Compostable Plastic Packaging

A White Paper

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Prepared for:

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Contents

Tables

Figures

1. Executive Summary

In an effort to expand the sustainability and circularity of consumer goods and associated packaging, the use of compostable packaging and foodservice items has emerged as a potential solution under certain circumstances. While recycling is usually the preferable means of managing packaging at the end of its useful life, from an environmental benefit standpoint, there are certain characteristics and applications under which it may be more appropriate and environmentally beneficial to use compostable packaging, such as when the packaging/item:

- can be manufactured without the use of toxics;
- is to be used in food contact applications where recycling of the package is not an option;
- will be used to contain food where the food leftovers will also be composted;
- can be readily distinguished and kept separate from non-compostable packaging, especially packaging to be collected for recycling; and
- has soil enhancing benefits.

Photo credit: Brian Yurasits via Unsplash

Compostable packaging, therefore, could be used with success in quick service restaurants, food preparation locations, and events such as street festivals, where food scraps and packaging can be collected together and delivered to a compost facility.

One of the most significant benefits of compostable packaging and foodservice products is that its use can facilitate the collection and composting of food scraps. This is important because food scraps are a large component of disposed waste, and food waste when landfilled produces methane, a particularly detrimental greenhouse gas (GHG).

Other benefits of compostable plastic packaging include the fact that, if biobased (e.g., made from renewable materials, such as soy or corn, rather than fossil resources), it is also usually more sustainable due to less energy use, pollution, and less resource use, as well as the sequestration and cycling of CO_2 rather than CO_2 releases for similar plastics made from fossil fuels. Environmental benefits can be even more significant if packaging is made using agricultural products grown using sustainable farming methods, and if using second generation material (e.g., crop residue, waste and byproducts, such as stems, husks, straw, or starch), versus first generation, whereby the crop is grown specifically for the production of the biobased plastic. Note that some compostable plastics are derived from fossil fuels, the use of which would not have these upstream benefits.

Another benefit of compostable packaging is that it can reduce contamination of recyclable materials, which would be collected separately for processing and marketing.

When assessing whether to switch to a compostable plastic package, it is important to consider the entire package/product system, including:

- impacts on food protection;
- impacts on secondary and tertiary packaging;[1]
- transportation impacts;
- resource use/feedstock source;
- package functionality (product protection and life);
- product manufacturing and package forming, filling, and sealing impacts; and
- end-of-life management.

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[1] Secondary packaging unitizes individual packages into a single multipack. Tertiary packaging aids in transportation from manufacturer to retailer, such as a corrugated box or stretch wrap.

Life cycle assessment studies indicate that end-of-life management can be a relatively small portion of the environmental impacts of a food product/package pair through its entire life cycle.

Compostable plastic packaging is in its early stages – currently, only about one percent of plastics and plastic products produced annually in the global marketplace are considered to be biobased, biodegradable, and/or compostable.[2] However, this percentage is expected to grow. Compostable plastic resins are relatively costly, and there are limited opportunities to compost such material in the U.S. and Canada. Expanded use of compostable plastic packaging is expected to result in compostable plastic packaging that is more cost competitive.

Also, as food scrap composting programs expand, it is expected acceptance of these materials will become more common, which in turn will increase the use of such packaging. Additional challenges to be addressed include funding compost processing enhancements, which could be aided by extended producer responsibility (EPR) policies and programs, as well as other funding mechanisms, such as grants. It is also important to develop a simple, visible, clear symbol to indicate acceptability of compostable plastic packaging in composting streams, and to ensure consumers are aware of the meaning of this symbol.

Successfully expanding the use of compostable plastic packaging will require the cooperation of stakeholders from the entire value chain, including feedstock suppliers, resin manufacturers, packaging manufacturers, and consumer packaged goods companies, as well as collaboration with food waste diversion program managers, compost facility operators, and policy makers. To date the Sustainable Packaging Coalition (SPC) has developed several guidance documents describing the benefits of compostable packaging and how it can enhance circularity. The Biodegradable Products Institute (BPI) and US Composting Council (USCC) have developed principles for including composting in EPR policies and programs. Other organizations actively engaged in such collaborative work include the Foodservice Packaging Institute and the Closed Loop Partner's Composting Consortium. A first step for any company or organization wishing to become involved in advancing the successful use of this type of packaging is to become familiar with the work of these organizations and determine with whom and how to participate.

2. Introduction

Purpose of this White Paper

The purpose of this white paper is to provide a description of compostable packaging, where compostable packaging "fits" in the circular management system of materials, the conditions under which its use is warranted, and associated benefits and shortcomings. Additionally, this white paper describes the potential role of packaging industry stakeholders in enhancing materials management systems and ensuring compostable packaging is used optimally so as to minimize the environmental impacts of the product/package during its life cycle.

Role of Packaging

Packaging's overarching function is to protect the product it contains. Different products require different types of protection, e.g., from breaking or crushing, and deterioration from sunlight, moisture, or oxygen. Food packaging also protects human health, in that food and beverages are protected from contamination and spoilage.

Other important uses for packaging include:

- portion control;
- portability and convenience;
- provision of information, such as:
  - nutritional information;

[2] European Bioplastics

- preparation instructions;
- unique product identification;
- brand information;
- product “best by” and tracking information; and
- how to manage packaging at end of life.

Ideally packaging also should be sustainably manageable after it has served its intended purpose.

When brands consider switching packaging – for whatever the reason – they consider the extent to which the package will retain or improve its ability to provide these functions, and what additional changes will be required as a result of the change. Examples include changes to filling and sealing equipment, labels, inks, lids, and adhesives; and changes to secondary and tertiary packaging, among others. Considering changes in packaging may mean making tradeoffs among different packaging attributes.

