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Markets to Watch:
Alternatives to Traditional Plastics

Executive Summary

Plastics are an important, nearly omnipresent, material in our lives, but their use and disposal has created a pollution crisis; at least 14 million tons of plastic end up in the ocean every year.[1] This has prompted calls from consumers and regulators to reduce the amount of fossil-fuel-based plastics used in their products. More than 70% of the world's largest companies have made public statements pledging to reduce plastic waste[2]—which in turn, has spurred growth in the market for alternatives to traditional plastics.

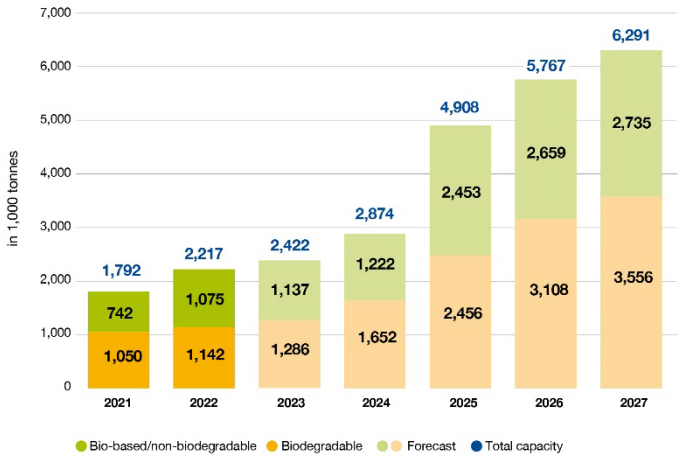
The subset of alternatives can include bioplastics (a term encompassing a range of materials derived from biological resources such as starch cellulose, proteins, and fermentation processes), as well as paper/fiber products, recycled-content plastics, and reusable product alternatives. Industries driving the growth of the plastic alternatives market include product packaging, textiles, and the automotive industry. Consumer product packaging has arguably received the most attention, and large consumer packaged goods (CPG) companies have set targets for reducing their plastic waste by 2025. In response, both established manufacturers and startups are creating new alternative plastic chemistries and products, providing interesting opportunities for innovation and investment.

The Market

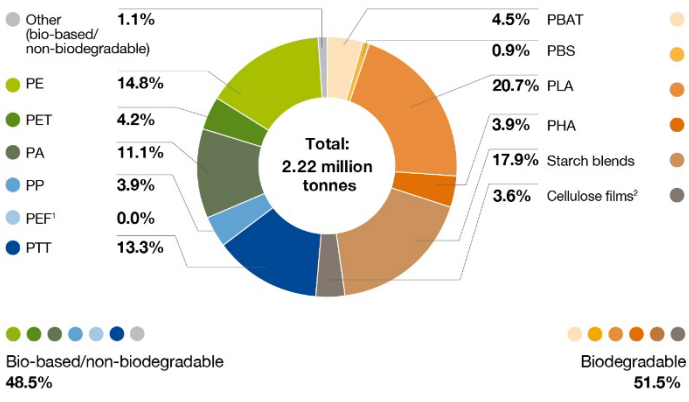
Plastics are used in nearly every aspect of modern life—from food packaging to apparel, medical equipment, toys, cars, computers, and more. By some estimates, the market for plastics globally amounts to around $600 billion annually.[3] Along with the growth of plastics consumption, however, has been a persistent and growing problem of plastic waste. Humans generate 400 million tons of plastic waste per year, and plastic pollution is expected to double by 2030.[4] Of the 8.3 billion metric tons of plastic that have been produced in the history of plastic, only 9% has been recycled; 12% has been incinerated, and the remaining 79% has been sent to landfill[5]—much of it ending up in soils, waterways, and oceans. At least 14 million tons of plastic end up in oceans every year.[6]

The highly visible plastic waste problem has led consumers, activists, and governments to push companies to look for alternatives to traditional plastics—especially in the case of "single use plastics" such as straws, cutlery, and packaging that is used once and then disposed of. Among the world's largest companies, more than 70% have made public statements pledging to reduce plastic waste[7]—including Nestlé, Apple, and PepsiCo. These commitments, along with consumer demand and government mandates, have led to a growing market for plastic alternatives—including bioplastics, recycled-content plastics, paper/fiber substitutes, and other types of reusable product substitutes.

