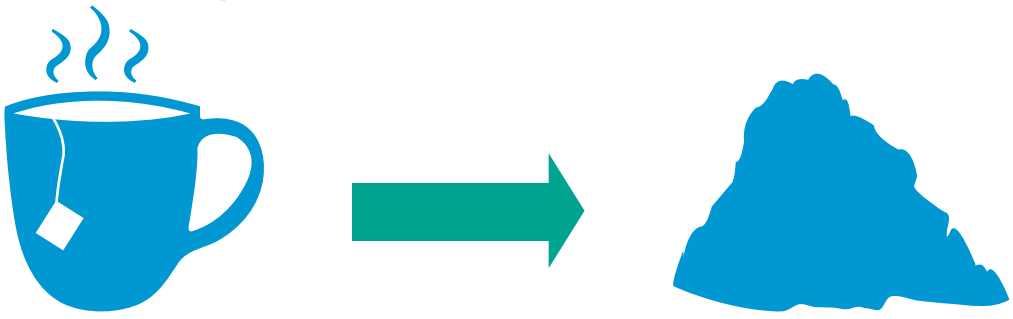
Context on **Composting:** Industrial & Home

Today, at our first Ingeo facility we transform atmospheric carbon into Ingeo using agricultural crops to sequester the carbon, "fixing" it as simple plant sugars through the process of photosynthesis. These unique origins create a material that enables multiple end-of-life solutions, including composting, for the right applications.

While composting and biodegradability are common terms, the processes themselves are narrowly defined and requirements for industrial-scale sites are well understood.

Home composting is a process with broad, unregulated conditions making it difficult to predict how certain products will behave.