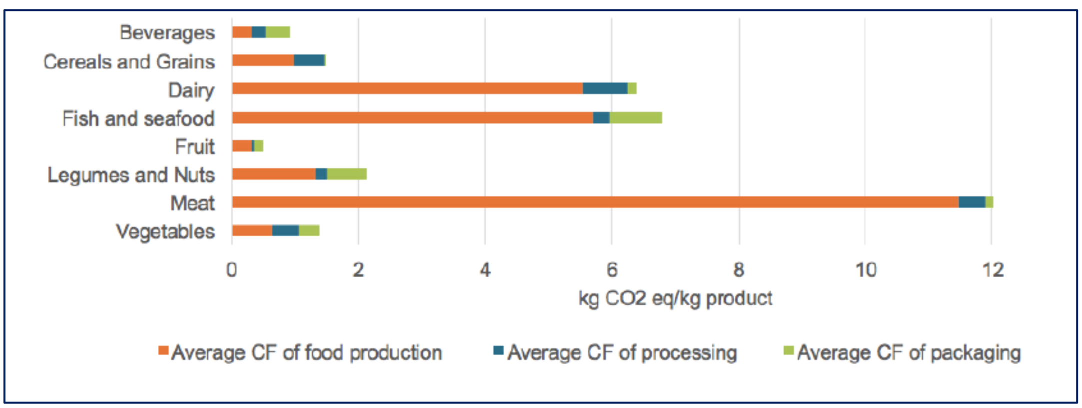
Sustainability Benefits from Protecting/Preserving Food

Protecting the product is not only good for business – it is also beneficial for the environment. This is because product loss means a waste of the resources used to produce the product (such as water, fertilizers, product ingredients), and a need to reproduce the product, which requires the use of additional resources. Furthermore, producing and distributing products to consumers results in the emission of greenhouse gases and other pollutants during product production, transport, and use. Proper packaging is especially critical to avoiding food waste. It is estimated that 20 to 25 percent of food waste could be avoided through better packaging practices and design.[3]

Life cycle assessments (LCAs) are increasingly used as a systematic approach to evaluating the environmental impacts of the package including impacts associated with resource extraction, transportation, product use, and end-of-life management. Given that impacts vary depending on the specific package application, it is important to perform such assessments on the entire lifecycle of the package/product pair.

Figure 1 shows the average environmental impacts as measured by carbon footprints of different categories of food and beverage product categories in specific front-end stages – including production, processing, and packaging.

Figure 1: Average Carbon Footprint of Food Production, Processing and Packaging



Source: Martin Heller, Center for Sustainable Systems, University of Michigan, for Oregon DEQ (2017), “Food Product Environmental Footprint Literature Summary: Packaging and Wasted Food.”

As Figure 1 shows, there are large variations among the impacts of producing food versus producing

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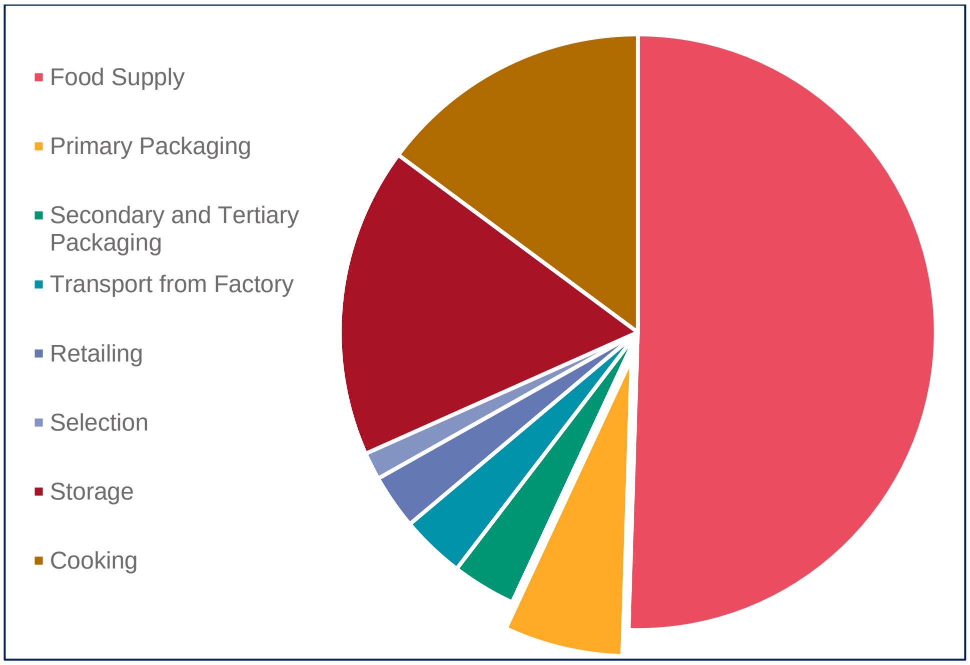
[3] Williams, Helen *et al.*, Journal of Cleaner Production (March, 2012), "Reasons for Household Food Waste with Special Attention to Packaging."

packaging among different product types. The production of certain products, such as dairy, seafood and meat, tends to have large carbon footprints, thus the relative impact of packaging production is less significant. Therefore, changes in packaging that can extend the life of such food products is likely to result in a decrease of net greenhouse gas emissions (GHGE), even if the change in packaging itself results in an increase in the package's GHGE. For other types of products, a change in packaging to extend shelf life may result in a negative net environmental impact compared to the original package.

In most cases, packaging results in a relatively small part of the overall carbon footprint of a product. On average, packaging accounts for 5 percent of the energy used in the life cycle of food products.[4] As Figure 2 indicates, when the average amount of energy for one person's weekly food consumption is considered, packaging accounts for, on average, 10 percent of the energy consumed. Primary packaging accounts for 6.5 percent, and transportation packaging accounts for another 3.5 percent.

Depending upon the package/product pair, that portion can vary somewhat, but by far the most impact in terms of energy use and GHGE is during the production and processing phases (i.e., "upstream") of a product's life cycle. Therefore, when considering making tradeoffs in packaging for environmental reasons, it is important to consider the impacts of those changes to the product's shelf life. Figure 2 shows the energy use for one person's weekly food consumption, and focuses on the supply, transport, packaging, storing, and cooking of the food, and excludes end-of-life management.

Figure 2: Energy Use for One Person's Weekly Food Consumption



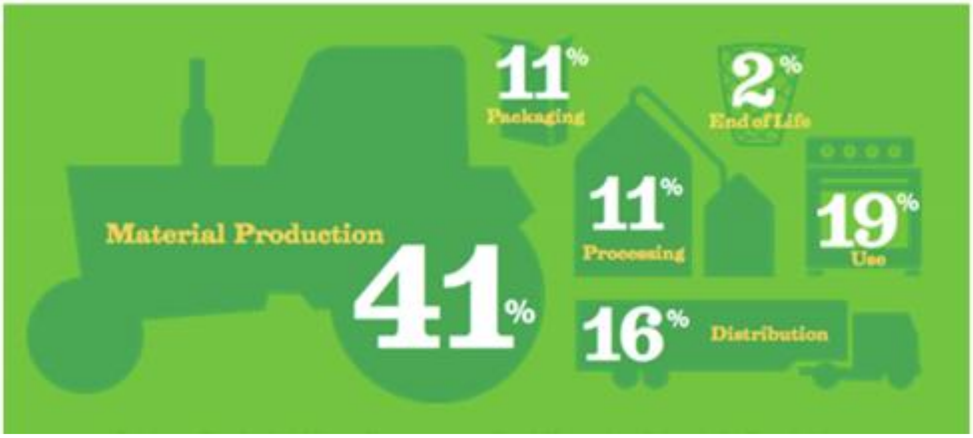
Data source: RMIT University (Dr Karli Verghese *et al.*, 2013), "Maximizing the Benefits of Circular Economy and Sustainable Materials Management Models for Product-Packaging Systems."

