Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

Biodegradable and compostable plastics in the environment

What is the problem?

There is global concern about the scale of plastic consumption. A significant amount of plastics end up in the environment, where it can be highly persistent.

It is not only visible plastics that are cause for concern, but also the smaller micro-plastics that form when larger pieces of plastic are fragmented through weathering processes. These micro-plastics can create 'plastic smog' in parts of the ocean and can accumulate in soils. Although their full impacts are still not known, recent evidence has demonstrated that micro-plastics are consumed by filter-feeders such as shellfish and can enter the human food chain.[1] Extensive research efforts are underway in New Zealand and overseas to understand both the scale and potential impacts of this problem.

Single-use plastics only represent a part of the overall volume of plastics that are used. However, they are visible and front-of-mind for many consumers, who confront items such as soft plastic shopping bags, coffee cups and takeaway containers on a daily basis. Recent surveys have shown that many New Zealanders would like to see more done to reduce single-use plastics, and some businesses are responding. Support for greater government leadership has come from several quarters, including the country's mayors and Retail NZ.[2]

To meet consumer concerns, more single-use products are appearing in the market that claim to be biodegradable or compostable. At face value, these are appealing claims, suggesting that the products will break down into benign end-products that are then seamlessly integrated back into nature. However, the reality is much more complex. Whether or not the substances into which plastics break down are benign depends on what they were made from. Furthermore, some claims may amount to little more than greenwash.

This situation is as confusing for consumers looking to decrease their impact on the environment as it is for businesses trying to respond to public concern.
The Commissioner has looked into what we know about biodegradable and compostable single-use plastics and has asked whether they offer a more environmentally sound alternative to conventional plastics.

What are plastics?

The word *plastic* is derived from the ancient Greek term *plastikós*, meaning 'shapable' or 'mouldable'. Plastics are made up of large chemical units known as *polymers*, which are in turn made up of repeated smaller units called *monomers*. Many polymers are capable of being moulded into different shapes when heated, a characteristic that has likely given this group of materials the name plastic.

We generally think of plastics as being manufactured from petrochemical (or fossil-fuel)-based sources.[3] For example, the gas ethene (ethylene) is produced by reacting fossil hydrocarbons with steam at very high temperatures and is used to create polythene (polyethylene), the polymer that we commonly see in the form of plastic bags at the supermarket. But plastics can also be derived from other sources, including microbes and plants. These plastics are known as 'bio-based' plastics.

Plastics often incorporate additives that change their specific properties, such as their strength and durability. These include UV stabilisers, anti-oxidants, dyes and flame retardants.

What does it mean to say that a plastic is biodegradable?

Biodegradable means that an item can be broken down by the action of living organisms, typically microbes. In the case of biodegradable plastics, this process is enabled by enzymes that are produced by microbes that use the plastic as a source of energy – the microbes are essentially eating the plastic for food.

It is important that biodegradation is not confused with other natural processes. For instance, most plastics will eventually break down into fragments through the weathering effects of sunlight, heat and friction if given enough time. This is degradation, not *bio*-degradation. To biodegrade, the polymers need to be broken down through the action of living cells into simple chemical elements.

The speed of biodegradation varies greatly and is highly dependent on the environment in which the plastics end up. This will affect the value of the biodegradable product – few would consider a plastic bag to be usefully biodegradable if the process takes hundreds of years. Likewise, biodegradability will be of questionable value if the breakdown process gives rise to toxic products. This is where standards are helpful.

New Zealand does not have a standard for biodegradable or compostable plastics. However, some plastic manufacturers have voluntarily sought certification using some of the existing international standards so that they can label their products accordingly. An industry working group has been set up to consider whether adoption of a standard in New Zealand would be useful.

What do biodegradable plastics break down into?

Ultimately, a biodegradable plastic will break down into small molecules, such as carbon dioxide, methane and water, as well as waste from microbial activity.