Global production capacities of bioplastics



Global production capacities of bioplastics 2022
(by material type)



¹PEF is currently in development and predicted to be available at commercial scale in 2023. ²Regenerated cellulose films

Source: European Bioplastics, nova-Institute (2022), https://www.european-bioplastics.org/market/

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Bioplastics

Bioplastics currently represent just 1% of global plastic production. However, analysts estimate that the bioplastics market will grow from $10.5 billion in 2021 to $29 billion in 2028.[8]
The term "bioplastics" encompasses a diverse range of plastics derived from biological resources such as starches, cellulose, proteins, and fermentation processes. These alternatives vary in their applications, their strength, and their ability to biodegrade; some of them are biodegradable in an industrial composting setting only, some are home-compostable or "bioresorbable" (for instance medical sutures)—while others are not biodegradable at all.

"Bioplastics" categorized by origin and biodegradability		Biodegradability		
		Non-Biodegradable	Industrially Biodegradable/ Compostable	Environmentally Biodegradable/ Backyard Compostable
Origin	Petrochemically Based	Thermoplastics: HDPE (#2), LDPE (#4), PP (#5), PET (#1), PS/ePS (#6)/HIPS, PVC (#3); #7's: GPET, PA/Nylons, PU, PC & blends, styrenics (ABS, SAN, SBR), Synthetic Rubbers (Neoprene, EPDM), PEG, PPG, PVA/PVOH, PVAc, EVA, acrylics, PVP, FPOs, TPEs, Silicones, PTFE & fluoro polymers, PEEK, POM, Pebax/polyether amides, polyesteramides, polyimides, polysulfones, polyketones; Thermoset resins (epoxies, phenolic resins, photopolymers for 3D printing); WB emulsions (Acrylics/PolyQuats, Vinyls/VAE, PUDs, PVP)	PCL, certain (co)polyesters	PDO, PGA, PBS, PLCL, PTMC, PPF, certain (co)polyesters, polyanhydrides, polyorthoesters (PEG)
	Biobased & Semi-Synthetic	Bio-PET30/PET100 (#1), bio-PE100 (#2,4), (bio polyols/NOPs for) PU, (bio ECH for) epoxies, PEF, PTF, PA/nylons, PBT, PTT, PC (isosorbide; CO_2 polymers: PPC, PEC, PCHC), PTMEG, cellulosic, acrylics, PEG, PP (#5), PVC (#3), SBR, EPDM, PC, PS (#6)	PLA, cellulosics (CA, TAC), modified starches, lignin-based polymers, certain (co)polyesters	Certain (co)polyesters; PLGA, PEG co-polyesters (PLA-PEG-PLA), PBAT, PBSA, PBS
	Biobased & Natural	Natural rubber	Cellulose (incl. nanocellulose), hemicellulose, lignin, shellac, certain copolyesters	Starches, carbohydrates, polysaccharides (homo- & heteroglycans); proteins (casein, keratin, gelatin); PHAs

Note: #1-#7 are ASTM Resin Identification Codes (RIC), All plastics are classified as #7, unless otherwise mentioned

Source: Jaap Schut, 4E Innovation Consulting, www.linkedin.com/company/4einnovation

PLA

PLA (polylactic acid) is typically made from the sugars in corn starch, cassava, or sugarcane, via several chemical manufacturing steps. It can be used in a variety of products, but perhaps is most visible to consumers in plastic cups, utensils, and containers in restaurants. NatureWorks, a joint venture between Cargill and PTT Global Chemical, is one of the larger producers of PLA.[9] While technically considered "compostable", products made of PLA need to be specially treated in industrial composting facilities and heated to at least 140˚F in order to be properly biodegraded.[10] Further, as a bioplastic, PLA is not recyclable, so it must be landfilled if it can't be composted in an industrial composting facility.