Figures 3 and 4 provide specific examples of packaging's impact on the carbon footprint of certain product types based on assessments conducted for products.

Figure 3 shows the results of a Life Cycle Assessment conducted in 2012 for Annie's.

[4] The Climate Collaborative, https://www.climatecollaborative.com/packaging, Accessed February 15, 2023. Note that energy use is sometimes used as a proxy for LCA, although it is not necessarily a perfect proxy.

Figure 3: Carbon Footprint Allocation Across the Lifecycle of Annie's Products

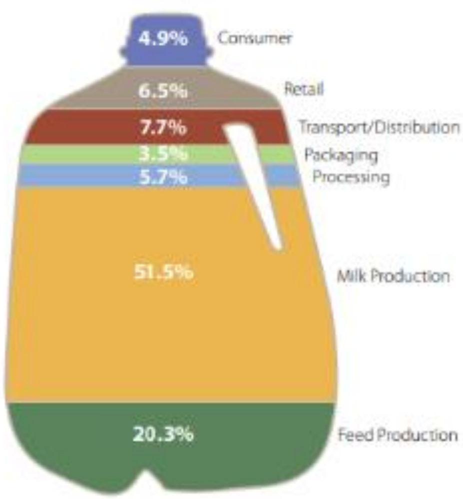


Source: Courtesy of Annie's, via The Climate Collaborative, https://www.climatecollaborative.com/packaging

As Figure 3 indicates, packaging is responsible for 11 percent of Annie's products' carbon footprint, on average, while material (product) production accounts for 41 percent of the company's carbon footprint.

As Figure 4 shows, packaging is responsible for 3.5 percent of liquid milk's greenhouse gas emissions.

Figure 4: Greenhouse Gas Emissions for U.S. Fluid Milk



Source: Innovation Center for U.S. Dairy (2013), "U.S. Dairy's Environmental Footprint."

3. Design Considerations to Optimize Packaging Sustainability

There are many packaging design approaches to consider in order to optimize the sustainability of packaging. The most significant ones include:

Reduce packaging. In general, the most effective first step in optimizing packaging sustainability is to eliminate unnecessary packaging and, if possible, reduce the amount of material used in manufacturing necessary packaging. "Lightweighting" has led to a pronounced change in certain packaging types over the years, such as thinner aluminum cans and plastic water bottles. There are also instances where packaging can be "right sized," such as not making a pasta or cereal box larger than it needs to be, resulting in the use of less packaging material and more efficient transportation of product, at the tradeoff of a smaller shelf presence. Some secondary and tertiary packaging has been reduced or eliminated, such as e-commerce businesses that sometimes ship items directly in their own primary packaging (i.e., ship in own container, or SIOC).

Use only necessary packaging attributes. It is important to ensure that the most appropriate packaging is selected for the product and its application. For example, it would not be appropriate to add a full-sleeve plastic overwrap to serve as a light barrier to a package for a product that does not require it.

Optimize transportation efficiencies. Another approach to enhance sustainability of packaging is to ensure that the package is designed to maximize cubing and transportation efficiencies, without sacrificing other needed packaging attributes. Any associated changes in secondary and tertiary packaging and associated LCA impacts should also be considered.

Sustainably source feedstocks. Packaging can also be made more sustainable by using sustainably sourced feedstocks. This could include using renewable feedstocks (for example, plastics made from sustainably grown agricultural products in lieu of petroleum-based feedstocks) and using recycled content. In some cases, third-party certifications are available to provide assurance that feedstocks are sustainably sourced. Sustainable sourcing can also mean using agricultural byproducts as a feedstock, instead of growing feedstocks primarily for packaging feedstock, which is described further in Section 5.

Eliminate toxics. Another approach to making packaging more sustainable is eliminating toxics, such as PFAS, used in packaging feedstocks, inks, and adhesives.

What are bioplastics?

A U.S. EPA document indicates that "biobased plastics (also referred to as "bioplastics") are simply plastics that are made from renewable materials, such as soy or corn, rather than fossil fuels." However, a representative of the U.S. EPA indicates that this is not an official codified definition. European Bioplastics, alternatively, uses the term "bioplastics" to mean any plastic that is biobased, biodegradable, or both.

To avoid confusion, we avoid the use of the term "bioplastics" herein.

Source: U.S. EPA (September 21, 2020), "Rethinking Plastic Packaging – How Can Innovation Help Solve the Plastic Waste Crisis?"

4. The Importance of a Systems Approach in Considering Packaging Options

It is important to use a systems approach when considering packaging options for a product. As is described above, the production and processing phase of a product's life can be energy and resource intensive – therefore, it is important not to waste those embedded resources. Additionally, changes in packaging can impact the entire packaging system including packaging machinery, secondary and tertiary packaging, and transportation. For example, selecting a thinner primary package in order to improve sustainability could require the use of additional transport packaging, which could offset or negate the intended benefits. Similarly, switching from a non-recyclable pouch to a recyclable rigid jar could enhance the recyclability of the packaging, resulting in environmental benefits, but could also result in requiring more trucks to deliver the same amount of product, offsetting the environmental benefits of switching to recyclable packaging.

It is important to recognize that end-of-life environmental impacts are just one aspect of sustainability, and typically a small proportion. Focusing solely on end-of-life outcomes may not result in the best overall environmental outcome. There are times, too, when attributes of a package can be at odds with each other. For example, a recyclable package might have a higher carbon footprint to produce in the first place, negating or offsetting the benefit when it is recycled relative to an alternative packaging type that is not recyclable or compostable.

5. Sustainable End-of-Life Management of Packaging

Recycling

Creation of recycle-ready plastic packaging, including recycling challenges and opportunities, are topics discussed in a previous white paper commissioned by Winpak and prepared by Circular Matters.[5] Because this topic is covered therein, recycling is not discussed in this white paper in depth, but the following is provided for context:

- Plastics recycling and recyclability have been recently called into question by a number of different stakeholders because less than one-third of even the most readily recyclable plastic packaging types (e.g., PET bottles and jars and HDPE milk jugs) are currently recycled in the U.S., and the recycling rate for all plastic packaging according to the U.S. EPA was 13.6 percent in 2018.[6]
- The U.S. recycling system needs improvement, in terms of infrastructure, participation, and designing packaging for recyclability. Recycling is generally the environmentally preferable end-of-life management option for many packaging types. However, recyclability and recycling cannot be unilaterally equated with sustainability. There are other end-of-life management options and associated packaging choices that may result in greater environmental benefits for certain packaging formats, applications, and generating locations.

