SAFER MATERIALS IN FOOD PACKAGING

MARCH 2019

FORSYTHIA

SAFER MADE

ABOUT THIS REPORT

This report was commissioned by Forsythia Foundation to accelerate the adoption of new materials that reduce or eliminate the use of hazardous chemicals in food packaging. The goals of the report are to:

- Identify specific needs for the innovation of safer materials, based on the functions delivered by chemicals of concern
- Showcase companies that are active addressing the innovation needs
- Bridge the gap between broad concepts of sustainability and specific challenges the food packaging industry faces adopting safer materials
- Facilitate the conversation about innovating safer materials, by creating a common language for industry, entrepreneurs, and investors.

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ABOUT SAFER MADE

Safer Made is a venture capital fund that invests in safer products and technologies. Our investment premise is that people prefer safer products. The technologies we invest in enable brands and retailers to tell a story of safety and sustainability that resonates with people. Safer Made works with brand manufacturers and retailers that lead in safety and sustainability to invest in technologies that address the needs for safer chemistry. Safer Made's General Partners are Adrian Horotan and Marty Mulvihill. For more about Safer Made, see: **http://www.safermade.net**.

ABOUT FORSYTHIA FOUNDATION

Forsythia Foundation promotes healthier people and environments by reducing harmful chemicals in our lives. Forsythia Foundation believes in putting the full spectrum of philanthropic capital — time, networks, grants, and investments — to work. For more about Forsythia, see: **http://www.forsythiafdn.org/**.

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EXECUTIVE SUMMARY

We are often asked to describe the investment opportunity in safer chemistry. With this report we answer this question for the food packaging space.[1]

We identify three forces that influence how people feel about packaging and therefore push companies to rethink their choice of packaging materials.

The first force is our distress about persistent plastic pollution in waterways and oceans. Almost all persistent plastic pollution is caused by petroleum-based plastics. This highly visible problem has drawn worldwide attention in recent years.

The second force is our discomfort with waste. Packaging is mostly a single-use, auxiliary product, which is discarded immediately upon serving its function. People interact with packaging briefly and then throw it away, and many perceive this as wasteful. According to the US Environmental Protection Agency, packaging makes up about one-third of municipal solid waste.[2]

The third force is our growing concern about exposure to potentially harmful chemicals getting into food from packaging. Examples of such potentially harmful chemicals include the endocrine-disrupting Bisphenol-A, or commonplace polystyrene, which is carcinogenic.

These concerns drive the need for innovation in the food packaging sector. *Once information about various materials and chemicals is public, compliance with FDA guidelines on food-contact materials is no longer sufficient to address consumer needs.*[3] Changes can happen quickly and without regulatory action. People are seeking safer packaging, such as multi-layer packaging instead of coated metal cans or paper coffee cups instead of Styrofoam cups.

Efforts to phase out polluting plastic packaging, as illustrated by the work of the Ellen MacArthur Foundation,[4] as well as efforts to improve end-of-life functions such as recyclability and compostability, are good examples of work to address these forces.

We distinguish two classes of food packaging materials: one includes the basic materials, such as plastic, metal, or fiber; the other encompasses the chemical additives and coatings used to make the basic materials perform adequately, as illustrated in Figure 1.

1 Throughout this report we use the term "food packaging space" to mean the sector of economic activity concerned with the production of raw materials (such as polymers, pulp, ingredients, and additives), intermediate products (such as polymer sheet, paper, cardboard), and final products used to package or hold foods or beverages

2 Table 23 retrieved from https://www.epa.gov/sites/production/files/2016-11/documents/2014_smm_tablesfigures_508.pdf on 12/18/2018

3 Munke, et al. Retrieved from http://www.tandfonline.com/doi/full/10.1080/.VBmKOUvvmcM and https://www.greenbiz.com/article/when-it-comes-food-packaging-what-we-dont-know-could-hurt-us

4 Retrieved from https://www.ellenmacarthurfoundation.org/news/a-line-in-the-sand-ellen-macarthur-foundation-launch-global-commitment-to-eliminate-plastic-pollution-at-the-source

Figure 1: Food Packaging Materials and Concerns
Source: Safer Made

The choice of basic materials determines the use of additives and coatings, and many of these are chemicals of concern. Figure 2 shows the chemicals of concern associated with the three major types of basic materials in packaging.

Figure 2: Chemicals of Concern in Food Packaging Grouped by Material
Source: Safer Made

> *The basic packaging materials determine most of the environmental impact and fate of the packaging, while the chemical additives and coatings used on these basic materials cause most of the exposure to harmful chemicals.*

Making food packaging less toxic to people coincides with making it less polluting to the natural world. People, brands, retailers, advocates, and governments want a world with *safe packaging* and *zero plastic pollution*. At the same time, single-use packaging is convenient and here to stay. There is no "silver bullet" safer and sustainable material that works in all applications. The competing priorities of cost, performance, toxicity, and environmental impact make choices difficult, but also open the door to innovation.

How do we get to a world of safe packaging and zero plastic pollution? We need an "all of the above" approach that promotes new and safer materials, while reducing the amount of plastic used through design changes, and maximizes the reuse and recycling rates, all while meeting functional needs at a reasonable cost.

To create safer food packaging alternatives, innovators, entrepreneurs, investors, product developers, marketers, researchers, and scientists will be helped by:

- A *common language* to adequately describe the innovation opportunities
- A *clear signal* from the industry about what innovation is needed
- *Examples* of technologies and companies that illustrate the needs for innovation

A key contribution of this report is articulating *innovation needs* that add up to an *innovation agenda* for the food packaging space. *Innovation needs* allow conversations and prioritization, tell inventors what innovations are needed, and help communicate the opportunity to investors and to buyers.

Figure 3: Food Packaging Innovation Needs

Source: Safer Made

We advance three major *innovation needs* in food packaging as shown in Figure 3, each with their own subsumed areas.

We intend this report to be accessible to a wide audience interested in the future of food packaging. As venture investors, we have focused on activities happening in young companies, rather than on initiatives being pursued by existing large companies. Where possible, we have linked to other resources so readers can find more details. We recognize that our picture is likely incomplete, and we welcome the opportunity to connect with people and organizations that work on solutions to the challenges and innovation needs presented in this report, and to learn about new challenges facing the industry as it evolves.

SECTION 1:

AWARENESS, TRANSPARENCY, AND WHAT BRANDS ARE DOING

We spend time and money to eat healthily yet often overlook the packaging healthy food comes in.

We want fresh, tasty, and nutritious food that is free of potentially harmful chemicals. We no longer take the industry's word on what's healthy and what's not — we read labels and inform ourselves. Most of us also want to know how our food was grown and made, and what impact it has on the natural world.

In 2015, organic food sales grew by 11% as compared with the previous year, while the overall food market grew by 3.3% over the same time period.[5] This difference in growth rate has been consistent over the last 15 years. Established food companies acquired more than 80 fast-growing organic food brands between 2010 and 2017. Of these acquisitions, 43 have published valuations that add up to a total of $45 billion.[6]

> *Food packaging has been left behind in the health food revolution and is causing harm to both people and the natural world.*

A statement published in August 2018 by the American Academy of Pediatrics outlines the risks to children's health posed by several chemical classes found in food. Three of the top six chemical classes of concern (Bisphenols, Phthalates and PFCs) are leaching into our food from packaging.[7]

In 2015, about 448 million metric tons of plastic were produced worldwide, of which about 180 million metric tons were destined for single use.[8] A significant portion of single-use food packaging ends up as pollution.

Many brands and retailers have adopted sustainability and circular economy goals and are actively searching for safer materials and ways to reduce packaging waste. A twofold vision, for food packaging to be less toxic to people and less polluting of the environment, aligns with these goals and necessitates innovation in safer materials and new packaging designs.

5 Retrieved from https://www.ota.com/resources/market-analysis

6 Retrieved from https://www.msu.edu/~howardp/organicindustry.html, Phil Howard, Associate Professor, Michigan State and Safer Made data

7 Retrieved from http://pediatrics.aappublications.org/content/142/2/e20181410

8 J.Jambeck, et. al. Science, http://science.sciencemag.org/content/347/6223/768

AWARENESS

Our instinct for self-preservation makes us suspicious of materials and chemicals that could harm us while fueling the demand for safer products.

In the last fifty years, the food sector has embraced petroleum-derived plastics for packaging, because such materials are cheap, light, and help preserve and present food well. This adoption happened mostly without evaluation of the potential harmful effects of these materials and without considering their fate at the end of a product's useful life. Evidence that some of these materials are harmful to human health and to the natural world has been accumulating.[9]

People's perception has also been changing. According to the Natural Marketing Institute, a market research organization, about 40% of adults in the United States in 2008 were either "socially responsible, driven to protect the environment, and avid users of green products" or those who "make most purchase decisions based on benefits to their personal health."[10] Numerous other "green consumer" surveys also confirm these changes.

Food packaging performs clear functions — it holds, preserves, and presents food. However, it remains an auxiliary product. In as much as it contains potentially harmful chemicals, it can harm us. Throwing it away after using it briefly strikes all of us as wrong, especially if the material will persist for hundreds of years in the natural world and potentially cause harm.

TRANSPARENCY

Once people are aware that there may be hazardous chemicals in their products, they approach their purchasing decisions with increased scrutiny. Many products become suspect until proven safe. People look to manufacturers and retailers as well as third-party sources, such as governments, certifiers, and not-for-profit organizations, for the information they need. They read labels, ingredient lists, and try to buy products that are safer. This change in purchasing patterns started with food, and moved on to personal care, apparel, packaging, furniture, building products, and other product categories.

Consumers enjoy more choices and power today than ever before, and they are looking for brands and products that reflect their values. Brands need to be transparent and proactive in their management of the chemicals and materials incorporated in their products or used in their manufacturing processes, or they risk losing people's trust. This includes both what goes into the food and the packaging.

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9 Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4492252/

10 Connecting Values with Consumers (2008). LOHAS Journal. The Natural Marketing Institute.

WHAT ARE BRANDS AND RETAILERS DOING?