PHA

PHA (polyhydroxyalkanoate) is a bacterial polyester produced by microorganisms using a fermentation process. PHA products degrade more easily than PLA, so manufacturers say they can be easily composted in residential composting facilities. Currently, PHA is more expensive than both PLA and conventional fossil-fuel based plastics, so its share of the market has been small to date. Danimer Scientific, which went public via SPAC in 2020, is one of the largest producers of PHA.

Starch blends

Blending PLA with thermoplastic starch (which is derived from plants) is another way to create a bioplastic that has different mechanical properties and (typically lower) production costs than PLA alone.[11] Starch composites can also incorporate recycled plastics.[12] These blends can be used in a wide range of applications, including packaging, food containers, and medical products.

Other

Other types of plastic alternatives include materials made from algae, hemp, or mushrooms. These are currently niche applications but capture the interest of some ecologically-minded consumers who are willing to pay significantly more for green products.

Recycled-content plastic

Only about 2% of plastic packaging is currently made from recycled plastics.[13] Goods created with post-consumer recycled content (PCR), while still plastic, help address the volume of plastic waste entering the environment. Danone's Evian brand will make all its plastic bottles from recycled plastic by 2025, for instance. Volvo has set a goal that at least 25% of plastics used in its new car models from 2025 on will be made from recycled materials.

Paper/fiber

Substituting flexible plastics with paper-based alternatives has become a common solution for many packaging applications, including shipping packaging, food and drink containers, and bags.[14] Footprint is an example of a company that makes paperboard food containers. It's estimated that paper products, given existing technology, could substitute for ~15% of flexible plastics.[15] Paper products are generally easier for consumers to recycle and they biodegrade more easily, making the optics with consumers better (e.g., paper straws are not generally a concern in the ocean the way plastic ones are). However, when environmental footprints are compared side-by-side, plastic products are frequently less resource-intensive to produce.[16]

Durable goods/plastic substitutes

The easy disposability of plastic is one reason its use has proliferated in recent decades. However, many consumers are rethinking the value of disposable products and preferring to return to durable, reusable goods like canvas grocery bags and reusable water bottles—markets that are growing at around 5% per year.[17,18]

Trends & Uncertainties

Changing consumer sentiment

Several studies have noted changing consumer feelings towards plastics, particularly plastic packaging and single-use plastics. A 2022 survey of U.S. and EU-based consumers conducted by Wunderman Thompson suggested that 72% of surveyed customers are "dissatisfied with the amount of plastic food-related packaging waste" that they receive.[19] Another study, by EY, found 55% of consumers consider the ability to recycle or reuse packaging and the product when making purchasing decisions.[20] McKinsey & Co. found that 50% of consumers are willing to pay a little bit more for sustainable packaging—but they are unclear on which alternatives are the most sustainable.[21] So, while it's likely that consumer sentiment will continue to be one of the primary drivers for the adoption of plastic alternatives, it's unclear which (if any) technologies will be preferred by consumers.

Government action

Governments are responding to consumer sentiment with restrictions on plastics—particularly single-use plastics. Since 2021, the European Union has banned the sale of certain single-use plastics.[22] China has banned single-use plastic bags and utensils from major cities, and single-use straws nationwide.[23] The U.S. will ban the sale of single-use plastic in national parks and other public lands by 2032[24], and eight states in the U.S. have plastic bans of some kind.[25]

Future policy action—particularly the pending United Nations Treaty on Plastic Pollution, a legally binding agreement to be released by the end of 2024—could see an expansion on the scope of government plastic regulations. As part of its circular economy action plan, the EU also has plans to incentivize more plastic recycling and increase the demand for recycled plastic content in products. The U.S. Dept. of Energy's Strategy for Plastics Innovation aims to achieve similar goals. Future policy actions could create more incentives for plastic alternatives, drive down costs, and spur further innovation.

