfE intends to provide support and education to households to boost food waste bin use and minimise contamination.[10] Information alone will be insufficient to drive sustained behaviour change. Other interventions such as prompts, norming, incentives, consequences, and providing supporting tools should also be considered.[15,45,47-49] Monitoring of diversion volumes, contamination, and the impacts of specific interventions to address these should be maintained so that continual improvements can be made.

Encouraging utilisation of food waste bins, composting services, or other food waste management solutions can undermine people's commitment to prevent food waste,[50] even though preventing food waste to begin with is the best course of action from a resource efficiency and emissions perspective.[6] Ensuring that household food waste management solutions don't undermine prevention efforts is crucial.

How can science advice help?

OPMCSA is undertaking an evidence synthesis exploring how each food waste processing option works (both in the commercial space and, where applicable, at the community level), the utility and quality of the processing products, key environmental considerations, key social and cultural considerations, and other factors for consideration such as lock-in risks (see annex 2 for provisional findings, not yet fully peer reviewed). We are putting particular emphasis on climate impacts and the contribution each processing option makes to the circular economy (see boxes 1 and 6).

We don't intend to recommend a single 'best' approach to food waste management, but rather highlight some of the key considerations when making food waste processing decisions. This work will be included in the third report in the OPMCSA food waste series and will also be published as a public-facing web explainer which may be useful for local and central government decision makers, likely in Q1 of 2023.

As part of this work, we are looking at international examples. Emissions accounting research published by the New South Wales Environmental Protection Authority is highlighted in annex 3, and case studies exploring what other jurisdictions do with their household food waste are included in annex 4, with more to come. We have been engaging with commercial and community food waste processing enterprises in Aotearoa and Australia and will include local case studies.

Box 6: Emissions, circularity, and a lifecycle lens

Our work has a particular focus on the emissions profile associated with each processing option and the contribution it can make to New Zealand's movement towards a circular economy. We focus on emissions given the imperative of climate change mitigation in the context of the climate crisis and to meet New Zealand's mitigation targets.[10] We focus on circularity given the need to use resources wisely to reduce our environmental footprint,[11] and because understanding lifecycle emissions requires product use and displacement to be factored in.[51,52]

A lifecycle assessment of the emissions associated with a given food waste processing option requires all emissions from all activities involved in the process to be factored in, from setting the system up, to transport emissions from moving organics to the processing site, pre-treatment of waste, and the process itself. In addition, a lifecycle assessment may consider emissions avoided when the output of the process (e.g. compost) displaces another product (e.g. fertiliser), and the impact of carbon sequestration. Product displacement has been found to be the decisive factor in lifecycle assessment of emissions associated with organic waste processing, so understanding the products of each process and how they can be used in a circular bioeconomy is crucial.[51,52]

The lifecycle lens we are applying in this work differs from the emissions accounting approach currently used by MfE. They have emissions factors for landfill without gas capture (1.881 tonnes CO_2e/tonne food waste) and landfill with gas capture (0.602 tonnes CO_2e/tonne food waste), as well as emissions factors from the Intergovernmental Panel on Climate Change for composting (0.172 tonnes CO_2e/tonne food waste) and anaerobic digestion (0.020 tonnes CO_2e/tonne food waste).[4,5] These emissions factors only account for emissions produced during food waste processing (thereby excluding the upstream or downstream emissions) and don't consider displaced emissions and carbon sequestration. In addition, they don't provide emissions factors for a wide range of other food waste processing options.

Annex 1: Kerbside food waste collection services and processing state of play

Understanding the scale, capacity, and diversity of New Zealand's food waste processing options is key to effectively diverting food waste from landfill and contributing to the shift towards a circular economy. A range of commercial and community food waste processors currently exist. As part of our evidence synthesis, we are working to develop a more comprehensive picture of food waste processors in Aotearoa. This annex includes the information we have gathered so far.

Community composting initiatives

The full extent of community composting in Aotearoa is unknown. However, several ongoing initiatives are starting to build a picture. For example, an ongoing survey by the Crown Research Institute Manaaki Whenua has reached out to more than 50 community composters across the country to determine their processing capacity, the origins of their feedstocks, their processes, their outputs, and their social impacts. As part of this research, Manaaki Whenua is populating a live map of community composters and affiliated enterprises in Aotearoa (see figure 1 for a screenshot of the Manaaki Whenua map).

