Compostable and biodegradable plastics

Plastics provide many benefits to society, but when they are not recycled or disposed of properly they can leak into the environment and end up as pollution.

Biodegradable plastics have been suggested as a sustainable alternative to conventional plastics which persist in the environment, with the goal that they will break down completely, leaving no harmful residues.

As more 'sustainable plastics' are introduced to the market, citizens are faced with the decision of which products to buy and how to dispose of them. The current confusion around the disposal of biodegradable plastic products, as well as the lack of infrastructure for dealing with them at end of life, may mean some biodegradable plastics end up doing more harm than good.

There are a variety of products, labelled compostable or biodegradable on the market, but each of these have different needs when it comes to waste disposal, collection and treatment.

In the diagram below we give examples of some such products, showing their intended end of life route (green arrow), alternative sustainable end of life routes that respect their intended use (green dashed arrow), and other destinations that in many cases leave their degradable features redundant.

1. A biodegradable plastic is defined as 'a plastic that undergoes accelerated degradation by organisms and biomolecules such as enzymes, forming small molecules that are metabolized by natural organisms. Biodegradable plastics should break down to natural materials that can be returned to the environment without pollution or deleterious effects.'[1] This is a scientific definition of biodegradability, but needs more consideration for applications, notably that degradation of a polymer or product needs to be possible in the environment of release, and within a defined time frame.

2. A compostable plastic is a type of biodegradable plastic which breaks down in specific composting conditions – either at home or in an industrial facility – into biomass, organic and inorganic compounds, CO_2 and water.

2a. A home compostable plastic should undergo 90% degradation after 12 months at ambient temperature, in the presence of microorganisms and oxygen, in a domestic composting unit. There is not currently a widely recognised standard for home composting, but it should meet the criteria suggested above and the industrial composting standard (explained below).

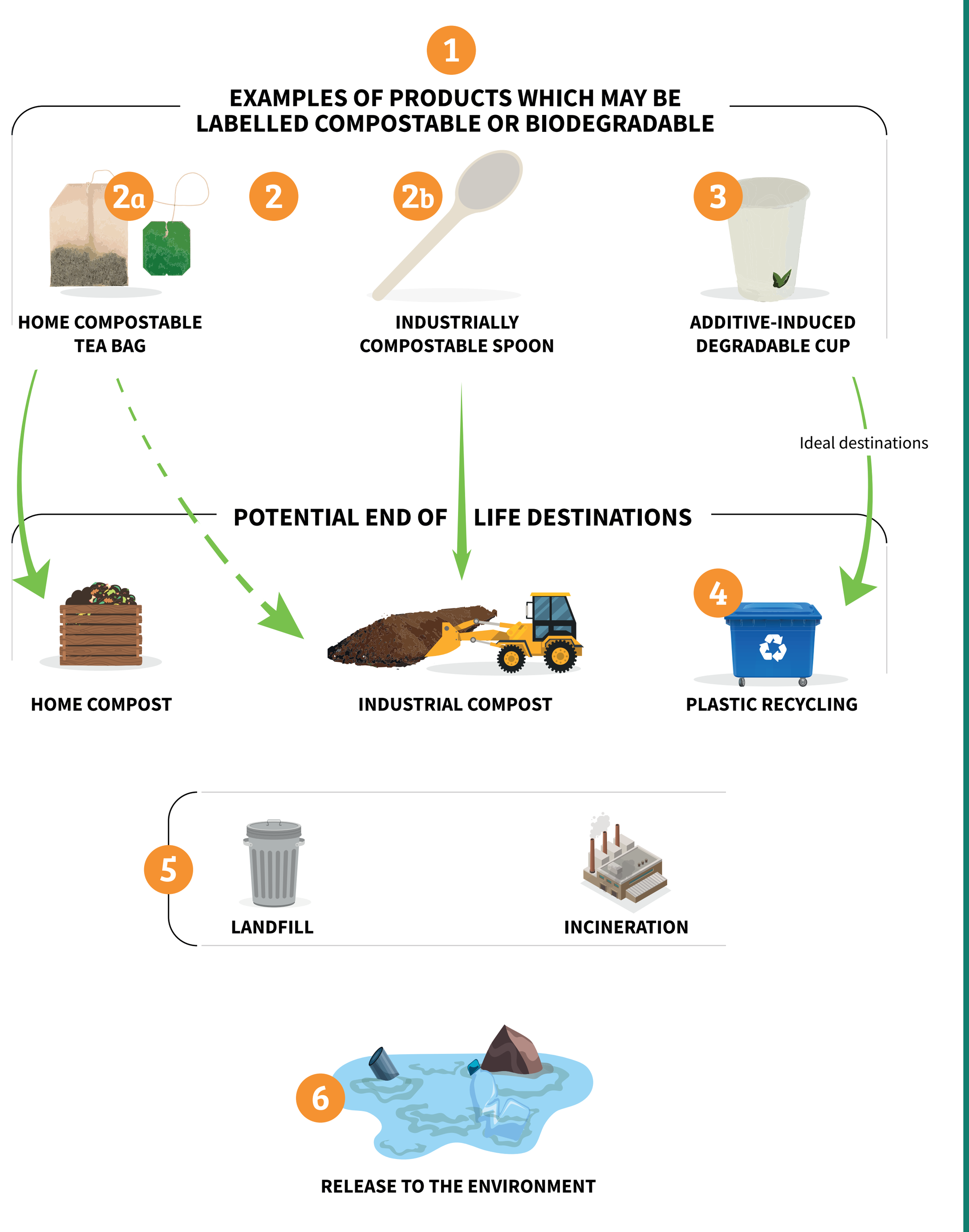
2b. An industrially compostable (which meets the standard EN13432) plastic undergoes at least 90% biodegradation within 6 months in an industrial facility in the presence of oxygen, microorganisms and high temperatures (50–60°C). These materials are regulated in the EU.[2] Check with your local authority if you can put compostable materials in your food waste collection.