Composting

Overview

Composting is the biological decomposition of organic materials under controlled conditions to produce a stable humus-containing biomass product that has benefit as a soil amendment. To be compostable, packaging must be able to break down via microbes, transforming into carbon dioxide/methane, water, and stable organic biomass, with soil-enhancing benefits, through available composting operations within a specified relatively short period of time. Products (e.g., cutlery, cups, and carryout containers) and packaging that are certified compostable have been thoroughly tested to ensure they break down fully in specified composting settings and timeframes and do not produce toxic residues that would contaminate the end product. Most compostable plastic packaging can only be composted in industrial-scale composting facilities where the right amount of heat, moisture, and microbes facilitates the composting process. A few types of compostable plastic packaging may be successfully composted in backyard composting systems as well. It is important to note that not all biobased plastics are compostable and/or biodegradable. Whether plastic packaging is compostable and/or biodegradable is determined by the molecular structure of the polymer, not the source of the feedstocks. Examples of plastics that can be made from biobased feedstocks but are not biodegradable (and therefore are not compostable), include PET, PE, and PTT.

The 2020 Winpak white paper on recycling states that recycling is generally considered superior to composting. However, thinking in this regard is evolving. There is growing consensus that there are circumstances under which the use of compostable packaging and the composting of such packaging is a preferred management option. This perspective of composting being an alternative ("biological" versus "technical") pathway to circularity is supported by the Ellen MacArthur Foundation, an internationally recognized and globally active organization

Compostable vs. Biodegradable Plastics

Compostable – Composting is aerobic biodegradation that transforms organic materials into nutrient-rich conditioner for soil. All compostable materials are biodegradable, but not all biodegradable materials can be considered compostable.

Certified Compostable – The primary entity in North America that certifies the compostability of packaging and products is the Biodegradable Products Institute. BPI Certified packaging must be proven to achieve compostability standards in ASTM D6400 or D6868 and break down in commercial compost within a specified (relatively short) timeframe.

Biodegradable – Materials that are broken down via natural processes in which microorganisms transform them into less complex compounds that can be used and reused by living systems over time. Note that not all biobased plastics are biodegradable.

Fragmentation – Plastics that are 'oxo-degradable,' 'oxo-biodegradable,' or 'photodegradable,' are non-degradable plastics mixed with additives to spur a process that mimics biodegradation. However, this results in fragmentation of the non-degradable material or product into small particles that remain in the environment. These products do not comply with the standards for compostability.

[5] Circular Matters for Winpak (2019), "Building a Sustainable End-of-Life Management System for Flexible Plastic Packaging and the Importance of Recycle-Ready Packaging"

[6] U.S. EPA, "Facts and Figures about Materials, Waste and Recycling: Plastics: Material-Specific Data."

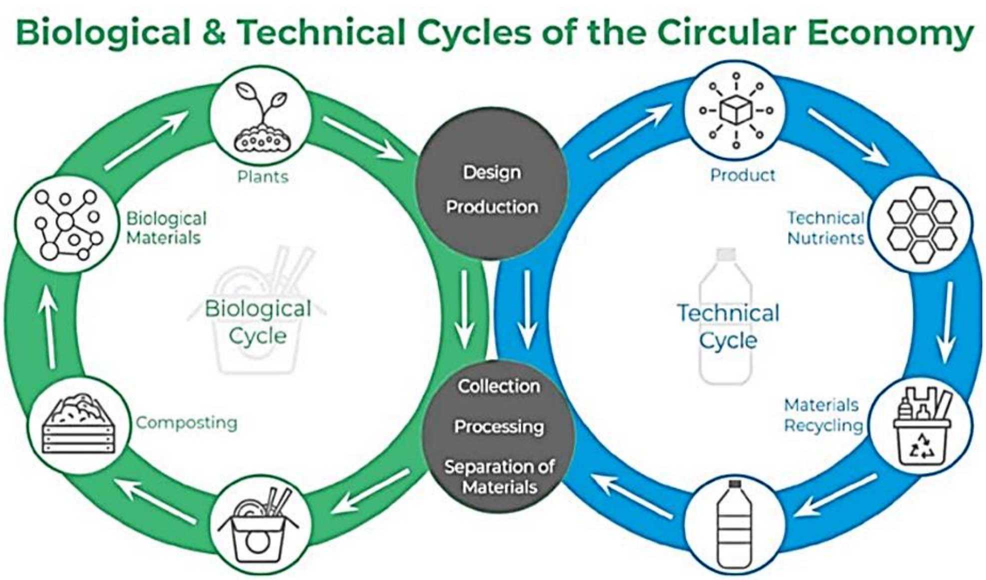
whose mission is to accelerate the transition to a circular economy. Whether this option would be a better choice than recycling depends on several factors, such as the type of product consumed, the type of packaging used, the setting, and whether there is access to a suitable composting program.

Given the growing interest in composting of packaging, the Sustainable Packaging Coalition (SPC) formed the Compostable Packaging Collaborative, whose mission is to identify best practices for compostable packaging design and labeling as well as support the composting industry to catalyze the growth of compostable packaging. Working with Collaborative members, the SPC completed several research projects and developed various guides for packaging industry stakeholders on compostable packaging and composting of packaging – both fiber and plastics based.[7] Key findings of SPC's work are referenced in this white paper.

Photo credit: Gabriel Jimenez via Unsplash

In Figure 5 below, the roles of both composting and recycling as pathways to circular economy building are shown.

Figure 5: Biological and Technical Cycles



Source: Sustainable Packaging Coalition (2022), "Ensuring the Success of Compostable Packaging."

Applications for Compostable Packaging

The work of SPC and other industry stakeholders indicates that the use of compostable packaging and subsequent composting of this material can be beneficial when the packaging characteristics and applications are favorable for composting, as outlined in Table 1 below.

[7] For readers seeking more information, the SPC has an online information center with links to multiple resources, including SPC's research reports and guides.