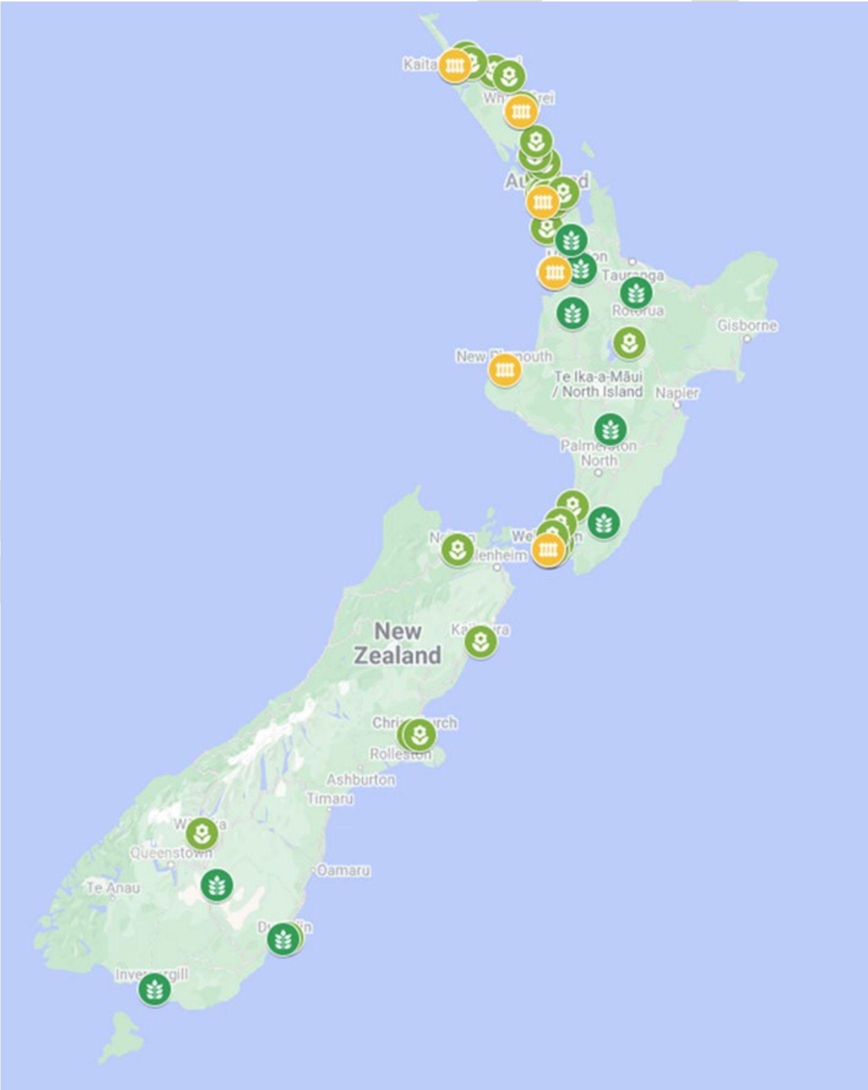


Figure 1: A map of community composters (green icons, with light green showing composters that are based in communities and dark green showing those that also serve the community but are affiliated with a school or other organisation) and organic waste networks (yellow icons) in Aotearoa, compiled by Manaaki Whenua. The map is a live and open resource, with enterprises able to add their own composting facilities.

Mapping efforts by Kore Hiakai provide further indication of the breadth of community composting efforts in Aotearoa, showing the spread of community gardens, locations which often engage in composting onsite (see figure 2 for a screenshot of the Kore Hiakai map). MakeSoil is a further source of information about the distribution of community composters, mapping sites around the world, including in Aotearoa. There is likely some overlap between the sites identified in these three community composting maps, while many community composting initiatives likely remain unmapped.

Figure 2: A map of community gardens in Aotearoa, compiled by Kore Hiakai. Many community gardens in Aotearoa have their own composting facilities, although the proportion of community gardens with composting facilities is unknown. Green icons represent initiative that primarily identify as community gardens, while other icons represent those that identify as community gardens as well as some other type of community food organisation (e.g. food bank).

In addition, the Compost Collective's ShareWaste map includes households with spare food waste processing capacity so that people who don't have home-based food waste management solutions can take their food waste to people in their neighbourhood who do.

Kerbside food waste collections and commercial processors

We are working on a map which depicts the status of kerbside food waste collection services in TAs throughout the country. We have also included commercial food waste processing enterprises on this map. **This is a work-in-progress.** We are still gathering information and working out how best to present it. We also hope to find out more about the processing capacity of each commercial processor, and eventually present this information on the map too.

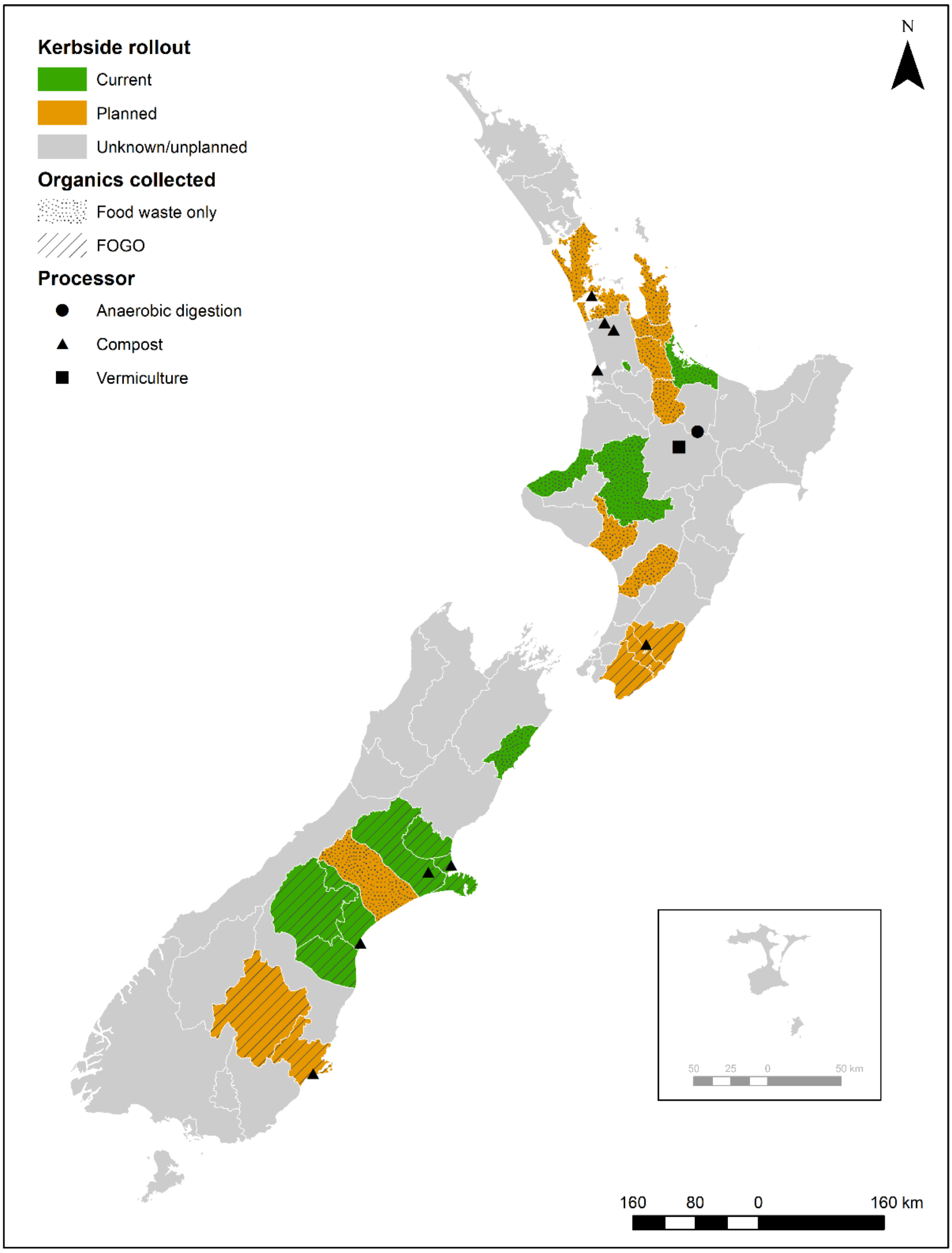


Figure 3: The status of kerbside food waste collection among New Zealand's TAs, showing current (green), planned (orange), and unknown/unplanned (grey) collection services See table on following page for details). For TAs with current and planned food waste collections, food waste is either collected in a standalone bin (stippling) or as FOGO (cross hatching). Overlaid on the map are commercial facilities listed by MfE and TAs as existing or potential commercial food waste processing sites. Map inset shows Chatham Islands.

