Office of the Prime Minister's Chief Science Advisor
Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia

Title:

WEBPAGE OUTPUT: What can I do with my food waste?

Author:

OPMCSA

Output type:
PDF/
webpage

Pages:
55 pp

Date:
Mar-2023

Language:
English

Review:

Versions

Record number:	*Version:*	*Date V1 created:*	*Date:*	*Printed version*
PMCSA-23-03-02-V2	V2	29-Mar-2023	12-Apr-2023	N

DOI:	-
ISBN:	-

Archive page link:
https://dpmc.govt.nz/our-programmes/special-programmes/prime-ministers-chief-science-advisor-archives/archive/gerrard-2021-2024

Notes:
-

Web resource

What can I do with my food waste?

12 April 2023

View the webpage at:
pmcsa.ac.nz/topics/food-rescue-food-waste/what-can-i-do-with-my-food-waste/

Office of the Prime Minister's Chief Science Advisor
Kaitohutohu Mātanga Pūtaiao Matua kit e Pirimia
Private Bag 92019
Victoria Street West
Auckland 1140
New Zealand

Phone: +64 9 923 6318
Website: www.pmcsa.nz
Email: info@pmcsa.ac.nz

Webpage sections

[NOTE – this is a PDF version of webpage content]

What can I do with my food waste?

In an ideal world, food waste would be prevented, but what happens to food waste that you can't avoid?

Here we explore how food waste can be transformed from rubbish to a resource through processes like composting, worm farming, anaerobic digestion, and beyond. Managing food waste as a resource, rukenga kai, can reduce greenhouse gas emissions and help us shift from a linear economy to an increasingly circular one.

This web resource explains how a wide range of food waste processing options work, key benefits and challenges associated with each, and links to further resources for those seeking more detail. It focuses on household food waste, but also contains information relevant to businesses and councils looking for food waste solutions.

To learn more about food waste, head to our topic webpage.

Hold on, why does food waste matter?

Food waste is a global and local problem with significant environmental, social, and economic impacts. It is a so-called 'iceberg problem', with a few impacts that are clear to see and many larger ones hidden beneath the surface.

At the tip of the iceberg are the direct financial costs and environmental harms associated with wasting food. In 2018, the average New Zealand household spent about $650 on food that they threw away – equivalent to almost $800 in 2023. When businesses waste food, they have to pay disposal fees to cover the landfill levy and the cost of waste collection and landfill operation. When our food ends up in landfills, it produces leachate and releases methane and other greenhouse gases as it rots. Even with gas capture systems in place, an estimated 0.6 tonnes of carbon dioxide (CO_2)-equivalent is released into the atmosphere per tonne of food landfilled.

Beneath the surface, it gets worse. When food is wasted, all the water, energy, labour, land, and other resources that go into food production are wasted too. Further, the emissions associated with the production of wasted food are for no benefit. Wasting food means we fail to embrace a circular approach to resource management and miss a chance to nourish people in a country where 13.4% of children live in households experiencing food insecurity. With te ao Māori worldviews highlighting the importance of sustainable relationships with the environment, wasting food also fails to honour New Zealand's deep-rooted knowledge of the importance of kaitiakitanga and intergenerational environmental stewardship.

The food waste iceberg, adapted from the Food and Agricultural Organisation of the United Nations. CO_2e = carbon dioxide equivalent.

Food waste is making the climate emergency worse. Project Drawdown found that minimising food waste is among the leading ways to reduce greenhouse gas emissions, both by reducing emissions from waste and, more significantly, cutting unnecessary emissions from the production of wasted food. Based on global food waste estimates for 2011, the Food and Agricultural Organisation of the United Nations found that 8% of all human-caused greenhouse gas emissions came from food waste. That means that if global food waste was a country, it would be the world's third biggest emitter.

A food waste poster created by a Year 7 New Zealand school student as part of a Food Waste Literacy research project undertaken by Dr Deepa Goswami. You can read Deepa's PhD thesis here. Thanks Lauren!

The scale of our food waste problem

Globally, an estimated 2.5 billion tonnes of food is wasted from farm to fork each year – that's about 40% of all food that's produced. In Aotearoa, data on food waste is patchy, but likely amounts to hundreds of thousands or even millions of tonnes across the food system each year. This includes about 300,000 tonnes wasted in New Zealand households, over half of which is avoidable (i.e. food that could have been eaten).

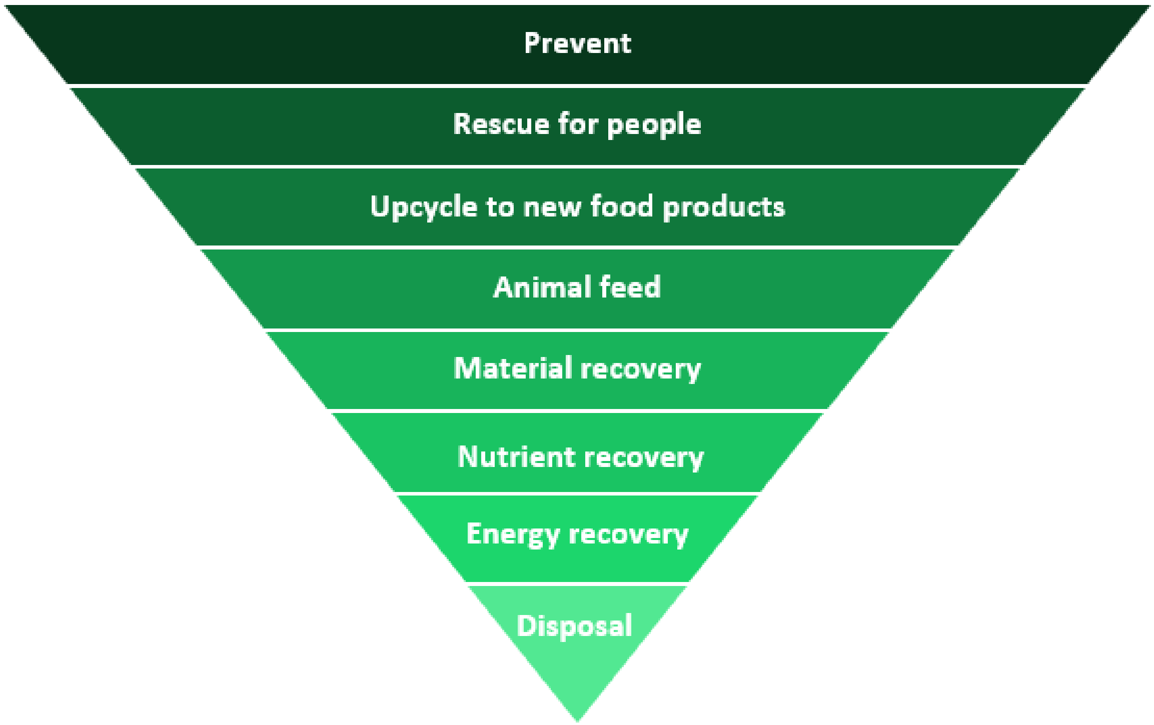
The Ministry for the Environment has committed to estimating how much food New Zealand wastes, which will help us better understand the scale of the problem. Understanding the scale of food waste will help with the design of strategic interventions to reduce food waste's negative environmental, social, and economic impacts.

However, lack of data shouldn't be an excuse for lack of action – we know enough about the problem to get started now.

The food recovery hierarchy: prevention is better than cure

This web resource focuses on ways that unprevented food waste can be kept out of landfills and given a second life. But before we dive into the details, it's important to understand where these solutions fit in the bigger picture of solving our food waste problem – which all starts with prevention.

A widely used framework for combatting food waste is the food recovery hierarchy. This framework prioritises food waste solutions to achieve the most environmental and social benefit. There are several variations of this hierarchy, including a simplified version used by the Ministry for Environment. The one we are using in the OPMCSA food waste project is pictured below.



Food recovery hierarchy being used in the OPMCSA food waste series, adapted from Teigiserova et al. and Moshtaghia et al. Key terms in the food recovery hierarchy are defined in the glossary.

The priority action is to prevent food waste in the first place. Based on 2020 figures, 4% of New Zealand's greenhouse gas emissions come directly from waste (including food waste) while 50% come from the agricultural sector. Preventing food waste across all parts of the supply chain is a more effective way to mitigate climate change than simply managing wasted food at the end of its life, because this prevents unnecessary agricultural emissions and waste emissions simultaneously.

For households, food waste prevention can be achieved through a range of activities like planning shopping trips and meals, cooking the right amount of food, eating leftovers, and storing food correctly. The whole household can contribute to reducing food waste, no matter what shape your household takes.

Love Food Hate Waste has lots of resources to help households prevent food waste, and the Ministry for the Environment has dedicated funding for food waste prevention initiatives in the coming years, including funding for household-focused programmes, business programmes, and programmes in Māori-led settings.

Not all food waste is readily preventable. For edible food or components of food, food rescue and upcycling to new food products, such as jam, keep food in the human food supply chain. Meanwhile, food or food components that are inedible to humans can be used as animal feed, or materials, nutrients, and energy can be recovered from them.

To learn more about frameworks for combatting food waste, take a look at our first report on food waste, Food waste: A global and local problem. You can also head to our quick explainer of the circular economy in the context of food waste.

I put my food scraps in the general rubbish: why is that a problem?

In addition to the environmental, social, and economic impacts of letting food go to waste, sending food waste to landfill means we can't utilise it to its full potential. For example, those mouldy carrots from the back of the fridge aren't so appealing to eat anymore, but they still contain valuable nutrients – they're still a useful resource, even if no longer edible. If the carrots go in the general rubbish bin, it's much harder to capture these nutrients and return them to the soil they came from. In a landfill, this potential is wasted, the carrots would simply rot, sending methane – a potent greenhouse gas – into the atmosphere.

To stop household food waste from being sent to landfills, part of the government's new waste strategy calls for councils to provide food scraps collection services for households, businesses to reduce their waste, and individuals to compost their food scraps at home or use collection services.

Check out Episode 4 of Wasted New Zealand, which highlights the huge volume of food waste that New Zealanders send to landfill and how this wastes money and contributes to environmental harms.

Landfills release greenhouse gases, but what if you capture the gas?

Sending food waste to a landfill without gas capture is among the most emissions-intensive things you could do with your food waste. When food waste is landfilled it breaks down without oxygen, releasing methane and other greenhouse gases. Without gas capture systems in place, the equivalent of 1.9 tonnes of carbon dioxide (CO_2) are released for every tonne of food waste. Thankfully, less than 10% of levied waste in Aotearoa goes to landfills without gas capture – most of our landfills capture greenhouse gases and convert it to CO_2 which is a less potent greenhouse gas than methane. Some do this as they use it to generate heat and electricity, others by flaring it. By 2026, all municipal landfills are slated to be required to have gas capture systems in place.

However, even at landfills with gas capture systems, some greenhouse gas escapes. This is in part because gas capture systems may only be installed a few years after waste has been deposited, during which time CO_2 (initially, while oxygen is present) and methane (later, when oxygen can no longer reach the waste) are released. For landfills with gas capture, an estimated 0.6 tonnes of CO_2e are released per tonne of food waste landfilled, but this varies between landfills. Modern, engineered landfills are much better at capturing landfill gas than open older-style landfills (e.g. Redvale Landfill and Energy Park in Auckland captures and uses more than 90% of the methane created, while Wellington's Southern Landfill captures just 55%).

Greenhouse gas emissions are not the only consideration: landfilling food waste also means its nutrient value is lost, with resources becoming inaccessible as they are buried in the ground.

Watch Waste Management's video explaining how their modern landfills work. The kind of landfill depicted here represents 'best practice' landfill operation. Not all landfills across Aotearoa are designed to this standard. Even in 'best practice' landfilling, where leachate in managed and much of the methane is captured, any materials that end up in the landfill can't be used anymore, breaking the loop of the circular economy, and wasting precious resources.

Could we incinerate mixed waste?

Incineration, where waste is burnt in the presence of oxygen, is an end-of-life waste management solution. It reduces the mass of waste and produces heat energy that can be used to generate power but otherwise doesn't yield any useful products. Different types of waste produce different amounts of heat when incinerated, with the incineration of food waste consuming more energy than it produces because of its high moisture content. This means that, for food waste, incineration isn't a form of energy recovery – it's a form of disposal.

As with landfilling, the nutrients in food waste are lost when it is incinerated. They are reduced to ash which has very limited usefulness. Incineration also produces fly ash and flue gas, which must be cleaned before discharge, and the residues from cleaning must be dealt with, generally as hazardous waste. In Aotearoa, there is no organised incineration of municipal waste. It is used on a small scale, mostly for hazardous waste, clinical waste, farm waste, and sewage sludge, and its use has declined over time.

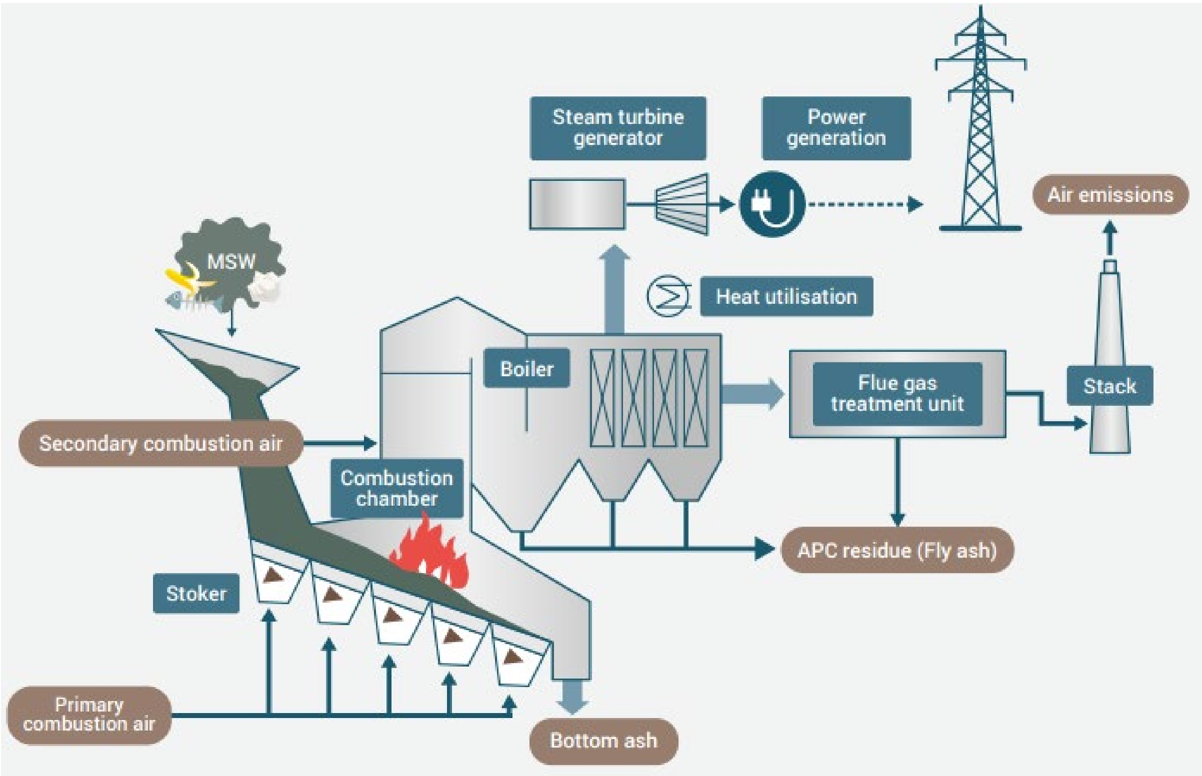


Diagram showing an example of the incineration process. In this example, municipal solid waste is used as a feedstock. The fly ash and bottom ash, which get landfilled, contain hazardous and environmentally persistent compounds like dioxins and PFAS. When food waste is incinerated, the amount of energy generated is less than it takes to run the incinerator. Image credit: United Nations Environment Programme.