Designing for performance **in-use** can affect product behavior **after-use**



100°C

Brewing for taste & aroma

25°C

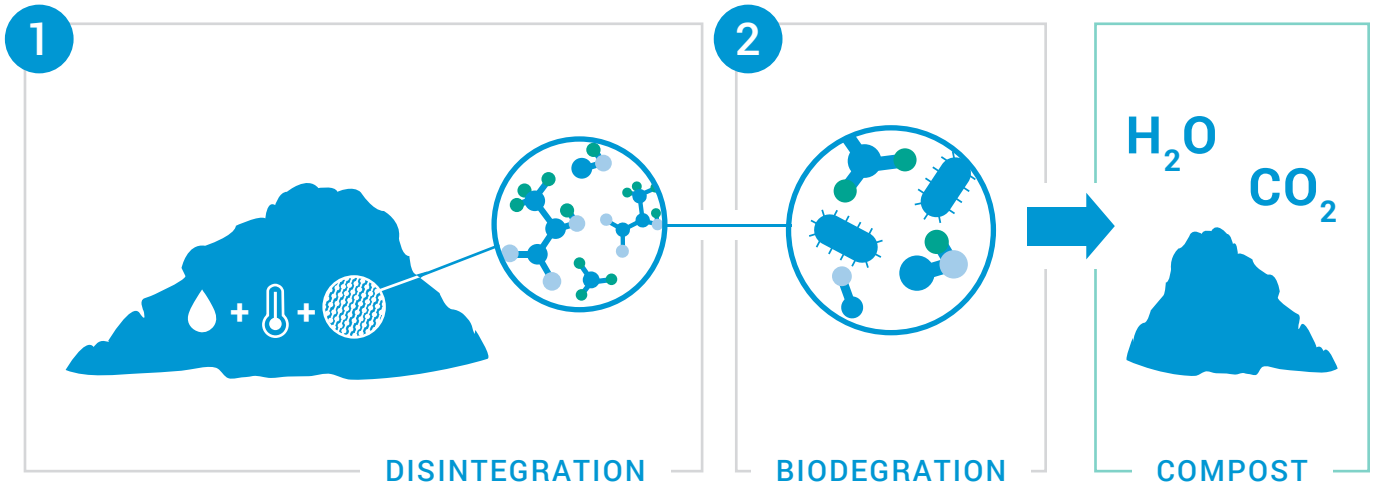
Home composting at variable conditions

NatureWorks

2 Steps to Compost

Industrial composting is a managed and monitored method of waste disposal that allows organic materials to be recycled into a product that can be used as a valuable soil amendment. Ingeo PLA undergoes a 2-step degradation process during composting. First, disintegration occurs when the moisture and heat in the compost pile fragment the long polymer chains into smaller polymers and lactic acid molecules. Second, through a process called biodegradation microorganisms in compost and soil consume the polymer fragments and lactic acid as nutrients. Since lactic acid is widely found in each of our bodies as well as in nature, a large number of microorganisms metabolize lactic acid. These two steps result in carbon dioxide, water, and compost.

In contrast, landfills are actively managed to prevent the conditions that lead to disintegration and biodegradation for any product. Thus, all items from banana peels to Ingeo-based products would stay sequestered.



Biodegradability / Biodegradation

The term "biodegradability" is defined as the breakdown of an organic chemical compound by microorganisms in the presence of oxygen (aerobic conditions) to carbon dioxide, water, mineral salt of any other elements present (mineralization), and new biomass. In the absence of oxygen (anaerobic conditions), organics breakdown into carbon dioxide, methane, mineral salts and biomass.

Biodegradation depends on time, temperature, humidity and the availability of the proper microorganisms. Therefore, the biodegradation of materials will be influenced by the conditions found in the environment where the material is disposed of as microorganism populations vary widely between geographic locations.

In an industrial composting environement, this population can be managed and monitored to ensure sufficient biodegradation of food or waste. Thus, Ingeo PLA will biodegrade in an industrial composting environment where the conditions for biodegradability are actively maintained unlike in a home compost environment.

The term "biodegradable" can be misleading on its own since the process is so dependent on multiple factors. As an example, a fallen oak tree is biodegradable, but that process can take more than 100 years. The biodegradable term always must be coupled to the environment that the material is exposed to. This is why the controlled, predictable environment of an industrial compost facility is preferred for ensuring a successful composting process.

Industrial Composting & Certification

To decide if a specific product brought on the market will compost in a specific environment, the final product must be tested to a standard and certified. In general, Ingeo bioplastic products are suitable for industrial composting (also referred to as organic recycling) where standards are in place and the process is well-defined. The standards discussed here are applicable to organic recycling of used packaging, and do not address regulations that exist regarding the recoverability of any residual packaged goods.

For packaging, the standards specify procedures and requirements to ensure suitability for industrial composting. Packaging is considered as recoverable by organic recycling only if all the individual components of the packaging meet the compostability requirements. If the components can be easily physically separated before disposal, then the physically separated components can be individually considered for organic recycling.

Regulatory guidelines and standards for composting revolve around four basic criteria: material characteristics, disintegration, biodegradation, and compost quality. Using these standards, the products are tested under well defined, uniform laboratory conditions. However, in practice conditions like throughput time can vary since composters work with a range of composting techniques and operation practices.

Europe

In Europe, Ingeo-based products can be submitted to DIN CERTCO and TUV Austria Belgium for certification as a compostable material for packaging purposes according to EN 13432. Ingeo PLA in its resin form has also been **certified as compostable** in Europe by DIN CERTCO.