The below table underpins the map on the previous page, summarising information about kerbside collection of household food scraps for TAs in Aotearoa. This is a work in progress, so if you have further information or corrections, please reach out: info@pmcsa@auckland.ac.nz

Territorial authority	Kerbside rollout status	Organics collected	Processor	Processor type	Process variation	End markets
Ashburton District	Planned	Food waste	Unknown	Unknown	Unknown	Unknown
Auckland Council (mainland)	Planned	Food waste	Ecogas	Anaerobic digestion	NA	Biogas, heat (tomato-growing), market for digestate as a biofertiliser unclear
Carterton District	Planned	FOGO	Masterton Recovery Park	Composting	Windrow	Sold to residential and commercial customers
Central Otago District	Planned	FOGO	Redruth Ecocentre	Composting	Aerated static pile	Unknown
Christchurch City	Current	FOGO	Living Earth Bromley	Composting	In-vessel, windrow	Used on farms in Canterbury region
Dunedin City	Planned	FOGO	Green Island Resource Recovery Park	Composting	GORE	Commercial businesses, community projects, public
Hamilton City	Current	Food waste	Hampton Downs	Composting	Aerated static pile	Sold to commercial businesses, available for purchase by the public
Hauraki District	Planned	Food waste	Unknown	Unknown	Unknown	Unknown
Kaikoura District	Current	Food waste	Unknown	Composting	Unknown	Unknown
Mackenzie District	Current	FOGO	Redruth Ecocentre	Composting	Aerated static pile	Sold to farmers and members of the community in South Canterbury region for farming, gardening, and landscaping
Manawatu District	Planned	Food waste	Unknown	Unknown	Unknown	Unknown
Masterton District	Planned	FOGO	Masterton Recovery Park	Composting	Windrow	Sold to residential and commercial customers
Matamata-Piako District	Planned	Food waste	Unknown	Unknown	Unknown	Unknown
New Plymouth District	Current	Food waste	Hampton Downs	Composting	Aerated static pile	Sold to horticulture and agriculture
Ruapehu District	Current	Food waste	Council-owned	Composting	HotRot	Used in local reserves and parks
Selwyn District	Current	FOGO	Pines Resource Recovery Park	Composting	Windrow	Distributed to landscape suppliers
South Waikato District	Planned	Food waste	Unknown	Unknown	Unknown	Unknown

South Wairarapa District	Planned	FOGO	Masterton Recovery Park	Composting	Windrow	Sold to residential and commercial customers
Tauranga City	Current	Food waste	Hampton Downs	Composting	Aerated static pile	Sold to commercial businesses, council buys for community projects, and available for purchase by the public
Thames-Coromandel District	Planned	Food waste	Unknown	Unknown	Unknown	Unknown
Timaru District	Current	FOGO	Redruth Ecocentre	Composting	Aerated static pile	Sold to farmers and members of the community in South Canterbury region for farming, gardening, and landscaping
Waimakariri District	Current	FOGO	Living Earth Bromley	Composting	In-vessel, windrow	Used on farms in Canterbury region
Waimate District	Current	FOGO	Redruth Ecocentre	Composting	Aerated static pile	Sold to farmers and members of the community in South Canterbury region for farming, gardening, and landscaping
Western Bay of Plenty District	Current	Food waste	Hampton Downs	Composting	Aerated static pile	Commercial businesses, community projects, public
Whanganui District	Planned	Food waste	Unknown	Unknown	Unknown	Unknown

Status of kerbside rollout unknown or unplanned for: Far North District, Whangarei District, Kaipara District, Waikato District, Waipa District, Ōtorohanga District, Waitomo District, Taupo District, Rotorua District, Whakatane District, Kawerau District, Ōpōtiki District, Gisborne District, Wairoa District, Hastings District, Napier City, Central Hawke's Bay District, Stratford District, South Taranaki District, Rangitikei District, Palmerston North City, Tararua District, Horowhenua District, Kapiti Coast District, Porirua City, Upper Hutt City, Lower Hutt City, Wellington City, Tasman District, Nelson City, Marlborough District, Buller District, Grey District, Westland District, Hurunui District, Chatham Islands Territory, Waitaki District, Queenstown-Lakes District, Clutha District, Southland District, Gore District, and Invercargill City.

NB: Although not a territorial authority, Raglan in the Waikato runs a food-waste only composting (HotRot) service for the town’s citizens.

Annex 2: What can we do with household food waste?

The below tables outline a wide range of food waste processing options. **This is a work-in-progress and hasn't yet been fully peer-reviewed, so all conclusions are provisional and subject to change.** Processing techniques are grouped according to where they fit in the food recovery hierarchy outlined in the first report in the OPMCSA food waste series, *Food waste: A global and local problem.*

We have only included processing options that are suitable for mixed household food waste, which is why food rescue, upcycling, and material recovery aren't represented. As well as being suitable for mixed household food waste, many of the processes below can also be used for other food waste streams (e.g. business food waste) and other organic wastes and materials. We highlight key details associated with each process, the products that result, key environmental, social, and cultural considerations, and other factors of note.

The processes below don't have to stand alone. The shortcomings of one process can be overcome by integrating it with another. Combining processes is particularly valuable where process by-products need to be modified before they can be utilised with confidence, where the alternative is that they are disposed of or used in the face of uncertainty about their performance. For example, digestate from anaerobic digestion and frass from insect-based bioconversion could be composted or vermicomposted before use as soil amendments. Alternatively, digestate and frass could be pyrolysed or gasified to generate syngas and biochar. Process complementarity can be factored into decision making.