What if we collect food waste mixed with general waste and separate it later?

Machines can be used to sort organic waste from general waste, so instead of requiring households and businesses to separate their food waste from other wastes, could we use these machines to do the job instead? Mechanical separation is an imperfect process: the separated organic stream can still contain 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 organic stream. Contamination extends beyond physical items like plastics: mixed waste can introduce unwanted chemicals into food waste too. This means that the quality of any products (e.g. compost) made from the separate organic stream will be compromised by contamination, limiting its acceptable applications or resulting in its rejection, requiring it to be landfilled after production.

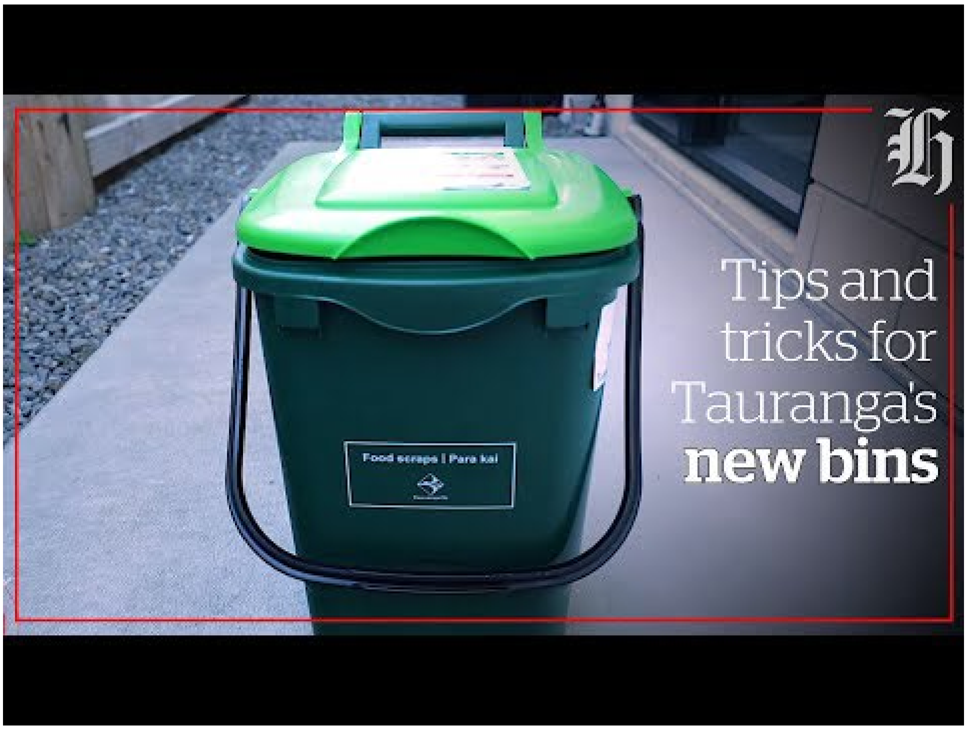
Food scraps won't separate themselves

Setting up home, community, or industrial collection and processing options for food scraps will only reduce food waste to landfill if people separate their food waste from their general waste in a way that reduces both waste streams, minimises contamination, and maximises diversion.

Minimising contamination: garbage in, garbage out

To make sure that the outputs of food waste processing options are high quality and able to be used for their intended purpose, it is crucial to make sure the right materials go into our food scraps bins. What constitutes 'the right material' is confusing because it depends on what happens to the food waste next. The processing option being used and its scale or sophistication will dictate what can be successfully processed. Therefore, while general advice on this topic can be useful (e.g., WRAP's resources on food waste collections), how food waste is separated and collected will always depend on your unique context.

For people living in areas where food scrap collection services are already provided, your council will have instructions about what can and can't be accepted. As the government moves forward with its waste strategy and planned kerbside food scraps collections, standardising the materials that can and can't go into kerbside food scraps bins will simplify these instructions nationwide.



Tauranga City Council rolled out a rates-funded food scrap collection service in July 2021. Take a look at New Zealand Herald's short clip on the service rollout, which includes tips for food waste separation and recycling people living in Tauranga. At the moment, each council with a food scraps service has its own systems and rules, but the Ministry for the Environment has suggested that, if kerbside collection of food scraps is mandated for all councils, the services should be standardised. In the first year of the service being in place, Tauranga residents almost halved the amount of food waste they sent to landfill.

The Ministry for the Environment suggests that kerbside food scraps bins should only contain food and garden waste and exclude all other potentially 'biodegradable' materials like coffee cup lids and cardboard. Other jurisdictions, like New South Wales, have taken a similar precautionary approach. The Ministry argues 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 end-products like compost. The proposed exclusion of compostable plastics (both plant- and fossil-based) reflects the fact that they aren't desirable inputs for many food waste processing options because they don't contain nutrients and are a source of confusion for households.

Community engagement, consultation, and product standards (e.g. strict rules on the composition of 'compostable' plastics, ban or voluntary phase out of plastics in tea bags) could enable more materials to be accepted, as could distinguishing between grades of compost (e.g. for landscaping use vs food system use).

Home, community, and large-scale enterprises: same, same but different

There are often subtle differences between what can go into your compost or worm bin at home and what might be suitable for community or large-scale processing facilities. That's because managed community composting operations and large-scale processors have the scale and expertise to ensure their processes reach temperatures that are high enough to kill pathogens from animal-based foods and break down certain compostable products, as well as minimise odour and pest risks.

Maximising food waste separation

Even when people have a separate bin or home solution for food waste, they don't always use it. A trial in the Wellington suburb of Miramar found that people given food scraps bins for weekly kerbside collection still put a substantial amount of food waste in their general rubbish, and those given a compost bin, worm bin, or bokashi bin trial continued to put food waste in the general rubbish too, in greater volumes than the kerbside group. Old habits die hard, and new ways of managing food scraps need to be well designed and easy for people to incorporate into their daily routines.

For councils designing kerbside food scraps services, insights from the UK suggest that more household food waste is separated if food waste bins are collected weekly (especially when coupled with fortnightly general waste collection) and when food waste is collected separately from green waste, although combined waste has been collected in Christchurch for many years. A New South Wales study confirmed that food waste diversion is better when landfill options are limited by smaller general waste bins collected less frequently. It also found that the longer an area has had food scrap collections for, the better the residents become at diverting their scraps from landfill.

Clear communication, reliable services, and good bin design (including possibly the provision of bin liners) are also crucial to high engagement. Supporting tools like prompts, information campaigns, incentives, and consequences could help too. Simple tips for keeping kerbside scraps bins ick-free are provided by Hamilton City Council and are an example of how councils can encourage their community to make the most of their bins. The easier it is for people to separate their food waste, the more likely they are to do it.

For people using home solutions, understanding the details about how to manage your compost, worm farm, or bokashi effectively is crucial. Concerns about pests, odour, and what to do if something goes wrong have been found to be barriers to full utilisation of home food scraps processing options. It's also crucial to make sure that you pick the right solution for you. For example, while bokashi bins are often marketed to people who don't have enough space for composting or worm farming, people opting for bokashi still need to think about what they'll do with their food waste pickle (the product of the bokashi process) and need an additional bin to cover the weeks during which their bokashi is maturing and can't be disturbed.

What about multi-unit dwellings?

As multi-unit dwellings become more common, it will be increasingly important to consider how to effectively manage waste in these settings, including food waste.

Multi-unit dwellings often don't have kerbside collection services for each unit: waste is aggregated and collected in bulk for offsite management. This approach can be applied for separated food waste too, but odour and pest risks need to be managed (e.g. through regular collections, use of biochar to neutralise odours, physical separation of food waste collection sites away from living areas). Dehydrators have been proposed as a solution to keep food scraps stable and smell-free between collections in multi-unit dwellings, but they use a lot of energy and can create odour, pest, and pathogen risks if the dried food is exposed to any moisture during storage.

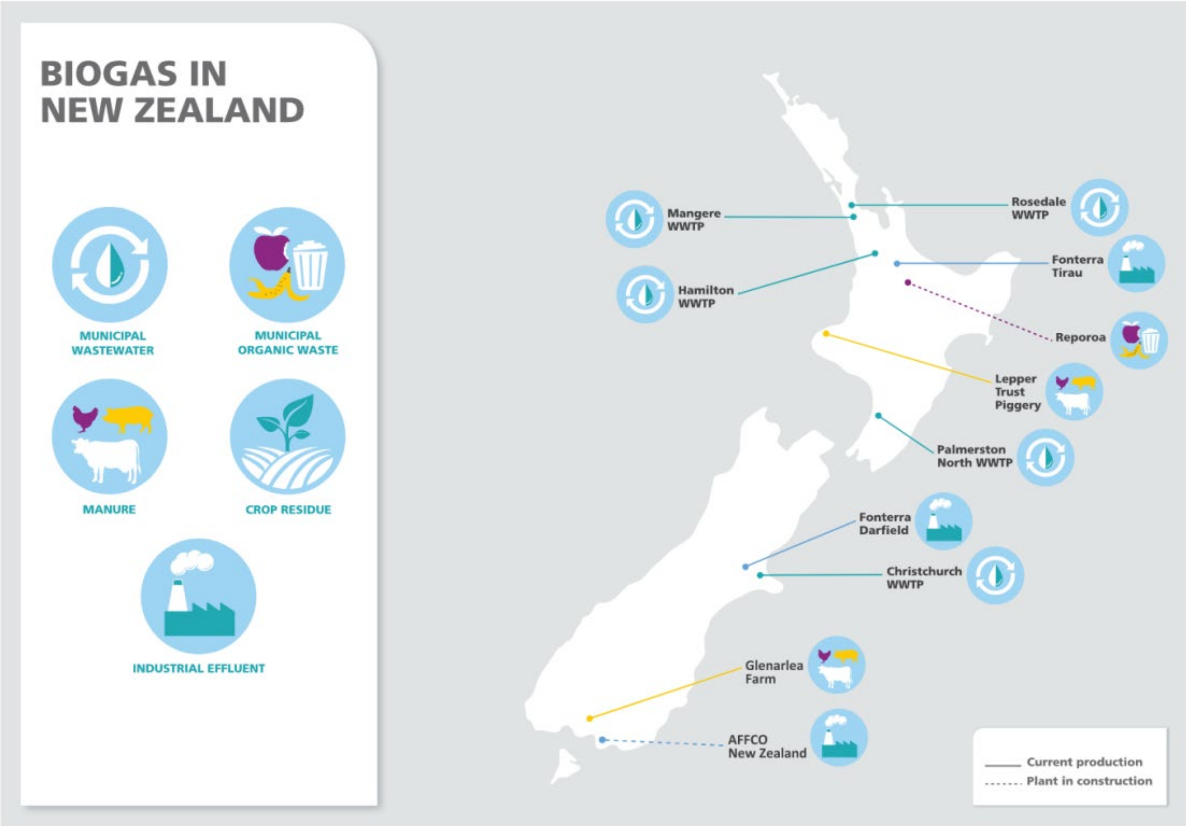
On-site processing (e.g. shared compost bins or worm farms in outdoor spaces associated with the complex) and partnerships with community composting enterprises may be part of the mix of solutions, and home-based solutions can play a role too, depending on space availability (e.g. a bokashi bin can fit under the sink, and a worm farm can fit on a balcony) and access to soils (e.g. the building's gardens, balcony pot plants, or a friend's backyard) to add resulting organic material to.

Bokashi is one solution for food scraps for apartment dwellers. The container holds material that has been processed for several weeks, and is now ready to add to soil in a friend's garden.

What about putting food waste down the sink?

People living in multi-unit dwellings often wonder whether they can dispose of their food scraps down the sink. The environmental impacts of in-sink disposal of food waste vary region-to-region depending on how wastewater in an area is treated.

Everything that goes down our sinks and toilets ends up in the sewers, which lead to wastewater treatment plants. In some parts of the country, wastewater undergoes anaerobic digestion (e.g. in parts of Auckland, Hamilton, Palmerston North, Christchurch, and others), meaning that methane is captured and used to generate energy. Meanwhile, about 40% of wastewater from the country's largest wastewater treatment plants is treated without energy capture meaning that food thrown down the sink will release greenhouse gases.



According to BECA, five wastewater treatment plants in Aotearoa anaerobically digest their municipal wastewater, capturing biogas which can be used as an energy source. This means that there is some energy recovery from food waste that is disposed of down the sink in these parts of the country. However, our wastewater infrastructure wasn't designed with food waste disposal in mind, so disposing of waste in this way can put extra pressure on our pipes and treatment facilities. The above map was produced in 2021; since then, the Reporoa anaerobic digestion site for municipal organic waste has been completed.

Following wastewater treatment, biosolids remain. The end fate of the biosolids varies, but the vast majority (about 70%) is either landfilled or used to rehabilitate quarries. A small portion is used on agricultural land (generally after composting, vermicomposting, or thermal pasteurisation).