Brands and retailers are in the business of understanding, designing, and bringing to market the products people want. *The transition to a sustainable and circular economy requires packaging materials that are free of harmful chemicals and benign to the natural world*.

Leading global brands have been addressing their packaging-materials-impact challenges by:

- **Setting targets for the reduction of waste** — most initiatives focus on the incorporation of recycled and/or bio-based content into their packaging along with reduction and recycling targets.
- **Banning certain materials** — within the packaging industry these initiatives are limited to well-known bad actors, such as Bisphenol-A and phthalates. More comprehensive analysis of chemicals of concern and the adoption of industry-wide-restricted-substance lists (or priorities) are needed.
- **Requiring transparency** — asking their suppliers to disclose more detail about chemicals, materials, products and their packaging.

In addition to increasing transparency and reducing waste and hazardous materials, some brands are adopting more proactive approaches including:

- **Telling the story** — they incorporate their work on safer packaging materials into their brand story, demonstrate leadership, differentiate and create a positive vision for the future.
- **Partnering and participating in the innovation ecosystem** — they develop initiatives to collaborate with innovators and become active participants in the innovation ecosystem.

Some examples of what some brands and retailers have done in 2018:

- More than 290 companies and organizations have joined “A Line in the Sand,” an initiative by The Ellen MacArthur Foundation to get companies, governments and institutions to commit to the elimination of plastic waste and pollution[11]
- Sodexo announced that it plans to eliminate bags and stirrers by 2019, polystyrene by 2025, and shift straws to a “by request” item[12]
- Dunkin’ Brands announced plans to eliminate polystyrene coffee cups[13]
- Trader Joe’s announced plans to eliminate BPA/BPS and PFOA[14]
- Coca Cola announced plans to collect and recycle the equivalent of every bottle or can that it sells globally by 2030[15]
- Evian vowed to use 100 percent recycled plastic in bottles by 2025[16]
- Several corporations, including Starbucks, Bon Appétit Management Company, Marriott Hotels, Alaska Airlines, and American Airlines have also committed to phasing out plastic straws
- Starbucks and McDonald’s have joined forces in an innovation challenge to design the next generation single-use cup[17]

11 Retrieved from https://www.ellenmacarthurfoundation.org/news/a-line-in-the-sand-ellen-macarthur-foundation-launch-global-commitment-to-eliminate-plastic-pollution-at-the-source

12 Retrieved from https://www.sodexousa.com/home/media/news-releases/newsListArea/news-releases/plastics-reduction.html

13 Retrieved from https://news.dunkindonuts.com/news/dunkin-donuts-to-eliminate-foam-cups-worldwide-in-2020

14 Retrieved from https://www.traderjoes.com/announcement/questions-regarding-toxic-chemicals-in-our-products-and-packaging

15 Retrieved from https://www.coca-colacompany.com/stories/world-without-waste

16 Retrieved from https://www.danone.com/impact/planet/packaging-positive-circular-economy.html

17 Retrieved from https://www.openideo.com/challenge-briefs/next-gen-cup-challenge

SECTION 2:

CHEMICALS IN FOOD PACKAGING

People, brands, retailers, advocates, and governments want *safe packaging and zero plastic pollution*. At the same time, single-use packaging is convenient and here to stay. How do we make it better? We start with what it does and ask how we can more safely deliver the function that it performs.

THE FUNCTIONS OF FOOD PACKAGING

Packaging holds, preserves, presents, and provides information about food. An essential function of modern packaging is to ensure the safety and quality of food through its barrier properties, which include physical, UV/light, gas, moisture, and oil barriers. Brands and retailers also use the packaging to provide information and to track food items through the supply chain.

In addition to these direct functions, the indirect functions of packaging materials relate to their ability to be reused, recycled, or composted at the end of their useful life.

Figure 4 outlines some of the essential functions of packaging.

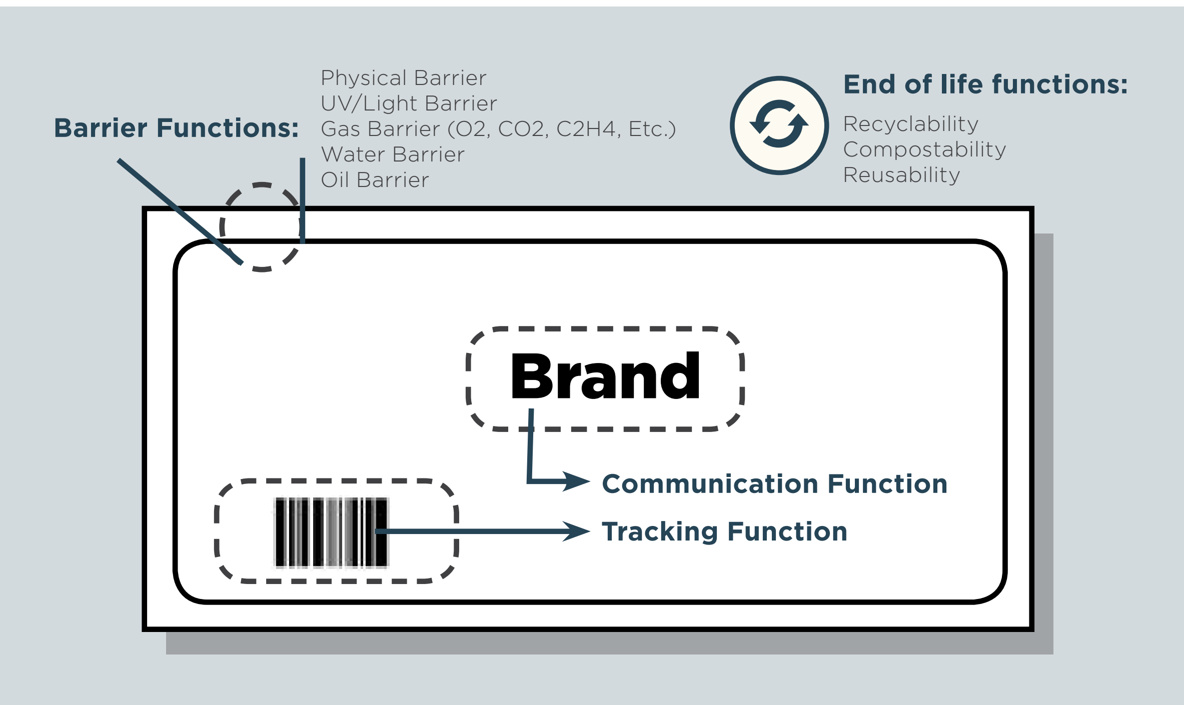

Figure 4: Food Packaging Functions
Source: Safer Made

Most materials provide one or two barrier functions, but so far, no material can deliver all barrier functions. For example, a cardboard box is a physical and UV/light barrier, but not a moisture, oil, or gas barrier. A plastic film (such as High-Density Polyethylene) is a good water and oil barrier, but not a good UV/light or gas barrier.

In order to deliver adequate barriers, packaging relies on multi-component designs, additives, and multilayer films. However, the additives that help improve barrier performance are often found on the lists of chemicals of concern. The multilayer films also make separating the different materials, and therefore recycling, impossible.

The chemicals of concern identified provide a wide range of functions and performance characteristics. Some of these chemicals are not intended to be a part of the packaging but are essential in the manufacturing process and have been identified as contaminants in sampled food.

To design better packaging, we have to understand the basic packaging materials used — plastic, metal, and fiber — and how chemistry or construction are used to deliver their functions. Next, we explore the chemistry of the main packaging materials from a functional perspective.

CHEMICALS POLICY IN THE FOOD PACKAGING SECTOR

Before we delve into the various food packaging materials, we would like to briefly address the state of chemicals policy in the food packaging sector.

In the U.S., food contact materials are regulated by the Food and Drug Administration (FDA), which maintains oversight over indirect food additives that may come into contact with food through packaging. The FDA has taken a generally permissive stance on the use of materials and additives in packaging. Authorization of many indirect food additives was granted following indirect food additive petitions submitted by companies. Today, food contact substances may be used legally after notifying the FDA if their migration into food is not expected to exceed 50 parts per billion (ppb). The FDA also allows any substances that are generally recognized as safe (GRAS) or that are expected to migrate into food below 0.5 ppb. *The Pew Charitable Trusts estimated that as many as 80% of the thousands of approved food contact substances are insufficiently evaluated regarding their toxicity.*[18]

In many industries, Restricted Substance Lists (RSLs) and/or Manufacturer Restricted Substance Lists (mRSLs) have become the main tools of implementing chemicals policy.

18 Academic Articles outlining regulatory shortfalls of FDA include: from Pew https://www.ncbi.nlm.nih.gov/pubmed/23954440; from the Food Packaging Forum https://www.ncbi.nlm.nih.gov/pubmed/24999917

Brands, manufacturers, and suppliers use RSLs and mRSLs to collaborate to eliminate chemicals of concern, going beyond what is required for regulatory compliance. These lists are often created, curated, maintained, and promoted by industry associations as a form of self-regulation and promoting uniform standards beneficial to all actors involved.

Most chemicals management policies in packaging focus on the chemicals banned or expected to be banned by regulatory authorities such as Bisphenol A. More recently, they have also included chemical classes, such as phthalates or fluorinated compounds PFASs, which are allowed by regulatory agencies but have come under scrutiny for their harmful potential. Many brands are banning or announcing their intentions to ban a handful of them. While this is a positive sign, we should remember that these few bad-actor chemicals represent a small fraction of the chemicals of concern not regulated. In addition, current industry standards are weak and highly fragmented.

> *Creating a widely accepted Restricted Substance List (RSL) for food contact packaging is essential for transitioning food packaging and food processing to safer chemistry.*

The Food Safety Alliance for Packaging, a technical committee of the Institute of Packaging Professionals, recently assembled a comprehensive RSL for the packaging sector.[19] The associated Guide to the RSL was prepared with input from brand owners, including Nestlé and Mars Wrigley Confectionery, and packaging supply chain members, including Decernis, Siegwerk, American Packaging Corp., Henkel, and Sun Chemical.[20] In addition, the Food Packaging Forum — a Swiss non-profit organization — has undertaken the most comprehensive analysis of allowed food contact materials, and cross referenced them with known chemicals of concern. They are currently developing a comprehensive list of chemicals of concern in food contact packaging.[21]

For this report, we compiled lists of chemicals of concern from several sources, including: ChemSec, REACH, FDA, Center for Environmental Health, The Endocrine Exchange, Food Safety Alliance for Packaging, and the Sustainable Packaging Coalition. We created the summary lists of chemicals of concern in food packaging along with their functions in the tables below, grouped by each of the major basic materials —plastic, metal, and fiber.