Table abbreviations: AD = anaerobic digestion, BAM = beneficial anaerobic microbe composting, DAF = dissolved air flotation (a technique used to treat dairy wastewater), ERP = Emissions Reduction Plan, FOGs = fats, oils, and grease, FW = food waste, GHG = greenhouse gas, PAHs = polyaromatic hydrocarbons, PCDD/Fs = polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (also called dioxins), PFAS = perfluoroalkyl and polyfluoroalkyl substances, PM = particulate matter, POPs = persistent organic pollutants, SPICE = static pile inoculated compost extension, WAS = waste-activated solids (dairy biosolids)

Make animal feed

Process	Key details about the process and product	Key environmental considerations	Key social and cultural considerations	Other considerations and comments
'Standard' animal feed production FW is used as animal feed, following varying degrees of treatment and processing (e.g. heating, blending, grinding, drying, pelletising).	• Long-established process, incl. in NZ • Can be simple (e.g. vegetal FW with minimal processing) or more complex (e.g. dehydration, pelletisation, conversion to liquid feed)[53] • Using mixed household FW presents biosecurity risks (e.g. pathogen transmission, esp. when meat is present) and nutrition challenges (e.g. ensuring balanced diet for animals, esp. important in commercial farming settings), which need to be managed[53]	• Process emissions and water use vary depending on degree and type of processing • Using FW as feed can reduce enviro impact of producing feed and/or importing feed and feed ingredients[54]	• FW held ahead of processing or feeding can be odorous • Without maintaining stringent regulation of FW to animal feed processing, NZ's strong biosecurity reputation could be damaged[53]	• Need to comply with biosafety law and regulations (esp. when FW contains meat)[53,55-59] • Homogenous, pre-consumer agricultural and business FW are better suited to this process due to better ability to control nutritional composition and reduced biosecurity concerns[53,54]
Insect-based bioconversion (also called protein farming) Insects (esp. black soldier flies) are raised on FW and fed to animals (esp. pigs, chickens, fish, reptiles). Insects generally undergo processing (e.g. drying, milling, oil extraction) before being used as feed. Extracted oil also has the potential to be used as a biodiesel. Residual material, mostly frass, and to a lesser extent shed exoskeletons, dead insect parts, and potentially uneaten feedstock, has the potential to be used as a soil amendment, although may require further processing.	• Emerging process,[60] not currently practiced in NZ • Requires entomology expertise[60,61] • Using mixed household FW poses process control and nutrition challenges and contamination risks[62] • Evidence around performance of frass as soil amendment is emerging, but promising[60-63] • More research needed into prion transmission; bacterial, viral, and parasite risks are non-negligible but can be mitigated (e.g. by feedstock control and pre-treatment)[64]	• Emissions-intensive process, but could be highly climate positive if protein-based animal feed is replaced by insects and where feedstocks that aren't readily absorbed into the food system are utilised[53,61,65] • Black soldier flies break down mycotoxins, pharmaceuticals, and some pesticides, but take up some heavy metals; contaminants not taken up by insects end up in frass, creating possible soil contamination risks from frass if feedstock is contaminated[60,61]	• Scope to use waste-fed insects as human food, but perceptions and food safety considerations as barriers[53,66,67] • Need to consider treatment of insects (e.g. rearing conditions, killing procedures), an area which is underdeveloped in the regulatory space internationally[53,68,69] • Can be odorous • Could also consider for sewage sludge and/or animal manure processing, although contaminant risks and possibly social and cultural concerns would likely need to be addressed[61]	• Homogenous agricultural and business FW are better suited to this process due to better ability to control insect lifecycle and quality (incl. contamination) of both insects and frass[64] • While not the desired product, frass is the dominant product by volume (and to a lesser extent shed exoskeletons, dead insect parts, and potentially uneaten feedstock)[60-62]

Recover nutrients for soils

Process	Key details about the process and product	Key environmental considerations	Key social and cultural considerations	Other considerations and comments
Composting Microorganisms convert FW and green waste to compost, in the presence of oxygen. Compost can be used as a soil amendment.	• Well-established process, incl. in NZ • Can be done by commercial enterprises, in the community, and at home[21] • Several process variations, including bin composting (common in home and community settings), windrow, aerated static pile, in-vessel, SPICE, BAM, and Johnson-Su composting[21,70] • Feedstock can include FW, green waste, manure, biosolids, paper fibre, and ground wood-based waste[71] • FW must be mixed with dry/woody materials[72-74] • Simple process requiring aeration and water replenishment, although at scale, can require machinery and large area[23] • Compost benefits for soil well established[70,73,75,76]	• Composting operations likely a minor source of GHGs[70] (including carbon dioxide, methane, and nitrous oxide),[77] but much less than landfill emissions,[72] even with gas capture[4,5] • Compost use can reduce the need for fertiliser but quantifying displacement is difficult; where compost displaces synthetic fertiliser, emissions can be close to or better than net zero[72] • Compost also sequesters carbon and can be used to regenerate 'unproductive' soils, in which case it may not displace any fertiliser but still provides soil and climate benefits • Requires moisture content of 45-60% by weight[73], moisture derived from feedstock (e.g. FW) and/or watering • Leachate can be environmentally problematic if poorly managed[71]	• At local scales, community composting facilities provide a range of social and environmental benefits[18,21-23] • Community composting has links with Māori soil and kai sovereignty[18,31-33] and reflects perspective of regenerative place-based relationships[34] • Odour can be a problem,[73] particularly in large-scale open-air composting operations near residential settlements • Contaminants such as human hair or biosolids may limit culturally acceptable end uses of compost in Te Ao Māori (e.g. may be deemed inappropriate for use in the food system)[78,79]	• Although NZ has a composting standard,[80] grading and quality assurance of compost remains an issue • Compostable plastics can pose challenges to composters and negatively affect the quality of the end product without adding any nutrient value[35,37]
Vermicomposting (also called worm farming) Worms convert FW to vermicast, in the presence of oxygen. Vermicast can be used as a soil amendment.	• Well-established process, incl. in NZ • Can be done by commercial enterprises, in the community, and at home[21] • Feedstock can include mixed FW, biosolids, DAF solids, WAS, AD digestate, meat, FOGs, sheep pelts, chicken carcasses, etc; these feedstocks need to be mixed with fibre (e.g. certain green wastes, cardboard, wood shavings, jib boards, etc)[81] • Vermicast can be used as soil amendment; can squeeze liquid out of vermicast to produce liquid fertiliser[81]	• No windrow watering required in NZ (climate is sufficiently wet and feedstock moisture content sufficiently high)[81] • Leachate can be environmentally problematic if poorly managed[81] • Similar emissions profile to composting (potentially with less methane and nitrous oxide),[82] incl. possible fertiliser displacement	• Many social and cultural considerations shared with composting (e.g. value of community scale operations, odour risk) • Contaminants such as human hair or biosolids may limit culturally acceptable end uses of vermicast in Te Ao Māori (e.g. may be deemed inappropriate for use in the food system)[78,79]	• Large pieces of green waste not suitable as feedstock, so potentially not compatible with FOGO collection • Compostable plastics viewed as a contaminant/undesired input to process[81]
Dehydration FW is thermally dried, sometimes in the presence of microorganisms and enzymes (i.e. bio-dehydration) to produce biologically inert dried FW. Dried FW has the potential to be used as a soil amendment, although may require further processing, or as an animal feed ingredient.	• Emerging FW management solution,[83] not used in NZ to our knowledge • Dried FW generally needs secondary processing (e.g. via composting) before being applied to land[83,84] • When applied to land, dried FW contributes to soil carbon and nutrient but risk of short- and longer-term toxicity impacts on plants[83,84]	• Reduced volume and weight of dehydration decreases collection and transport emissions, but drying consumes a lot of energy[84] • Carbon sequestration means the process can be carbon neutral, but only if renewable energy is used for drying[84] • To compost, dried FW may need to be rehydrated, thereby using water[85] • Need to manage liquid condensate and exhaust gases[84]	• Dried FW must be kept dry; it is gets wet it will rehydrate, potentially growing mould, becoming odorous, attracting pests, etc[85]	• Potentially suitable for multi-unit dwellings to store FW without odour concerns between collections, but not broadly useful for household FW[84,85] • Efficiency drops if not operated at full capacity[84]