In addition to considering how wastewater is managed, it is also important to consider the impacts of increasing the wastewater treatment burden and risk of pipe blockages, given this infrastructure wasn't designed with food waste management in mind. Even when food waste is ground up using in-sink disposal units, it can still block pipes (especially fats, oils, and greases). We also waste fresh water when we wash food down the sink.

So, what should I do with food scraps at home?

There are many ways to manage your own food scraps. A 2021 survey published by the Ministry for the Environment suggests that over half of New Zealanders manage at least some of their scraps at home by worm farming, composting, or using a bokashi bin. Moreover, the majority of surveyed New Zealanders who manage food scraps at home think it is easy and worthwhile, and nourish the plants in their gardens using what they produce.

	Composting	Worm farming	Bokashi
You'll need…	Composting bin, pile, box, etc Medium/large amount of space Food scraps (30%) and brown carbon-rich matter (70%, e.g. dry leaves, wood chips, toilet roll tubes)	Worm bin Tiger worms Medium amount of space Cool, sheltered spot Food scraps (70%) and brown carbon-rich matter (30%)	Airtight bokashi container system Small amount of space (inside is fine) Bokashi 'sprinkle' Food scraps (no brown carbon-rich matter needed)
Key benefits	Produces compost to spread on gardens Great if you have lots of garden waste Can take relatively large volumes of food scraps	Produces 'worm tea' and castings to fertilise plants Don't need to aerate (the worms do the work!)	Bokashi liquid can be used to clean drains, fertilise plants, etc Bokashi 'pickle' can add nutrients to soil or compost Can handle a wide range of food scraps (including meat and dairy)
Considerations	Need to keep aerated (e.g. by turning) to prevent rotting Best not to include meat, fish, dairy, or cooked food	Best not to include meat, fish, dairy, or cooked food Also need to exclude spicy or acidic foods Need to build capacity gradually	Need somewhere to bury or compost bokashi 'pickle' Need 2 bokashi bins, so that full bin can stay closed to 'mature'

Home solutions at a glance.

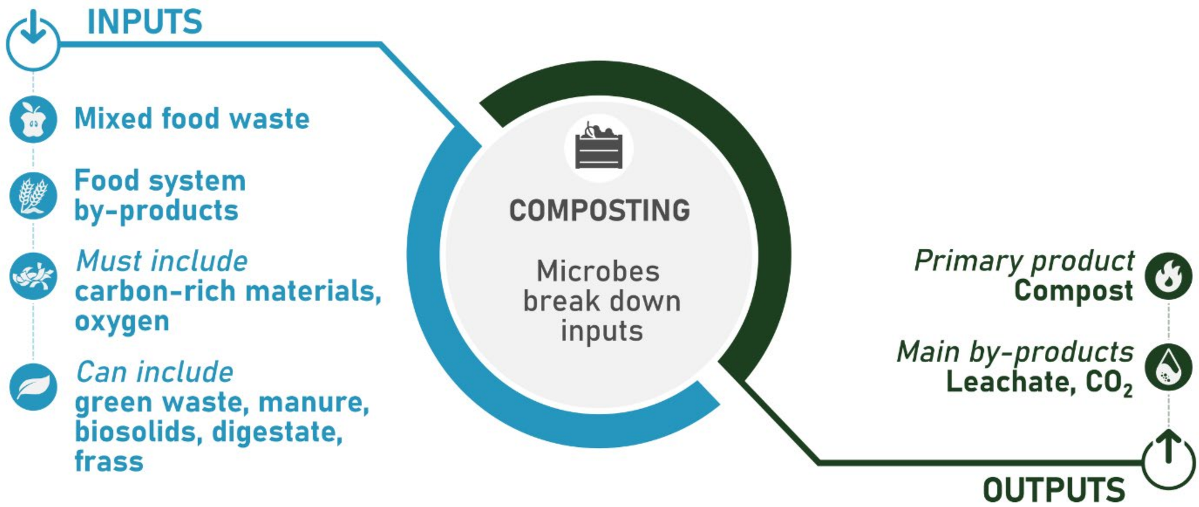
To reduce the costs of setting up a composting system at home, subsidies are available in parts of the country (e.g. Auckland, Nelson). Not knowing how to get started can also serve as a barrier, but the Compost Collective has produced helpful resources in multiple languages to empower people to manage their food scraps effectively at home.

The main options for food scraps processing at home are discussed below. Meanwhile, community composting and linking up with neighbours (e.g. via ShareWaste) who have spare food waste processing capacity are good options where space is a limitation – these are discussed in the community section.

Composting at home

A good option if you have plenty of space, a garden that needs nourishing, and a source of brown matter like leaves and twigs.

- Requires outdoor space, including a garden to spread your mature compost on.
- Requires food scraps (about 30% of inputs) and brown carbon-rich matter (about 70% of inputs, e.g. leaves, twigs, untreated wood shavings, paper, spray-free dried grass clippings).
- Must be turned to keep the pile oxygenated, reducing the risk of rotting food emitting methane and other greenhouse gases, some of which are odorous. While well-managed compost doesn't produce much methane, carbon dioxide (CO_2) (which has a much lower warming potential than methane) is still produced, so composting isn't emission-free.
- Can be done using enclosed bins, open piles, or composting bays.
- Can take a wide variety of food scraps, but it is generally best to avoid meat, fish, and cooked food to prevent odour and pests (although large-scale, centralised composters often take these materials).
- Can't readily break down commercially compostable packaging and might struggle with home-compostable packaging.



Infographic showing the main inputs and outputs of composting, a food waste processing option that can be applied in the home, community, or by large-scale, centralised enterprises. Food waste and by-products need to be combined with carbon-rich materials to get the ratio of nitrogen and carbon right, and compost piles need to be kept aerated (e.g. by turning) to keep methane production as low as possible. The resulting compost contains nutrients that can be added back to soils. The process also generates CO_2 and can produce leachate, although the latter can be minimised through good management practices.

For practical tips to help you get started, check out the Compost Collective's compost factsheet and Love Food Hate Waste's composting webpage, as well as the Compost Collective's video, linked below. Predator Free NZ has also produced some helpful instructions to [make sure your compost is rat-proof](#).

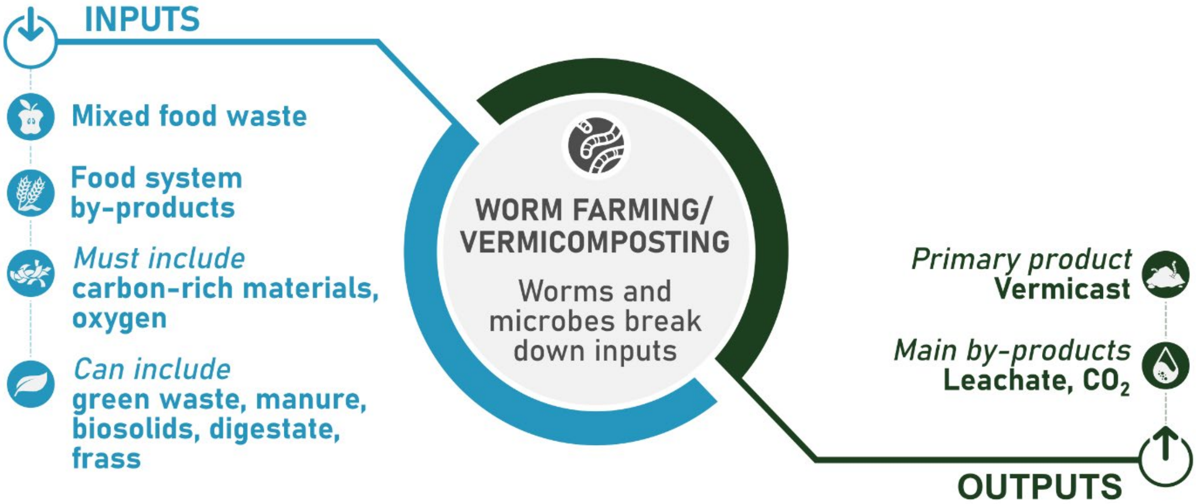
Watch the Compost Collective's home composting video to help you get started.

For more information about composting, check out our case studies on Kaicycle and Living Earth, and our content on large-scale, centralised composting.

Worm farming at home

Technically known as vermicomposting, worm farming works well in smaller gardens or on balconies and requires less brown carbon-rich matter (e.g. leaves, twigs) and labour than composting – the worms do the work!

- Takes up less space than composting, requires less brown matter, and requires less space to spread outputs on. This makes worm farming suitable for smaller gardens or even balconies with container gardens.
- Requires food scraps (about 70% of inputs) and a small amount of brown carbon-rich matter (about 30% of inputs). The material should be shredded or cut into small pieces to help the worms process it.
- Doesn't need turning – the worms aerate the food waste as they eat their way through it, stopping the worm bin from becoming anaerobic and emitting methane – CO_2 is the main greenhouse gas emitted.
- Produces worm castings which can be spread around plants or made into 'worm tea,' a liquid fertiliser. Nitrogen-rich liquid is also produced by worm farms, and can be diluted and used to fertilise plants.
- Worms can process a wide variety of food scraps, but don't like spicy (e.g. onions, chillies) or acidic (e.g. citrus) scraps and, as with composting, shouldn't be given cooked food, or meat or fish.



Infographic showing the main inputs and outputs of worm farming, a food waste processing option that can be applied in the home, community, or by large-scale, centralised enterprises. Fibrous material needs to be added to food waste inputs, and oxygen is crucial too, although the worms themselves incorporate it to the process so no active aeration is needed. The main product is vermicast, which can be used as a fertiliser. The process also generates CO_2 and can produce leachate, although the latter can be minimised through good management practices.

For practical tips to help you get started, check out the Compost Collective's worm farming factsheet and Love Food Hate Waste's worm farming webpage, as well as the videos from the Compost Collective and Para Kore, linked below.

Watch the Compost Collective's home worm farming video to help you get started.

If you're a budding worm farmer and want to understand how to make your set up run as smoothly as possible, check out Para Kore's longer video on worm farm trouble shooting.

For more information about worm farming, check out our case study on MyNoke, and our content on large-scale worm farming, or vermicomposting.

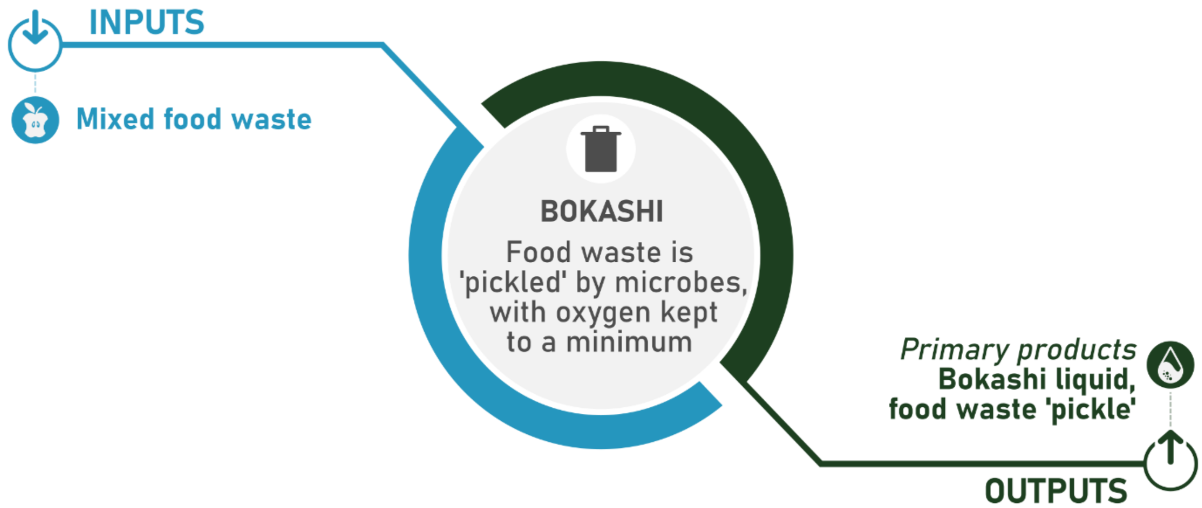
Bokashi at home

If you're short on space, bokashi could be the solution for you – but you'll still need occasional access to a bit of garden space. Bokashi can also be used in conjunction with composting or worm farming and can process food scraps that these other methods can't handle.

- Bokashi is a type of fermentation. Microbes (commonly called bokashi 'sprinkle') such as *Lactobacilli spp.* (also found in yoghourt) are used to 'pickle' food scraps in a near-airtight container, producing a liquid which can be used to clean drains in the home, condition septic tanks, or diluted to fertilise plants.
- The food scraps themselves don't reduce substantially in volume. Once the bokashi container is full and has had a few weeks of further fermentation, the pickled food scraps need to be dug into a garden or added to a compost bin, where they then decompose. If you don't have space of your own, you could take your pickled food scraps to a community garden or connect with a neighbour.
- Suitable for a wide range of scraps, including food which you normally wouldn't compost directly or put in a worm bin, such as meat, fish, and cooked food. The pickling process reduces bad odours.
- While claims that bokashi fermentation produces less greenhouse gas emissions than composting are common, these aren't well substantiated across the whole bokashi lifecycle (including both the fermentation stage and what happens once the pickled food is added to soil or compost). More research is needed.

For practical tips to help you get started, check out the Compost Collective's bokashi factsheet and Love Food Hate Waste's bokashi webpage, as well as the Compost Collective's video, linked below.

Watch the Compost Collective's bokashi video to help you get started.



Infographic showing the main inputs and outputs of bokashi, a food waste management solution that can be used in the home. Along with mixed food scraps (which, for bokashi, can include meat, fish, and dairy), it is crucial to ensure that oxygen is kept to a minimum by opening the bin as little as possible. Note that the food waste doesn't significantly reduce in mass, so the food waste 'pickle' that results from the process remains as a by-product which must be either buried in the soil or composted. The bokashi liquid is an acidic leachate that contains carbon, nitrogen, organic acids, and other compounds. When diluted, it can be used as a fertiliser, among other applications.

Feeding scraps to animals

Food scraps can also be fed to a wide variety of animals – cats, dogs, chickens, pigs, etc. As with using food scraps as animal feed at a larger scale, it is important to consider disease transmission risks and animal nutrition and wellbeing. For example, to manage disease transmission risks, pigs should never be fed meat or offal products or food waste that has been in contact with meat or offal products, unless it has been properly treated. Ruminants (e.g. sheep and cattle) should never be fed ruminant protein.