The Organisation for Economic Co-operation and Development uses the term *ultimate biodegradability* – the level of degradation achieved when the test compound has been totally utilised by micro-organisms resulting in the production of carbon dioxide, water, mineral salts and new microbial cellular constituents (biomass).[4]

Plastics, including biodegradable ones, often have other components mixed in as 'additives' for various reasons. These additives may be released when the plastics degrade.[5]

The speed of biodegradation will also be important in terms of the environmental impact.

What does it mean to say that a plastic is compostable?

Composting involves the breakdown of biological material such as green waste from garden clippings or food scraps into humus.[6] Industrial compost facilities are designed to accelerate microbial growth by controlling moisture, airflow, microbial activity and the proportions of different organic wastes. As the microbes consume the waste, they generate heat, which accelerates the breakdown. The resulting product, compost, is then used to return organic matter to the soil.

Home composting involves a similar process but on a much smaller scale, so it may not generate as much heat and will likely result in a slower breakdown process. Home composting is also much more varied depending on which method is used.

What does it mean to say that a plastic is certified as biodegradable?

A product that is certified biodegradable should meet a robust international standard. Examples of such standards include those that apply in Europe and Australia.

These standards include a range of tests for biodegradability that consider different receiving environments, such as wastewater treatment plants, freshwater or marine environments. The ability of plastic to biodegrade specifically in compost is explained further below.

These tests typically include the following:

- Chemical analysis of the starting material: checking to ensure that the components do not contain unacceptable levels of harmful chemicals, such as heavy metals.
- Biodegradation: measuring how much of the carbon that was present in the starting material has been consumed and respired by microbes. In some environments, microbes also produce methane, which needs to be measured.
- Disintegration: checking that no large fragments remain.
- Toxicity of the degraded material: testing whether the degraded material will have an impact on the growth of organisms that are commonly present in the environment where the material is intended to degrade.

Questions have been raised around the extent to which standards adequately address all of the receiving environments where plastic litter could end up.

What does it mean to say a plastic is certified as compostable?

Products that are certified compostable will usually have been tested in commercial composting conditions. They will not necessarily biodegrade in a home compost heap. Standards for home composting are very different in respect of the length of time over which products are tested for and the temperatures required. Few home composting standards exist.

International standards for compostability (home or commercial) typically contain four tests:

- Chemical analysis of the starting material: this involves checking the components to ensure they do not contain unacceptable levels of harmful chemicals such as heavy metals.
- Biodegradation test: measuring how much of the carbon present in the starting material has been consumed and respired by microbes in the compost.
- Disintegration: this involves checking that large fragments do not remain.
- Toxicity of the compost: testing if the resulting compost will have an impact on living organisms such as earthworms or germinating plants.

A product that is certified as compostable should meet a robust international standard. Examples of such standards include those that apply in Europe and Australia.

Do plastics have to be bio-based to be biodegradable or compostable?

No. These plastics can be made from biological sources, such as plants or microbes, or fossil sources. Biodegradability and compostability is a matter of chemistry, the disposal environment and time.

What types of plastics are biodegradable or compostable?

The following groups of plastics are considered biodegradable or compostable, based on the description provided by European Bioplastics. Whether these plastics can be certified as biodegradable or compostable depends on whether they pass the tests required for certification. Whether they can be biodegraded or composted as intended depends on the conditions in their place of disposal.

Biodegradable bio-based plastics: These types of plastics are sourced from biologically produced compounds and can be broken down by microbial action. The following examples fall into this category.

Polylactic acid (PLA)

PLA is made from lactic acid, which is usually produced by fermenting sugar or starch from vegetable sources such as corn and is then processed to form a polymer. Other chemicals may also be used in the PLA production process or introduced as additives. Products made from PLA include food packaging and coffee cups (which may use PLA for the lid or cup lining). PLA also has medical uses, such as dissolvable stitches, as it breaks down into lactic acid, which is easily processed by the human body.

Poly(hydroxyalkanoates) (PHAs)

PHAs are polyesters that can be synthesised by microbes that are fed starches and cellulose. They have a wide range of potential uses – for example, disposable cutlery, bags, bottles and cups.