Recover energy

Process	Key details about the process and product	Key environmental considerations	Key social and cultural considerations	Other considerations and comments
Anaerobic digestion Microorganisms convert FW to biogas, in the absence of oxygen. Digestate (i.e. the wet mixture of liquid and solid residues left behind) has the potential to be used as a soil amendment, although may require further processing.	• Well-established process, new to NZ for mixed FW but used for wastewater treatment, manure, and industrial effluent (esp. dairy industry)[41] • Relatively complex, requiring infrastructure and machinery for waste capture and sorting, pre-heating, digestion, biogas capture, scrubbing, storage, power and heat generation, and solid and liquid digestate management[86] • Various bio-reactor types suited to different feedstocks, while co-digestion of different wastes can change methane yields[86] • Wide range of feedstock including mixed FW, crop biomass, fruits and vegetable waste, manures, industrial wastewater, and sewage sludge[41] • Digestion effluents (liquid or solid digestate) are typically processed (to a greater or lesser extent) before land application or other use[37,87,88]	• AD facilities can be carbon neutral[86] or carbon negative when biogas is used as a substitute for natural gas[89] • Water used to adjust moisture content of organic content early in AD process (although less than is typically required for composting)[23] • Unprocessed digestate applied to soils may produce uncontrolled GHG emissions and be potentially phytotoxic[42,74,86] • Ammonia losses and odour are the main risks associated with land application of unprocessed digestate;[42] nitrate leaching is also a risk[42]	• Contaminants such as human hair or biosolids may limit culturally acceptable end uses of digestate in Te Ao Māori (e.g. may be deemed inappropriate for use in the food system)[78,79]	• Biogas is not recognised as a renewable energy source in NZ (so not subsidised by govt) and is more expensive than natural gas[41] • Digestate from AD in NZ is classed as waste and often landfilled,[41] with no certification for digestate as a fertiliser or soil amendment product in NZ (regulatory context among other countries varies widely)[41,42] • Variations in feedstock volume and composition can present process challenges and impact digestate composition and biogas output[42] • Not anticipated that digestate could replace chemical synthetic fertiliser[41] • Not readily compatible with FOGO collection[41] • Compostable packaging doesn't readily break down during AD[37]
Pyrolysis and gasification To undertake pyrolysis, FW is dried and then burnt in the absence of oxygen, at atmospheric pressure. Biochar, bio-oil, and syngas result, with their relative yields depending on the feedstock and operating parameters such as temperature. Biochar can potentially be used as a soil amendment and to stably sequester carbon, among other possible applications. Bio-oil and syngas are sources of energy. Gasification is a variant of pyrolysis, optimised for syngas and biochar production. This is primarily achieved by introducing a limited supply of oxygen to the system.	• Pyrolysis and gasification are well-established processes for some feedstocks, but emerging for biomass feedstocks (esp. mixed FW), and not currently practiced in NZ[90-93] • Relatively complex, requiring pre-treatment equipment (centrifuges and thermal driers to reduce moisture content, choppers/grinders to reduce particle size) the pyrolyser/gasifier itself, and syngas, bio-oil, and biochar management and storage (incl. gas scrubbing)[94-97] • Wide range of feedstocks, both organic and inorganic, can be used (incl. mixed feedstocks), but feedstock choice impacts quality and utility of products[91,93-95,98,99] • Biochar (the carbon-rich solid product of pyrolysis and gasification) can be used to stably sequester carbon and mitigate soil leaching, increasing fertiliser utilisation and improving	• The process consumes a lot of energy (esp. drying to reduce moisture content of FW to acceptable level – ideally <25%)[104] – often the same amount of energy as it produces, or more • Biochar achieves centurial sequestration of carbon in stable aromatic ring structures (1-2 orders of magnitude longer than residence time than un-pyrolysed organic residues)[98,101,105,106] • Biochar also has sorbent properties which mean it has also received recent attention for its soil and water remediation potential[94,100] • Biochar can be used as a fertiliser replacement or complement, and can also reduce lime usage[98] • If heavy metals are present in feedstock, they end up in biochar fraction;[93,102] while they are stably	• Social licence to operate can be a significant barrier for any energy from waste process[108] • Distinction between pyrolysis and incineration not often understood, contributing to social licence barriers[114]	• If pyrolysis feedstock isn't dry enough, the resulting bio-oil's corrosion index (which measures whether liquid will cause corrosion of pipes) and cetane index (which measures the combustion speed of diesel fuel) can be too high for the bio-oil to be used as biofuel[94] • Risk of undermining the food recovery hierarchy or (if other wastes are used) the waste hierarchy more broadly[108] • While air pollution control residues are produced (see environmental considerations), when organic materials are used as feedstock the amount produced is generally less, and is also less than incineration (see incineration row)[110,111] • Fire risk associated with poorly managed[101] • The International Biochar Initiative has produced biochar standards, incl. contaminants to test for and