You can find more details about what foods you can safely feed to your pets on the Love Food Hate Waste website, and learn more about the Ministry for Primary Industry's animal feed rules on their website.

Community solutions for food waste

Don't have the space or time to process food scraps at home but still want to manage your food waste locally? Community enterprises such as community gardens, urban farms, and dedicated composting enterprises have been working hard for many years to enable New Zealanders to sustainably manage their food scraps close to home, keeping resource and waste flows to smaller, more localised scales.

Composting is a particularly common solution used for food waste within New Zealand communities. Community composting efforts can be broadly divided into volunteer-run 'compost clubs' and decentralised social enterprises that have emerged as a community response to food waste. Unlike composting clubs, composting social enterprises are often commercial operations, reliant on contracts and customers to support their business model. Enterprises like Kaicycle use a subscription-based model, charging fees for collecting and composting food waste from households and business. In contrast to larger scale industrial processors of food waste, social enterprises are embedded within the communities they serve, collecting and recirculating resources on local scales. Many composting clubs and social enterprises are keen to scale out across multiple communities to be a larger part of the solution going forward.

Place-based use of compost is common for community composting initiatives. For example, on Auckland's Hibiscus Coast, City to Farm collects food scraps from local businesses, which it composts on a regenerative banana farm in Waitoki, improving soil quality and building soil carbon. Similarly, Waiheke Resources Trust collects compostable material from local businesses around Waiheke Island and sells the compost produced on-island back to the community.

Community solutions for food waste are often associated with broader benefits such as community building and resilience, sustainability education, intergenerational knowledge exchange, physical and mental wellbeing, and links to Māori soil and kai sovereignty. When factoring in community and social good, a French study found that an urban farm and composting school delivered a 2:1 return on investment over a one-year period, forecast to reach 27:1 over ten years.

To find a community-based food scraps solution near you, check out Manaaki Whenua's live map of community composters, Kore Hiakai's map of community gardens and other community food initiatives, and MakeSoil's global map of composting initiatives. Alternatively, your neighbours might be able to make use of your food scraps; ShareWaste is a web resource that helps connect people who have food scraps to spare with people who have extra processing capacity.

Case study: Composting and urban farming with Kaicycle

Kaicycle Composting is a subscription-based community composting enterprise which processes 40 tonnes of household and office food waste in Wellington each year. Since it started operating in 2015, Kaicycle Composting has processed an estimated 230 tonnes of food scraps, in addition to arborist waste, coffee chaff, and untreated wood shavings. The resulting compost is used at the Kaicycle Urban Farm in Newtown, and any extra is donated to City Housing and local community gardens. Kaicycle Urban Farm produces fresh vegetables for the local community, with people able to buy a share in the outputs of the farm.

Kaicycle currently uses composting boxes in Newtown and is at capacity, but a new site in Rongotai and an in-vessel composter, which fully contains and automatically stirs compost, will enable Kaicycle to process an additional 90 tonnes of food scraps per year. As capacity grows, Kaicycle will look to sell surplus compost to supplement its income from the urban farm and scraps collections.

Compost manager Kate Walmsley building a compost pile with collected food scraps.

Kaicycle collects food scraps from around 200 offices and households, including from groups in multi-unit dwellings where home-based solutions for food scraps are often limited. Collections are done by e-bike, reducing transport-related emissions from Kaicycle's activities. In addition, about 65 household subscribers drop scraps off at three sites across the city.

Liam and Tom, former Kaicycle staff members, collecting food scraps by e-bike in Wellington's CBD.

Aerial view of the Kaicycle urban farm in Newtown, Wellington. Image credit: Te Kawa Robb, Toroa Creative.

Kaicycle uses scales to measure the ratio of nitrogen-rich food waste to carbon-rich garden waste, coffee chaff to regulate water content, and thermometers to ensure compost piles reach at least 55°C so that harmful microbes and seeds are killed. Compost nutrition and contamination testing at Eurofins and Hill Laboratories helped Kaicycle improve its processes when it was getting started, and it intends to do more testing this year to continuously improve its product.

The voluntary compost standard in Aotearoa (NZS 4454) focuses on the chemical composition of compost rather than its biological health (other than a limit on the presence of *E. coli*, a pathogen), but Kaicycle is keen to understand the diversity and relative levels of beneficial microbes in its compost too, which the standard acknowledges is important for the release of nutrients but doesn't provide a methodology for. Labs like Soil Foodweb New Zealand which analyse the microbial health of compost and soils are scarce.

Kaicycle works to ensure its subscribers know what to include in their scrap bins. It recently undertook an education campaign explaining why it doesn't accept any compostable packaging, highlighting that compostable packaging embeds the linear economy and risks introducing contaminants while bringing little to no nutritional value to the compost.

While well-managed compost piles mean odour and pest risks are minimised, Kaicycle works with Predator Free Wellington to support trapping efforts and the wider predator free kaupapa.

Kaicycle employs the equivalent of 4.5 fulltime staff, split across fulltime and parttime roles in the composting, farm, and community engagement arms of the enterprise. Kaicycle also provides many education and community engagement opportunities through public volunteer sessions, community events, workshops, and an urban farm school. The urban farm school is delivered with education provider Papa Taiao Earthcare. In 2023, the urban farm school will have more than 25 local high school students attending a year-long, NCEA accredited programme. In the last year Kaicycle has hosted 125 volunteers at the farm.

Kaicycle hosting local community members at a farm open day with pumpkin soup made from farm pumpkins. Open days usually include workshops, seedling sales, shared kai, live music, and farm tours.

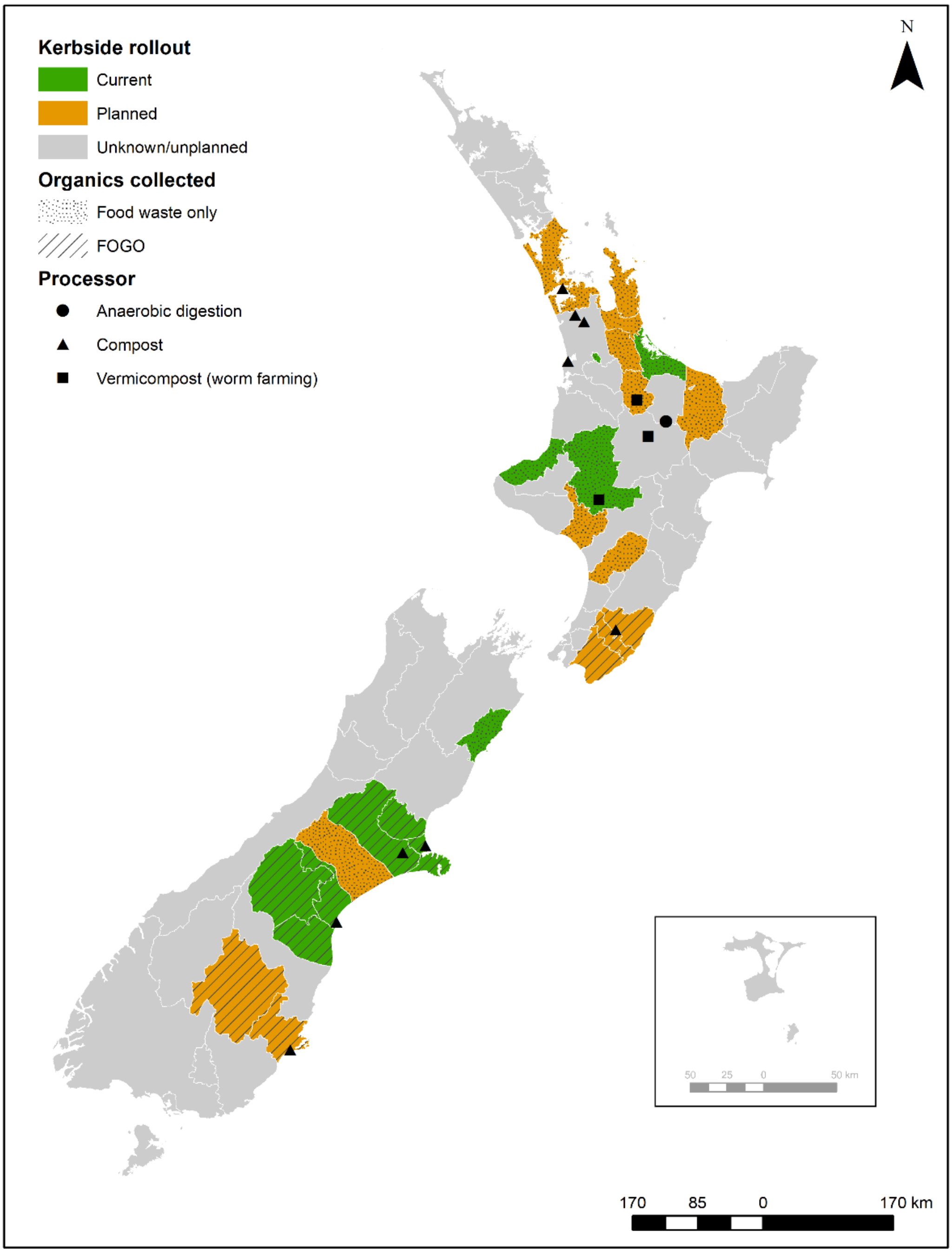
While all composting leads to some greenhouse gas emissions (albeit substantially less than emissions from landfilling food waste), Kaicycle works to keep methane emissions to a minimum by managing the composition of its compost piles, turning them regularly to ensure they are oxygenated, and inoculating piles with Beneficial Anaerobic Microbes (BAM) like those used in bokashi. BAM contains facultative anaerobes which can continue to break down food scraps in the absence of oxygen without producing methane, with the intention being that if the pile becomes anaerobic, methane-producing bacteria won't dominate. Using BAM reduces the frequency with which the compost piles must be turned, reducing labour and allowing beneficial fungal networks to develop with less disruption.

As with many district plans, the Wellington District Plan is ambiguous about the legal status of community gardens, urban farms, and community composting. Wellington's plan is currently being updated and looks to include composting at community gardens as an expected and permitted activity. Kaicycle hopes to see community composting directly included as well, to clarify the status of and rules associated with small- and mid-scale composting enterprises.

Kaicycle is currently undergoing a three-year process to attain Hua Parakore verification for its operations. The Hua Parakore verification scheme is a kaupapa-based approach to organics certification developed by Te Waka Kai Ora, the Māori Organics Authority. Participating organisations must demonstrate how they embed the kaupapa of whakapapa, wairua, mana, māramatanga, te ao tūroa, and mauri in their mahi.

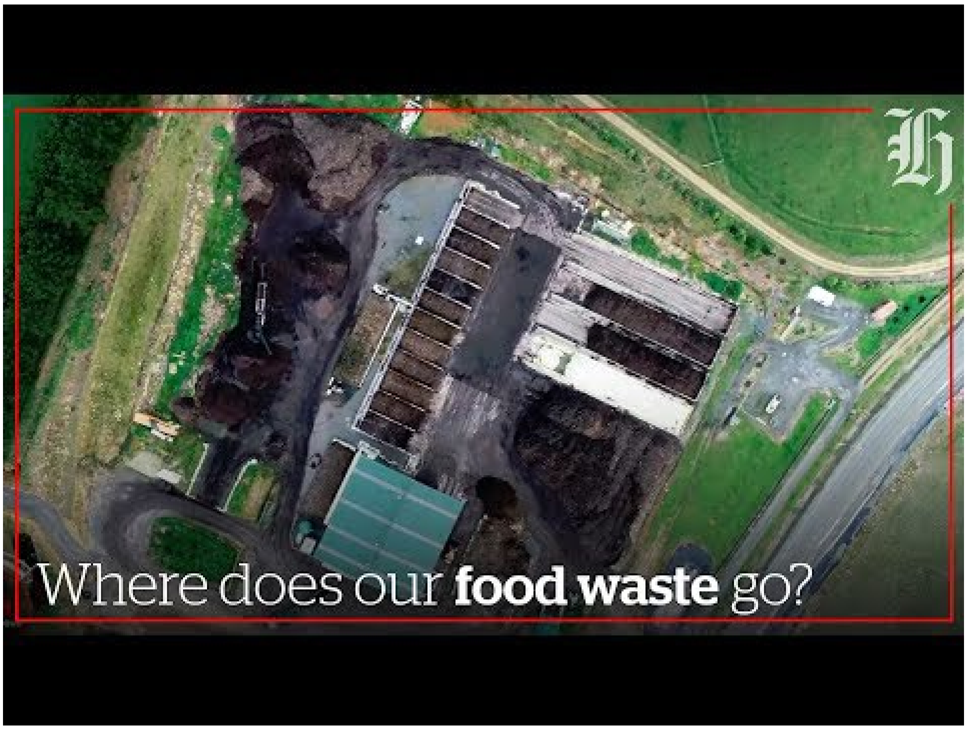
Processing food waste at large scales

In New Zealand, many cities are faced with significant volumes of food waste thrown away by households and businesses alike. At the moment, only 12 city and district councils collect food scraps separately from general waste. However, many more are planning to roll out kerbside food scraps collection services, and the government might make this mandatory for councils in the coming years.



The status of kerbside food waste collection among New Zealand's territorial authorities (TAs), showing current (green), planned (orange), and unknown/unplanned (grey) collection services. Importantly, TA plans for waste collection services are continually evolving, whereas this map represents a single point in time (data were last updated in early 2023). For territorial authorities with current and planned food waste collections, food waste is either collected in a standalone bin (stippling) or as Food Organics and Garden Organics (FOGO), where food waste is mixed with green waste (stripes). The map also shows large-scale, centralised facilities listed by the Ministry for the Environment and territorial authorities as existing or potential food waste processing sites. Map inset shows the Chatham Islands.

For those councils currently offering kerbside food waste collection, composting is the dominant processing method, although in some regions worm farming is used to process business food scraps. However, in a new initiative, Auckland Council will be sending its food scraps – an estimated 38,000 tonnes per year – to a new EcoGas anaerobic digestion plant in Reporoa as it rolls out kerbside collections across 2023, following trials in Papakura and selected streets in North Shore suburbs.