19 The RSL is available for download at: https://www.iopp.org/files/Food%20Packaging%20Product%20Stewardship%20Considerations%20FSAP-IoPP%20v1_0.pdf

20 Retrieved from https://www.iopp.org/i4a/pages/index.cfm?pageid=2264

21 Retrieved from https://www.foodpackagingforum.org/

THE CHEMISTRY OF PLASTIC IN FOOD CONTACT MATERIALS

Petroleum-derived plastics are the most ubiquitous material in the food system, found at every step in our foods' journey to our plates. These plastics have become the dominant materials, because of their unique functional properties and low cost. This section will explore some of the most common types of petroleum-based plastics, their functional properties, their relative safety and sustainability, and provide a list of chemicals of concern found in these materials.

We group the basic petroleum-derived plastic materials into two categories, based on their human toxicity potential: safer plastics and potentially harmful plastics.

Safer petroleum-derived plastics include polymers such as polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET). These plastics make up the majority of beverage bottles (PET), dairy containers (PP), and non-deforming thin films (PE, HDPE, LDPE, etc.), such as grocery bags, candy wrappers, and chips bags. These materials are light and flexible. All of these plastics can be recycled, with clear PET beverage bottles being the most widely collected and processed back into recycled PET (rPET), often used as a feedstock in other sectors like textile and apparel. Some PE is recycled and used in non-food applications like personal care packaging. Some PP is also recycled for different uses, like toys.[22] None of these materials are compostable.

Some food and beverage companies have started using bio-based versions of PET and PE.[23] These bio-based versions have the same attributes in terms of recyclability and safety as their petroleum counterparts, but they are made from renewable feedstocks. Today most of the bio-PET and bio-PE are made from sugar-derived ethanol, which is then transformed into ethylene that can be used to make PE or PET in traditional manufacturing facilities. The bio-based versions can be recycled alongside petrochemical versions without affecting the performance of the resulting recycled resin.

Potentially harmful petroleum-derived plastics include polystyrene (PS), polyvinyl chloride (PVC), polyvinylidene chloride (PVDC), polyurethane (PU), and polycarbonate (PC).

Polystyrene is mostly known as the precursor to Styrofoam, a well-known insulating foamed form of the polymer used in cups, clamshells, school lunch and meat trays. While many companies have moved away from Styrofoam cups, PS is still one of the most common plastics used in clear and black takeout clamshells and coffee cup lids.

22 Retrieved from http://www.greentoys.com/

23 Retrieved from https://www.coca-colacompany.com/plantbottle-technology and from https://www.greenerpackage.com/bioplastics/pepsico_joins_naturall_bottle_alliance

Recognizing the growing consumer awareness around the potential harm of PS, some companies have begun using the safer, slightly more expensive PP, or in some cases bio-based compostable plastics, such as PLA.

Most people associate vinyl with plumbing pipes or vinyl floor coverings. Until 2004, flexible plastic wraps like Saran Wrap used polyvinylidene chloride (PVDC) along with plasticizers to create a clear barrier with good oxygen blocking properties. Now, the safer LDPE is much more common in plastic wrap, but PVOH, PVDC, and others still find applications in box overwraps, stand-up plastic pouches, clear plastic pouches, and multicomponent packaging.

CHEMICALS OF CONCERN IN PLASTICS

Building on the work of the Food Packaging Forum, we added and cross-referenced lists of chemicals of concern from ChemSec, REACH, FDA, Center for Environmental Health, and the Sustainable Packaging Coalition, and have created the summary list of chemicals of concern found in plastic food contact packaging in Table 1.

One of the technical advantages of plastics is that they can be easily blended with other materials to improve their performance. Most chemicals on this list are additives that deliver or augment functional performance, such as improving flexibility, durability, or resistance to UV/light.

One challenge to adopting safer additives is that we often don't have any information on what additives have been used to make a particular packaging material. *Greater transparency of the supply chain and greater disclosure of the additives used in plastics manufacturing are essential for driving the adoption of safer alternatives.*

Table 1: Chemicals of Concern in Plastic Food Packaging

CHEMICAL NAME	CHEMICAL CLASS	FUNCTIONAL NOTES
Diethyl sulphate	Alkylating agent	Residual alkylating agent in cellulosic film packaging
Dimethyl sulphate	Alkylating agent	Residual alkylating agent in cellulosic film packaging
Resorcinol monobenzoate	UV-Blocker	Used in clear plastic films
Vinyl chloride	Monomer	Found in PVC
Sodium perchlorate	Anti-static in plastics	Used in packaging manufacturing

Source: Safer Made

Tributyltin oxide (TBTO)	Metal	Catalyst, Stabilizer
Tributyltin acetate	Metal	Catalyst
Dibutyltin (dilaurate)	Metal	Catalyst, Stabilizer
Dibutyltin dichloride	Metal	Catalyst, Stabilizer
Antimony trioxide	Metal	Catalyst, Stabilizer
Silver (nanoparticles)	Metal	Antimicrobial additive
4-Methyl-m-phenylenediamine	Monomer	Found in some polyurethane
Diphenyl-p-phenylenediamine	Monomer	Polymer additive, residual
Acrylamide	Monomer	Found in polyacrylamide
Styrene	Monomer	Found in polystyrene
4,4'-Methylenedianiline (MDA)	Monomer	Found in polyurethane
Buta-1,3-diene	Monomer	Found in hard ABS plastics
Vinyl acetate	Monomer	Found in polyvinyl acetate
Melamine	Monomer	For hard plastics including Formica and other durable food contact surfaces
Bisphenol A diglycidyl ether	Monomer, Bisphenol	Poly bisphenol a diglycidyl ether monomer, bisphenol
Chloroethylene	Monomer, Organohalogen	Found in polyvinyl chloride (PVC)
Isoprene	Natural Extract	Found in natural rubbers
Chlorinated paraffins (CPs)	Organohalogen	Plasticizer and flame retardant in Polyolefins
1,2-Dichloroethane	Organohalogen	PVC residual
Dichloromethane	Organohalogen, Solvent	Solvent
Styrene oxide	Oxirane	Breakdown product of Styrene monomer
2,3-Epoxypropyl phenyl ether	Oxirane	Adhesive
4-tert-Butylpyrochatechol	Phenol	Monomer Stabilizer
4-tert-Butylphenol	Phenol	Monomer Precursor
p-Cresol	Phenol	Precursors

Source: Safer Made

Triphenyl Phosphate	Phosphate	Flame retardant and plasticizer
Tris(2-Chloroethyl)-phosphate (TCEP)	Phosphate	Flame retardant and plasticizer
Dicyclohexyl phthalate	Phthalate	Plasticizer
Diphenyl phthalate	Phthalate	Plasticizer
Diethyl phthalate (DEP)	Phthalate	Plasticizer
Diisobutyl phthalate	Phthalate	Plasticizer
Dibutyl phthalate (DBP)	Phthalate	Plasticizer
Dihexyl phthatlate	Phthalate	Plasticizer
Benzyl butyl phthalate (BBP)	Phthalate	Plasticizer
Bis(2-ethylhexyl) phthalate (DEHP)	Phthalate	Plasticizer
Dioctyl phthalate	Phthalate	Plasticizer
Diisodecyl phthalate	Phthalate	Plasticizer
Diisononyl phthalate (DINP)	Phthalate	Plasticizer
Diisononyl phthalate (DINP)	Phthalate	Plasticizer
2-Octyl-(4-dimethyl-amino) benzoic acid	Plastic Additive	UV-Blocker
Di(2-ethylhexyl)adipate	Plasticizer	Used to replace Phthalates in PVC plastic wrap and containers
4,4'-Methylenebis[2-chloroaniline]	Residual	Curing agent in Polyurethanes
Phenyl salicylate	UV-Blocker	UV-Blocker
Benzophenone	UV-Blocker	UV-Blocker
Benzophenone-3; Oxybenzone	UV-Blocker, Bisphenol	UV-Blocker
4,4'-Dihydroxy-benzophenone	UV-Blocker, Bisphenol	UV-Blocker
1,3-Dihydroxybenzene	UV-Blocker, Phenol	UV Blocker and Adhesive
2,3-epoxypropyl methacrylate; glycidyl methacrylate	Monomer	Found in adhesives
2-ethylhexyl 10-ethyl-4,4-dioctyl-7-oxo-8-oxa-3,5-dithia-4-stannatetradecanoate	Metal	Polymerization catalyst

Source: Safer Made

UV-327	UV-Blocker	Used in clear plastic films
2-Methoxyethanol	Solvent	Solvent
2-Ethylhexanoic acid	Organic Acid	Metal coordination complex for some catalysts
Chloromethyl methyl ether	Organohalogen	Alkylating agent

Source: Safer Made

CHEMICALS OF CONCERN IN METAL FOOD CONTACT MATERIALS

Metals are durable and have excellent physical and gas barrier properties. Metal cans are often the packaging of choice for the long term storage of food. The biggest challenge for metals is that they are susceptible to corrosion, especially by acidic foods. The easiest way to address this is through the addition of a plastic coating. Most metal cans and lids for glass jars and bottles are coated with resins to provide corrosion resistance and a gas seal, which does not affect their recyclability. The most common chemicals of concern found in metal packaging are these coatings and corrosion inhibitors, as highlighted in Table 2.