	nutrient availability; other possible uses include environmental remediation and animal feed supplementation[94,96,98,100,101] • Bio-oil (the liquid product of pyrolysis) has diesel- and petroleum-like properties and can be used as fuel for power, heat, and transport,[94] but generally requires upgrading[102] • Syngas is a gaseous product of pyrolysis and gasification, comprised of methane, hydrogen, carbon dioxide, carbon monoxide, and other gaseous hydrocarbons,[94] which can be used to generate heat or electricity or used to produce liquid fuels[103]	adsorbed, they are likely to be very gradually desorbed over the long-term[96] • Biochar produced by gasification (vs pyrolysis) can contain a high amount of alkali and alkaline earth metals and PAHs, which are toxic, potentially limiting the appropriateness of using the resulting biochar on soils[96] • If PFAS is present in the feedstock, emerging evidence suggests it is effectively broken down, but more research is needed[100,107] • Tars and bottom ash as waste residues[108] • While flue gas is 'cleaned' before discharge (e.g. by filtering PM and scrubbing), this transfers pollutants from one domain (i.e. pollutants in flue gas) to another (e.g. pollutants in wet scrubber wastewater, which have to be separated and landfilled)[109] • Air pollution control residues include PAHs and PDDD/Fs (i.e. dioxins), which can be toxic and, in the case of dioxins, persistent (i.e. are POPs)[110-113]		recommended maximum concentrations[115] • There is a verified carbon standard for biochar, developed by Verra to help companies claim carbon credits in voluntary markets for carbon sequestration achieved by biochar use[101]
Hydrothermal processing FW is converted to a slurry and pressure-fed into a high-temperature reactor. A range of liquid and gas energy products result, as well as hydrochar, which can potentially be used as a soil amendment and to sequester carbon, among other possible applications. Depending on the temperature and pressure, the process is known as either hydrothermal gasification, liquefaction, or carbonisation, with product ratios and composition varying between each.	• Hydrothermal processes are emerging, largely occurring at the lab-scale and in small operations or pilot plants,[94,116,117] and are not currently practiced in NZ • Complex, hazardous, and expensive,[96] with multiple technical barriers (e.g. catalyst recycling,[118] slurry optimisation, high-pressure feeding system optimisation)[119] still being worked through • A wide range of biomass feedstocks can be used, including lignocellulosic biomass, micro- and macro-algae, manure and animal by-products, sludge from wastewater treatment plants, AD digestate, food processing waste, and mixed FW[88,96,120] • High moisture feedstocks are suitable because water is a necessary solvent in the process[94]	• Biocrude oil from hydrothermal liquefaction can be used as an alternative to heavy fuel oil but needs upgrading[119] and its high viscosity makes it hard to use[94] • Hydrothermal liquefaction also produces light gas (which can be used for energy)[116] and an aqueous phase which as essentially a wastewater product that needs to be dealt with, although valorisation options are being explored[116,121] • Hydrochar, the dominant product of hydrothermal carbonisation,[116] has similar possible applications to biochar, but is less studied; emerging evidence suggests it doesn't have the same ability to stably sequester carbon as biochar, but may work well as a replacement for coal[96] • Syngas produced in hydrothermal gasification has same applications as syngas from gasification[103,116]	• Given immature status of technology and absence from NZ, it is likely not well understood here, with public perceptions not known but potentially similar to other thermochemical processing options (see pyrolysis and gasification row)	• Lignocellulosic biomass and algae feedstocks are particularly common feedstocks;[116,118,119] FW has received little attention as a possible feedstock • Potential as a technology for further processing of digestate from AD (i.e. complementary technology)[88]

Incineration (also called combustion) FW, typically combined with other municipal solid waste, is burnt in the presence of oxygen, generating heat and ash. The heat is a source of recoverable energy while the ash is a waste product.	• Well-established process (although modern air pollution control technologies have only been developed in the last few decades),[122] but not practiced in NZ • Incineration is an end-of-life waste management solution which reduces the mass of waste and produces heat that can be captured, but other than that doesn't yield any useful products[122] • Incineration itself is relatively simple but air pollution control is complex[123] • A wide range of feedstocks are possible, but plastic, wood, paper, cardboard, rubber, and leather combust most readily and yield net energy gains;[123] separated FW is a poorly suited feedstock (see next column) • Can accept mixed waste (i.e. don't have to separate FW)	• FW has a high moisture content so there is a net energy expenditure when it is incinerated[123] (i.e. for FW, incineration isn't technically an energy recovery process) • Bottom ash needs to be dealt with; it can be mixed into concrete, further processed to be used in other construction materials, or landfilled[123] • Flue gas contains air pollutants incl. dust, acidic gases, nitrous oxides, PDDD/Fs (i.e. dioxins), PAH, and mercury which need to be 'cleaned' out before discharge;[123] flue gas cleaning (e.g. by filtering, scrubbing) leaves air pollution control residues (also called fly ash) to be dealt with, typically by landfilling as a hazardous waste[110,111,123]	• Social licence to operate can be a significant barrier for any energy from waste process[108] • Early failures and air pollution, while now more stringently regulated and manageable with modern technology, continue to impact public perceptions esp. relating to perceived air pollution[122,123]	• Incineration of waste is predominantly practiced in places where available landfill space is limited and transport distances are small (especially Europe), using municipal solid waste as a feedstock[122] • Risk of undermining the food recovery hierarchy or (if other wastes are used) the waste hierarchy more broadly[108]
Landfill with gas capture FW, typically combined with other municipal solid waste, is buried in a landfill. As it breaks down in the absence of oxygen, gas (predominantly methane) is captured. The gas can either be used as a source of energy or flared.	• Well-established process, incl. in NZ • Can accept mixed waste (i.e. don't have to separate FW) • Most levied waste in NZ is sent to landfills with gas capture[124] • Doesn't produce any usable outputs other than energy from captured gas; gas capture rate is imperfect (see environmental considerations column), compared to anaerobic digestion where the majority of biogas is captured[42]	• Imperfect gas capture and GHG emission before gas capture begins means about 0.6 tonnes of CO_2 equivalent (CO_2e) is released for each tonne of FW;[4,5] this is a generalisation, with variation between landfills (e.g. 55% at Wellington's Southern landfill and 90% at Auckland's Redvale landfill)[125] • While landfilling sequesters carbon and captured gas can be used for energy, net emissions produced by FW substantially outweigh any offset[126] • Leachate (liquid which contains soluble components of landfill waste) can enter waterways and ground water,[127,128] although modern landfill design reduces the extent of leaching;[129] leachate contains compounds which are potentially hazardous to ecosystems and human health[128] • Leachate and gases continue to be produced even after a landfill is closed, creating intergenerational environmental management challenges[128]	• Social licence for landfilling in NZ waning; proposals for new landfill capacity recently challenged in multiple TAs[125] • Out-of-site location of landfills (generally fringe areas) can lead to disconnect between people and their waste, limiting opportunities to increase waste awareness and ownership and encourage prevention of FW[19]	• Bioreactor landfills are an emerging variation on a 'regular' landfill, optimised for more efficient decomposition of material under anaerobic and/or aerobic conditions; liquids are circulated through the landfill to facilitate microbial movement and nutrient transport and air is used to accelerate biodegradation and biostabilisation and prevent methane generation[130]