Thermoplastic starch (TPS)

Starch is a polymer composed of glucose monomers that is found in many vegetable and fruit sources. Unprocessed starch does not generally have desirable properties (for example, it does not flow at a high temperature and so cannot be moulded easily). Therefore, it is often mixed with other plastics to form a stronger and more malleable material known as TPS.

Biodegradable fossil-based plastics: These types of plastics are sourced from petroleum-based products and can be broken down into simple base compounds through microbial action. The following examples are in this category.

Polybutylene adipate terephthalate (PBAT)

PBAT belongs to the polyester family of polymers and is produced from petroleum-based substances. It is known for its flexibility and strength, and is used to make biodegradable plastics, including plastic bags and wraps.

Polycaprolactone (PCL)

PCL is often mixed with starch-based polymers to produce a range of products used in the packaging and biomedical fields.

What types of plastics are NOT biodegradable or compostable?

Non-biodegradable fossil-based plastics: There are many types of conventional, non-biodegradable fossil-based plastics. These are extremely durable, often taking centuries to break down depending on where they end up.

Oxo-degradable plastics: Oxo-degradable plastics are essentially conventional plastics such as polyethylene and polypropylene that contain additives known as 'pro-oxidants'. These additives are typically metal salts, which are intended to speed up degradation of the plastics into smaller fragments without any help from microbes.

Fragmentation is facilitated by exposure to sunlight and air, which causes oxidation – a chemical reaction that leads to the loss of electrons and often involves oxygen – hence the name oxo-degradable. Oxo-degradable plastics typically result in a large number of micro-fragments or micro-plastic pieces. A key concern is that oxo-degradable plastics may be contributing to micro-plastic pollution in the marine environment.[7]

If fragmentation occurs, some biodegradation *may* occur in the right environment.[8]

Oxo-degradable plastics are sometimes marketed as biodegradable. However, they should not be unless they pass robust international standards for biodegradability. Beyond that, a 2018 report concluded that:

"The evidence suggests that oxo-degradable plastic is not suitable for any form of composting or anaerobic digestion and will not meet the current standards for packaging recoverable through composting in the EU."[9]

There is a lack of conclusive evidence relating to the benefits of oxo-degradable plastics, and restrictions on their use are being considered in Europe.[10]

In New Zealand, two oxo-degradable bag manufacturers have been charged under the Fair Trading Act for false claims regarding the environmental benefits of these products.

Non-biodegradable bio-based plastics: These types of bio-based plastics are indistinguishable from conventional fossil-based plastics in terms of their chemical composition, properties and decomposition characteristics. As the name suggests, they are manufactured from at least some biologically produced compounds, typically of plant or microbial origin. However, the terms 'bio-based' or 'plant-based' can be ambiguous as they do not convey what proportion of the plastic is bio-based. Polyethylene terephthalate (PET) illustrates this problem.

PET – partially bio-based but not biodegradable

> PET is a polyester that is manufactured from ethylene glycol and either dimethyl terephthalate or terephthalic acid. Ethlylene glycol comprises approximately 30% of the final PET material and can be made from plants, such as sugar cane or sugar beet. However, plant-based terephthalic acid is not yet available, which would be required to make PET 100% bio-based. Large companies, including Coca-Cola, are currently investing in research on ways to produce the entire PET plastic from bio sources.[11]

What happens when biodegradable or compostable plastics end up as litter?

While some certified biodegradable or compostable products can be completely broken down into benign molecules within a reasonable timeframe, this will only occur under the right conditions. The presence of heat, moisture, and microbes would help create favourable conditions. For example, while a biodegradable coffee cup may break down within several weeks in a carefully controlled commercial compost facility, the same cup may take decades to break down in the ocean.[12] This means that such products may not necessarily biodegrade – it depends on how they are disposed of.

Which plastics can I compost?