Table 2: Chemicals of Concern in Metal Food Packaging

CHEMICAL NAME	CHEMICAL CLASS	FUNCTIONAL NOTES
Aluminum	Metal	Metal packaging Drying agent in food
Manganese	Metal	Aluminum alloy Steel corrosion inhibitor
Sodium chromate	Metal coating	Corrosion inhibitor
Potassium dichromate	Metal coating	Corrosion inhibitor
6:2 Fluorotelomer alcohol (6:2 FTOH)	PFAS	Residual from PTFE linings
8:2 Fluorotelomer alcohol (8:2 FTOH)	PFAS	Residual from PTFE linings
Bisphenol B	Bisphenol	Metal lining

Source: Safer Made

Bisphenol A	Bisphenol	Metal lining
Bisphenol S	Bisphenol	Metal lining
Diphenolic acid	Bisphenol	Metal lining, substitute for BPA
Bisphenol F	Bisphenol	Metal lining
2-Chlorobuta-1,3-diene	Organohalogen, Monomer	Adhesive Aluminum coating agent
Tris(2,3-epoxypropyl) isocyanurate	Oxirane	Crosslinker found in some metal coatings

Source: Safer Made

CHEMICALS OF CONCERN IN FIBER FOOD CONTACT MATERIALS

Molded fiber (e.g., paper or cardboard) packaging is very common in single-use food service items like cups, plates, bowls, and trays. Cardboard boxes are also used extensively as secondary packaging for food shipping. Benefits of molded fiber packaging include the wide range of input fiber sources, including many waste materials that can be used as a feed stock. Molded fiber is also relatively inexpensive as compared with other materials. Molded fiber creates good physical and UV barriers, but is an ineffective liquid and gas barrier without the addition of chemical additives or plastic coatings. Many of the chemicals of concern included in Table 3 are added to fiber, to improve its barrier properties and to add strength and durability.

Table 3: Chemicals of Concern in Pulped Fiber Food Packaging

CHEMICAL NAME	CHEMICAL CLASS	FUNCTIONAL NOTES
2,3,4,5-Tetrachlorophenol	Organohalogen, Phenol	Wood preservative
2,3-Epoxypropyl-trimethylammonium chloride	Oxirane	Improves bacterial and mold resistance
4-Nonylphenol	Phenol	Surfactant precursor
Anthraquinone	Oxidizer, Crosslinker	Improves wet pulp stability

Source: Safer Made

Boric acid	Crosslinker	Preservative and binding agent
Carbon disulfide	Solvent	Used to make cellophane from pulp
Epichlorohydrin	Organohalogen, Oxirane	Binding Agent
Ethyleneimine	Oxirane like	Intermediate or resin additive
Methyloxirane	Oxirane	Starch modifier
Pentachlorophenol	Organohalogen	Pesticide, disinfectant
Perfluorobutane sulfonic acid (PFBS)	PFAS	Moisture/Oil Barrier
Perfluorobutanoic acid (PFBA)	PFAS	Moisture/Oil Barrier
Perfluoroheptane sulfonic acid (PFHpS)	PFAS	Moisture/Oil Barrier
Perfluoroheptanoic acid (PFHpA)	PFAS	Moisture/Oil Barrier
Perfluorohexane sulfonic acid (PFHxS)	PFAS	Moisture/Oil Barrier
Perfluorohexanoic acid (PFHxA)	PFAS	Moisture/Oil Barrier
Perfluorononanoic acid (PFNA)	PFAS	Moisture/Oil Barrier
Perfluorooctane sulfonic acid (PFOS) (3)	PFAS	Moisture/Oil Barrier
Perfluorooctanoic acid (PFOA) (5)	PFAS	Moisture/Oil Barrier
Perfluorooctanoic acid, ammonium salt	PFAS	Moisture/Oil Barrier
Perfluoropentane sulfonic acid (PFPeS)	PFAS	Moisture/Oil Barrier
Perfluoropentanoic acid (PFPeA)	PFAS	Moisture/Oil Barrier
Sodium fluoride	Mineral	Wood preservative

Source: Safer Made

CHEMICALS OF CONCERN IN INKS AND COATINGS USED IN FOOD CONTACT MATERIALS

Brand and product communication are an essential function of food packaging. Several chemicals and inks are used to provide color for the various materials used. While these inks and coatings are usually on the outer surface of packaging, they are sometimes found on food contact surfaces. There have been reports of chemicals of concern from inks and coatings used on plastic and pulped fiber packaging materials leaching into food.[24] Table 4 highlights chemicals of concern from inks and coating.

Table 4: Chemicals of Concern in Inks and Coatings Found in Food Packaging

CHEMICAL NAME	CHEMICAL CLASS	FUNCTIONAL NOTES
4-Octylphenol	Phenol	Ink solvent and biproduct
4-(1,1,3,3-Tetra-methylbutyl)phenol	Phenol, Adhesive	Tackifier
4-Chloro-3-methylphenol	Phenol	Preservative, Adhesive
4-Benzyloxyphenol	Phenol	Dye precursor
2,4-Dihydroxybenzophenone	Phenol	Photocuring-UV initiator
2-Naphthol	Phenol	Precursors
Aniline	Residual	Residual from polyamide resin or analine dyes (banned)
2-Ethoxyethanol	Solvent	Solvent
N-Methyl-2-pyrrolidone	Solvent	Solvent

Source: Safer Made

NON-INTENTIONALLY ADDED SUBSTANCES

In addition to the components of food packaging that are added to perform specific functions, there are also many non-intentionally added substances (NIAS) found in food. These chemicals are often introduced earlier in the food supply chain and include pesticides, disinfectants, solvents, and other common industrial chemicals. Some of these NIAS chemicals like the pesticide glyphosate have been found at high levels in processed foods. A study from the Environmental Working Group recently found that all of the oat-based cereal products they tested had detectable levels of glyphosate.[25] A full list of these potential contaminants that are associated with a packaging material can be found in Appendix A.[26]

The list of Non-Intentionally Added Substances includes many chemicals of concern that

24 Retrieved from https://www.tandfonline.com/doi/abs/10.1080/02652038909373802

25 Retrieved from https://www.ewg.org/release/roundup-breakfast-part-2-new-tests-weed-killer-found-all-kids-cereals-sampled

26 Appendix A: NIAS Chemicals of Concern is available at https://www.safermade.net/packaging-report

are used in food processing and should also be considered within the larger picture of the chemicals and pesticides in our food system. Some of these substances can be avoided through changes to the materials and processes used to create packaged foods. This is another reason why we advocate for a comprehensive food industry RSL and mRSL.

MATERIALS AND WASTE: RECYCLING AND COMPOSTING

The end-of-life functions of packaging materials deserve their own analysis. Conversations related to sustainable packaging design usually focus on increasing recycling and composting (breaking down into soil in commercial facilities) of packaging materials. Many sustainability initiatives focus on optimizing for one or the other type of process.

One of the challenges of sustainable packaging design is that materials optimized for some functions may be inadequate for others. To solve for this, we often resort to multi-material or multi-layered packaging, but this makes it hard, if not impossible, to separate out streams of waste.

Table 5 includes the major types of substances found in food contact material and considers the potential compatibility with composting and recycling systems.

Materials may have the ability to be recycled or composted, but that does not mean that the appropriate infrastructure exists or that the materials are properly separated and eventually recycled or composted. Wide use of materials that are both recyclable and compostable, such as PLA and PHA, would be beneficial. However, to date, infrastructure doesn't exist at scale to handle these materials.

Regardless of whether materials go the route of recycling or composting at end of life, it is critical that we use safer materials and chemical building blocks, otherwise we may contaminate compost and recycled streams.[27]

27 The importance of safe chemistry to the success of a circular economy has been articulated by several organizations and is beginning to gain traction within the community. Google and EMF: https://storage.googleapis.com/gweb-sustainability.appspot.com/pdf/Role-of-SafeChemistry-HealthyMaterials_CircularEconomy.pdf; Food Packaging Forum: http://dx.doi.org/10.1016/j.jclepro.2018.05.005; Green Chemistry: https://pubs.rsc.org/en/content/articlehtml/2016/gc/c6gc00501b

Table 5: Materials Used in Food Packaging and Compatibility with Composting and Recycling

MATERIAL	MATERIAL LIFETIME	RECYCLING FEASIBILITY	NUMBER OF CYCLES	RECYCLED MATERIAL USED IN FOOD CONTACTS	COMPOSTABLE
Plastics (PP, PE, PVC, PS, PLA, PHAs, PBAT, Starch based)	Non-permanent	Yes (single thermoplastic polymers)	Limited	Yes	Limited to PLA, PHAs, PBAT, and Starches
		No (plastic multilayers, thermoset polymers)	-	-	-
Paper & cardboard	Non-permanent	Yes	Limited	Yes	Yes
Metals	Permanent	Yes	Unlimited	Yes	No
Glass	Permanent	Yes	Unlimited	Yes	No
Multi-material multilayers	Non-permanent (paperboard)	Yes	Limited	Yes	Limited to PLA coated papers
	Non-permanent (plastic)	No	–	–	No
	Permanent (aluminum)	No	–	–	No

Source: Adapted from Muncke et al. Journal of Cleaner Production, https://doi.org/10.1016/j.jclepro.2018.05.005

Metals and glass are stable in the environment indefinitely. These are considered permanent materials and for these materials it is essential that we identify efficient reuse and recycling systems. Both metals and glass also take a very large amount of energy to make and recycled materials mostly have the same functional properties as virgin sourced materials, so they have a potentially unlimited number of lives.

Plastic and fiber materials are non-permanent and can be recycled only a limited number of times, because they break down over time. Some plastics (thermosets, Polystyrene, PVC, and Polycarbonate) all persist in the environment for significant amounts of time and have contributed to persistent problems due to plastics pollution. Plastics pollution is one of the main drivers for better packaging, so we will consider in detail the problems of persistence, recyclability, biodegradation, and the use of harmful chemicals in the following sections.

SECTION 3:

SAFER CHEMISTRY INNOVATION NEEDS IN FOOD PACKAGING

THE INNOVATION MAP

We have addressed the main factors driving safer chemistry innovation in Section 1 and have organized the chemicals of concern found in food packaging in Section 2. In Section 3, we explore how we can advance safer chemistry innovation in food packaging.

We define the "*Innovation Needs*" in food packaging to facilitate conversations about the innovation and investment opportunities among multiple stakeholders, including brands, suppliers, investors, innovators, and start-up companies.