* NB: A range of other emerging processes exist for the conversion of FW to energy. E.g. transesterification,[131] alcoholic fermentation,[132] microbial and microalgae fuel cells, and photobiological hydrogen production.[94] These generally have low technology readiness, have niche applications, or aren't highly applicable to FW feedstocks but are mentioned for completeness.

Dispose

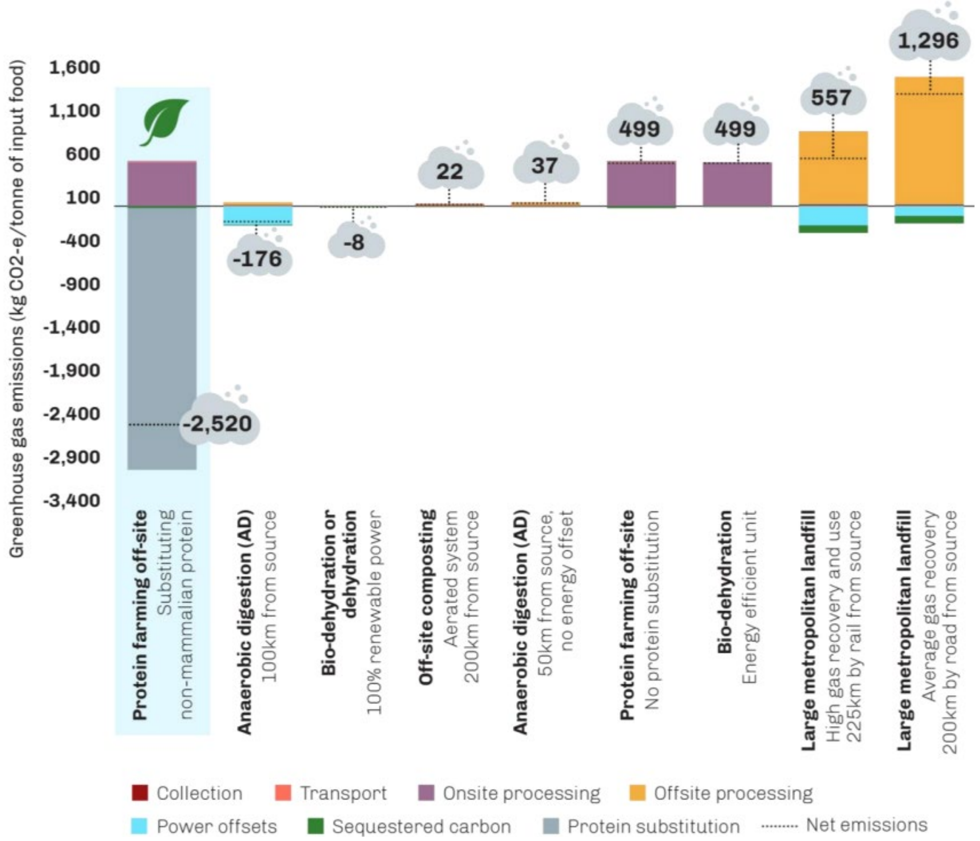
Process	More about the process and products	Key environmental considerations	Key social and cultural considerations	Other considerations and comments
Landfill without gas capture FW, typically combined with other municipal solid waste, is buried in a landfill. As it breaks down in the absence of oxygen, gas (predominantly methane) is released into the atmosphere.	• Well-established process, incl. in NZ • Currently less than 10% of levied waste goes to landfills without gas capture[124] • Doesn't produce any usable outputs • Can accept mixed waste (i.e. don't have to separate FW)	• About 1.9 tonnes of CO_2 equivalent (CO_2e) is released for each tonne of FW[4,5] • Small amount of carbon sequestration is achieved, but insufficient to meaningfully impact net emissions climate impact[126] • As with landfills with gas capture, leachate is generated, and long-term environmental management of closed landfills must be considered (see landfill with gas capture row)	• Social licence for landfilling in NZ waning; proposals for new landfill capacity recently challenged in multiple TAs[125] • Out-of-site location of landfills (generally fringe areas) can lead to disconnect between people and their waste, limiting opportunities to increase waste awareness and ownership and encourage prevention of FW[19]	• Being phased out in NZ; the ERP signals the intention for all municipal landfills to be required to have gas capture systems by 2026[10]
Send to wastewater treatment plant FW is ground up and disposed of down the sink, joining other wastewater at wastewater treatment plants. Wastewater is treated and discharged and the remaining biosolids must be managed.	• Well-established process, incl. in NZ • To reduce pipe blockages, FW should ideally be ground up using in-sink disposal unit, but even then FOGs can lead to blockages[20]	• Environmental impact is contingent on how wastewater is managed – if sewage sludge is landfilled, in-sink disposal is just a convoluted way of essentially putting FW in the general waste, but if other sludge management options are used (e.g. anaerobic digestion, vermicomposting) then in-sink disposal has a better environmental footprint[41]	• Can lead to disconnect between people and their waste, limiting opportunities to increase waste awareness and ownership and encourage prevention of FW[19,20]	• Potentially suitable for multi-unit dwellings with limited FW options

Annex 3: New South Wales assessment of the emissions impacts of food waste processing options

The New South Wales Environment Protection Authority (NSW EPA) has assessed the greenhouse gas impacts a range of food waste processing options.[133] They have factored in emissions produced during collection, transport, and processing, and (in some cases) emissions displaced and carbon sequestered when products are used. This work and other similar studies will be key sources for the OPMCSA evidence synthesis (e.g. see the Food Loss and Waste Protocol's guidance for connecting food waste and emissions).[134] The NSW EPA's key findings are copied below.