Take a look at how Tauranga's kerbside food scraps get turned into nutrient-rich compost. As well as providing an overview of how centralised, large-scale composting works, the video clip highlights that residents are still getting used to what can and can't go into their bins. Keeping contaminants out is crucial, with much of the compost being used to grow avocados and kiwifruit in the region.

The range of large-scale, centralised processing options for kerbside food scraps that are canvassed below can complement the home-based and community-based solutions, which can also be invested in by councils and agencies keen to support place-based solutions and embed social procurement into their practices.

Many of the processing options listed below can be used to process organic waste streams other than food waste, such as biosolids, manure, or forestry waste. Importantly, the quality of what goes into each process will dictate the quality of what comes out, with contaminants like heavy metals, microplastics, and 'forever-chemicals' being particularly difficult to manage. Thus, controlling inputs is a key part of the process, as no process provides a silver bullet to contaminant-heavy streams of waste.

There are other processing options beyond those covered below, but these generally have niche applications or low technological readiness so aren't included here. A wider range of food waste processing options will be covered in the OPMCSA food waste reports.

A risk for large-scale commercial operations is that their profitability can be contingent on a continual or increasing supply of food waste, which may not be possible if food waste prevention efforts are successful, so thought needs to be given to off-ramps.

Conversion to animal feed

How does it work?

If spare food can't be rescued or upcycled to feed to people, it can often be fed to animals, preferably as part of a balanced diet. In accordance with government regulations, food waste can be fed to animals, either directly or after processing. This is a long-established practice, occurring in Aotearoa at small scales (e.g. cafés collecting food scraps for a local farmer) and at an industrial scale (e.g. Eco Stock). While the animal feed industry already utilises surplus food and food system by-products, feeding mixed household food scraps to animals at scale isn't currently practiced in Aotearoa. Animal nutrition and disease transmission risks are crucial factors to think about when feeding food waste to animals.

Infographic showing the main inputs and outputs involved with converting food waste to animal feed. Conversion to animal feed is a diverse process, depending on the type of feed being produced and the inputs involved. For example, it can be as simple as feeding plant-based food scraps directly to pigs or chickens or may involve heat treatment of food waste that might contain animal products. Food waste may be dried, added to pellets, converted to a slurry, or otherwise processed before feeding.

Key benefits

- Can reduce competition for resources with human food production and decrease the environmental footprint of existing agricultural systems.
- Has the potential to positively impact the price of food by bringing down production costs for farmers.
- Reduces the need to import animal feeds, reducing feed system transport emissions and increasing the resilience of our domestic agricultural systems.

Key challenges and risks to mitigate

- Utilising mixed household or business food waste can pose disease transmission risks, especially if meat is present in the food waste. Strict controls and regulatory compliance, especially heat-treating food waste that contains meat or has been in contact with meat products, and ensuring ruminants don't eat ruminant-containing food waste, can reduce this risk.

- Food waste streams aren't optimised for animal nutrition, and some argue that it isn't transformational enough, embedding animal-based agricultural systems. Balancing food waste with other feeds and being specific about the kinds of food waste accepted can help. Using insect intermediaries also mitigate these concerns.

Case study: Food waste to animal feed in Aotearoa

Food waste is transformed to animal feed by a number of companies in Aotearoa, including Ecostock, Castlegate James, and Takanini Feeds, which produce feed for the agricultural sector, and Omega Plus and United Fisheries, which produces treats and dietary supplements for pets. Direct relationships between food businesses and local farmers is another pathway from food waste to animal feed, and households often feed scraps to their pets too.

For animal feed businesses in Aotearoa, feedstocks, processes, and products vary. Overall, there is a focus on production of animal feeds from homogenous, pre-consumer food waste streams, rather than mixed household or food service food wastes. This focus is driven by the need to minimise potential disease transmission, comparative ease of process control and increased certainty around feed safety and nutritional properties that comes from knowing exactly what is going into the feed.

Ecostock, for example, specialises in de-packaging manufactured food products at risk of going to waste and converting them into food waste blends to be used in stock feed. Castlegate James and Takanini Feeds, meanwhile, produce finished feed products, combining food waste-derived ingredients such as biscuit meal and brewers' grain with other ingredients, making feed mixes and pellets. Across Australia and New Zealand, Castlegate James converts 700,000 tonnes of food at risk of going to waste to animal feed every year. Commercial fisheries in Aotearoa convert by-products (e.g. offal) to fish meal, which can be used as feed for chickens, pigs, and farmed fish. Omega Plus demonstrates how more financial value can be gained from animal feed conversion of fisheries by-products by catering for the premium pet food market, as do United Fisheries in making mussel-based nutritional tablets for pets.

Opportunities to convert inedible and unpreventable food waste streams to animal feed continue to be explored in Aotearoa, such as use of milk processing waste, crop residues, and grape marc as feed components.

Another less-explored avenue is conversion of mixed household and food service food waste to animal feed. The main concerns associated with using post-consumer mixed food waste as animal feed relate to nutrition, transmissible spongiform encephalopathy risks, pathogen transmission, and chemical contaminants. Commercial feed manufacturers have the required processes to comply with biosecurity regulations and apply adequate heat treatment which negates pathogen risks, and nutritional needs of animals can be met with food waste-derived feeds, especially when they are used as part of a wider diet programme. However, current food waste treatment technologies may not eliminate the risk of diseases like mad cow disease (a transmissible spongiform encephalopathy disease) caused by transmissible proteins able to move between animals and humans in the food supply chain. In addition, some chemical contaminants, if present in the food waste feedstock, may accumulate in animal feed. New Zealand's animal feed rules ban the use of ruminant protein in feed for ruminants given the risk of transmissible spongiform encephalopathy spread, which would mean that any animal feed derived from mixed household food waste wouldn't be suitable for ruminant animals if it might contain meat.

Insect-based bioconversion

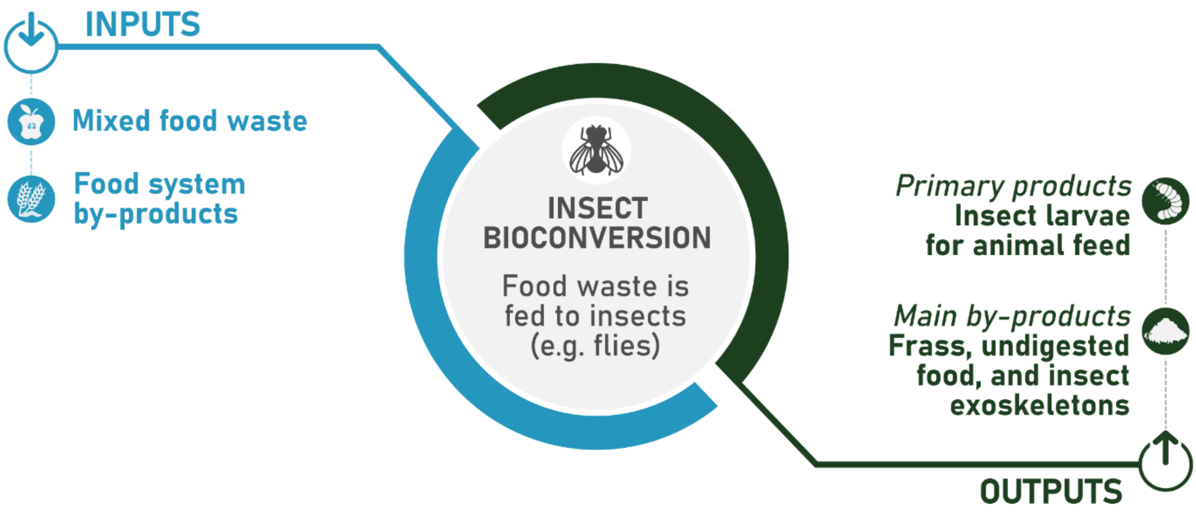
How does it work?

Food waste is fed to insects and the insect larvae are used as animal feed. The larvae, which are rich in protein and fat, are often dried, milled, or otherwise processed before being fed to animals. Extracted larvae oil could also be used as a biodiesel, and one day people might eat insects raised on food waste, although food safety risks would have to be managed and the 'ick factor' would have to be overcome.

While there are clear end markets for the larvae, they leave behind a mixture of frass (i.e. insect poo), undigested residual food waste, and exoskeletons. This could be used as a soil conditioner (either as it is or after further processing, e.g. composting), but further research is needed to understand its performance and possible risks.

Insect-based bioconversion isn't currently practiced in Aotearoa but is starting to be explored. It is a growth industry in Australia and other parts of the world.

Learn about insect bioconversion using black soldier flies in this teaching module produced by two Swiss research institutes. The exact set up of commercial black soldier fly farms varies; this video illustrates just one example of how a fly farm could be run.



Infographic showing the main inputs and outputs of insect bioconversion, a food waste processing option which uses insects as an intermediary to convert food waste into a more nutritionally consistent animal feed. If inputs are restricted to food system by-products such as spent brewers' grain or vegetable trimmings, the process can be tightly controlled, and potential sources of contamination excluded. Where mixed food waste is used as an input, it is crucial to understand what happens to potential biological (e.g. bacteria, viruses) and chemical (e.g. pharmaceuticals, toxins) contaminates. The main by-product, frass, has the potential to be used as a fertiliser either directly or with further processing.

Key benefits

- If insects replace other protein-rich animal feeds, this food waste processing option can have a substantially positive impact on greenhouse gas emissions, reducing emissions from the feed production industry by using food waste as a resource instead of growing animal feed anew. This emissions benefit far outweighs any electricity-associated emissions, which can be quite high (e.g. for lighting, temperature regulation).
- Feeding food waste directly to animals can make it hard for farmers to ensure their animals are eating a nutritionally balanced diet for optimised productivity and wellbeing. Using waste-fed larvae instead helps to overcome this challenge.
- Selective breeding programmes can be used to increase the efficiency of bioconversion, meaning that more of the nutrient and energy content in the food waste is converted to insect larvae for animal feed.
- Compared to feeding untreated food waste to animals, bacterial, viral, and parasite and other risks are reduced when food waste passes through the insects (e.g. viruses which are evolved to infect mammals can't readily replicate in insects) and can be further mitigated by managing the food waste streams that go into the process and by rinsing, blanching, and drying the larvae.

Key challenges and risks to mitigate

- Inconsistent waste streams (e.g. mixed household food waste) can make process and product management hard – the insects will develop differently with variations in the food waste they are raised on meaning that not all batches of insect larvae will be the same, and process variations might be needed.
- If there are contaminants in the food waste, some are broken down by the insects (e.g. some organic pollutants, toxins, pesticides, and pharmaceuticals), but others (e.g. heavy metals) may either be taken up by the insects or end up in the frass mixture, creating possible health risks for the animals that eat the larvae or soils where frass is applied, and food derived from them. These risks are best managed by tight control over inputs.

Case study: Converting food waste to animal feed at FlyFarm in Brisbane

FlyFarm is a growing agri-tech business focusing on developing highly automated black soldier fly (*Hermitia illucens*) larvae farms that convert organic waste into high quality protein for animal feeds. Insect frass is also produced during bioconversion, which FlyFarm is trialling as a fertiliser.

The company is headquartered in Singapore and has a presence in Hong Kong, Taiwan, and Brisbane. The Brisbane team runs a pilot plant, recently expanded and fitted with robotic handlers, environmental sensors, and software control mechanical shifters, enabling much of the vertical insect farm to be automated.

OPMCSA and Fight Food Waste Cooperative Research Centre visiting FlyFarm, hosted by co-Founder Andres Crabbe, Queensland FlyFarm manager Oliver Warcup, and entomologist Chen Wu, alongside the FlyFarm robotics team.

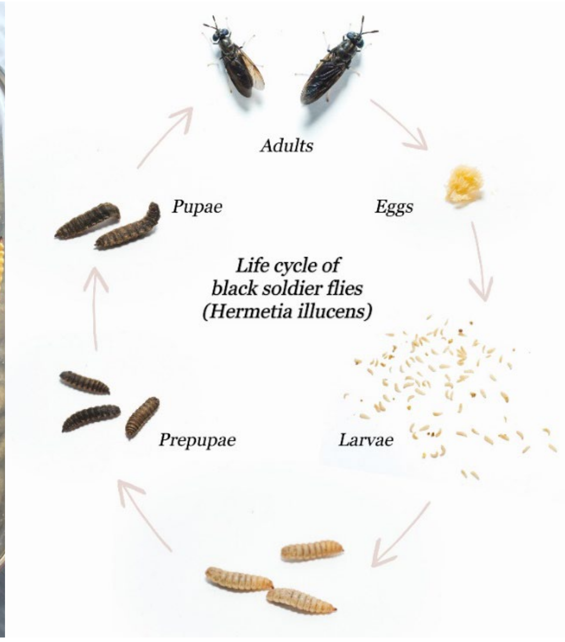
FlyFarm is focused on producing high quality outputs so currently processes homogenous plant-based food waste (e.g. brewers' grain) rather than mixed waste to avoid contamination of the larvae or frass.

The process begins with adult black soldier flies, which are raised in mosquito net enclosures where they lay eggs. Because black soldier flies are most active during the day, they are kept under UV light to stimulate activity.

The larvae are put into trays and introduced to a soy by-product initially, before being fed on the primary food waste stream, which usually must be ground into small particles to optimise bioconversion. Over the course of 9–11 days, the larvae consume the food waste. FlyFarm works to minimise the residual food waste remaining, so the trays mostly contain larvae and frass at the end of this time.

The larvae are sifted from the frass and blanched and dried before bio-oil is extracted from them ('defatting'). The protein-rich dried larvae can then be powdered, and the bio-oil and powder (along with other ingredients) can be combined in ratios that meet the nutritional needs of different animals and operational requirements of farmers. This post-processing also stabilises the larvae, giving them a long shelf life, while a live larvae product would have to be used more rapidly (although is offered by some bioconversion businesses, e.g. for captive reptiles). A small number of larvae are kept, maturing into adult flies to repeat the process. When adult flies die, some are combined into an attractant mixture that is used to get live flies to lay their eggs in a collection substrate, while the rest (which have a small total mass) go to waste. FlyFarm intends to explore ways to purify chitin from dead flies and pupae shells in the future (chitin has a range of applications, e.g. as a food additive or emulsifier).

The frass contains nutrients with fertiliser value. It can be further processed (e.g. by composting) or applied directly to fields. FlyFarm is trialling direct application of its frass with a local strawberry grower.



Left to right: Dried larvae produced at FlyFarm; Black soldier fly (*Hermitia illucens*) lifecycle. Image credit: Chen Wu, FlyFarm.