In defining the *innovation needs*, we focus on the relationships between the pollution and toxics challenges of the basic materials and their additives on the one hand, and the universe of better alternatives and solutions on the other. Figure 5 illustrates our approach, which considers both the functional challenges on the left, and the universe of alternatives and solutions on the right.

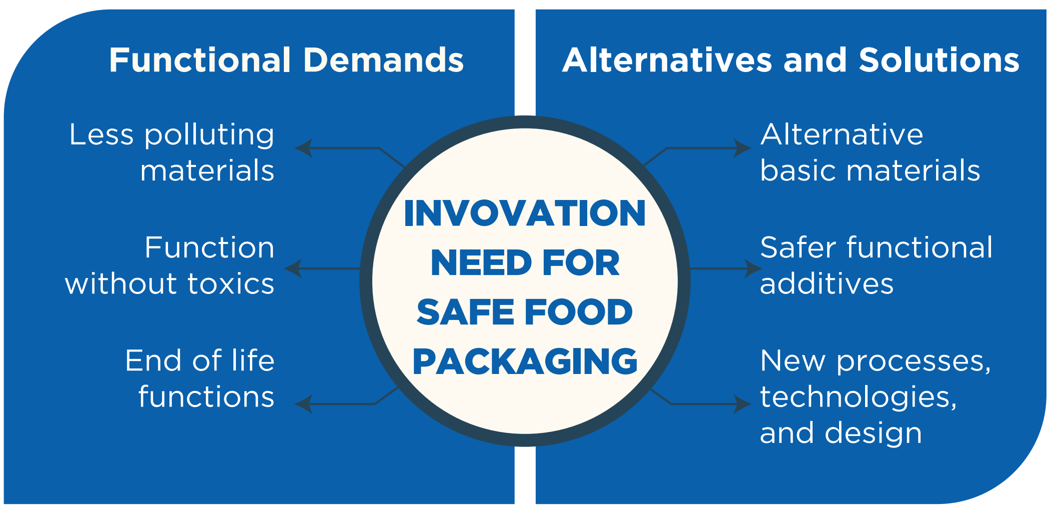

Figure 5: Defining the Innovation Needs for Safer Food Packaging
Source: Safer Made

A new basic material may address the challenges of an existing basic material, but may also address a harmful additive problem. Likewise, a new, safer additive or a new manufacturing process may enable the successful use of a safer, basic material. Therefore, to compare potential solutions to a specific challenge, we focus on the *function* of the packaging product as the common denominator and take a broad perspective on what could be used to deliver that function.[28]

28 This approach follows that proposed by Tickner, et al. (2015), "Advancing Safer Alternatives Through Functional Substitution" Environmental Science and Technology, (49), 742-749. DOI: https://dx.doi.org/10.1021/es503328m

A focus on function contrasts with an approach that tries to characterize and manage particular problematic chemicals or materials and find specific substitutes. A functional approach also re-focuses chemicals management from the risks of single chemicals to evaluating all the available options to deliver specific functions.

Materials and system-level changes also sometimes address additional sustainability goals (including the reduction of energy and water use) more effectively than chemical substitution. For example, it may be possible to eliminate potentially harmful additives in plastics by shifting to fiber materials, which may also be a way to reduce greenhouse gas emissions.

A focus on function also helps to avoid instances when one harmful chemical is replaced with another chemical similarly harmful, but with a less-known toxicity. These kinds of "regrettable substitutions" happen more often than we would like, because when we ask for substitutes, we are most likely to get compounds similar in structure having a similar impact.

A recent example of regrettable substitution was industry action in response to concerns about bisphenol-a (BPA). Searching for alternatives to bisphenol-a (BPA), a known endocrine disruptor, certain manufacturers used similar compounds, such as bisphenol-s (BPS) and bisphenol-f (BPF) in certain applications. Unfortunately, BPA, BPS, and BPF are also all endocrine disruptors with estrogenic activity of comparable potency, even though only BPA was called out initially. Many products labeled "BPA-free," while technically true, also contained the endocrine disrupting chemical BPS.

One application of BPA is electronic receipts, where the chemical is used as a dye transfer agent. In that application, the approach to eliminating BPA included transitioning to ink-printing the receipts, eliminating the need for dye transfer agents altogether. This type of "platform change" approach to eliminating a chemical of concern may often be missed in discussions of safer chemistry, because they do not have a one-to-one correspondence with a chemical of concern.

We define three broad innovation needs within food packaging: *Alternatives to Petroleum Based Plastics, Improved End-of-Life Functions, and Safer Functional Additives* (including coating and films). Within each of these broad innovation needs we identify specific, subsumed needs, as illustrated in Figure 6.

ALTERNATIVES TO PETROLEUM-BASED PLASTICS

- Fiber
- Bio-based Plastics

IMPROVED END-OF-LIFE FUNCTIONS

- Degradable Plastics
- Recycling Technologies
- Reusable Packaging

SAFER FUNCTIONAL ADDITIVES

- Barriers and Coatings
- Shelf Life Extension
- Safer Inks and Smarter Packaging

Figure 6: Food Packaging Innovation Needs
Source: Safer Made

For each innovation need we identify current examples of young companies working on safer chemistry, materials, and technologies. This is not a comprehensive list of all the innovation activities and young companies that are active, but we do think it is useful to highlight the extent of current activity and to showcase examples.

INNOVATION NEED 1: ALTERNATIVES TO PETROLEUM BASED PLASTICS

Petroleum-based plastics are packaging's biggest problem. They are the main group of materials used in food contact packaging, as they are cheap and light and help preserve and present food well. However, while some of the petroleum-derived plastics such as PS or PVC are harmful themselves, the longest part of the list of chemicals of concern in packaging is associated with petroleum-based plastics.

The main alternatives to petroleum-based plastics are pulped-fiber and bio-based plastics. Bio-based plastics technically include: naturally occurring polymers, such as polylactic acid (PLA), polyhydroxy alkonates (PHAs), other naturally occurring building blocks (cellulose, starch, agar, and chitosan), as well as biologically-derived, drop-in alternatives to petroleum-based plastic (such as PP and PE). Table 6 summarizes some of the advantages and disadvantages of bio-based alternatives as compared with petroleum-based plastics.

Bio-based alternatives solve some of the sustainability challenges of petroleum-based plastic, but they are not perfect. The summary in Table 6 underlines the complicated choice of selecting packaging materials. The addition of chemicals or materials to improve performance of these materials may also change both their safety as well as their end-of-life performance attributes.

Table 6: Alternatives to Petroleum Based Plastics - Advantages and Disadvantages

BIO-BASED ALTERNATIVES TO PLASTICS	FIBER	STARCH AND OTHER NATURALLY OCCURRING	PHAS	PLA	BIO-BASED PP AND PE
Comparative Safety	Better	Better	Better	Better	Same
Comparative Performance	Significantly Lower	Significantly Lower	Somewhat Lower	Somewhat Lower	Same
Industrial Compostability	Yes	Yes	Yes	Yes	No
Home Compostability	Yes	Yes	Yes	No	No
Marine Bio-Degradability	Yes	Yes	Yes	No	No

Source: Safer Made

Chemical Recyclability	No	No	Yes	Yes	Yes
Recycling Availability	Limited	Limited	No	No	Yes
Risk to Plastic Recycling Streams	No	Yes	Yes	Yes	No
Value of Consumer Signal	High	Medium	Medium	Medium	Low
Feedstock Sustainability Issues	Low	Medium	High	High	High
Comparative Cost	More Expensive	More Expensive	More Expensive	Somewhat More Expensive	More Expensive
Availability at Scale	Yes	Somewhat	No	Yes	Somewhat

Source: Safer Made

Fiber

Paper and pulped-fiber products have traditionally been used for food packaging, however, over time they have lost market share to petroleum-based plastics. More recently, pulped fiber products have come back into use, as companies look for alternatives to petroleum-based plastics and innovate to address some of fiber's performance drawbacks.

The perfoluorinated class of chemicals (PFAS) has become an issue in the pulped fiber sector. PFAS chemistry, usually added to the bulk fiber in the slurry phase, helps improve the water and oil resistance of the final products without the need for coatings. We explore the PFAS issue in greater depth in the section on *Safer Functional Additives innovation need.*

Innovation in fiber covers all aspects of the design, material, and manufacture of pulped-fiber packaging products:

- Materials innovations focus on using lower quality input fibers and various crop wastes without compromising strength and durability.
- Design and manufacturing innovations focus on addressing fiber performance

and bringing pulped fiber products into sectors traditionally dominated by plastics, such as bottles, cutlery, and cup lids.

Table 7 highlights companies developing fiber alternatives to petroleum-based plastic packaging. This list is not exhaustive, but it gives a good overview of the types of activities and innovations.

Table 7: Examples of Companies with Innovations in Fiber

COMPANY NAME	PRODUCT/TECHNOLOGY	WEBSITE
Aloterra	Miscanthus and crop sourcing platform	http://www.aloterrallc.com
Biome Bioplastics	Starch based coatings for pulped fiber	http://biomebioplastics.com/
EarthPack	Custom retail packaging	http://www.earthpack.com/
EcoEnclose	Boxes and mailers	https://www.ecoenclose.com/
EcoLogic Brands	Fiber bottles	https://ecologicbrands.com/
EcoProducts	Compostable packaging Food Service	https://www.ecoproductsstore.com/
Ecotensil	Pulped paper spoons	http://ecotensil.com/
Ecovative	Foamed packaging materials	https://ecovativedesign.com/
Evanesce Packaging	Foamed fiber trays and food service	https://www.evanescepackaging.com
Footprint Packaging	Molded fiber custom manufacturing with certifications and impact reports	http://www.footprintus.com/
Green Packaging Group	Packaging retailer, boxes, bags, etc.	https://greenpackaginggroup.com/
HyO-Cups	Gourds grown to be cups	http://cremedesign.com/product/gourds
Just Water	Multilayer bio-based beverage bottle	http://www.justwater.com/ourpackaging/
LeafCOAT	Lignin and glycerol-based coating for paperboard	http://leafresources.com.au/leafcoat/
Lumi	Light weight packaging for direct to consumer companies	https://www.lumi.com/
Melodea	Compostable oxygen barrier films based on nano crystalline cellulose	http://www.melodea.eu/

Source: Safer Made

Nanotech Industries	Biodegradable coating for fiber products to improve oil and grease resistance	http://www.nanotechindustriesinc.com/greencoat.php
Paper Water Bottle	Fiber bottles	https://paperwaterbottle.com/
Repurpose	Single-use food service items in retail channels	http://www.repurposecompostables.com/
Trio Cup	Paper cup and lid	https://www.triocup.com/
World Centric	Single-use food service items in commercial channels	http://www.worldcentric.org/

Source: Safer Made

Bio-based Plastics

Bio-based Plastics include both naturally occurring polymers such as polylactic acid (PLA), polyhydroxy alkonates (PHAs), other naturally occurring building blocks (cellulose, starch, agar, and chitosan), as well as a biologically-derived drop in alternatives to petroleum-based plastic (such as PP and PE). Companies provide either bio-based resin pellets to be extruded and formed into final packaging products by existing manufacturers and/or ready-to-use packaging.