Key findings from *Emissions impacts of food waste recovery technologies*[133]

- Emissions from collection and transport of food waste off-site are usually a minor component of the net emissions.
- Even landfills with high levels of gas energy recovery still have significant net emissions from food waste because food rapidly decomposes and emits methane before the gas recovery systems are in place.
- Options that recover biogas energy using anaerobic digestion systems can have net reductions in GHG emissions if the energy substitutes for fossil fuel power.
- Protein farming using insect larvae has potential to significantly reduce net GHG emissions if the harvested protein substitutes for other protein, particularly mammalian protein. This benefit is uncertain as the protein may add to total protein production rather than replace other sources. Without this benefit, the energy use in protein farming will result in a high carbon footprint unless units are powered by renewable or lower emissions energy.
- Similarly, dehydration and bio-dehydration systems can have a high carbon footprint unless they are powered by renewable or low emissions energy sources.
- Composting can be expected to be a low, but overall net producer of GHG emissions unless the compost outputs result in greater soil carbon sequestration than modelled or result in less use of synthetic fertiliser.



Annex 4: What do other jurisdictions do with their household food waste?

Case studies exploring household food waste management in other jurisdictions are provided below. They have been selected to illustrate a wide range of approaches to household food waste management, with lessons for Aotearoa. We are continuing to look for more examples that can provide lessons for Aotearoa, with more case studies to be included in the third report in the OPMCSA food waste series.

Queensland, Australia – a flexible approach with well-considered sequencing

The Queensland Government's recent *Organics Strategy* and *Organics Action Plan* provide a good example of well-considered sequencing of household food waste policies.[135,136] The Queensland Government has signalled in its *Organics Action Plan* that it intends for at least 65% of households to have access to organics capture services of some kind by 2025, and 80% by 2030.[136] Brisbane City Council is pursuing this state government goal by supporting at-home food waste processing (with composting and worm farming workshops, and AUD$70 rebates for eligible composting equipment), the provision of 28 community composting hubs, and the possible rollout of kerbside collection services (currently being trialled in a pilot involving 6,000 households).[137,138]

The Queensland Government is also consulting on a ban on organics to landfill. This gives organic waste processors a stable signal to invest in the infrastructure necessary to process organic waste, in the expectation that it will be diverted from landfill in increasing volumes over the next decade.[136]

In addition, the *Organics Action Plan* includes actions to support infrastructure development and stimulate market demand through government procurement policies and promotion of sustainable procurement among businesses. To further secure demand, the Queensland Government is supporting the review of the Australian Standard for Composting, which will give end users confidence in the quality of the output and will help the composting sector design processes which yield compliant outputs.[136]

This is all combined with actions to prevent household food waste, which are frontloaded in the *Organics Action Plan* to ensure food waste volumes drop before processing infrastructure develops around current volumes of food waste.[136]

The Queensland Government has also published an *Energy from waste guideline*, encouraging energy-from-waste processors to think about how reductions in waste volumes or changing waste composition will affect their processes and products.[108] The guidelines include a decision tree for energy-from-waste processors to ensure they aren't processing food waste which could be utilised in another way, and specify that energy-from-waste facilities "should not undermine future options or innovations in waste avoidance, reuse, and recycling."[108]

Austria – a decentralised approach that prioritises processing at home and in the local area

Separate household food waste collection in Austria began in 1986 in Vienna and subsequently spread throughout the country.[21] The Biowaste Ordinance was enacted in 1992, making separate biowaste collection mandatory at all stages of the food supply chain, including at the household level, unless biowaste is recovered by the household (e.g. by home composting) or generator.[139]

Source-separated household food waste are predominantly processed by a decentralised network of at least 400 composters (roughly one per 20,000 people), with an average processing capacity of 3,000 tonnes per composter per year.[140] Austria's composters are mostly farmers, who process food waste on-farm and use much of the compost to improve soil fertility. Decentralised processing may be coupled with centralised collection in larger cities such as Graz, where collection and pre-processing is centralised before organic waste is distributed to 18 local farms for composting.[21]

Austria has composting manager training schemes, strict rules and guidelines for making and managing compost, and a compost testing regime to ensure quality. Food waste is collected separately from green waste, which may be collected in separate bins or at drop-off points.[21] Contamination levels are very low, facilitated by education for households[21] and likely further supported by the visible connection households can make between their utilisation of food waste bins and the compost that results,[45] given composting occurs predominantly on local farms.

South Korea – mandatory food waste separation with costs borne by households

Household waste in South Korea is separated into general waste, recycling, and food waste streams, and the cost of disposal is borne by the households themselves (except for recyclables, which are collected for free).[141] The so-called 'pay-as-you-throw' system has been in place since 1995 and has successfully decreased waste volumes and increased recycling rates,[142] including an increase in the recovery rate of food waste from 2% in 1995 to a reported 95% in 2019.[143]

Organics were banned from landfill in 2005.[143] The landfill ban was preceded by the 1998 Waste-to-Resource Plan which included measures to reduce food waste by 10% and recycle more than 60% of the remaining food waste by 2002. Legislation was also put in place to ensure the safe operation of food waste processors and the quality of their outputs, including revisions to the Feed Control Act in 2001 and the Fertilizer Control Act in 2003 and implementation of mandatory inspections for food waste processors. In addition, the government invested US$144 million in food waste processing facilities and technology development between 1996 and 2011.[143]

In some parts of South Korea, households pay a flat fee for disposal (by buying pre-paid biodegradable bags or pre-paid stickers to attach to their food waste bins), but in parts of the country food waste disposal fees are charged by weight, with radio-frequency identification (RFID) chips linking the disposer to their waste when they deposit it at a smart bin located on the street or associated with an apartment building. The weight-based system has reportedly helped to reduce food waste volumes.[143,144]

The pay-as-you throw system doesn't come without challenges. Illegal dumping and contamination of bags must be managed, with enforcement delegated to local governments.[141]

Food waste is processed using a range of different approaches, undertaken by both government and private providers. Production of animal feed (including a growing insect-based bioconversion sector) and composting are dominant approaches, often complemented by anaerobic digestion: food waste is often screw-pressed to remove moisture, with the liquid component undergoing anaerobic digestion and the solid food waste being composted or converted to animal feed.[144]

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