3. An additive-induced degradable plastic is conventional plastic with additives intended to cause triggered breakdown of the product in the environment. Many new materials also claim to promote subsequent biodegradation but more independent assessment is needed to verify this takes place. As these materials are often marketed as such, it is assumed that these plastics are recyclable without contaminating the waste stream, in which case recycling is the most desirable outcome. See our explainer on 'Additives for degradable plastics' for more information.

4. It is important to note that while recycling is assumed safe and therefore desirable for additive-induced degradable plastics, it is one of the worst destinations for any type of compostable plastic, as these act as contaminants in the recycling stream. Plastics designed to be biodegradable or compostable can be difficult to distinguish from conventional plastics, and can contaminate recycling streams, so should be carefully labelled and disposed of properly.

5. Landfill and incineration are the current most likely destinations for compostable plastics due to insufficient infrastructure.

6. Release to the environment is not an intended destination for any of these products. Often additive-induced degradable plastics are promoted as biodegradable in case of leakage from the recycling or waste management system. However further independent assessment is needed to show that this truly occurs without any negative impacts to the environment of release.



New plastic materials are in development, but in order for us to reap the full benefits it needs to be made easier for citizens to identify materials and dispose of them appropriately.

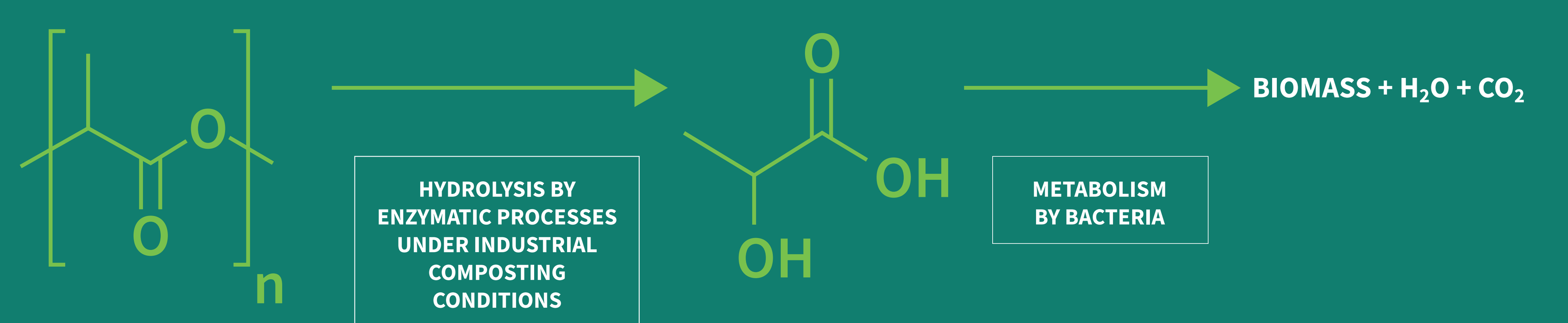
In a survey recently conducted by the RSC, over half of respondents said they did not know what this symbol meant, with **only 25%** correctly identifying it as compostable packaging. The seedling logo (European Bioplastics trademark) is a label for identification of industrially compostable packaging (certified according to standard EN 13432).