Table 8 highlights startup and existing companies that are developing bio-based alternatives to petroleum based plastics, and describing the main product/technology, as well as the type of polymer used and how it can be treated at end of life.

Table 8: Examples of Companies with Innovations in Bio-based Plastics

COMPANY NAME	PRODUCT / TECHNOLOGY	POLYMER	END OF LIFE	WEBSITE
Avani Eco	Compostable bags and films	Starch	Biodegradable	http://www.avanieco.com/
BiologiQ	Modified starch additive for films and bags	Starch	Depends on the other polymers	https://www.biologiq.com/
BioPlastech	PHA from synthetic plastics	PHA	Biodegradable	http://www.bioplastech.eu/

Source: Safer Made

Braskem	Ethanol to Bio PET and PE polymers	PET, PE	Recycled with traditional plastics	http://www.braskem.com.br/usa
Crown Poly	Plastic bags and films	Various	Compostable or recyclable	http://www.crownpoly.com/eco-friendly-bagging-solutions/
Danimer Scientific	PHA from sugar	PHA	Biodegradable	https://danimerscientific.com/
Evoware	Edible food packaging	Agar	Biodegradable	http://www.evoware.id/
Full Cycle Bioplastics	PHA from food waste	PHA	Biodegradable	http://fullcyclebioplastics.com/
Futamura	Cellulose and plastic films and pellets	Cellulose	Composting or recycling with paper	http://www.futamuragroup.com/
Georgia Tech Renewable Bioproducts Institute	Chitosan films	Chitosan	Biodegradable	http://rbi.gatech.edu/about-renewable-bioproducts-institute
Gevo	Fermentation process for BioPET	PET	Recycled with PET	https://gevo.com/
Greencell Foam	Compostable starch for insulating materials	Starch	Compostable	https://www.greencellfoam.com/
Coramat (Grow Plastics)	Foamed PLA sheet for food service	PLA	Compostable	www.growplastics.com
Incredible Foods	Edible food packaging	Agar	Biodegradable	http://incrediblefoods.com/
Loliware	Edible food packaging	Agar	Biodegradable	https://www.loliware.com/
Mango Materials	PHA from waste	PHA	Biodegradable	http://mangomaterials.com/
Origin Materials	Furan intermediates for BioPET and other applications	PET	Recycled with PET	https://www.originmaterials.com/
Paptic	Plastic bags and packaging materials	Cellulose	Composting or recycling with paper	https://paptic.com/
Skipping Rocks Labs	Edible food packaging	Agar	Biodegradable	http://www.skippingrockslab.com/

Source: Safer Made

Shrilk	Chitosan based plastic	Chitosan	Biodegradable	https://wyss.harvard.edu/technology/chitosan-bioplastic/
Smart Solve	Dissolvable paper, film, and yarn products	Cellulose	Biodegradable, water soluble	https://www.smartsolve.com/shop/
Synbra	Foamed PLA pellets for insulating materials	PLA	Composting	https://www.synbratechnology.com/biofoam/
Tidal Vision	Chitosan	Chitosan	Biodegradable	https://tidalvisionusa.com/

Source: Safer Made

INNOVATION NEED 2: IMPROVED END-OF-LIFE FUNCTIONS

Much of the demand for alternatives to plastic packaging comes from the need to address the persistence of plastic and other packaging materials in the environment. Packaging should be designed with the end-of-life function in mind across all material types, not just plastic.

Within the *Improved End-of-Life Functions innovation need, we distinguish three subsumed areas: Degradable Plastics, Recycling Technologies, and Reusable Packaging.*

Degradable Plastics

When talking about degradable materials, people mean compostable and biodegradable materials.

Biodegradable: Materials that can be broken down in the environment by bacteria or other living organisms. The European Union further defines biodegradability as the conversion of more than 90% of the original material into CO2, water and minerals, by biological processes within 6 months.[29]

Marine Biodegradable: Materials that meet the Biodegradable definition above when in a marine environment.

Compostable: Materials that break down in municipal/commercial composters to create soil within less than 180 days, according to the Biodegradable Products Institute (BPI) and ASTM D6400 standards. In practice, most commercial composting facilities need these materials to break down within 45-60 days, based on how they cycle materials through their facilities.

29 Retrieved from https://docs.european-bioplastics.org/publications/bp/EUBP_BP_En_13432.pdf on 12/13/2018

Disintegrable / Oxo degradable: Materials that can be broken down so that least 90% of the original mass is decomposed into particles that are able to pass through a 2x2 mm sieve. This may be enough to pass certain compostable standards. This has incentivized the creation of additives for traditional plastics so that they disintegrate into small pieces relatively quickly without breaking down chemically. This class of additives is often referred to as Oxo-degradability additives. *Oxo-degradable additives are being restricted in Europe and are considered undesirable by advocacy groups, because they contribute to the creation of microplastics that have been shown to persist in the marine environment.* For example, the Ellen MacArthur Foundation authored a statement against these additives signed by 150 organizations.[30]

Table 9 highlights examples of companies developing solutions to make plastics degradable.

Table 9: Examples of Companies with Degradable Plastics Innovations

COMPANY NAME	PRODUCT/TECHNOLOGY	USE	WEBSITE
Cove	PHA biodegradable bottled water	Food Service	http://drinkcove.com/
Elevate Packaging/Pure Label	Custom packaging	Stickers	https://elevatepackaging.com/about/
Etiket-shiller	Food labels	Stickers	https://www.etiket-schiller.de/
Global Environmental Polymers	Biodegradable Plastics TDPA™ proprietary oxo-biodegradable plastic additives for (PE), (PP), and (PS).	Oxo-additive	http://www.degradablepolymers.com/products.html
Greencell Foam	Compostable Starch packaging material	Insulating Materials	https://www.greencellfoam.com/
Coramat (FKA Grow Plastics)	Foamed PLA using pressurized CO2 in a continuous process	Food Service and Retail	www.growplastics.com
Loliware	Edible packaging based on agar	Food Service	https://www.loliware.com/
Melodea	Compostable oxygen barrier films based on nano crystalline cellulose	Barrier Film	http://www.melodea.eu/

Source: Safer Made

30 Retrieved from https://www.bioplastics.org.au/150-organisations-worldwide-back-ellen-macarthur-call-ban-oxo-degradable-plastic-packaging/ on 12/13/2018

Mobius (Grow Bioplastics)	Lignin based plastic additive	Biodegradable Agricultural Films	https://www.mobius.co/
Nohbo	Personal care pods	Single Use Packaging	http://www.nohbodrops.com/
Poppits Oral Care	Toothpaste and oral care pods	Single Use Packaging	http://www.poppitstoothpaste.com/
PVA Blends	Researchers blending PVA, chitosan, starch, extracts as degradable packaging	In development	https://www.tandfonline.com/doi/abs/10.1080/15583724.2017.1403928
Radical Plastics	Degradability additive	Oxo-additive	https://www.radical-plastics.com/
Smart Plastics	Polyolefin additive for composability of lined paper products	Additive	http://sptweb.com/
Snact	Compostable packaging using tipa films and selling snacks	Bag/Film	https://snact.co.uk/2016/09/26/compostable-packaging/
TIPA	Compostable flexible film	Bag/Film	https://tipa-corp.com/
Vericool	Cold chain compostable packaging	Insulating Materials	https://www.vericoolpackaging.com/
Willow Ridge Plastics	Oxo-degradable additive to make synthetic polymers more degradable	Oxo-additive	http://www.willowridgeplastics.com

Source: Safer Made

Recycling Technologies

A diverse and complex mix of materials often end up in our recycling bins. To be recycled, they first need to be separated by material, which is labor intensive and costly. The high separation expense, as compared with the relatively low market price for recycled feedstocks and the already low cost of virgin material, is in our view the most significant challenge to recycling a significant portion of our post-consumer waste. To address this challenge, we need to reduce the cost of separating out the materials and increase the demand for recycled feedstocks.

To reduce the cost of separating materials, recycling infrastructure needs to be improved and scaled-up. Automating separation processes would reduce labor costs. Importantly, companies also need to design packaging to be easy to separate.

Increasing the demand for recycled products is important, as without demand for recycled materials, no amount of recycling infrastructure and separation automation will move the needle in creating a circular economy. Increasing demand for recycled content comes from incorporating more recycled content into products and inventing new products that can integrate recycled materials.

Table 10 highlights companies and innovators developing innovative recycling solutions.

Table 10: Example Companies with Innovative Recycling Solutions

COMPANY NAME	PRODUCT/TECHNOLOGY	WEBSITE
Alygix	Polystyrene recycler	https://www.agilyx.com/
Biocellection	Oxidative cracking to intermediates	https://www.biocellection.com/
Blockcycle	Blockchain for materials tracking and sorting	http://www.blockcycle.co/
Eric Beckman (Pitt)	PE films with good barrier properties to make single material recyclable packaging	https://www.engineering.pitt.edu/EricBeckman/
Ioniqa Technologies	Chemical separations and cleaning based on ionic liquids and magnetic materials	http://www.ioniqa.com/
Loop Industries	PET chemical recycling	https://www.loopindustries.com/en/
Looptworks	Upcycling of a wide range of packaging materials	https://www.looptworks.com/
Recycling Technologies	Thermal cracking of mixed plastic to fuel and intermediates	https://recyclingtechnologies.co.uk/
RePoly	Sorting and Recycling of mixed plastic	http://www.qrsrecycling.com/who-we-are/companies/re-poly/
Terra Cycle	Leading recycler of multilayer films and other composite materials	https://www.terracycle.com

Source: Safer Made

Reusable Packaging

Reusable containers reduce waste and address many of the issues associated with single-use packaging. They also enable the use of a wider range of materials. However, reusable materials are almost always more expensive per unit and may require behavior changes and cleaning. These costs and behavioral barriers have constrained the size of the market for reusable packaging.