Corporate action

Given the concerns of both consumers and governments about plastic waste, many companies have made public pledges to eliminate or reduce their plastic use, particularly in packaging. More than 1,000 companies globally, including Nestlé, Coca-Cola, Mars, and L'Oreal, are signatories to the New Plastics Economy "Global Commitment 2022", which includes committing to using 100% reusable, recyclable, or compostable packaging by 2025. Meeting these commitments will undeniably drive up demand for all types of plastic alternatives, including bioplastics, paper/fiber alternatives, recycled-content plastics, and durable substitutes, and could spur new R&D.

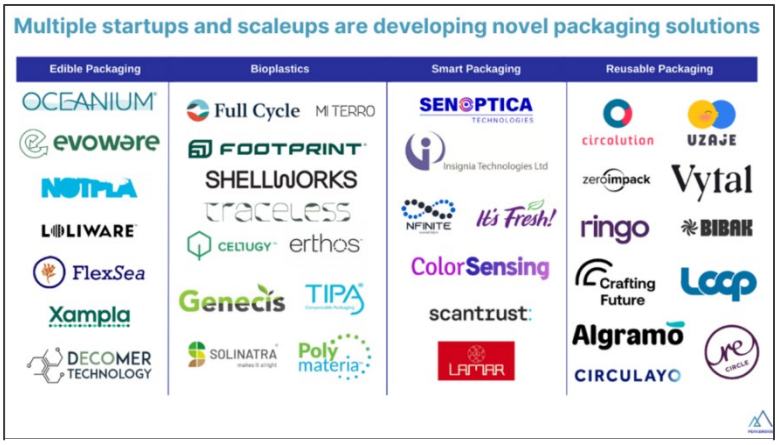
Potential breakthrough innovations

Breakthrough innovations in chemistry and material science, as well as business model innovations in the collection, reuse, and recycling of materials could drive market changes in the future. For example, scientists at the Lawrence Berkeley National Laboratory have announced the invention of a new plastic called poly(diketoenamine) (PDK) that they claim "can be recycled indefinitely with no loss in quality." [26] While still in development, this—and other material innovations yet to be invented—could change the landscape of the market in the future.

Business Opportunities

Plastic alternative packaging materials

According to one report, the plastic alternative packaging market was valued at $5.2 billion in 2022, and expected to grow to $9.67 billion in 2027.[27] The packaging industry has inspired a wide range of materials innovation. Origin Materials, for instance, makes a 100% bio-based PET packaging using woody biomass as a feedstock to serve customers like Nestlé Waters, Danone, and PepsiCo. Mars Wrigley is using recyclable paper packaging for several of its brands in Australia,[28] and has partnered with Danimer Scientific to package SKITTLES and other foods in home-compostable PHA packaging in the U.S..[29]



Source: PeakBridge, 2023. https://peakbridge.vc/unwrapping-the-future-innovative-food-packaging-solutions-for-a-sustainable-tomorrow/

Startup Notpla makes a seaweed-based plastic packaging product, while Ecovative has created a packaging material made from mushrooms. TIPA offers compostable plastic packaging products for the apparel industry (including mailer bags and garment bags).[30] Sealed Air, the company that makes the air pouches seen inside Amazon packages, has partnered with Kuraray America Inc., and announced a $39 million investment to begin to produce plant-based packaging[31]—just to name a few examples.

Plastic alternative single-use products

Coca-Cola has begun selling beverages in a recyclable PET plastic bottle made with up to 30% plant-based materials (30% bioPET); the company is now prototyping a 100% plant-based plastic bottle.[32] Fabri-kal ("Greenware") and Eco-Products make PLA bioplastic

products like cups and takeout containers. Startup OMAO makes straws from the more biodegradable PHA bioplastic, while Loliware markets an edible seaweed-based straw.