New standards needed?
In practice there can be a disconnect between the standards for compostable plastic, and the way it is composted at the end of life. For example, the industrial composting standard requires 90% biodegradation in 6 months, but in reality industrial facilities might turn over batches of waste in a matter of weeks. Standards should be revisited to ensure they reflect the true treatment timescale of these materials, therefore avoiding a compost contaminanted with not-yet-composted plastic.

Applications
Compostable plastics are best used for specific applications, where collection and proper processing is easily facilitated to avoid loss into other waste streams, or contamination of recycling. For example, with caddy liners for food waste bins, the best end of life pathway is facilitated as part of the use of the product.[3]

PLA, or polylactic acid is one of the most commonly used compostable plastics[4], and is made from fermented plant starch. It is used for a variety of single use items, such as coffee cups and disposable cutlery, and is the default filament for many 3D printers.

Molecular breakdown of PLA



It is important that PLA and other industrially compostable plastics are treated properly to realise their benefits, which includes capturing them as a separate waste stream.

When discussing the use of biodegradable and compostable plastics, we need to consider how to deal with them in the existing system as well as how they will fit into a future circular economy:

PRO	CON
Composting provides an alternative to landfill or incineration for products that cannot be recycled e.g. because they are contaminated.	Not true 'circular economy' as the material is not recycled (in the traditional sense). Some products, for example single use food packaging, may in fact be more sustainably made from recyclable plastic, as long as citizens can be encouraged to clean them efficiently to remove any contamination before recycling.
Some say that all plastic should ultimately be biodegradable to account for leakage from recycling or collection systems.	There is debate about whether or not it is feasible to design a material that will reliably decompose across all environments. For example, compostable plastics will likely not degrade in the sea or in cold, dry environments.
Compostability in industrial settings can be improved by pre-treatments, or optimisation of the conditions. Composting produces useful biomass with enzymes and microbes, which can then degrade other plastics or natural materials.	Most established 'biodegradable' products rely on industrial composting conditions and will not degrade in home composting conditions or the open environment.
Better collection, sorting and processing infrastructure, as well as clearer instructions for citizens, will help us reap the benefits of biodegradable and compostable plastics.	Most compostable materials contaminate recycling streams, although some biodegradable materials claim also to be recyclable. Additionally, without the right separation infrastructure, non-biodegradable plastic can also act as a contaminant in compost.

To ensure that the benefits of biodegradable and compostable plastics can be captured, more efforts are needed to ensure that they end up at their intended end of life destinations.

This will require appropriate infrastructure to be in place as well as labelling of products that includes clear instructions on their intended disposal. Current labelling is confusing, and citizens often can't tell the difference between compostable (either home or industrial) and biodegradable plastic products, or don't know what these terms mean, nor how they should dispose of a product that carries these labels.