Table 1: Favorable Conditions for Use of Compostable Packaging

Packaging Characteristics / Applications	Examples
Can be manufactured without the use of toxics	• No toxic inks, adhesives • No PFAS (e.g., paper pulp clam shell)
Used in food contact applications where recycling of the packaging is not an option	• Packaging format is not accepted for recycling (e.g., food service ware, multi-resin film plastic) • Food residue contaminates the packaging (e.g., meat trays, yogurt tube)
Will be used to contain food where the food leftovers will be composted	• Packaging used in food service establishments that have composting bins and where non compostable packaging that could contaminate the organics being collected for composting is not used
Has soil enhancing benefits	• Nutrient value or bulking agent

Compostable packaging is best used when recyclable packaging is not an option, or when recycling systems don't exist for the packaging, such as for condiment sachets. Using compostable packaging, in that circumstance, helps prevent other recyclable materials from becoming contaminated, and delivers the food residue to a compost facility. It is particularly beneficial to use compostable packaging to assist with capturing and diverting food scraps to create compost. This is especially advantageous in closed settings where materials are collected for composting exclusively, and where food waste is generated in large quantities. Examples include quick service restaurants (QSRs), festivals and commercial kitchens.

Unfortunately, the cost of diverting and composting food waste and compostable packaging is an obstacle to expansion. The Biodegradable Products Institute and the US Composting Council have developed guiding principles for EPR that could lead to growth in composting, and state that they support promoting the production, use, and appropriate end of life management for materials and products that are designed to fully biodegrade in specific biologically active environments. They state that "Certified compostables are items or packaging that are designed to be associated with food scraps (e.g., food-soiled items) or yard waste and be collected in a source separated organics stream (e.g., food scraps), not co-collected with recyclables or other mixed waste destined for landfill."[8]

Environmental Benefits of Composting Suitable Packaging

While recycling is generally preferable to composting, there are certain circumstances where using and properly managing compostable packaging is preferable from a life cycle analysis standpoint. They include the following:

Facilitates the collection and composting of food scraps and reduce contamination of compost stream. SPC research determines that the use of compostable packaging can facilitate the collection of more food scraps than would otherwise be recovered at generating locations where non-compostable packaging is also used, as well as reduce contaminants in the food waste stream that would result from use of non-compostable packaging. Additionally, the US Composting Council (USCC) states that it "supports the use of compostable products to the extent that they assist in the efficient collection of food and other organics that can be composted, and, by replacing conventional plastics, reduce physical contamination in finished compost products."[9] Use of compost as a soil amendment helps enrich soil and improve soil porosity, thereby improving water absorption, reducing water and fertilizer needs and increasing crop yields. In addition, composting is a process that sequesters carbon from the atmosphere and locks it in the soil and plants growing in soil.

Diverts food scraps from landfills. Keeping food scraps out of landfills is environmentally beneficial as

[8] USCC and BPI, "Guiding Principles: Compostables in Extended Producer Responsibility (EPR)," accessed on 3-20-23.

[9] USCC website, accessed on 3-17-23.

landfilling organics can result in methane (and other GHG) generation and emission. Methane is a significantly more potent greenhouse gas than carbon dioxide, so avoiding its release into the environment is important.

Can reduce contamination of recyclables. Another benefit of compostable packaging is that diverting food-soiled packaging to composting instead of using recyclable packaging that contains food residue can reduce contamination of other materials in the recycling stream. Again, this is particularly important in situations where residue cannot be successfully rinsed from the package.

Using compostable biobased feedstocks can reduce upstream environmental impacts. Looking upstream, the manufacture of compostable packaging often results in lower greenhouse gas emissions, particularly if biobased rather than petroleum-based feedstocks are used, according to the Sustainable Packaging Coalition.[10] This is because:

1) Crops absorb CO_2 when growing; and
2) It requires less energy to manufacture plastics from biobased feedstocks than fossil feedstocks, resulting in fewer GHGE.

The environmental benefit of biobased feedstocks is greater when feedstocks are sustainably sourced. This includes:

- Using sustainable agricultural practices (avoiding petroleum-based fertilizers, careful management of water, rotating crops as needed to replenish soils, etc.) and;
- Using second generation material, e.g., crop residue, waste and byproducts, such as stems, husks and straw, versus first generation, whereby the crop is grown specifically for the production of the biobased plastic. Besides being more environmentally sustainable, this helps ensure that land use is not diverted from food production.

6. Types and Uses of Compostable Feedstocks for Plastic Packaging

Overview

Compostable plastic packaging is in the innovation stage. Currently, only about one percent of the 390 million metric tons of plastic manufactured globally each year are considered to be biobased, biodegradable, and/or compostable.[11] However, innovation is taking place, and a recent survey by AMERIPEN (American Institute for Packaging and the Environment) and PMMI (The Association for Packaging and Processing Technologies) indicates that many consumer packaged goods (CPG) brands intend to increase their use of compostable plastic packaging significantly in the next 5 – 10 years.[12]

A major advantage of compostable plastics is that many of them, but not all, can be made completely from renewable resources. A disadvantage of most compostable plastics is that they are not widely available at the current time and therefore are relatively costly when compared to non-compostable plastic packaging. This cost differentiation is expected to decrease as compostable plastics become more commonly available as they become more frequently sought by brands and consumers, and are incentivized by increasing legislation. Another disadvantage of compostable plastics is that they cannot be advertised to consumers as being recyclable. Although compostable plastics are technically recyclable, they are not accepted for recycling in the vast majority of recycling programs, and like all other plastics, each type of compostable resin would need to be sorted from other plastic types, including other compostable plastic types, to be recycled. Due to low generation and use rates, at the current time it is not practical nor cost effective to sort compostable plastics collected as part of a mixed recyclables stream for recycling.

There are numerous compostable resins being made globally, including Polylactic Acid (PLA), thermoplastic

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[10] SPC (2021), "Understanding the Role of Compostable Packaging in North America."
[11] European Bioplastics
[12] Dan Felton, Rhodes Yepsen, and Rebecca Marquez, Resource Recycling (January, 2023), "A Compostable Future," p. 26 – 28.

starch (TPS), Polyhydroxyalkanoates (PHA), Polybutylene Succinate (PBS), Polybutylene Adipate-co-terephthalate (PBAT), Polycaprolactone (PCL), and cellulose derivatives, such as cellulose acetate. PLA, TPS, PHA, PBS, and cellulose derivatives are made in North America, but the others need to be imported from overseas. The three most common types of compostable plastics used for packaging in North America are PLA, TPS, and PHA. Key elements of each are summarized in Table 2.

