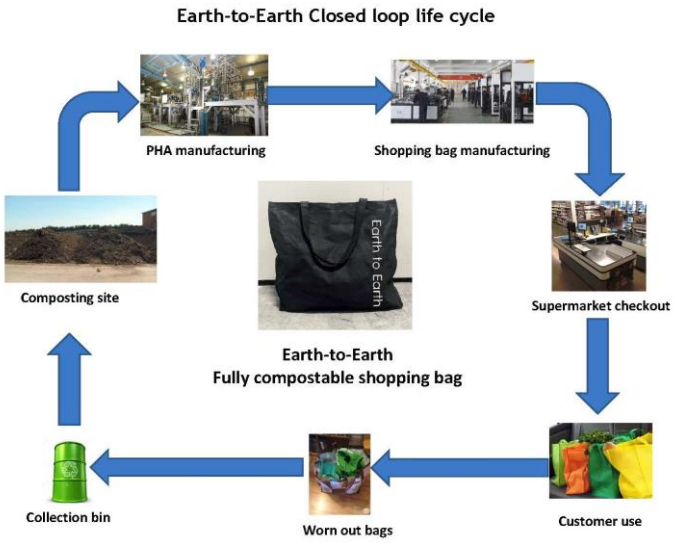
Earth-to-Earth
A Fully-Compostable PHA Shopping Bag

Solution summary: The vast majority of biodegradable PLA products incorporate fossil fuel based, non-degradable plastics in the mix. This includes many PLA-based shopping bags. We are designing "Earth-to-Earth" (EtE) a fully-compostable, heavy duty shopping bag that comes from compost and returns to compost. EtE is made of biologically-based Polyhyroxyalkanoates (PHAs) and is entirely compostable in low-temperature conditions and suitable for a closed-cycle use matrix. It is consumed by bacteria leaving behind only soil and water. The PHA feed stock is manufactured from composted organic wastes. The bag is of a gauge sturdy enough to be reused 5-6 times. At the end of its useful life, the customer adds the bag to a backyard compost pile. Alternatively, the bag is dropped in collection bins to be picked up for commercial or local composting. Such compost becomes raw material for new PHA feed stock.

Company/organization: Sustainable Systems Research Foundation (non-profit) & Full Cycle Bioplastics (for profit)

Websites: https://sustainablesystemsfoundation.org & https://fullcyclebioplastics.com/

Current stage of development: EtE is in the research, conceptualization and design stage. Full Cycle Bioplastics is providing the compost-based PHA feedstock, and we will be producing several prototypes via 3-D printer in the near future. We are seeking manufacturers of heavy-duty reusable bags that may be willing to pilot the project on their production lines.



Full description: Across the Global North, government-mandated bans and/or fees on single use plastic shopping bags have motivated shoppers to purchase low-cost, heavy duty, reusable shopping bags, a practice that is becoming customary rather than the exception in many places. Such bags are, however, manufactured primarily from polypropylene and polyester, neither of which is biodegradable or compostable. The ideal heavy-duty shopping bag would be fully made of biological inputs, be compostable at low temperatures, easily collectible and have minimal life cycle impacts on the environment. *EtE is that shopping bag*.

The vast majority of plastic shopping bags, whether single use or reusable, are manufactured from fossil fuels. Even those advertised as being made of biologically based polylactic acids (PLA), and advertised as "biodegradable" and "compostable," break down only if composted under high temperature industrial conditions. PLA-labeled products often incorporate quantities of non-PLA plastics in order to add functionality. If not composted, even PLA breaks down over time into microscopic plastic particles (nanoplastics) that diffuse throughout the environment.