Some plastic products have been tested and are certified to break down in home compost bins. However, there are currently no guidelines or recommended methods for home composting. Most certified compostable products are designed to be processed in industrial composting facilities at the end of their usable life, where the temperature, moisture and oxygen levels can be carefully controlled.

In some parts of New Zealand, organic waste such as garden clippings and food scraps are collected for composting in an industrial composting facility. However, these collection schemes do not readily accept compostable packaging. For example, Christchurch has a kerbside collection for organic waste, but packaging is not allowed.[13] At some events, compostable packaging material may be collected alongside food waste and sent to composters, provided strict protocols are followed.

Even where collection systems for organic waste are available, composters cannot always accept compostable packaging. A 2017 survey of 27 composting facilities found that only about half would accept compostable packaging such as coffee cups lined with PLA.[14] Composters face a number of challenges with compostable packaging, including:

- identifying and sorting compostable packaging from other packaging
- getting the proportion of food waste to packaging material right (this may be compromised if a facility receives an influx of one particular type of packaging material)
- variation in the form of the material, which can influence the process – e.g. a thick plastic fork takes longer to compost than a thin takeway food container
- the processing methods that are used in their particular composting facility – these vary substantially, with some facilities being ill-equipped to process certain items. For example, in open composting environments, loose items such as plastic bags could blow away
- the materials that can be accepted – many facilities accept green waste but are not consented to accept food waste or compostable packaging, and so cannot process these items
- the components of the packaging, some of which can affect organic certification.[15]

These challenges need to be addressed if genuinely biodegradable or compostable packaging is to be biodegraded as intended.

The Compostable Packaging Standard Adoption Working Group (CPSA-WG) has been established to pursue agreement on standards and labelling. This work may help resolve some challenges for consumers and composters around standards and labelling, but some of the complexities faced by composters may remain, e.g. getting the right balance of packaging to food waste, and the identification and separation of non-compostable packaging.

Can I recycle biodegradable plastics?

Some types of biodegradable plastics can be recycled, others cannot. Biodegradable plastics can cause problems for recyclers if they get mixed up with plastics destined for recycling[16] because they can render these unrecyclable. It all depends on the type and amount of biodegradable plastic.

Overseas, problems with incompatibility have sometimes resulted in mixed recyclable and compostable plastics being sent to landfills because of contamination with other plastics.[17]

Some challenges for recycling include:

- **PLA** – this is not suitable for recycling in New Zealand and can also pose challenges for PET recycling because it is difficult to sort without special technology (as it often resembles PET) and can reduce the quality of the recycled material.[18]
- **Oxo-degradable plastics** – there are questions around the recyclability of these plastics as they include additives to make them fragment, which may weaken the recycled plastic.[19]
- **Starch-based plastics** – some of these plastics can be recycled, but others cannot. Starch-based polymers are incompatible with some conventional plastics, so they should not be mixed. For example, the Warehouse Group's new starch-based bags carry a warning not to recycle them.

What happens if biodegradable or compostable plastics end up in a landfill?

In New Zealand, *municipal general waste landfills* receive the bulk of domestic waste, including many types of plastics.[20]

Because composting and recycling biodegradable products can be challenging and demanding, much of this packaging currently ends up in landfills. The extent to which a biodegradable compostable plastic will break down in a landfill depends on the amount of air, water and microbial activity. Digestion occurs at highly variable rates and sometimes not at all.

While landfills are not designed to promote biodegradation, biodegradable or compostable plastics placed in a landfill may be broken down via anaerobic digestion, in the same way that other organic waste is. However, it is unclear if this always happens or how long it may take.

When biodegradable plastics break down in a landfill via anaerobic digestion, they release some methane and carbon dioxide, which are *greenhouse gases*.

Water that comes in contact with waste, or *leachate*, is also an issue that landfills need to deal with. Leachate can be a risk to nearby surface and ground water if not managed carefully – for example, by having a lined and sealed landfill facility with leachate collection and treatment. If toxic compounds are present in plastics, they may contribute to leachate risks.

So am I making a difference by putting biodegradable or compostable products in the right bin?