United States of America

In the USA, Ingeo-based packaging can be submitted to the Biodegradable Products Institute (BPI) for industrial composting certification according to ASTM D6400. Ingeo PLA resin has **received listing** on the BPI positive list for compostable materials.

compostable

european-bioplastics.org

din.de

tuev-sued.de

COMPOSTABLE IN INDUSTRIAL FACILITIES
Check locally, as these do not exist in many communities. **Not suitable for backyard composting.** CERT # 890975

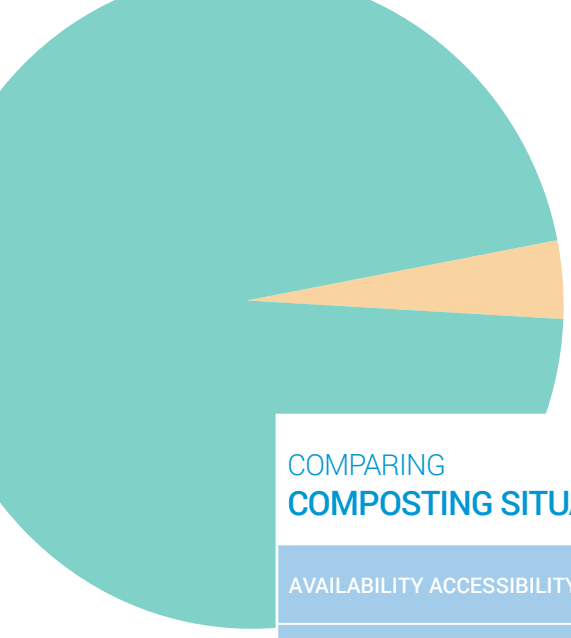
bpiworld.org

EXAMPLE CERTIFICATIONS

Home Composting

Globally, home composting is a not a well-defined process because of inconsistent and variable operating conditions (ex. temperature, humidity, presence of oxygen, geographic location). The range of applied operating practices differs by each individual composter as well. Consequently, it is not guaranteed that the minimal conditions for biodegradation of Ingeo are met by the individual home composter.

CEN (European Committee for Standardization) has started a project to develop a European home composting standard based on a draft mandate from the European Commission. The final mandate is still not available. Today products can be certified according to the TÜV Austria Belgium standards, but it is still difficult to guarantee the certified products will actually disintegrate and biodegrade in practice. A way to close the "gap" between measuring home compostability in laboratory conditions at low temperature and what is happening in practice is to define a minimum set of operational guidelines which the home composter must meet. However, these guidelines have yet to be developed and will be difficult to homogenize across countries with different policies.



Home composting diverts approximately 4% of food, garden, & kitchen waste generated in the UK.[1]

COMPARING **COMPOSTING SITUATIONS**	**Industrial** Composting	**Home** Composting
AVAILABILITY ACCESSIBILITY	HIGH VIA ORGANIC WASTE BINS	LOW
CAPACITY	HIGH	LOW
LEVEL OF CONTROL	HIGH	LOW
CONDITIONS FOR DISINTEGRATION[2]	58°C +/- 2°C 12 WEEKS	20-30°C 52 WEEKS
CONDITIONS FOR BIODEGRADATION[2]	58°C +/- 2°C 26 WEEKS	20-30°C 26 WEEKS
REQUIRED GUIDANCE OF CONSUMER	LOW	HIGH
APPROPRIATE FOR MEAT & DAIRY[3]	YES	NO
PROFESSIONALLY MANAGED AND MONITORED	YES	NO
INTERNATIONAL STANDARDS FOR PACKAGING	EN 13432 ISO 18606 / 17088 ASTM D6400 / 6868	NOT IN PLACE

CONCLUSION

Compostable biopolymers like Ingeo can be part of the solution to divert organic waste to an organic recycling system. The most robust and defined system is industrial composting, which is professionally managed and monitored, and covered by international regulations.

Home composting is a waste solution with limited accessibility, and outcomes of the process vary widely depending on the environmental conditions as well as on the skills and experience of the individual home composter.

1. Market Situation Report, Realizing the value of organic waste, WRAP, April 2008 http://www.wrap.org.uk/sites/files/wrap/Organics%20Market%20Situation%20Report%20Spring%202008.pdf
2. Based on OK COMPOST test methods | http://www.bpf.co.uk/topics/standards_for_compostability.aspx
3. For hygienization purposes, temperatures need to remain above 60°C for at least one week, in order to eliminate pathogenic microorganisms.