FlyFarm's ideal operating model involves partnership with food waste owners, co-locating bioconversion infrastructure at a food processing or manufacturing facility and valorising their waste onsite. FlyFarm has multiple revenue streams – including food waste handling fees, larvae product sales, and frass product sales, and are looking to verify the greenhouse gas emissions benefits of their work so that they can sell carbon credits on voluntary markets.

When establishing in Australia, FlyFarm faced few regulatory barriers as black soldier flies were already reared commercially there, and the species is found globally and not considered to be an invasive species. Focusing on homogenous, plant-based food waste also eases regulatory barriers.

FlyFarm is continuing to refine its processes and undertakes research into a range of topics including selective breeding for flies that efficiently convert food waste, the fate of contaminants during the bioconversion process, and the performance of frass as fertiliser.

Composting

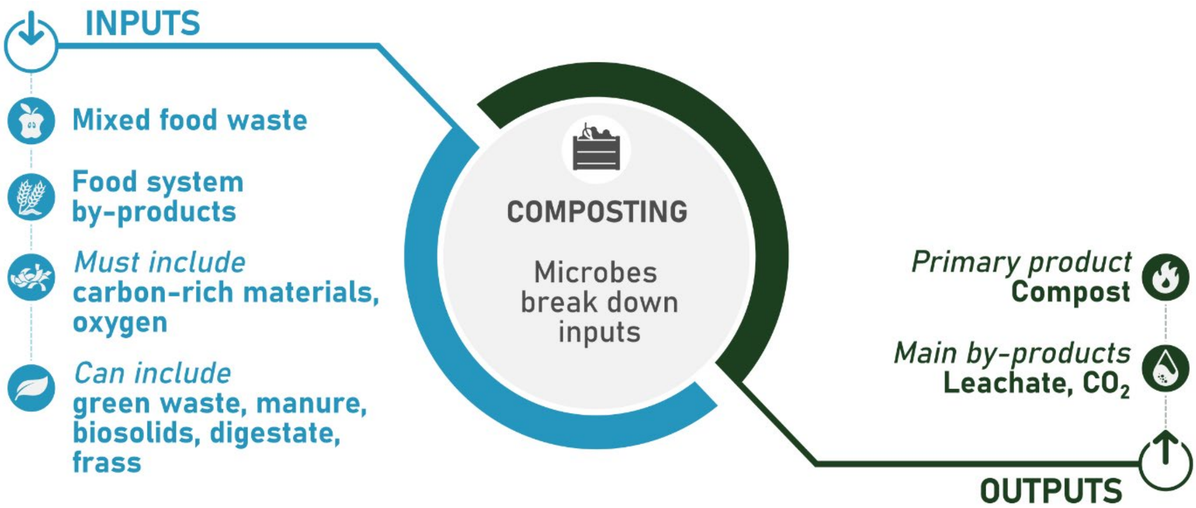
How does it work?

Food waste is combined with garden waste and other carbon sources and then, if the mixture is sufficiently aerated, broken down by microbes in the presence of oxygen. The resulting compost can be used as a soil amendment, returning nutrients and carbon to the land.

Composting can take many forms, from familiar backyard bins, to windrows, turned piles, aerated static piles, and to enclosed and in-vessel systems. In some cases, specific microbe formulations can be added in to optimise the process and reduce the need for turning.

Composting and the use of compost in landscaping, gardening, and agriculture is established, with well-understood soil fertility benefits. In Aotearoa, composting takes place at the home, within communities, and at large-scale, centralised facilities.

Learn about different composting technologies in this teaching module produced by two Swiss research institutes. Note, the examples shown in this video are context-specific; composting operations around the world will all look slightly different.



Infographic showing the main inputs and outputs of composting, a food waste processing option that can be applied in the home, community, or by large-scale, centralised enterprises. Food waste and by-products need to be combined with carbon-rich materials to get the ratio of nitrogen and carbon right, and compost piles need to be kept aerated (e.g. by turning) to keep methane production as low as possible. The resulting compost contains nutrients that can be added back to soils. The process also generates CO_2 and can produce leachate, although the latter can be minimised through good management practices.

Key benefits

- Relatively simple process that can be scaled up or down depending on volume of food waste.
- Compost is generally rich in organic matter, nutrients, and microbes which contribute to soil ecosystems. The composting process also reduces the volume and weight of the initial organic weight.
- Compost can build soil carbon and reduce the need for fertiliser. When the process is done effectively and carbon sequestration and displacement of synthetic fertiliser are factored in, emissions from composting can be close to or better than net zero.
- When undertaken within communities, whether it be at home, compost clubs, or social enterprises, composting provides a range of broader social and environmental benefits, such as facilitating community connections, supporting urban agriculture, and promoting broader food waste awareness and sustainability initiatives, and creates 'small circles' in the circular economy.
- While animal products can't readily be composted at home, large-scale centralised composters generally accept these types of food waste and are able to produce quality-controlled outputs.

Key challenges and risks to mitigate

- If managed poorly, leachate, odour, pests, and greenhouse gas emissions can become an issue (including methane, which will always be produced in small amounts but can be produced in large amounts if the pile isn't sufficiently aerated).
- Sufficient garden waste and other carbon-rich material must be sourced and layered with food waste to balance the ratio of nitrogen (from food) and carbon, while additional water may be needed to maintain moisture content in composting material (especially in summer months in outdoor operations).
- Different composters have different abilities and willingness to accept and process biodegradable and compostable products. These products can be a source of contamination (e.g. microplastics, chemicals including PFAS) in compost.

Case study: Living Earth, New Zealand's largest compost operator

Living Earth is a New Zealand-based composting business owned by Waste Management. Living Earth has been in operation for more than 20 years, with primary sites in Christchurch and Auckland, and is New Zealand's largest organic waste to compost operator. Annually, Living Earth's composting facilities can process over 100,000 tonnes of garden and food waste, turning it into compost. Compost is sold as a soil amendment, used by gardeners, farmers, and landscapers to improve the fertility, structure, and water retention of their soils.

Living Earth's composting operations differ between its two sites. At its Organics Processing Plant in Bromley, Christchurch, Living Earth composts 60,000 tonnes of mixed garden waste and food waste annually in 18 in-vessel composting tunnels, generally at a carbon-to-nitrogen ratio of 30:1. Much of this waste is collected from households in Christchurch, as part of the city's organics kerbside collections. Once organic material is shredded, it is placed in windrow tunnels for 2–3 weeks before being moved outdoors and offsite for maturation to manage odour. During maturation, organic material is broken down by microbes over the course of 2–3 months. During this process, the microbes are kept active and efficient by ensuring that air, temperature, and moisture levels remain consistent within composting material by mechanically turning the windrows and adding water as needed during summer months. Water runoff from the windrows is managed using a pond system. Typically, composting material at

Living Earth sits at 50–60°C (a result of the metabolic process of microbes), temperatures which help kill off pathogens and weed seeds in the organic material. Compost from the Bromley site is primarily sold in bulk to farmers in the Canterbury region, as well as local gardeners and Christchurch City Council for restoration projects.

In Auckland, Living Earth runs an outdoor windrow composting system on Puketutu Island, a site which spans 12 hectares (eight of which are currently used for open-air composting, with 4 hectares set aside for potential expansion). At its Puketutu site, Living Earth processes 30,000 tonnes of green waste annually, sourced from yard trimmings and plant material, primarily from waste transfers stations and residential collections. It takes microbes 3–4 months to break down green waste and convert it into compost. As composting operations at Puketutu are outdoors, up to 200 cubic meters of water is added to windrows per day in summer months to maintain moisture content in windrows. Water and leachate runoff is diverted to large storage ponds. Once compost at Puketutu has fully matured, it is mixed with angular sand, pumice, and aged bark to improve its properties as a soil amendment product. This compost product is primarily sold into the Auckland urban landscape market, both in bulk and in bags, as well as to infrastructure projects in and around the region.

Compost sold from both of Living Earth's facilities meet voluntary New Zealand standards for compost, soil conditioners and mulches, while some of their products are certified for use in organic production by BioGro or AssureQuality.

Living Earth works to mitigate several challenges which often affect large-scale composting. For example, micro-contaminants, including heavy metals and herbicides like clopyralid, can reduce the quality of compost. At Living Earth, batches of compost are tested regularly on- and offsite for micro- and macro-contaminants, nutrient value, maturity, and growth performance. During the composting process, Living Earth also monitor and control process parameters, especially temperature, moisture, and oxygen. This ensures that compost undergoes pasteurisation and prevents windrows from becoming anaerobic and producing methane.

Living Earth currently employs 13 staff in Auckland and 18 in Christchurch. Beyond its business activities, Living Earth sponsors a restoration project on Motutapu island and supports a number of community initiatives.

Windrows of composting material at Living Earth's site on Puketutu Island

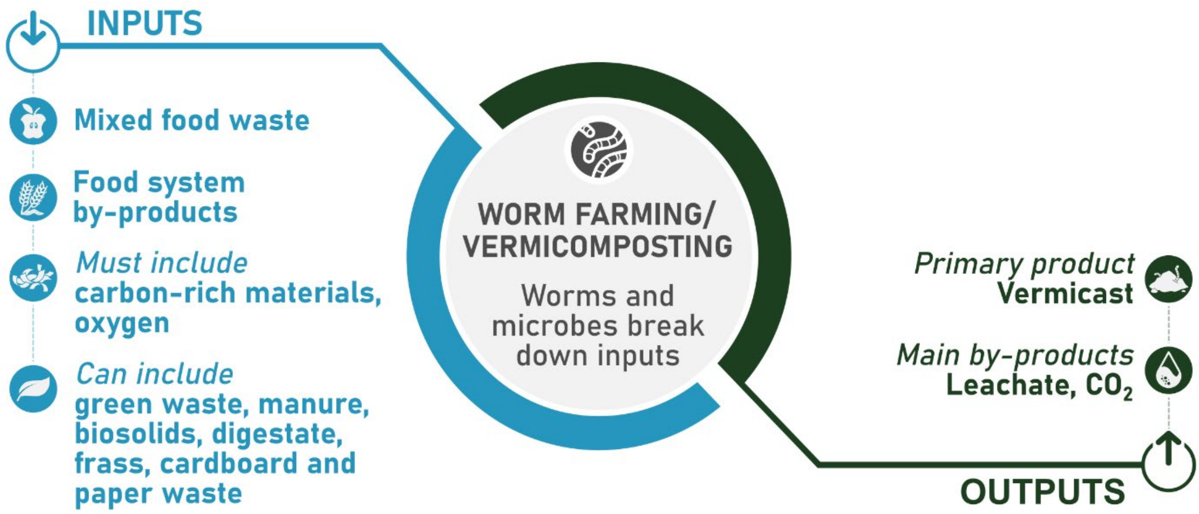
OPMCSA's George Slim (left) and Living Earth's Logan Dingle (right) stand in front of piles of mature compost ready for market. A compost screening machine stands to their right.

Vermicomposting (worm farming)

How does it work?

Food waste is eaten by worms, producing a product called vermicast which improves soil. Vermicomposting can be undertaken using closed vessels or in windrows.

Vermicomposting is well-established in Aotearoa, with one large-scale enterprise and many people engaging in vermicomposting – commonly known as worm farming – in their communities and homes.



Infographic showing the main inputs and outputs of vermicomposting, a food waste processing option that can be applied in the home, community, or by large-scale, centralised enterprises. Fibrous material needs to be added to food waste inputs, and oxygen is crucial too, although the worms themselves incorporate it to the process so no active aeration is needed. The main product is vermicast, which can be used as a fertiliser. The process also generates CO_2 and can produce leachate, although the latter can be minimised through good management practices.

Key benefits

- Similar or slightly lower emissions profile when compared with composting, including with carbon sequestration and fertiliser displacement benefits.

- Vermicast is typically a stable, nutrient-rich substance which can be used as a soil conditioner. The vermicomposting process also reduces the volume and weight of initial organic waste.
- Unlike composting, no pile turning is required to keep the system aerobic – the worms do this work themselves, reducing labour and processing emissions (if compost turning is done by machine).
- Can process a wide variety of inputs, including mixed food waste, biosolids, digestate from anaerobic digestion, and industrial effluent.
- Pathogens such as aerobic bacteria, viruses, and fungi found in organic waste are broken down as they pass through the digestive system of worms.

Key challenges and risks to mitigate

- Need to manage the process and design facilities to avoid leachate (e.g. windrow rotation across farmland, maintaining the correct carbon to nitrogen ratio).
- There is less literature on the emissions profile of vermicomposting than for compost, making comparative emissions-based assessments of this food waste processing approach challenging.
- As with composting, biodegradable and compostable packaging can be a source of contaminants.
- As vermicomposting is not a thermophilic process (it doesn't get hotter than about 35°C), vermicast may need to be pasteurised to produce a seed-free product and remove any pathogens which are unaffected by worms' digestive systems.

Case study: The team of three billion at MyNoke

MyNoke is a New Zealand-based vermicomposting business that uses earthworms to process dairy waste residues, food waste, paper and cardboard waste and wastewater sludge, wood ash and other feedstocks at multiple sites across the North Island. MyNoke was started by soil-scientist Michael Quintern in 2007 and today has sites in Ohakune, Taupō, and Tokoroa. Across these sites, MyNoke estimates some three billion worms eat 160,000 tonnes of organic waste annually, converting it into vermicast. Vermicast is primarily used as a soil conditioner to improve fertiliser efficiency and substitute some synthetic fertiliser.

To produce vermicast, trucks collect various organic waste from customers and unload it onto concrete slabs at MyNoke's vermicomposting sites. Here, the waste is sorted to remove contaminants such as plastic, glass, wood, and plastic lined cups. Organic waste is then mixed with fibrous, carbon-rich materials (e.g. newspaper, egg cartons, sawdust, or cardboard) and laid out on fields in long piles (called windrows) using agricultural machinery. The first of these windrows are seeded with worms (typically *Eisenia fetida* and *Eisenia andrei*). As the worms eat their way through waste, they reduce its volume up to 80% and leave behind vermicast. In addition, worms keep the windrows aerated as the move through the pile, helping soil microbes to break down waste further. Once the worms have eaten through the organic waste in one windrow, they migrate to the next windrow in line. A single windrow, which can contain more than 100 tonnes of organic waste, is typically processed by worms and soil microbes within 9–12 months. Vermicast is harvested from windrows annually and is mechanically screened to remove remaining physical contaminants like stones and plastic.