Some reusable packaging has made progress by embodying a lifestyle of safety and sustainability. Reusable water bottles had been relegated to camping stores and college campuses until brands, such as KleenKanteen and others, capitalized on the consumer distrust of plastic. In recent years we have seen the growth and acquisition of Lifefactory (acquired by Thermos), Bobble (acquired by Seventh Generation), and HydroFlask (acquired by Helen of Troy). A similar pattern is emerging in food containers, where brands like Stasher (silicone bags), Beeswrap (cloth with beeswax), and Blue Avocado (reusable bag) provide reusable alternatives to single-use plastic food storage containers, such as sandwich bags.

The growth in home delivery services for fresh food (like BlueApron and HelloFresh) and other consumer goods has also created a visible reminder of packaging waste. Cardboard boxes and other secondary packaging such as ice packs or wrappers are used to protect goods during transit and add up to a significant volume. Retail and food service companies are looking for ways to minimize this waste, exploring solutions both in the reusable category as well as in the bio-based and compostable packaging sectors. Table 11 highlights companies developing reusable packaging solutions.

Table 11: Example Companies with Innovative Reusable Packaging Solutions

COMPANY NAME	PRODUCT/TECHNOLOGY	WEBSITE
Airship Packaging	Reusable inflatable IoT packaging	https://www.youtube.com/watch?v=pf-p5JQWykQ
Algramo	Formulated products in returnable and reusable packaging	https://www.algramo.com/
Beeswrap	Reusable cloth and beeswax food wrappers	https://www.beeswrap.com/
Blue Avacado	Reusable bag	https://www.blueavocado.com/
BlueCup	Reusable nespresso pod	https://bluecup.nl/
Bobble	Reusable Water Bottle with a carbon filter	https://waterbobble.com/

Source: Safer Made

Buckhorn	Reusable plastic crates for shipping and packaging	http://www.buckhorninc.com/
Can2Close	Resealable aluminum can top	http://www.can2close.com/company/mission/
Capsulier	Device and stainless steel pods for Nesspresso coffee	https://www.capsulier.com/
Cartonplast	Reusable plastic crates for shipping beverage containers	https://www.cartonplast.com
CHEP pallets	Pallets as a service	https://www.chep.com
EV Container	Beer Keg system to simplify sterilization	https://evcontainer.com/
Gobox	Resuable fastfood packaging as a service	https://www.goboxpdx.com/
HydroFlask	Reusable Water Bottle	https://www.hydroflask.com/
KleenKanten	Reusable Water Bottle	https://www.kleankanteen.com/
LifeFactory	Reusable Glass Water Bottle	https://www.lifefactory.com/
Limeloop	Reusable Packaginge, textiles	https://www.thelimeloop.com/
Preserve Products	Reusable food packaging and other products made from recycled plastic	https://www.preserveproducts.com/
Stasher	Silicon reusable bag	https://www.stasherbag.com/
WayCap	Stainless steel nespresso pods	https://www.compatible-capsules.com/

Source: Safer Made

INNOVATION NEED 3: SAFER FUNCTIONAL ADDITIVES

The choice of basic material (plastic, fiber, glass, metal, etc.) determines the largest portion of environmental impact that a package makes. The additives and coatings we apply to these basic materials to make them work well functionally also include many of the chemicals of concern that may affect human health.

In this section we focus on innovation in safer additives and coatings. Given the cost-constrained nature of the packaging industry, bringing new basic materials to market is difficult. Developing safer functional additives that help address the sector's challenges has the potential to provide relatively large benefits while requiring relatively modest amounts of capital.

Within the *Safer Functional Additives innovation need*, we distinguish three subsumed areas: *Barriers and Coatings, Shelf Life Extension, and Safer Inks and Smarter Packaging.*

Barriers and Coatings

Barriers and coatings are essential for ensuring durability and performance. Metal packaging is typically coated to prevent corrosion. Fiber products have additives and coatings applied to make them more durable when exposed to moisture or oils. Plastics often have additives and coatings applied to improve their moisture, UV-light and gas barrier properties.

However, several essential barrier and coating functions are delivered using harmful chemistry or undesirable materials. Examples include:

- Multilayer flexible films, such as candy wrappers and potato chip bags, use metal foils to provide good oxygen, moisture, gas, and UV barrier properties. However, this renders them unable to be composted or recycled.
- Coatings on metal cans used to prevent corrosion often contain BPA or other potential endocrine disruptors.
- Coatings on fiber products with perfluorinated alkyl substances (PFASs) are used to increase their resistance to water and oils, but have been linked to cancer, endocrine disruption, and are known to persist in the environment.

In addition, inks and coating systems may use harmful solvents, plasticizers, or pigments; and shelf life extension solutions may use harmful preservatives and/or antimicrobial systems.

Delivering each of these functions without harmful chemistry or materials is a significant innovation opportunity.

We highlight some of the innovation work focused on the three needs below. We focus on young companies here but acknowledge that efforts along the same lines are being pursued by existing providers.

BPA Can Liners

The leaching and associated endocrine disruption potential of BPA in food packaging has been known since 1992 when a Stanford researcher first characterized the migration of BPA from hard plastic polycarbonate bottles.[31] Since then, several alternatives have been outlined or developed ranging from the adoption of new packaging like TetraPak multi-laminate boxes, to the regrettable substitution of Bis-phenol S (BPS).

While BPA-free cans are now commonplace, a significant percentage of canned food still use BPA or other harmful chemicals as a barrier to reduce corrosion. A report by the Center for Environmental Health in 2017 found that roughly 40% of canned food they tested from major super markets still contained BPA, down from 67% in 2015.[32] Several BPA alternatives have been assessed for safety by governments and advocacy organizations,[33] but more work remains to be done to ensure the alternatives are preferable for human health. Table 12 outlines the range of BPA alternatives developed by both small and large companies.

Table 12: Innovative BPA Alternatives

ALTERNATIVE	DESCRIPTION	SOURCE
Oleoresin	Metal cans used for low-acid foods	Eden Foods, 2013; Det Økologiske Råd, 2011; LaKind, 2013
Acrylic resin	Metal can liner	LaKind, 2013; http://cen.acs.org/articles/91/i6/Clear-Winner-Race-Find-Non.html
Phenolic resin	Metal can liner	LaKind, 2013; http://cen.acs.org/articles/91/i6/Clear-Winner-Race-Find-Non.html
Polyester resin	Metal can liner	LaKind, 2013; http://cen.acs.org/articles/91/i6/Clear-Winner-Race-Find-Non.html

Source: Safer Made

31 Link to the original paper from Dr. Feldman: https://academic.oup.com/endo/article-abstract/132/6/2279/3034917

32 Retrieved from https://www.ceh.org/wp-content/uploads/Kicking-the-Can-report-final-1.pdf

33 Alternatives Assessments have been carried out by both the US: https://www.epa.gov/saferchoice/partnership-evaluate-alternatives-bisphenol-thermal-paper and EU: https://echa.europa.eu/safer-alternatives-for-bisphenol-a for bisphenol A. Retrieved from https://www.foodpackagingforum.org/fpf-2016/wp-content/uploads/2016/12/FPF_Dossier11_can-coatings-1.pdf

Vinyl resin	Metal can liner	LaKind, 2013; http://cen.acs.org/articles/91/i6/Clear-Winner-Race-Find-Non.html
Epoxy resin	Metal can liner	www.aafcs.org/res/policy/BPA.ppt
Isosorbide	Metal can liner	Det Økologiske Råd, 2011
2,2,4,4-tetramethyl-1,3-cyclobutanediol (TMCD)	Metal can liner	http://www.uml.edu/News/stories/2013/BPA-substitute.aspx
4-[2-(4-hydroxycyclohexyl)propan-2-yl]cyclohexan-1-ol (HBPA)	Metal can liner	Seattle Polymer LLC
Provalin	Metal can liner	Actega DS; Pano Verschluss GmbH
DAREX Polyester	Metal can liner for low-acid foods	http://www.calwic.org/storage/documents/state/2010/bpa_alternatives.pdf
Polyethylene Terephthalate	Metal can liner	http://www.calwic.org/storage/documents/state/2010/bpa_alternatives.pdf
Tetra Pak	Components: 70% paper, 24% LDPE, 6% aluminum foil; can be used for highly acidic foods	http://www.calwic.org/storage/documents/state/2010/bpa_alternatives.pdf
Valpure	Metal can liner	https://www.valsparpackaging.com/valpure/item/our-materials/

Source: Safer Made

PFAS Free Water and Oil Resistant Coatings and Additives

Perfluorinated chemicals are used to provide oil and water resistance on fiber-based food contact materials. They have gained widespread use because they can be added directly to the fiber slurry during production, which simplifies the production process. The performance of these chemicals also enables the use of a wider range of lower quality input materials including agricultural wastes and recycled paper. Unfortunately, this class of chemicals has been linked to cancer, endocrine disruption, and are known to persist in the environment.

The search for alternatives to PFAS coatings and additives for fiber-based food contact packaging is intensifying. In addition to the work being done to find an alternative coating for fiber-based products, multiple organizations including Clean Production

Action and Center for Environmental Health have put together a resource guide for people trying to source PFAS free food service products.[34] Table 13 shows several PFAS alternative innovations.