Authoritative studies report that "PHA is the only biopolyester family completely synthesized by biological means"[1] and, when composted, is "completely degraded to water and carbon dioxide as the final products of their oxidative breakdown."[2] PHAs are therefore attractive for three reasons: (1) they can be created from renewable sources, such as organic food waste and compost; (2) they biodegrade into constituent molecules (carbon and water); and (3) they are biocompatible (that is, they are not incorporated into living tissue as may be the case with nanoplastics. In addition, PHAs:

- Decompose when exposed to soil, compost or marine sediment.
- Are water insoluble and relatively resistant to degradation by water.
- Have relatively good ultraviolet resistance.
- Suitable for medical applications, hence safe and nontoxic.
- Sink in water, facilitating anaerobic biodegradation.
- Considerably less 'sticky' than traditional polymers when in high temperatures.[3]

Because carbon in PHAs manufactured from biological sources is largely captured in composting, decomposition of PHAs by bacteria makes minimal contribution to greenhouse gas emissions.

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[1] George Guo-Qiang Chen & Alexander Steinbüchel, "Preface," p. v, in: George Guo-Qiang Chen, *Plastics from Bacteria—Natural Functions and Applications* (Heidelberg: Springer, 2010).
[2] Martin Koller, et al., "Microbial PHA Production from Waste Raw Materials," pp. 86-119, in George Guo-Qiang Chen, *Plastics from Bacteria—Natural Functions and Applications* (Heidelberg: Springer, 2010), p. 87.
[3] Creative Mechanisms, "Everything You Need to Know About PHA," January 22, 2017, at: https://www.creativemechanisms.com/blog/everything-you-need-to-know-about-pha-polyhydroxyalkanoates (accessed August 27, 2020).

Our goal is to close the shopping bag life cycle, so that old bags are recycled into the raw material feedstock for new ones. Today, the shopping bag production cycle and supply chain are designed for fossil-fueled based plastics, which are the only type sold by retailers. A key objective is to foster and facilitate changes in the shopping bag *supply* chain, through a shift from fossil fuel and mixed PLA *inputs* to PHA feedstock exclusively. The change from oil-based plastics to PHA will require scaling up of feedstock production and may require some retooling of bag manufacturing machinery. At the retailer end and for the customer, the transition to heavy duty PHA bags is seamless.

To fully close the life cycle, PHA bags must be collectible at the end of their useful life in a way that is easy and convenient for both retailers and shoppers, as follows:
1. Retailers offer heavy duty PHA bags at the check stand, as is currently done—for free or at a serious discount;
2. Customers are provided with a brochure describing the bag chemistry and life cycle, including the manufacturing process, expected lifetime, disposal and what happens after it reaches the end of it useful life;
3. When the bag begins to show signs of heavy wear and tear, customers deposit the bag in dedicated collection bins—perhaps near the entrance to the store. These are emptied regularly and transported to a composting facility or returned to the PHA manufacturer;
4. Compost is sold or distributed to community farms and gardens.

We will produce several prototype EtE bags for testing by shoppers and to measure rates of decomposition under varying conditions. These tests allow us to more closely estimate the useful lifetime of a PHA bag and the rates at which they fully decompose. The resulting compost will be analyzed for presence of any nanoplastics associated with the decomposed PHA.

Business plan:

2020: Conceptual design; create partnerships; seek seed funding; identify revenue streams; 3D print prototypes for use and testing
2021: Project pilot phase; place initial orders; provide them to selected retail partner(s); monitor project for retail partner(s); interview & track customers; follow collection, disposal, composting; reports on results
2022: Scale up production base; solicit larger retailers to adopt PHA bags; seek outside investment to support scaling up and distribution
2023: Full rollout of EtE.

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Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
1. Full Cycle Bioplastics 2. Bag manufacturers 3. Retailers 4. Environmentalists 5. Local government	1. Design cycle 2. Identify partners 3. Pilot project 4. Publicity and Marketing 5. Fundraising 6. Local government policy and infrastructure support	1. Close the shopping bag life cycle. 2. Reduce plastic bags in the environment 3. Enhance retailer reputation 4. Provide business to PHA makers 5. Reduce green-house gas emissions 6. Reduce costs of packaging to retailers 7. Support local composting 8. Plays well with other solutions 9. Worst case end-of-life is rapid biodegradation in ambient conditions 10. Replicable and scalable	1. Focus interviews 2. Stakeholder participation 3. Retailer/Distributor partnerships 4. Informing & educating 5. Incentive programs 6. Ongoing assessment, revision, engagement, improvement	1. Consumers 2. Stores and restaurants 3. Bag distributors 4. Bag manufacturers 5. PHA manufacturers 6. Composting operations 7. Local governments
	Key Resources 1. Research capacity 2. Networking capacity 3. Project integration capacity 4. Low-cost early phase development capacity		Channels 1. Partners 2. Interviews 3. Assessments 4. Outreach 5. Distribution	