Medical plastics
According to industry estimates, bioplastics make up about 3% of the polymers used in medical devices and 1% of the market for medical polymers as a whole,[33] but that number could grow in the future with increased demand. Evonik, for example, markets a bioresorbable polymer called RESOMER for medical implants in orthopedics, wound healing, and cardiovascular care.[34]

Automotive plastics
Cars are produced with a lot of plastic components. The American Chemistry Council estimates that an average car includes about 411 pounds of plastics in components that make up approximately 50% of its volume. Manufacturers that are looking at alternatives include Polestar, which uses car carpeting made from recycled plastic fishing nets.[35] Israeli startup UBQ Materials (which has raised $170 million to date[36]) has developed a process to convert trash to bio-based plastic alternatives that will be featured, among other applications, in the electric Mercedes-Benz VISION EQXX.[37]

Apparel and footwear
Patagonia currently reports that 69% of their apparel materials are derived from recycled materials.[38] To make a net-zero carbon shoe, Allbirds replaced plastic with bioplastic made from methane by the startup Mango Materials, while Mizuno's Wave Rider 24 shoe includes a bioplastic made from castor beans.[39]

Reusable products
It's not a new idea to replace disposable products with durable goods, but growing concerns about plastic waste have driven up consumer interest in products like travel silverware and reusable water bottles. Some companies offer new reuse business models—like Terracycle's Loop service, which ships food items to consumers in containers that can then be returned by mail. Similarly, DeliverZero partners with restaurants to deliver takeout in reusable containers. Blueland sells consumers glass soap bottles and then provides soap refill tablets on a subscription basis.

Plastic recycling technology & infrastructure
A circular economy solution for plastic products will require a systemic redesign of the plastics supply chain to improve recycling and recyclability. Some investors are working to facilitate this transition. For example, Closed Loop Partners launched the Circular Plastics Fund to invest in a range of solutions, including facility development and AI technology, to create circular economy solutions for plastics.[40] Startup Nexus Circular, which has a proprietary plastics recycling process, recently raised $150 million.[41] Major chemical companies are also investing in recycling solutions; Eastman, for instance, announced in 2022 that it would invest up to $1 billion in a recycling facility in France that would "recycle up to 160,000 metric tons annually of hard-to-recycle plastic waste that is currently being incinerated".[42]

Plastic "offsets"
Following the model of carbon offsets, some organizations are offering companies the opportunity to "offset" their plastic waste with the removal of plastics from the environment. For instance, companies can assess the pounds of plastic used in a product or business line and pay 4Ocean to remove an equivalent amount of plastic waste from oceans, rivers, and coastlines.[43] Similarly, rePurpose Global offers companies a portfolio of projects that collect, recover, and verify plastic waste removal.[44]

Takeaways for MBAs

1. Consumers are increasingly seeking alternatives to plastics in the products they purchase, and governments are responding by implementing plastics bans. As such, businesses are transitioning to a variety of alternatives to traditional plastics, including recycled content plastics, bioplastics, paper products, and other natural materials.
2. Plastic packaging in the consumer packaged goods (CPG) industries is the leading application of plastic alternatives, followed by textile and the automotive and transportation industries.
3. Plastic alternatives are gaining market share, but more innovation needs to happen to bring costs down and increase scale; government investment and plastic bans in several regions may spur faster market development.

Further Reading

"Plant-based plastics gain favor as companies pursue sustainability goals", *The Wall Street Journal*, 2023.

The New Plastics Economy: Rethinking the Future of Plastics, World Economic Forum, Ellen MacArthur Foundation, and McKinsey & Co., 2016.

The Global Commitment 2022 Progress Report, Ellen MacArthur Foundation, UN Environment Program, 2023.

Unwrapping the Future: Innovative Food Packaging Solutions for a Sustainable Tomorrow, PeakBridge, 2023.