The bin you choose matters. However, how much you help the environment depends on how good the disposal services that will deal with your rubbish are.

In theory, certified biodegradable products could be processed in compost facilities. However, practicalities mean that composters cannot always accept these products – and unless the product has a corresponding recycling scheme in place in New Zealand, it cannot be recycled.

These challenges for waste management facilities highlight the need for clearer guidance on disposal methods. The Commissioner has written to the Minister for the Environment urging clarity of guidance on disposal methods for compostable and biodegradable plastics.

Are biodegradable or compostable plastics better for the environment than conventional plastics?

It depends.

Biodegradation means that the plastic will not persist in the environment for as long. However, it should not be viewed as a way of dealing with litter. If littered, even certified biodegradable plastics may not break down in the way expected.

Composting may be a way of diverting waste from landfill, but the ability to deal with compostable plastics depends on the availability of facilities to process this waste.

Compostable or biodegradable plastics may contain additives. Questions remain as to whether currently available standards adequately address these additives. If additives are present, ultimate biodegradation into small molecules may not be possible within timeframes that reduce or remove their environmental impact.[21]

There are also questions around the climate change implications of breakdown of biodegradable and compostable plastics.

Are bio-based plastics better for the environment than fossil-based plastics?

While the raw materials that are used to produce conventional plastics are generally sourced from fossil-fuel production, plastics can be made from many different raw materials, including plants and microbes. The source of the plastic does not determine whether it is biodegradable or not.
There is no simple answer to the question of whether bio-based plastics are better than fossil-based plastics, as the entire 'life-cycle' of any alternative must be considered and contrasted. There are several key considerations.

The properties of the plastic: How does the bio-based material perform when being used? Does it last longer? Is more material required to do the same job?

Renewable resource: Is it a renewable resource? What are the advantages of using a renewable resource?

Energy consumption: How much energy is used in the extraction, production and transport of the plastic?

Pollution: What pollutants, including greenhouse gases, are released during the life-cycle of the product?

Land use: Are new crops required to produce the raw materials that may take up

land that is needed for food production? Or are the raw materials a by-product of some other industrial process, such as timber harvesting?

Bio-based alternatives are being researched and developed here in New Zealand and internationally and show great promise (https://www.scionresearch.com/science/bio-based-products-and-technologies/biopolymers-and-chemicals). However, the impact of these alternatives remains to be seen.

Are there any solutions to the problem presented by single-use plastics?

Use less of it!

Some types of plastics serve an important purpose or are hard to avoid. For instance, packaging plays a role in minimising food waste, and single-use syringes used in the healthcare sector can guard against hygiene concerns. But to minimise our pressure on the environment as individuals, it is best to look for opportunities to reduce our consumption of plastics, or reuse them wherever possible. Good examples include refusing a straw at a café or taking a durable, reusable shopping bag to the supermarket.

Product design

Products can also be designed so that they can be easily recycled into high-quality products, reused or re-manufactured.

The circular economy/Ōhanga āmiomio[22] concept (Andrew Morlet, CEO Ellen MacArthur Foundation) captures the design principles of:
- designing out waste and pollution
- keeping products and materials in use
- regenerating natural systems.

Product stewardship is a complementary approach, whereby manufacturers take responsibility for reducing the environmental impact of their products. Product stewardship is embedded within the Waste Minimisation Act 2008.
he Ministry for the Environment is encouraging both circular economy and product stewardship.

What can I do if I think a business is making a false, misleading, or unsubstantiated claim about a product?

You can ask the business to provide evidence for its claim (e.g. certification from a reputable certifying body) – it must be able to back up its claims.

If you are still concerned that a claim being made is potentially misleading or false, you can complain to the Commerce Commission: http://comcom.govt.nz/the-commission/making-a-complaint/online-complaint-form/

The Commerce Commission may investigate and can initiate court proceedings against a business that makes claims the Commission considers breaches the Fair Trading Act. For example, in 2013, two companies were charged under the Fair Trading Act for misleading environmental claims.