Earthworms are put into a mixed feedstock of biosolids (black and dark brown material), dairy wastes (orange), and paper pulp (grey) on the concrete slab where MyNoke mixes their inputs. Feedstock mixes like this are subsequently laid out in large windrows on fields.

The nutrient content of vermicast depends on the feedstock used, but vermicast generally contains high amounts of water-soluble nutrients like nitrogen and phosphorous. Earthworms can remove pathogens (e.g., fungi, aerobic bacteria, and viruses) as they consume organic waste, and vermicast can be further pasteurised using geothermal heat to kill off weed seeds. Unlike composting, windrows do not reach high temperatures, instead maintaining temperatures below 35°C. A benefit of the lower temperature is that it reduces odour emissions from windrows. To protect soils, Mynoke rotates the location of its windrows across paddocks to mitigate soil compaction and prevent the accumulation of excess nutrients.

OPMCSA staff member Jacques with MyNoke's General Manager Phil Holland standing in front of a freshly harvested pile of vermicast at MyNoke's Taupō site.

The majority of MyNoke's vermicast is sold in bulk to farmers and orchards in Aotearoa, with a smaller share sold to retailers as packaged product for home gardeners. Although vermicast sold to New Zealand markets is not pasteurised, it meets the voluntary New Zealand standard for compost, soil conditioners, and mulches (NZS 4454). When MyNoke's vermicast is on the international market, it is pasteurised by steaming it to 72°C for a couple of hours before it is tested and shipped overseas.

MyNoke currently employs 30 staff across its three vermicomposting sites on the North Island. The company is planning to expand, with several new sites planned for the North and South Island. In total, MyNoke has a growth goal of 16 sites across New Zealand and further expansion into Australia.

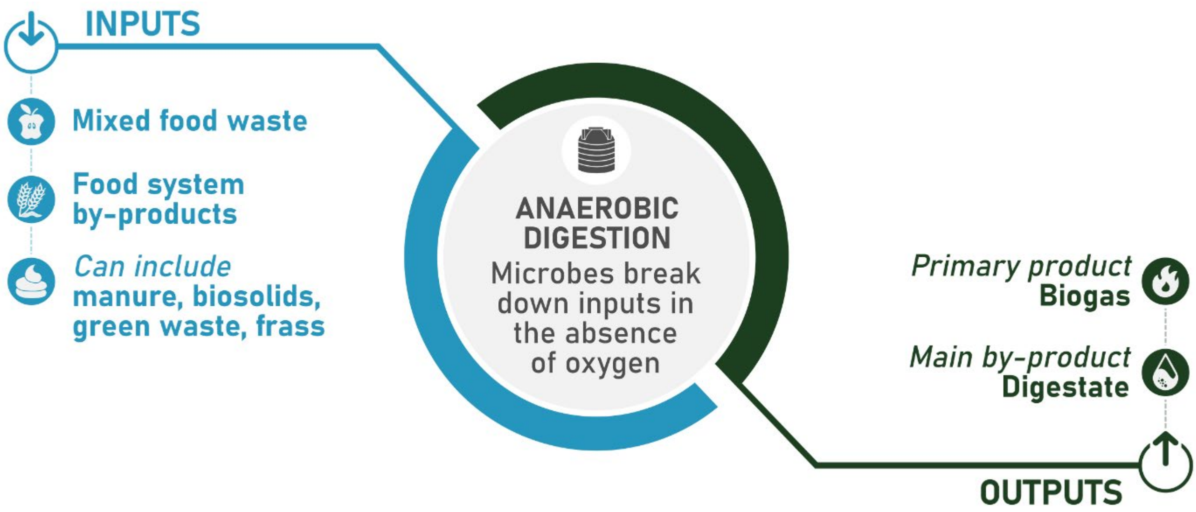
Anaerobic digestion

How does it work?

Food waste is broken down by microbes in the absence of oxygen. The methane (and small amount of CO_2) that the microbes produce, known as biogas, can be burnt to generate heat and electricity, or upgraded to serve as a substitute for natural gas. The wet mixture of solid and liquid residue that remains after methane is extracted is called digestate and can be used as a fertiliser. Further processing of digestate can make it more suitable for use, with a wide range of options available such as composting, vermicomposting, and pyrolysis.

Anaerobic digestion is a well-established process. While it is new to Aotearoa for food waste processing (we currently have one facility in Reporoa managed by EcoGas, which opened in 2022), it has been used here for many years to process biosolids, manure, and industrial effluent (especially from the dairy industry). Anaerobic digestion main feedstocks overseas vary; for example, facilities in Germany mostly process pig manure and crop residues from its many farms, while in the UK over half of the organic material processed by anaerobic digestion plants is food waste, crop waste, and other waste streams.

In 2019, John Campbell interviewed Ecogas director Andrew Fischer about the company's plans to establish an anaerobic digestion facility in Reporoa. The facility was officially opened in 2022 and will be processing all of Auckland's household food scraps when the collection service is rolled out across the supercity this year.



Infographic showing the main inputs and outputs of anaerobic digestion. A wide variety of inputs are possible – anaerobic digestion of dairy by-products and biosolids is an established practice in Aotearoa, while anaerobic digestion of food waste is new to the country. The process relies on the exclusion of oxygen so that the inputs break down anaerobically, producing methane-rich biogas that can be used to generate heat and electricity, or as a replacement for natural gas. Digestate is the primary by-product. Depending on the inputs (and their contaminant loading), digestate can be used as a fertiliser directly or with further processing. Note, while some anaerobic digestion systems can process green waste, it is typically does not aid the efficient production of biogas

Key benefits

- Anaerobic digestion facilities can be carbon neutral or carbon negative when biogas or its purified form, biomethane, is used as a substitute for fossil fuels to produce electricity, heat, or transport, and when digestate is used to displace fertiliser.
- Anaerobic digestion facilities are fully contained. This means that, unlike landfills with gas capture, they recover almost all the methane produced. Containment also reduces odour risks meaning anaerobic digestors can be situated closer to major population bases than many other food waste processing options.
- Can process a wide range of organic waste types including mixed food waste, crop residues, biosolids, manure, and industrial effluent.
- Potential to use the generated carbon dioxide (CO_2) in greenhouses and elsewhere (e.g. as food grade CO_2).
- Where inputs and processes are properly regulated, digestate can be used as a fertiliser in agricultural settings

Key challenges and risks to mitigate

- Requires significant investment in infrastructure to capture and process the methane from organic waste.
- Biogas needs to be purified (removing the CO_2, water vapour, and trace gases) before it can be readily used as a natural gas substitute.
- Application of digestate to land needs to be done with care, and more research on its use in agronomic settings is needed. Excessive application of digestate can harm plants, leach excess nitrate, and produce odours (mostly from ammonia) and greenhouse gas emissions.
- Controlling for the quality of feedstocks from residential or urban organic waste streams can be a challenge, with potential knock-on effects for digestate quality.

Case study: Anaerobic digestion with Ecogas

Ecogas is a New Zealand-based company which specialises in the anaerobic digestion (AD) of organic waste from households and businesses. Food waste is used to generate biogas (a fuel source) and digestate (a potential fertiliser). Ecogas, a partnership between Pioneer Energy and Eco Stock Supplies, is new to the AD scene in New Zealand, having recently opened their flagship facility in Reporoa in mid-2022.

Once fully operational, Ecogas plans to process 75,000 tonnes of organic waste at its Reporoa facility – including a mix of household food scraps, commercial and retail food waste, and dairy waste – producing biogas and digestate from these feedstocks. Kerbside food scraps from Auckland as set to make up for 38,000 tonnes of Ecogas' feedstock as collections is rolled out during 2023. After being collected, this household food waste will be consolidated in Ecogas' sorting and consolidation centre in Papakura, and then sent to the Reporoa Organics Processing Facility using freight trucks that otherwise would have been empty on their return journey from Auckland to Reporoa. There it will be separated from contaminants like plastic, biodegradable packaging, and metal prior to processing in anaerobic digesters.

Biogas, the primary product of AD, is a mixture of methane, CO_2, and small quantities of other gases. To create biogas, feedstock at Ecogas' Reporoa facility is machine-sorted, passed through a grinder, and fed into large airtight tanks, where microbes are used to break down organic matter in the absence of oxygen, releasing biogas in the process. Biogas is siphoned out of the top of digestion tanks whereafter it is conditioned (cleaned to remove unwanted sulphur compounds and moisture) and stored for use. Biogas can be used in place of virgin natural gas, providing energy without the environmental tolls associated with natural gas extraction. Concurrently, biogas produced from food waste mitigates methane emissions that would otherwise occur if waste was sent to landfill. Presently, Ecogas generates electricity and heat for their Reporoa facility by burning a portion of the biogas produced on site. Once fully operational, Ecogas plans to send the heat and CO_2 from biogas to a local tomato glasshouse to improve growing conditions. Looking forward, Ecogas plans to upgrade the biogas it produces into biomethane to inject into the natural gas grid.

Beyond biogas, the AD process also produces digestate, a wet mixture of processed solids and water. Where digestate is primarily derived from food waste – as is the case for Ecogas – it typically contains high levels of nutrients like nitrogen, phosphorous, and potassium, minerals and trace elements. Given that most of the carbon in the feedstock is converted into biogas, digestate contains little carbon relative to other soil amendment products like compost. At Ecogas, digestate will be pasteurised before being sent to farmers as an alternative to mineral fertilisers. This is a common practice in several European countries, as well as parts of North America and Asia. To help inform the introduction of digestate on the New Zealand farming market, Ecogas has run trials with digestate from at a small pilot plant in Wiri to compare the effects of digestate on pasture growth with common fertilisers and soil treatments, although results aren't yet available. In addition, Ecogas, in partnership with the Bioenergy Association, is working on an industry-lead set of standards for digestate use and certification in New Zealand. This is a key step in ensuring that there are end markets for digestate, especially as it is currently considered a waste product in New Zealand. Ecogas' approach to these standards seeks to mirror initiatives abroad (e.g. the PAS110 in the UK and the SPCR 120 in Sweden) which control digestate quality and minimise any potential adverse effects of its application.

Ecogas currently provides fulltime employment for seven people, which will potentially increase to 10–15 as capacity at Reporoa increases. Ecogas plans to expand its operations in Aotearoa in the future, with discussions ongoing for new facilities in Canterbury and Manawatu in the next five years.

The digester tanks at Reporoa which hold up to 3,500,000 litres of organic waste. Methane rises to the top of the tanks and are captured using a hose system.

Sorting hoppers which receive and filter organic waste streams at Ecogas' Reporoa plant.

Pyrolysis and gasification

How does it work?

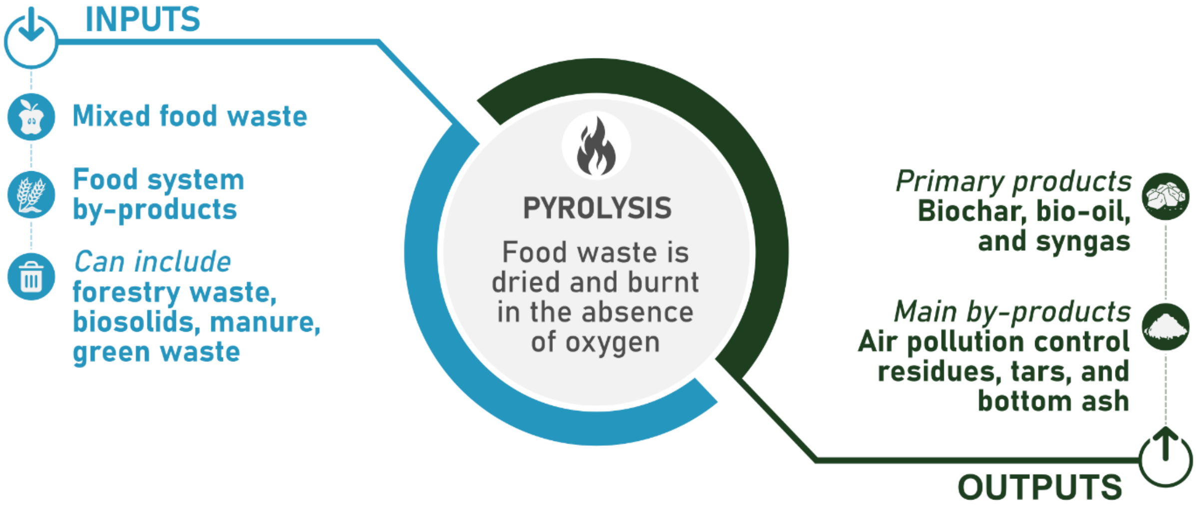
Pyrolysis and gasification are two similar processes for converting food waste to biochar and energy. Food waste is partially combusted in the absence of oxygen (in the case of pyrolysis) or presence of a limited amount of oxygen (in the case of gasification). Instead of reducing food waste to ash and heat energy (as is the case with incineration), pyrolysis and gasification of organic materials produces biochar, a solid, carbon-rich product that can store carbon for centuries, improve soils, and remove pollutants or toxins from the environment. In addition, syngas (produced by both pyrolysis and gasification) and bio-oil (produced by pyrolysis) can be used as energy sources.

Pyrolysis and gasification are well-established processes for some feedstocks but have only recently started to be used for organic waste, especially mixed food waste. Here we focus on the use of these processes for organic material processing only; where other feedstocks are used (e.g. municipal solid waste), the outputs vary, and the acceptable uses of those outputs become constrained. For example, if municipal solid waste is used, the solid product is called char (rather than biochar) and must be disposed of to landfill.

While biochar, bio-oil, and syngas have many uses, it's important to note that the nutrients in food waste are lost during pyrolysis and gasification, so these processes sit towards the bottom of the food waste hierarchy and run counter to the principles of the circular economy[1]. The Ministry for the Environment has produced a useful waste to energy guide for New Zealand, which deals with these topics and other key considerations such as the risk that waste to energy investments will undermine resource recovery efforts and source prevention of waste.

Use of these processes for organic material processing in Aotearoa is largely limited to demonstration and pilot scale operations.

[1]Importantly, pyrolysis can help "close the loop" for some difficult-to-manage waste streams beyond food scraps. The role and context in which pyrolysis can support the principles of a circular economy will be discussed further in our forthcoming report on capturing value from food waste.