Cost Structure	Revenue Streams
1. Initial self-funding 2. Operations & organization 3. Pilot manufacturing & distribution 4. Outreach & PR 5. Assessment	1. Public and private grants 2. Shopping bag fee 3. Early sales

Designed for: IDEO Beyond the Bag Designed by: Ronnie Lipschutz Date: 9/4/20 Version: 3.0

This solution is fully biological & innovative materials, point of sale checkout, reusable models, closed-cycle products.

Target markets: Over time, EtE can fully replace both “paper and plastic” and polypropylene and polyester heavy-duty shopping bags. This will reduce costs for retailers and help customers to avoid the heartbreak of large numbers of shopping bag. Secondary markets include farms and gardens, landfill operators and PHA producers.

How does solution meet or exceed performance of single-use bags? EtE is tough, durable and easily composted. Even if discarded carelessly, it will decompose in a relatively short time.

How does solution impact/improve workflows for stakeholders? Stakeholders are not subject to any significant workflow changes, except for provision of the collection bin.

What additional benefits might solution provide? In addition to keeping nanoplastic particles out of landfills and the environment and reducing fossil fuel use, PHA bags close the carbon cycle and release little or no carbon into the atmosphere. As compost, they can also be used to improve soil and “farm carbon.” Customers can also be educated about the need for closed cycle product chains and new source materials for plastics.

How is solution scalable? EtE does not require scaling. It is a "drop-in" solution to be integrated into the current shopping bag supply chain and life cycle. It can be purchased by any retailer. It does not require any behavior change—except for depositing old bags in collection bins—or legislation.

Where will solution apply? The solution is applicable wherever single use and reusable heavy duty plastic bags are available to customers.

How is your solution recoverable? When the shopping bag shows signs of wear and decomposition (we estimate after two months), it is deposited in a collection bin that is regularly emptied and shipped to an industrial or community composting site.

Have you incorporated additional sustainability attributes? As noted above, PHA itself adds little carbon to the atmosphere. The production process generates some wastes and emissions, as does distribution from the factory to the retailer.

How does solution prompt behavior change? How will solution design for this change? The solution does not prompt "behavior change" among customers. It "nudges" the customer by reducing available alternatives and encouraging virtuous practice. It also changes the procurement behavior of retailers, who order and provide PHA bags in place of single use and non-PHA plastic heavy-duty reusable bags.

Unintended consequences? This solution might delay implementation of "bagless" approaches to shopping.

Health & safety concerns? Reusable PHA bags could pose some sanitary and health risks (as is claimed about reusable bags during the current pandemic). There could be safety hazards, should a bag tear or split while in use (but this could also happen with single use and heavy-duty bags).

Biggest challenges: Driving bag manufacturers to shift from nonbiological plastics and mixed PLAs to PHAs, and scaling up PHA production to meet demand.

Mentorship needs: Engineering & manufacturing; materials & technical development; Industrial design & prototyping

You & your team: Our team consists of research analysts developing a project to change business procurement practices and chemical engineers who have developed the PHA production process using compost and organic wastes.

Location: Santa Cruz, California, United States

Legal structure: Sustainable Systems Research Foundation is a 501(c)3 non-profit; Full Cycle Bioplastics is a for profit corporation

How will being a winner support growth of concept: It will make it possible to pilot PHA bag production, to go beyond an idea to a practice, and to identify potential investors in a startup.

How did you hear about the Challenge? Webmail.

Are organizations actively equitable and anti-racist, with examples. Our organizations seek out qualified minority staff and researchers, work with minority communities to develop and deploy strategies and solutions and incorporate considerations of social and environmental justice in our projects. For example, the Sustainable Systems Research Foundation is partnering with minority farmers in Central California to deploy small-scale agricultural technologies.