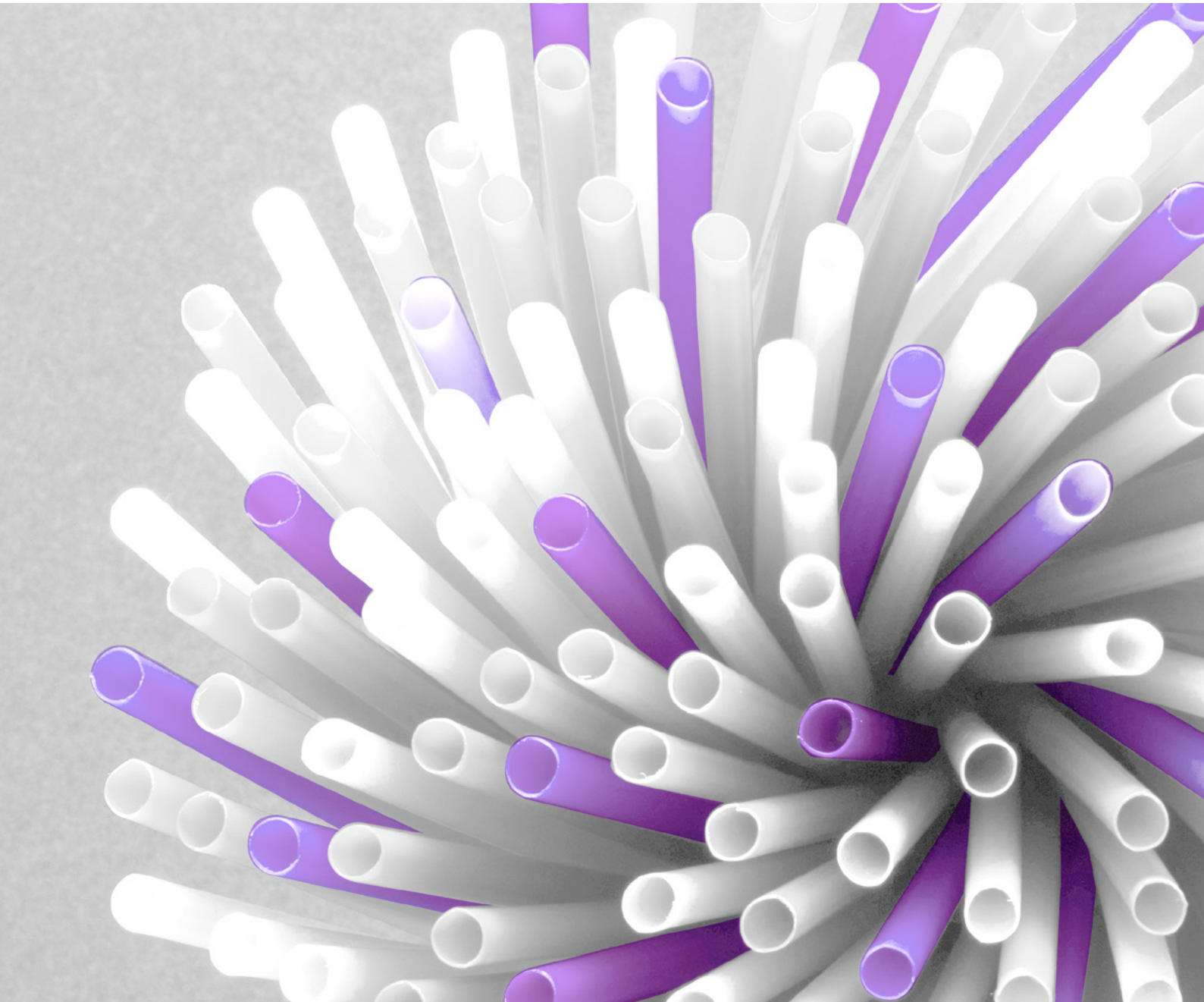
Clarivate™

# From the plastics present to a sustainable future

## The bioplastics innovation landscape, players and market opportunities

**By Ed White, Rosemary Bassilakis and Sofia Nogués**



# Executive summary

In this paper, we explore the state of the bioplastics industry today, including the re-emergence of bioplastics, obstacles hindering development and adoption, and the innovators and trends in this field from a patented innovation and brand leader perspective. We review how the public sentiment towards plastics has changed, and what governments and businesses are doing to tackle environmental challenges. Finally, we discuss the role that the public, government and businesses now play in creating a sustainable plastics future – one where plastics coexist with credible alternatives like bioplastics to best support global societies, economies and the natural world.