Table 2: Most Common Compostable Resins Used for Packaging in North America

	Polylactic Acid (PLA)	**Thermoplastic Starch (TPS)**	**Polyhydroxyalkanoates (PHA)**
Broad Description	▪ Synthesized by fermentation and chemical conversion from renewable materials including corn starch, sugar cane, sugar beets, and cassava ▪ Semicrystalline with a glass transition of 60–65 °C and a melting point of 150 to 160°C depending on formulation	▪ Derived directly from maize, potato, tapioca, wheat, peas, and other plant starches ▪ Relatively plentiful, inexpensive feedstocks, which are a byproduct of primary food production ▪ Amorphous with glass transition of 18 to 130°C. Temperatures vary depending on the plant the starch came from, moisture content, and plasticizer amount/type	▪ Made from bacterial fermentation of beets, sugar cane, canola oil, potatoes, and waste oils ▪ A family of resins each with varying properties ▪ Semicrystalline with glass transition of -9 to +9°C, and melting points range from 50 to 180°C depending on chemical structure and formulation
Strengths	▪ Easy to work with, suitable for multiple fabrication processes ▪ Can be used for flexible and rigid packaging ▪ Biocompatible ▪ Biodegradable ▪ Compostable in industrial composting operations only ▪ Can be mechanically or chemically recycled, but must be sorted as its own stream	▪ Easy to work with, suitable for multiple fabrication processes ▪ Relatively inexpensive compared to other compostable resins ▪ Biocompatible ▪ Biodegradable ▪ Compostable in industrial composting operations as well as at-home composting ▪ Oxygen barrier under dry conditions	▪ Low permeation of water ▪ Biocompatible ▪ Biodegradable – degrades relatively quickly, in a variety of environments ▪ Compostable in industrial composting operations as well as at-home composting
Weaknesses	▪ Costly compared to petrochemical plastics and thermoplastic starch ▪ How to manage can be confusing to consumers – can look like PET but can't be recycled with it ▪ Higher permeability than other plastics – not suitable for long-term food packaging ▪ Brittle, not tough	▪ Not resistant to moisture ▪ Flexibility requires plasticizer ▪ Low tensile strength	▪ Costly compared to petrochemical plastics and thermoplastic starch ▪ Difficult to process ▪ Limited mechanical strength
Common Applications	▪ 3D printing, medical devices, agricultural film, single use foodservice packaging	▪ Packaging (rigid and flexible), single-use cutlery, packaging material, single-use bags	▪ Medical devices, packaging, agricultural products, drinking straws

The properties of the three plastics are listed above because these properties provide insights into how the resins perform. These polymers can have good strength and toughness if their polymer structure and orientation is optimized, and/or if their glass transition temperature is below room temperature. Energy input for melting is important for thermal stability of the package, blending with other polymers, and heat-sealing properties, which is important for multilayer flexible plastic packaging.

Because the three types of compostable plastics listed in the above table individually have weaknesses, it is common to blend them with each other and/or include additives to improve their properties and tailor them for specific applications. The following subsections provide additional discussion regarding the three types of compostable plastics summarized in the table above.

Polylactic Acid

Polylactic acid (PLA), or polylactide, is a thermoplastic aliphatic polyester derived from renewable resources, such as corn starch, tapioca roots, cassava, sugar beets, or sugarcane. It is one of the most common types of biobased plastics used in the U.S. PLA was invented in the early 1920s but was not broadly commercialized until approximately 20 years ago. It has been used in applications such as agricultural plastic, beverage cups, tea bags, medical devices, and 3D printing.

As PLA use has expanded, it has become more cost effective to use in other products, such as packaging. PLA can be processed via extrusion, injection molding, casting, blown film, thermoforming, and fiber spinning. It also makes no fumes when being formed with heat. Rarely is PLA used in pure form – to achieve desired properties it is normally modified or blended with other biobased plastics. PLA is biodegradable in the environment over an extended period of a year or two, can be composted in shorter times in industrial composting facilities, and can be recycled mechanically or chemically if separated from other types of plastics.

A disadvantage of PLA is that it does not provide a strong barrier against moisture and oxygen, making it unsuitable for long-term food storage use. Also, it is not a particularly strong or tough plastic, therefore it is not suitable for applications where toughness and impact resistance are critical. PLA bottles look like PET bottles, and it can be confusing if consumers have to manage them differently at the end of their useful life. Because of the potential to contaminate the PET recycling stream, PLA is not used in the U.S. for plastic bottle packaging. PLA blends can be used as a heat seal layer in multilayer multi-material flexible packages, or in a compostable flexible package with various layers made from different formulations of PLA and other materials (such as a blend with thermoplastic starch).

Thermoplastic Starch

Thermoplastic starch is produced by mixing natural starch with a plasticizer at a temperature above the starch gelatinization temperature, typically in the 70-90 degree Celsius range. This process weakens the hydrogen bonds in the native starch which results in a formable material. Thermoplastic starch is made from a variety of agricultural starch-bearing feedstocks, including corn, potatoes, wheat, peas, and cassava. Starches from each of these plants have different compositions and therefore TPS produced from each will have different properties. Further, byproduct starch from food manufacturing can be used as a raw material in TPS production ensuring relatively low GHGE, low waste processes, and efficient overall use of agricultural crops.

Compared to other compostable resins, TPS is inexpensive, and composts rapidly and easily. It is also easy to process. However, unmodified TPS plastics tend to have poor physical properties, such as low resilience, high moisture sensitivity, and high shrinkage. To improve on these deficits, TPS plastics are normally modified and enhanced by including other fillers, polymers, and/or fibers in their manufacture. Common blending agents include PLA, cellulose, polyvinyl alcohol, natural rubber, a corn product called Zein, acrylate, polyethylene and ethylene co-polymers, polyesters, and polyurethanes. Added fibers are typically wood pulp, hemp, and other plant fibers. The choice of plasticizer and loading level also significantly impact properties.

There are many biodegradable polymer blends made with thermoplastic starch, including blends where TPS is an additive and not the primary component. TPS materials are mainly used for manufacturing packaging such as cups, bowls, bottles, single-use cutlery, egg cartons, and drinking straws. Other applications include grocery sacks, trash bags, and agricultural film.

PHA

Polyhydroxyalkanoates or PHAs are a family of linear polyesters produced in nature by fermentation of sugar or lipids. During fermentation, bacteria convert different types of feedstock into various products, and certain strains of bacteria will produce various types of PHAs. This natural process can be scaled up in an industrial setting. More than 150 different monomers can be combined within this family, resulting in a variety of PHA materials with properties that vary greatly from each other. Thus, PHAs can essentially be designed to suit the needs of the application, with some limitations.

PHA has been made from corn, sugar and vegetable oils. More recently, efforts have focused on creating PHAs from wastewater, plastic waste, methane, and carbon dioxide. Depending on type and grade, PHAs are suitable for multiple types of processes, including injection molding, film or sheet extrusion, thermoforming, foam, non-wovens, fibers, 3D-printing, paper and fertilizer coating, glues, adhesives, and more. PHAs are used for packaging, food serviceware, agriculture, and medical products. PHA is also being used to make biodegradable/compostable drinking straws.