Infographic showing the main inputs and outputs of pyrolysis, a thermochemical processing option for food waste. Pyrolysis must take place in the absence of oxygen and at high temperatures. While inputs can theoretically include inorganic municipal solid waste as well, this impacts the quality and potential uses of the resulting char, making it unsuitable for use as a soil amendment or for environmental remediation. Syngas and bio-oil are also produced when food waste is pyrolysed, energy products which are largely or entirely consumed by the energy demands of the process itself. By-products include air pollution control residues, tars, and bottom ash, all of which need to be managed, including treatment of air pollution control residues as a hazardous waste.

Infographic showing the main inputs and outputs of gasification, a thermochemical processing option for food waste. Gasification is much the same as pyrolysis, but a small amount of oxygen is let into the system, which means bio-oil isn't produced.

Key benefits

- Biochar can sequester carbon for centuries because the carbon in biochar exists in a stable form which lasts for a lot longer than untreated food waste.
- Biochar can also be used a fertiliser replacement or complement, improving availability of nutrients, making soils better at retaining moisture, and improving soil chemistry. Evidence also suggests it can be used to improve the efficiency of composting and anaerobic digestion, and the quality of products from these processes.
- Biochar can be used to remediate soils and waterways because it can adsorb things like heavy metals and persistent organic pollutants. It can also control odours.

Key challenges and risks to mitigate

- The quality and properties of the biochar depend heavily on what is fed into the process and, if contaminants are present, it might not be suitable to apply to land.
- A lot of energy is consumed when food waste is dried to an acceptably low moisture level (ideally less than 25% or even as low as 10%). This means that the amount of energy used in the process is equal to or greater than the amount of energy available from the syngas that is produced. Energy is also expended when the feedstock is chopped into small pieces (which is necessary to ensure rapid heat transfer).
- While bio-oil has the potential to be used as a diesel- or petrol-like fuel, it generally requires upgrading – often it can contain too much water to combust efficiently and could cause engine rusting.
- While air pollution can be kept in line with air quality regulations by filtering and scrubbing before discharge, this creates contaminated wet scrubber wastewater which needs careful disposal. Some of the pollutants produced are toxic and environmentally persistent.

Case study: Pyrocal, an Australian gasification company

Queensland-based Pyrocal is an Australian company that specialises in the gasification of residual waste. Pyrocal began developing its technology in 2008, and its flagship project started operating in 2022 – a gasification facility in Loganholme that processes biosolids produced at the Logan City wastewater treatment plant.

Instead of spreading biosolids on agricultural land, as was the city's previous practice, biosolids are gasified at the wastewater treatment plant. Land spreading of biosolids is receiving increasing scrutiny in Australia given the introduction of PFAS to soil, a persistent organic pollutant which is reportedly broken down by Pyrocal's gasification technology, as well as the transport emissions accrued when biosolids produced in cities are transported to rural areas.

Because biosolids are so wet, requiring energy-intensive drying before gasification, the process is energy neutral, with no surplus energy being produced. However, gasification reduces the volume of biosolid waste by up to 90% and produces biochar which can be partly or fully recovered, depending on the waste feedstock and char composition. The biochar can be applied to soil, stably sequestering carbon and serving as a soil conditioner. Given its adsorptive properties, biochar also has applications in environmental remediation and as a stockfeed. Pyrocal also gasifies agricultural and forestry residues which, in Loganholme, it uses to get the gasification system up to temperature before processing biosolids.

In addition to its operational facility in Loganholme, Pyrocal has a facility in Wellcamp, where it is developing knowledge about the use of its gasification technology for other feedstocks, including food and green waste.

Pyrocal's gasification facility at Loganholme (background) next to two wastewater treatment ponds (foreground). Image credit: Pyrocal.

Biosolids from wastewater treatment following drying (left) and gasification (right).

Pyrocal also undertakes projects exploring the properties and performance of its biochar, including contributing to a recent project with Dubbo Regional Council where it was found that biochar, used as part of a rock pit tree planting system, contributed to enhanced tree growth and reduced need for watering given its water retention and cation exchange properties.

The most complicated part of Pyrocal's process is air pollution control. It must make sure that particulate matter, sulfur dioxide, nitrous oxide, and other emissions are kept within legal limits. Continuous emissions monitoring and full air emissions analysis during trials enabled Pyrocal's air pollution control processes to be finetuned to ensure compliance while also improving energy efficiency. The water used in the process of air pollution control is used to quench biochar before being returned to wastewater treatment ponds, and the small amount of soot produced by the system (approximately 200 kg per year) is disposed of as general waste.

OPMCSA staff member Emily with Pyrocal's Cherie Pugh (manager) and Durell Hammond (director), and Downer's Mark Newland (principal process design engineer) following a tour of the Pyrocal gasification plant at Logan Water.

Pyrocal sells carbon credits based on biochar produced from nutshells and wood waste on voluntary carbon markets. This is facilitated by Puro.earth, a carbon crediting programme specifically focused on credits for engineered carbon removal and long-term sequestration. Selling independently verified carbon credits on voluntary markets provides an additional revenue stream on top of waste processing fees and biochar sales.

Glossary

Note: The list of key terms below relates to the particular context of this web resource on food waste.

Adsorb – When small particles like atoms and molecules stick to the surface of a material, they have been adsorbed. This is different from absorption, where a liquid is soaked up, like water into a sponge.

Biochar – The carbon-rich product which occurs when plant-derived biomass (such as wood, manure, or crop residues) is heated in a closed container with little or no available air.

Biodegradable plastic – Plastics, typically polycaprolactone (PCL), polylactic acid (PLA), and polyurethane (PU), which can be degraded by biological, and principally microbial processes.

Biodegradable product – The meaning of biodegradable is very broad, but generally means a product will break down naturally with the help of microbes, producing water, CO_2 (and methane if oxygen isn't present), and biomass. Biodegradable products can be made from a wide range of materials, and don't all break down as readily as one another or in the same environments or time scales. Note that 'degradable' (rather than biodegradable) can be used to describe plastics that simply fragment into small pieces or microplastics, persisting in the environment. One of the main types of degradable plastics, oxo-degradable plastic, has recently been banned in Aotearoa.

Bokashi 'sprinkle' – A mix of microbes, water, sugar, and carbon-rich material (also called bran) which is used to maintain a healthy environment for bokashi microbes.

Carbon dioxide equivalent (CO_2e) – CO_2e is a metric used to compare the emissions from various greenhouse gases based on their global warming potential (GWP). It is calculated by converting amounts of greenhouse gases to the equivalent amount of CO_2 with the same global warming potential.

Carbon sequestration – The removal of CO_2 from the atmosphere (where it contributes to global warming) and storage through natural or artificial processes.

Circular economy – A sustainable approach to resource use where waste and pollution are viewed as design flaws, products and materials are kept in use as long as possible, and nutrients and energy are captured at the end of a product's life to regenerate natural systems.

Compostable product – Compostable products are certified products which are expected to break down in large-scale, community-level, and/or home compost systems. Compostable products may be plastic-based or fibre-based.

Energy recovery – Capturing the energy held in food waste so that it can be used to generate heat or electricity, or as a fuel or natural gas equivalent.

Food recovery hierarchy – A framework for thinking about solutions to food waste, prioritising interventions according to which types of solutions are likely to deliver the most environmental and social good.

Food rescue – The process by which edible surplus food at risk of going to waste is distributed for human consumption, typically through a charitable model.

Frass – Insect poo.

Leachate – Water that has move through a solid (such as the contents of a landfill or compost bin) and carried some material with it. It not managed, leachate can seep into the ground, introducing contaminants or excessive concentrations of certain nutrients.

Material recovery – The use of inedible components of food at risk of going to waste to produce useful materials, such as fibre-based packaging.

Nutrient recovery – Capturing nutrients from food waste so that they can be used in agricultural systems, gardens, and to regenerate natural environments.

Organic – Being or coming from living plants and animals (e.g., food waste, manure, sewage sludge, crop residues).

PFAS - Per-and polyfluoroalkyl substances (PFAS) are chemicals which are used to make coatings in products like food packaging that resist heat, oil, stains, grease, and water.

Thermal pasteurisation – A relatively mild heat treatment in which a liquid is heated to less than 100°C to kill or inactivate microbes.

Upcycling – Keeping food at risk of going to waste in the human food supply chain by creating new food products from by-products or unmarketable foods such as stale bread, offcuts, or damaged produce.

Vermicast – Worm poo.

Vermicomposting – The technical name for worm farming.

Windrow – A long line or row of heaped material.

Te reo Māori terms

Kai – Food.

Kaitiakitanga – Guardianship.

Kaupapa – Subject, theme, or purpose.

Mana – In the context of the Hua Parakore initiative, mana refers to autonomy, security and self-determination, and the role that food production can play in expression of these values.

Mana motuhake – Self-determination, independence, autonomy.

Māramatanga – In the context of the Hua Parakore initiative, māramatanga refers to the insight and enlightenment gained through food production.

Mauri – In the context of the Hua Parakore initiative, mauri refers to environmental health and the energy and essence of life, and how this can be upheld through sustainable practices such as holistic ecosystem management.

Papatūānuku – In Māori tradition, Papatūānuku is mother earth. Pūrākau about Papatūānuku emphasise the relationship between people and the planet, with the earth mother described as being the source of all life, including people.

Pūrākau – Myth, ancient legend, or story. According to Dan Hikuroa, some pūrākau codify knowledge generated using techniques consistent with the scientific method, explained according to a Māori world view.

Ranginui – In Māori tradition, Ranginui is the sky father. As with Papatūānuku, pūrākau about Ranginui emphasise the relationship between people and the planet.

Rukenga kai – Food that is re-used or cast onwards, a phrase used by Auckland Council following consultation with mana whenua to describe food waste, reflecting its value as a resource.

Te ao Māori – The Māori world.

Te ao tūroa – In the context of the Hua Parakore initiative, te ao tūroa refers to maintenance of the natural order of the world, for example by understanding, protecting, and restoring native species and restricting the use of synthetic inputs to food systems.

Te taiao – The natural world or environment.

Wairua – In the context of the Hua Parakore initiative, wairua refers to the spiritual health and peace of the land, food, and people.

Whakapapa – In the context of the Hua Parakore initiative, whakapapa refers to our connection to the natural environment.

Appendix I: From lines to circles – embracing the circular economy

The food recovery hierarchy relates closely to the circular economy (or 'circular society'), which calls for a shift away from a linear take-make-use-waste approach to resource use. The circular economy describes an approach to resource use where waste and pollution are designed out, products and materials are kept in use as long as possible, and nutrients and energy are captured at the end of a product's life to regenerate natural systems.

Embracing the circular economy is crucial for achieving sustainable food systems because many of the resources that are used to produce food are scarce or non-renewable, and virgin extraction or production can be environmentally and socially harmful – so we can't afford to be wasteful.

Circular economies can exist on a variety of scales, from local, place-based circles to regional, national, or even global ones. When we apply circular economy concepts at the local level, there's often a spinoff benefit of community building, reduced transport emissions, and community resilience.

The core principles of the circular economy. Image from the Ellen MacArthur Foundation.

The circular economy isn't a new concept. In Aotearoa, it has deep roots in a te ao Māori worldview, which links people and the environment through whakapapa relationships, making holistic, intergenerational kaitiakitanga of te taiao a no-brainer. Para Kore, a Māori not-for-profit organisation, provides an example of this worldview in action as they work towards the goal of zero waste by developing systemic solutions, advancing mana motuhake, and strengthening whakapapa connections to Papatūānuku and Ranginui.

Appendix II: Wait, is my compostable packaging not compostable?

Compostable and biodegradable products – including bio- and fossil-based plastics and fibre-based products (e.g. wooden cutlery) – are becoming more common as the public becomes increasingly aware of the environmental harm plastics can cause. However, compostable products aren't a silver bullet to our plastics problem, and are widely misunderstood in Aotearoa.

Throwing your 'home compostable' coffee cup lid into your home compost bin may mean you find it still sitting there months later. Even with certification, compostable products may not be all that they seem. A recent study found that 60% of sampled plastic packaging items certified as 'home compostable' didn't fully break down in real world home composting situations.

Even commercially compostable products aren't straight-forward. Products that are commercially compostable are often undesirable inputs to the composting process (they add little nutrient value, could introduce contaminants to the compost, and essentially treat our soils as waste disposal pathways for single use products), and may not be suitable for anaerobic digestion. Plus, a commercially compostable product must make its way to a composting facility where it can be processed, but New Zealand currently lacks the logistics to reliably achieve this.

Further information about compostable and biodegradable products can be found in a 2018 report prepared for the Parliamentary Commissioner for the Environment, the Commerce Commission's Environmental Claims Guidelines, the OPMCSA Rethinking Plastics report, the New Zealand Composter's position statement on compostable packaging, the Ministry for the Environment position statement on compostable products, and a 2019 report on plastics in the environment produced by the Royal Society Te Apārangi.

Acknowledgements

We thank the following people, who peer reviewed this web resource. All errors and omissions remain our own.

Alzbeta Bouskova (Ecogas), Barry Wards (Ministry for Primary Industries) , Betsy Kettle (City to Farm), Brittany Rymer (Ministry for the Environment), Chen Wu (FlyFarm), Cherie Pugh (Pyrocal), Daniel Yallop (Re.Group), Deepa Goswami (Porirua City Council), Gradon Diprose (Manaaki Whenua), Gerald Rys (Ministry for Primary Industries), Hannah Blumhardt (The Rubbish Trip), Harry Livesey (Ministry for the Environment), Ingrid Cronin-Knight (Living Earth), Ivan Chirino-Valle (Ministry for the Environment), Jenny Marshall (Ministry for the Environment), Joanne McGregor (Ministry for the Environment), Kaitlin Dawson (Food Waste Champions 12.3), Kate Walmsley (Kaicycle), Katherine Silvester (Ministry of Business Innovation and Employment), Kelly Dombroski (Massey University), Liam Prince (The Rubbish Trip and Kaicycle), Logan Dingle (Living Earth), Marc Gaugler (Scion), Michael Quintern (MyNoke), Neil Birrell (University of Auckland), Nick Hanson (NZ Pork), Olga Pantos (ESR), Rob Tinholt (Watercare), Roderick Boys (Ministry for the Environment), Sarah Pritchett (WasteMINZ), Sheree Kearney (Whakatane District Council), Warren Fitzgerald (Victoria University of Wellington).