Table 13: Companies with PFAS Alternative Innovations

COMPANY NAME	PRODUCT/TECHNOLOGY	WEBSITE
Nanotech Industries	Biodegradable coating for fiber products to improve oil and grease resistance	http://www.nanotechindustriesinc.com/greencoat.php
LeafCOAT	Lignin and glycerol based coating for paperboard	http://leafresources.com.au/leafcoat/
Biome Bioplastics	Bioplastic resin manufacture with starch based coatings	http://biomebioplastics.com/
CoralPack	Line of PFAS-free paper used in popcorn and pastry bags in EU	https://www.ahlstrom-munksjo.com/Products/food-packaging-and-baking/

Source: Safer Made

Shelf Life Extension

A key function of packaging is to preserve shelf life and minimize spoilage. This is an important aspect of reducing food waste. The United Nations Food and Agriculture Organization (FAO) estimate food losses and waste in the supply chain at roughly 30% for cereals; 40% to 50% for root crops, fruits and vegetables; 20% for oilseeds, meat, and dairy; and 30% for fish.[35]

The new technologies highlighted in this section address food loss using new packaging and or processing additives that extend the shelf life and minimize spoilage. The companies highlighted in Table 14 are creating more effective solutions using safer and, in many cases, bio-based solutions.

34 PFAS-Free Food contact guidance can be found here: https://www.cleanproduction.org/images/ee_images/uploads/resources/PFAS_Procurement_Guide_Aug2018.pdf and here: https://www.ceh.org/wp-content/uploads/CEH-Disposable-Foodware-Report-final-1.31.pdf

35 UN Global Initiative on Food Losses and Waste Reduction retrieved from http://www.fao.org/fileadmin/user_upload/ags/publications/1_GIFLWR_web.pdf

Table 14: Companies with Innovative Shelf Life Extension Technologies

COMPANY NAME	PRODUCT/TECHNOLOGY	WEBSITE
Apeel Sciences	Natural extracts to prolong the shelf life of produce	http://apeelsciences.com/
Bluwrap	Fuel cell to reduce O2 and spoilage in transport	http://bluwrap.com/
Boost Biomes	Microbiome additives to prevent fungus in strawberries	http://boostbiomes.com/
Cambridge Crops	Edible bioplastic food coating to extend shelf life of perishables	http://cambridge-crops.com/
Exigence	Oxidative antimicrobial coating that can be recharged with bleach	http://exigencetechnologies.com/
FFC Technologies	Developing organic/green, cost-effective, and broad-spectrum anti-microbial solutions	http://www.ffctechnologies.com/
Hazel Technologies	Food packaging additive to keep produce fresh	https://www.hazeltechnologies.com/
Tidal Vision	Chitosan films and preservative coatings	https://tidalvisionusa.com/

Source: Safer Made

Safer Inks and Smarter Packaging

Communication, information, and tracking functions are also essential aspects of packaging. Inks are an essential part of packaging because of the need for communication and tracking through the supply chain. That said, the materials used for printing in food packaging have often been an afterthought, and the industry has relied on technologies from other industries adapted to food applications. Unfortunately, this has introduced some chemicals of concern into food packaging, which can end up in the final food product.[36]

In searching for alternatives, from a materials innovation perspective, functional properties need to be considered, such as printing compatibility and color in the design of new materials. Table 15 shows some of the companies developing safer printing solutions for packaging, as well as highlighting some of the related active packaging innovations to monitor freshness and enable supply chain tracking.

36 Summary article from Environmental Health Perspectives on Chemical Migration from food contact materials retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4492252/. See also specific article on inks and coatings retrieved from https://www.tandfonline.com/doi/abs/10.1080/02652038909373802

Table 15: Safer Inks and Smarter Packaging Innovations

COMPANY NAME	PRODUCT/TECHNOLOGY	WEBSITE
Chakr	Particulate pigment/ink pulled from air pollution	http://chakr.in/
Colorcon No-tox	Food safe/compliant inks	https://www.colorcon.com/notox
Insignia Technologies	Freshness monitor	https://www.insigniatechnologies.com
LivingInk	Algae Ink	https://livingink.co/
Magicadd	IoT for packaging	http://www.magicadd.com/
Magnomer	Magnetic Label for easier separation	https://www.magnomer.com/
Needham Inks	Food packaging inks, including direct contact	https://www.needham-ink.com/food-grade-ink/
Scan Trust	Supply chain trasnparency app	https://www.scantrust.com/
Tidal Vision	Chitosan films and perservative coatings	https://tidalvisionusa.com/
Timestrip	Temperature tracking package technology	https://timestrip.com/
Tocano	Laser carbonization printing on paper	https://inkless.ink/
VTT Research	Food spoilage sensor for packaging	https://www.vttresearch.com/services/bioeconomy/food-feed-and-beverage
Water.IO	Smart packaging for consumer reoder or sorting	https://www.water-io.com/

Source: Safer Made

SECTION 4:

A SAFER FOOD PACKAGING FUTURE

Our goal with this report is to help articulate challenges for and showcase solutions to safer food packaging. We have tried to find the language that bridges the gap between sustainability in a broad sense and the specific technical challenges related to chemistry in the packaging industry.

Increasing public awareness of the health impact and pollution associated with packaging, the call for transparency from consumers, retailers, and the advocacy community, and the renewed focus on reducing plastic pollution all propel the changes in packaging materials and designs that we see today. The search for safer alternatives and solutions is intensifying, and there is a great deal of opportunity for both existing and start-up companies to provide impactful solutions that address these concerns.

As we push for better materials in food packaging, we need to be aware of the interplay between base materials and functional additives. Base materials (plastic, fiber, metal, and glass) are currently the focus of most packaging discussions, because they are easily identifiable and they drive much of the environmental impact of packaging especially at end of life. Less attention has been paid to the functional additives that are used to make these materials perform well. However, they are often the major source of consumer exposure to chemicals of concern, for example PFAS in fiber, BPA in can linings, and phthalates in plastic. *The selection of both base materials and functional additives must be considered together to ensure that the next generation of packaging is better for our health and the natural world.*

We see significant opportunities for improvement in both the near and medium term. Our vision for this future of food packaging includes:

- Adopting an industry-wide Restricted Substance List and Manufacturing Restricted Substance List to facilitate the phasing out of harmful materials and additives used in food-contact materials and in food processing
- Eliminating harmful plastics, such as Polystyrene, Polyvinyl Chloride and Bisphenol-containing plastic coatings from food contact materials
- Developing more high-functioning, fully compostable, packaging materials
- Communicating end-of-life as a key function of packaging design, by:
    - Designing multi-component packaging for easy separation and sorting
    - Making sure that primary food contact materials that get contaminated with food are safely compostable with food waste
    - Optimizing functional coatings to be compatible with recycling streams across base material types

  - Improving on-product communications about recycling, including the use of standardized labels such as the "How to Recycle" label[37]
- Investing in improving and scaling up recycling infrastructure and the recyclability of packaging
  - Developing safe and recycling compatible additives and coatings for PP, PE, and PET
- Incorporating recycled content in food packaging to drive demand for recycled materials
- Increasing adoption of reusable packaging

CATALYZING THE TRANSITION

Accelerators, incubators, and early-stage investment funds like Safer Made[38] provide platforms and structures for young companies to share information about their new technologies and products and also for brands to keep up-to-date with new technologies and to share their innovation priorities. This two-way collaboration can guide the development of new technologies to make them more compatible with industry needs and accelerate their deployment. Table 16 shows several organizations supporting and funding innovations in food packaging today.

Table 16: Organizations Supporting Innovation in Food Packaging

Chobani Incubator: An organization focused on helping small organic brands grow and understand the food industry including packaging: https://chobaniincubator.com
Think Beyond Plastics: An accelerator in CA that provides funding and mentorship to entrepreneurs addressing plastic pollution: https://www.thinkbeyondplastic.com/startups
Plug and Play: A Silicon-Valley-based incubator with strong corporate ties that has had cohorts focused on new materials and packaging: https://www.plugandplaytechcenter.com/new-materials/

Source: Safer Made

37 Retrieved from http://www.how2recycle.info/

38 Retrieved from https://www.safermade.net/

USDA Bioproducts Research: A government research institute in Albany, CA also supports and houses a number of new bio-based material companies: https://www.ars.usda.gov/pacific-west-area/albany-ca/wrrc/bru/
Green Chemistry and Commerce Council: A not-for-profit organization that drives the commercial adoption of green chemistry across different industries: https://greenchemistryandcommerce.org/
One Step Closer to Organic Sustainable Community (OSC2): A consortium of natural and organic brands addressing industry sustainability challenges including packaging: https://www.osc2.org/
Sustainable Packaging Coalition: A consortium of large brands, retailers, and materials suppliers addressing packaging challenges and setting standards: https://sustainablepackaging.org/
Foodservice Packaging Institute: A consortium of large foodservice retailers, converters, and materials suppliers focused on increasing recovery of foodservice items through recycling and composting. https://www.fpi.org/
Safer Made: A venture capital fund that invests in teams that bring safer products and technologies to market (and the authors of this report): https://www.safermade.net/
Biodegradable Products Institute (BPI): The leading standard setting and research institute certifying industrial compostable products. https://www.bpiworld.org/
NextGen Consortium: A partnership of food-service industry leaders to address single-use food packaging waste, and sponsors of the NextGen Cup Challenge: https://www.nextgenconsortium.com/
Closed Loop Partners: An infrastructure investment fund, a venture fund, and non-profit under one umbrella focused on accelerating the adoption of circular economy solutions: http://www.closedlooppartners.com/

Source: Safer Made

Ellen MacArthur Foundation: A non-profit engaged with large companies and research institutes to advance the adoption of a circular economy: https://www.ellenmacarthurfoundation.org/
Circulate Capital: An impact-focused investment management firm focused on Asia and dedicated to financing innovation and infrastructure that prevent plastic pollution and advance the circular economy: https://www.circulatecapital.com/.

Source: Safer Made

Bringing new safer technologies to market in the packaging industry takes both collaboration and capital. We are grateful to all of the brands, entrepreneurs, and supply chain partners who spoke to us about their work and who continue to share insights and connections to interesting new companies. We look forward to continuing the conversation, and we invite anyone interested in supporting companies developing the next generation of safer chemistry and materials to contact us: safermade.net/contact-us.