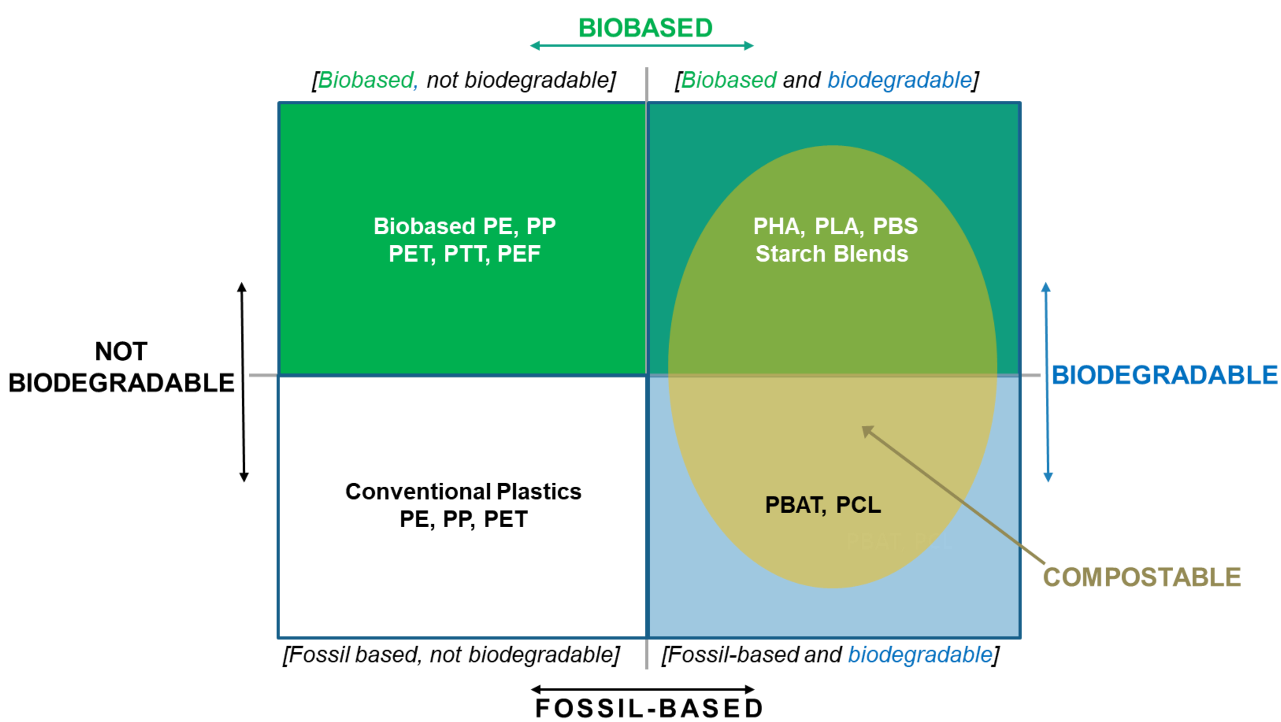
A strength of PHAs is that they can be designed for a variety of applications. They resist moisture transmission, which is important for some packaging applications. Another benefit of PHAs is that they biodegrade in nature into innocuous materials in a variety of environments (land, salt water, fresh water), more quickly than many other biobased plastics. Like PLA, PHAs are biocompatible, making them suitable for manufacturing medical devices.

PHAs have very limited North American production capacity and are not yet widely available in the U.S.

Plastics Terminology

Terms used to describe and classify "green" polymers are often not well-defined and can result in confusion. Figure 6 illustrates the relationships between biobased plastics, biodegradable plastics, and compostable plastics.

Figure 6: Relationship Between Biobased Plastics, Biodegradable Plastics, and Compostable Plastics



As Figure 6 shows, biobased refers to the origin of the plastic, not how it will behave under various end of life management scenarios. Biobased does not assure that a plastic will biodegrade or be compostable, and though biobased, those resins in the top left quadrant won't biodegrade or compost. Biodegradable refers to the ability of the plastic to be broken down biologically at end of life, regardless of whether it was made from biobased or fossil-based resources (resins on the right half of the illustration). The focus of this white paper, however, is compostable plastic packaging. Compostability is based on testing a specific package, with all additives, laminations, and coatings included, to verify that it will break down a short and similar period of time compared to other organic materials. Virtually all packaging made from the biodegradable plastics discussed in this white paper would be expected to be compostable.

7. Challenges Associated with Composting Plastic Packaging

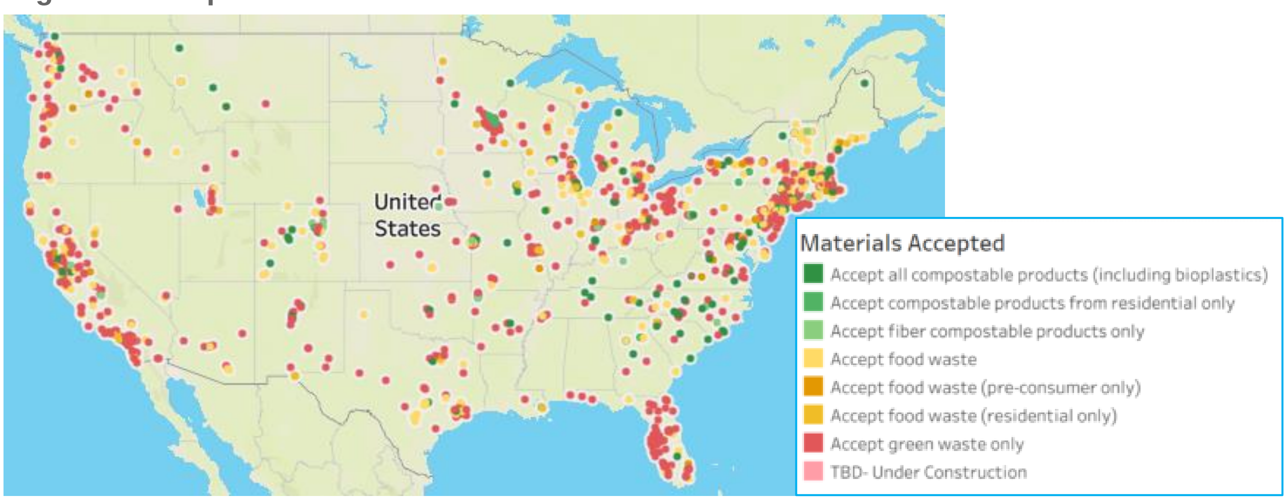
Each type of compostable plastic has its own strengths and weaknesses. Also, just as all types of plastic packaging are not collected for recycling, there is no assurance that manufacturing compostable plastic packaging will result in it being composted.