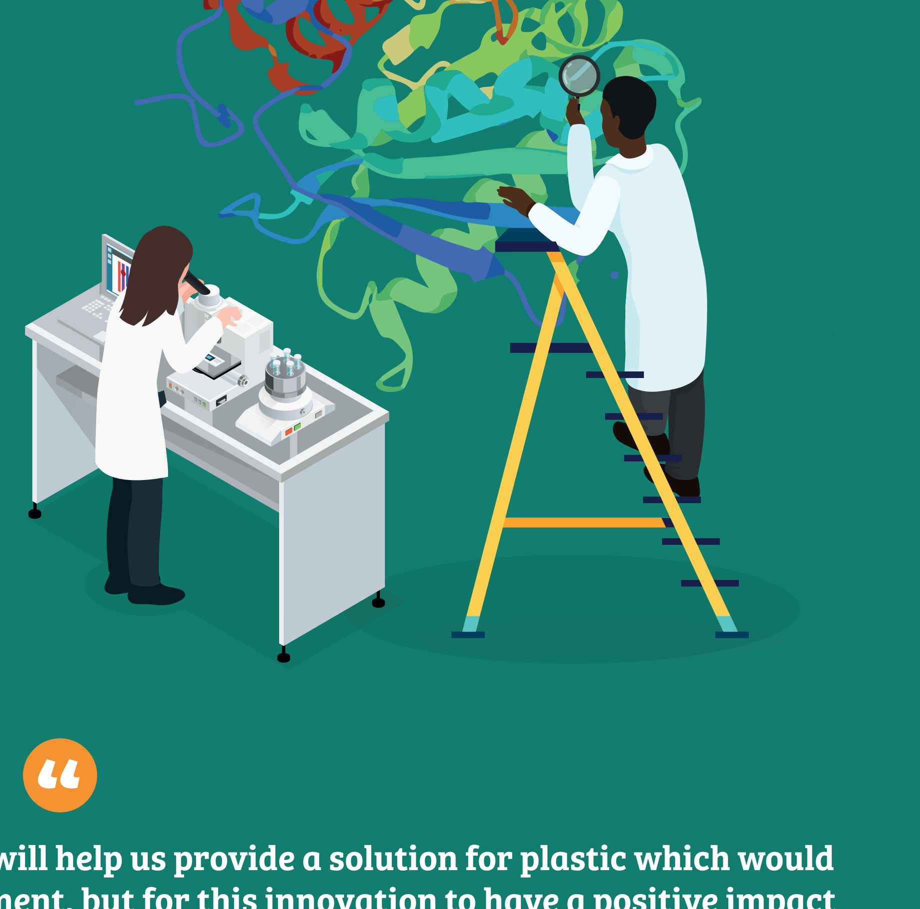
CASE STUDY

Enzymes are biological molecules which catalyse chemical reactions, for example the formation or breakdown of larger molecules. Some enzymes specialise in the breaking down of plastics.

A team at the University College London Plastic Waste Innovation Hub are investigating enzymes that naturally exist in compost digesters, and which types perform the best in breaking down compostable plastics. Their aim is to optimise these processes to accelerate the natural breakdown of compostable plastics.

They are also researching useful pre-treatments which reduce the time necessary for plastics to be broken down into biomass, carbon dioxide and water.

Specific enzymes can even be isolated to work on non-compostable plastics, like the PETase enzyme which works on conventional PET plastic bottles. The team are looking to identify and develop new enzyme systems for other types of plastic such as nylon or lycra. These systems could be used to recycle waste plastic into higher value compounds which can then be used in a variety of industries, replacing fossil derived starting materials. While chemical recycling currently out competes enzyme systems when it comes to speed of plastic breakdown, enzymatic systems are more selective.



"This is an exciting avenue of research which will help us provide a solution for plastic which would normally go to landfill or pollute the environment, but for this innovation to have a positive impact the right collection, sorting and treatment infrastructure will need to be in place.

PROFESSOR HELEN HAILES, UNIVERSITY COLLEGE LONDON

[1] https://www.rsc.org/globalassets/22-new-perspectives/sustainability/progressive-plastics/c19_tl_sustainability_cs3_whitepaper_a4_web_final.pdf
[2] https://post.parliament.uk/research-briefings/post-pn-0606
[3] Assuming in this case that the food waste processing is an appropriate treatment for the compostable plastic used in the caddy liner product.
[4] https://www.european-bioplastics.org/market/