- Eco-Pal Ltd, a company manufacturing and selling plastic rubbish bags, was found guilty of 15 charges under the Fair Trading Act and charged $60,000 for claims made about its plastic bags containing an additive known as d2w, which gives it oxo-degradable properties. The bags were being marketed as biodegradable, and suitable for domestic composting and recycling, when they were not.
- Pac-Rite Industries was fined $30,000 for misleading environmental claims relating to its oxo-degradable plastic bags. The company is no longer selling these bags.[23]

What is the chemistry of polymer breakdown?

Molecules come in all shapes and sizes, from the very small to the very large. Many large molecules are composed of repeating, smaller units that are linked together in long chains. Such large molecules are called polymers, and the repeating units are called monomers. The monomers are themselves comprised of atoms of carbon, hydrogen, oxygen and other elements.

All plastics are polymers and the two terms are often used interchangably. However, DNA and proteins are also types of polymers, as are other naturally-occurring substances, such as rubber and cellulose.

The atoms in monomers are held together by covalent bonds – strong chemical bonds that involve the sharing of electrons between atoms. Polymers are formed by linking together monomers through chemical reactions that create covalent bonds between the monomer building blocks.

Breaking the covalent bonds in polymers requires an initial input of energy. However, this is more than outweighed by the amount of heat energy that is subsequently released by the reaction. An example of this is the burning of plastic – it takes only a small flame to start the fire (or initiate the reaction) but even more heat is given off as the plastic burns.

The energy input that initiates the breakdown of polymers typically comes from the sun in the form of heat, light or ultraviolet solar radiation. But other factors are also important, such as the presence or absence of water, oxygen, enzymes and other chemical compounds.[24] It is therefore vital to consider the conditions in the environment where a plastic ends up.

The speed and extent of chemical degradation depends on many factors, including the type of plastic, the shape and thickness of the material, and the environment in which it is placed. Historically, much effort has been put into delaying these degradation processes (to extend the life of the polymer) – it is only recently that efforts have turned to accelerating them.

What is the difference between aerobic and anaerobic digestion?

Aerobic digestion occurs in an oxygen-rich environment, whereas anaerobic digestion occurs in the absence of oxygen. This lack of oxygen is similar to the conditions when life on Earth first began. The atmosphere is now very different from this, with oxygen supporting a vast array of aerobic life forms. However, anaerobic conditions do still exist – such as in swamps, bogs, wetlands and waterbodies.

Anaerobic processes can occur in landfills where there is sufficient moisture. They are also the basis of anaerobic digesters, which can be used on an industrial scale to convert organic waste into resources such as energy and fertiliser.

The rate of anaerobic digestion is highly dependent on temperature: it is much slower in the cold and different temperatures favour the growth of different species of microbes.

In a landfill, the waste is dumped, compacted and covered once the site is full to seal in the material. If enough water is present, microbes that are naturally present in the landfill will rapidly consume all of the available oxygen in the remaining air as they consume biological waste via aerobic digestion. The ensuing anaerobic environment will then favour the growth of other microbes that produce methane and carbon dioxide.

Anaerobic digestion is much slower than aerobic digestion.

What are the climate change implications of biodegradable and compostable plastics?

There is a fundamental difference between fossil-based and bio-based plastics in terms of the production of greenhouse gases.

Even when a fossil-based plastic completely biodegrades, it will be adding new carbon dioxide to the atmosphere.[25] By contrast, a bio-based plastic that completely biodegrades will effectively simply cycle the carbon that was removed from the atmosphere when the plant grew – i.e. this is a carbon-neutral process that does not add any more carbon dioxide to the atmosphere.