Composting of packaging overall faces specific challenges in the U.S. and Canada but is poised to advance in the coming years. Key challenges are described below.

Access to composting facilities that accept compostable packaging is limited. According to the SPC, "at least 11 percent of the U.S. population has access to composting programs that accept some form of compostable packaging in addition to food waste."[13] Of the compost facilities operating in the U.S., 15.8 percent accept food waste and some type of compostable packaging. In Canada, curbside composting programs are more commonplace for food scraps; however, a lower percentage of compost facilities accept compostable plastic packaging – only about one percent. In Canada about 44 percent of compost facilities accept uncoated fiber, and 10 percent accept coated compostable fiber products.[14] For widespread use of compostable plastic packaging to be truly beneficial, the composting infrastructure needs to expand, and needs to accept compostable plastic packaging (or accept packages that are marked as being certified compostable packaging) as an incoming material stream. EPR for packaging laws now passed in four states appears to include composting along with recycling as an acceptable management method for covered materials; however, many details are still lacking. Such legislation may provide a source of funding for planning and implementation of more robust composting systems that accept packaging.

Limited number of food waste diversion programs. Given that compostable packaging applications largely pertain to the packaging of food products in settings where food waste is collected for composting, lack of food waste collection and composting programs limits where compostable packaging can appropriately be used. Currently only around one fourth of the U.S. population has access to food waste composting opportunities.[15] This stems directly from the limited number of processing facilities that accept such material, as described above.

Figure 7: Compost Facilities in the U.S.



Source: SPC, "Composting Facilities in the U.S.," Accessed on 3-13-23.

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13 SPC (2021), "Understanding the role of Compostable Packaging in America," p. 11.

14 Ibid, p. 13.

15 SPC (2022), "Ensuring the Success of Compostable Packaging," p. 11.

Uncertain fate of compostable plastics in composting facilities. Composting facility operators have concerns, based on past experience, that some packaging that is supposed to be compostable – even packaging that reportedly meets ASTM standards – will not compost effectively in their facilities. Consequently, some compost facilities only accept compostable packaging that is BPI certified and labeled as such. More information is needed to better understand how various packaging types fare in composting systems. The US Composting Council suggests that composters field test already-certified products to be sure the product will disintegrate in their specific system. The Composting Consortium, a collaboration of industry partners managed by Closed Loop Partners, recently launched its Compostable Packaging Degradation Pilot. The project aims to gather improved data on how certified compostable food serviceware and packaging is breaking down at various types of composting facilities. Pilot study results are expected to be available in 2024.

Consumer confusion regarding what, how, and why to participate in the diversion of compostable materials for composting. While many consumers are aware of composting, there is confusion regarding what can be successfully composted in a backyard composting system versus what requires composting in an industrial composting facility as well as lack of understanding that compostable plastics should not be placed in recycling bins. There is a need for more consistency in consumer expectations, more public education about composting terminology, options, and benefits, and clear and consistent labeling to inform residents about what is compostable and how to participate.

Composting facility operator concerns about contamination. Compost facility operators are often hesitant to accept compostable packaging, and particularly compostable plastic packaging, as non-compostable "look alike" items can be mistakenly placed in the incoming material stream. This unwanted material is costly and time consuming to remove and is a contaminant if left in the compost, jeopardizing material quality. Unfortunately, equipment that removes such material often removes compostable plastic packaging as well, due to the inability to readily distinguish compostable from non-compostable material. There are emerging labeling protocols and technologies such as digital labeling to help compost facilities identify both compostable and non-compostable materials in the incoming material stream. Broad use of such equipment could help facilitate the successful use of compostable plastic packaging. Funding mechanisms, including EPR for packaging and grants, such as USDA compost grants, may help fund the use of such equipment.

Regulatory barriers. Currently regulations are inconsistent in different geographic areas with respect to definitions and labeling. This leads to confusion among generators as well as program managers. Of particular concern to compost facility operators is that the National Organics Program (NOP) does not permit facilities to receive certification for their finished compost as suitable for use by farms growing certified organic products if they accept compostable packaging in the incoming material stream. The issue is that additives, chemicals, inks, and adhesives are important to achieving the packaging's functional requirements, and these non-organic additions contaminate the compost, making it no longer organic. Composting advocates are petitioning for policy change, which may be possible in the future through the use of more sustainable compostable packaging and/or improved technology.

8. Potential Role of Packaging Industry Stakeholders in Advancing Appropriate Compostable Plastic Packaging Use and Composting

While there are significant challenges to establishing composting systems that accept and effectively compost plastic packaging made from compostable feedstocks and growing the appropriate use of such packaging, there are numerous opportunities for addressing these challenges. Examples include:

- Clear, consistent universal labeling for compostable packaging to minimize consumer confusion. Such labeling must be clear and visible yet small enough to fit on small items such as condiment sachets and coffee pods.
- Broad support for standardization of labeling and certification protocols.
- Packaging manufacturers to sustainably produce compostable packaging and market it for

appropriate applications.

- Brand commitments to buy and appropriately use compostable packaging, participate in testing/certification, and use labeling that meets industry accepted standards.
- Industry support for legislation providing funding for composting infrastructure development (possibly via EPR), legislation for food scrap disposal bans, and labeling requirements.
- Industry support for further research to build understanding of how specific types of packaging compost in various types of compost facilities and composting conditions.
- Compost industry to ensure standards are in place and kept up to date (ASTM standards are currently under revision).
- Customer and food service industry involvement in promoting composting as well as education on how to provide for composting, for example at events and QSRs.
- Industry funding for and development and dissemination of consumer education campaigns regarding why and how to participate in composting.
- Support market development for compost and ensure consumers understand the benefits of compostable packaging, composting, and use of compost products.
- Industry and governmental leadership to focus on what is best for the environment overall.

Compostable packaging can bring value for companies searching for more sustainable options than conventional packaging. Success will require collaboration throughout the value chain including feedstock suppliers, resin manufacturers, packaging manufacturers, and brands as well as collaboration with food waste diversion program managers, compost facility operators, and policy makers. Many organizations are already actively engaged in such collaborative work. These groups include the SPC, BPI, USCC, the Foodservice Packaging Institute, and the Closed Loop Partner's Composting Consortium. A first step for any company or organization wishing to become involved in advancing the successful use of this type of packaging is to become familiar with the work of these organizations and determine with whom and how to participate.