[1] https://www.iucn.org/resources/issues-brief/marine-plastic-pollution
[2] https://www.sciencedirect.com/science/article/pii/S2590332222005346#undfig1
[3] https://www.grandviewresearch.com/industry-analysis/global-plastics-market
[4] https://www.unep.org/interactives/beat-plastic-pollution
[5] https://education.nationalgeographic.org/resource/whopping-91-percent-plastic-isnt-recycled/
[6] https://www.iucn.org/resources/issues-brief/marine-plastic-pollution
[7] https://www.sciencedirect.com/science/article/pii/S2590332222005346#undfig1
[8] https://www.cbsnews.com/news/bioplastics-pha-pla-companies-invest-billions/
[9] https://news.climate.columbia.edu/2017/12/13/the-truth-about-bioplastics/
[10] https://www.forbes.com/sites/columbiabusinessschool/2022/05/17/the-plastic-alternative-the-world-needs/?sh=39cffe0c1461
[11] https://www.mdpi.com/2073-4360/14/21/4557
[12] https://www.greendotbioplastics.com/starch-based-plastics/
[13] https://ellenmacarthurfoundation.org/plastics-and-the-circular-economy-deep-dive
[14] https://bioresources.cnr.ncsu.edu/resources/paper-based-products-as-promising-substitutes-for-plastics-in-the-context-of-bans-on-non-biodegradables/
[15] https://ellenmacarthurfoundation.org/substitution-to-paper-based-flexibles-design-and-circulation
[16] https://education.nationalgeographic.org/resource/sustainable-shoppingwhich-bag-best/
[17] https://www.databridgemarketresearch.com/reports/global-canvas-bags-market
[18] https://www.grandviewresearch.com/industry-analysis/reusable-water-bottle-market
[19] https://footprintus.com/hubfs/documents/footprint-wunderman-thompson-the-plastic-problem.pdf?hsLang=en
[20] https://www.ey.com/en_us/strategy/how-meeting-sustainability-goals-can-be-wrapped-into-packaging
[21] https://www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/sustainability-in-packaging-us-survey-insights
[22] https://environment.ec.europa.eu/topics/plastics/single-use-plastics/eu-restrictions-certain-single-use-plastics_en
[23] https://www.soalliance.org/soablog/plastic-free-july-20-countries-taking-action
[24] https://www.cnbc.com/2022/06/08/us-to-ban-sale-of-single-use-plastic-on-public-lands-national-parks-by-2032.html
[25] https://www.seasidesustainability.org/post/the-u-s-progress-with-single-use-plastic-bans
[26] https://newscenter.lbl.gov/2021/04/22/infinitely-recyclable-plastic/
[27] https://www.thebusinessresearchcompany.com/report/plastic-alternative-packaging-global-market-report
[28] https://aus.mars.com/news-and-stories/articles/mars-wrigley-australia-launches-recyclable-paper-based-packaging-mars
[29] https://www.mars.com/news-and-stories/press-releases/mars-wrigley-and-danimer-develop-sustainable-packaging
[30] https://tipa-corp.com/portfolio/packaging-by-segment/fashion/
[31] https://www.plasticsnews.com/article/20190321/NEWS/190329974/sealed-air-kuraray-join-forces-for-plant-based-packaging
[32] https://www.coca-colacompany.com/media-center/100-percent-plant-based-plastic-bottle
[33] https://www.medicalplasticsnews.com/medical-plastics-industry-insights/medical-plastics-polymers-insights/an-introduction-to-bioplastics-in-medical-applications/
[34] https://healthcare.evonik.com/en/medical-devices/bioresorbable-polymers/standard-polymers
[35] https://www.nytimes.com/2020/06/04/business/sustainable-materials-cars.html
[36] https://www.crunchbase.com/organization/ubq-materials
[37] https://www.ubqmaterials.com/news-events/ces-2022-mercedes-benzs-new-vision-eqxx-to-feature-ubq-materials-sustainable-plastic-substitute/
[38] https://www.patagonia.com/stories/what-were-doing-about-our-plastic-problem/story-72799.html
[39] https://renewable-carbon.eu/news/our-bio-based-pebax-material-in-the-heart-of-the-wave-rider-24-of-mizuno/
[40] https://www.closedlooppartners.com/closed-loop-partners-circular-plastics-fund-announces-new-investors-catalyzing-capital-toward-a-circular-economy/
[41] https://www.prnewswire.com/news-releases/nexus-circular-secures-150-million-to-accelerate-momentum-of-advanced-recycling-solution-for-plastics-301712375.html
[42] https://www.eastman.com/en/media-center/news-stories/2022/eastman-invest-accelerate-circular-economy
[43] https://www.4ocean.com/pages/partnerships
[44] https://repurpose.global/businesses/verified-plastic-recovery