Both types of biodegradable plastics could produce methane, a potent greenhouse gas, if they decompose under anaerobic conditions.[26]

Notes

1. European Commission, 16 January 2018. Report from the Commission to the European Parliament and the Council on the impact of the use of oxo-degradable plastic including oxo-degradable plastic carrier bags, on the environment, p.2.
2. Retail NZ. 16 June 2017. Letter to Hon. Scott Simpson, MP; LGNZ, 17 July 2017. Huge support for levy on single-use plastic bags. http://www.lgnz.co.nz/news-and-media/2017-media-releases/huge-support-for-levy-on-single-use-plastic-bags/
3. Sources from oil and gas make up over 90% of the feedstock for plastics (World Economic Forum. 2016. The New Plastics Economy: rethinking the future of plastics, p. 13).
4. ECETOC, 2013. Environmental Exposure Assessment of Ionisable Organic Compounds. Technical report No. 123, p.26. http://www.ecetoc.org/wp-content/uploads/2014/08/ECETOC-TR-123-Environmental-risk-assessment-of-ionisable-compounds.pdf
5. Grant Northcott, pers. comm, 5 July 2018.
6. The part of soil that comes from dead or decaying plant or animal matter. https://www.biology-online.org/dictionary/Humus
7. European Commission, 2018; United Nations Environment Programme, 2015. *Biodegradable plastics and marine litter: misconceptions, concerns and impacts on marine environments*, p. 22.
8. Hann et al. 2016. The impact of the use of "oxo-degradable" plastic on the Environment. Final report for the European Commission DG Environment, p. ii.
9. European Commission, 2018, p. 3.
10. European Commission 2018, pp.7-8.
11. Anderson, 2015. Great Things Come in Innovative Packaging: An Introduction to PlantBottle™ Packaging. https://www.coca-colacompany.com/plantbottle-technology
12. For example, Harrison et al. 2018 Biodegradability standards for carrier bags and plastic films in the aquatic envirnmnent: a critical review. Royal Society Open Science 5: 171792, p.14.
13. Christchurch City Council advises that the following should not be put into the green bins: plastics of any sort (e.g. plant pots, any plastic or bio-plastic bags, cling film); coffee/takeaway cups and lids (https://www.ccc.govt.nz/services/rubbish-and-recycling/sorting/organics-green-bin).
14. Beyond the Bin 2017, The availability of New Zealand compost facilities to process compostable coffee cups and food packaging.
15. Sources: Kim Renshaw, pers. comm. 5 July 2018; Beyond the Bin 2017.
16. UK Department for Environment, Food and Rural Affairs (DEFRA) 2015: Review of standards for biodegradable carrier bags, p. 19. "Generally, polymers of different chemical composition are incompatible. For example, simple mixtures of polypropylene and low-density polyethylene (LDPE) are incompatible, as are high-denisty polyethylene (HDPE) or LDPE when mixed with starch and cellulose. HDPE is also incompatible with PLA plastics."
17. DEFRA 2015, p. 19.
18. Soroudi and Jakubowicz, 2013. Recycling of bioplastics, their blends and biocomposites: A review. European Polymer Journal 49.

19. DEFRA 2015 highlighted the long-term impact of pro-oxidant additives in oxo-degradable plastics as a key knowledge gap, as well as a liability issue (p.20).
20. Centre for Advanced Engineering, 2000. Landfill Guidelines: towards sustainable waste management in New Zealand. p. 3. Municipal solid waste is any non-hazardous, solid waste originating from a combination of domestic, commercial and industrial sources. (http://www.mfe.govt.nz/sites/default/files/4139_landfill.pdf).
21. Grant Northcott, pers. comm.
22. See https://www.mfe.govt.nz/waste/circular-economy
23. Commerce Commission, 19 November 2013. Rubbish bag company fined heavily for misleading environmental claims. http://www.comcom.govt.nz/the-commission/media-centre/media-releases/detail/2013/rubbish-bag-company-fined-heavily-for-misleading-environmental-claims
24. Catalysts reduce the energy required to break the bonds but are not consumed in the process.
25. Some have suggested that the burial of non-biodegradable plastics in a landfill is a good method of disposal. They point out that since most plastics originate from fossil-fuel sources, returning them underground in an inert and permanent form could be better than alternative fates.
26. If this methane gas is captured, it may be flared or burned to generate heat or electricity.