# Author biographies

**Ed White** is Head of IP Analytics at Clarivate. He joined Derwent in 2001 as graduate indexer and abstractor in the team creating the Derwent World Patents Index. In 2005 he moved to the then-emerging field of professional patent analysis, designing and fostering many of the patent metrics and visual styles in use today. Ed has a degree in Electronic Engineering from the University of Nottingham.

**Rosemary Bassilakis** is a Patent Analyst. Since 2016, she has provided Clarivate clients with critical patent analyses to inform strategic business and R&D decisions. She has 18 years of patent research and analysis experience encompassing prior art, freedom to operate and invalidity studies, including drafting preliminary international search reports, benchmarking and landscape studies.

**Sofía Nogués** is Senior External Communications Manager at Clarivate. She studied journalism in the Universitat Autònoma de Barcelona and Universiteit Gent and has over five years' experience in corporate communications across the IP industry. Sofia is a sustainability advocate and she sailed with eXXpedition Round the World in December 2019 to study the presence and behavior of microplastics in our oceans.

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# Foreword: drowning in plastic

**By Sofía Nogués**

As part of eXXpedition Round the World, I spent 10 days at sea analyzing the waters to make the unseen seen: microplastics in our oceans. These tiny fragments, some primary (plastic fragments or particles that are already 5.0 mm in size or less before entering the environment) and some secondary (created from the degradation of larger plastic products), were found in every single surface sample that we took – even in open seas and clear waters.

**Why are these microplastics floating about and, more importantly, where do they come from?**

We reached an uninhabited island, part of Cayos Holandeses in San Blas and from afar, it looked like a scene out of *The Blue Lagoon*: clear blue waters, wild palm trees, mangroves caressing the sea. As we approached the island, a very different picture emerged. The whole coastline was completely invaded by waste – primarily plastic waste.

As we stepped on the beach, to the unpleasant squeaking of empty plastic bottles under our feet, we found energy drink bottles, flip flops, combs, deodorant containers, light bulbs, an assortment of food packaging, toxic insect repellent and styrofoam pieces. The list was endless. Some materials were in very good condition while others were completely worn down and easily fragmented into tiny microplastics. This plastic-strewn view was a sad reflection of our consumption habits.

As consumers, we all have a responsibility to stem this growing tide of plastic waste. Governments and corporations have the power to do so at a much larger scale – offering consumers alternatives that are now lacking in most supermarket shelves and moving towards circular economy models that reduce waste at the source.

**Time and again, human ingenuity has led to the discovery of game-changing innovations, solutions to some of the world's complex problems.**

At Clarivate™, we operate at the heart of the innovation lifecycle. We deliver critical information and insights to organizations that are seeking alternative and innovative solutions to our plastic waste problem – potential solutions such as bioplastics. We hope that, using our industry leading solutions, organizations can continue to bring life-changing, perhaps environment-saving, innovations to market, faster.

# Plastics' rise, revolt and bioplastics' re-emergence

Bioplastics have been around for over a hundred years, as the first bioplastic was invented in the late 19th century by Alexander Parkes[1]. It was expensive and easily breakable, and issues with quality control meant the material did not gain wide acceptance. Parkes' company went bust only a decade after his discovery. Ever since, bioplastics have developed in the shadow of the plastics industry, which exploded into prominence and mass production in the 1950s. The arrival of plastics heralded new opportunities for producers, now able to create a multitude of products from this versatile and cost-effective material.


Source: European Bioplastics

**Bioplastic definition:** A plastic material is defined as a bioplastic if it is either biobased, biodegradable, or features both properties. Biobased means that the material or product is derived (partly) from biomass (plants). Biomass used for bioplastics currently come from sources such as corn, sugarcane, or cellulose. Whether a bioplastic is biodegradable depends on its chemical structure. For instance, 100% bio-based bioplastic is not necessarily biodegradable.

Suddenly, a dizzying array of affordable products were available to the average consumer including plastic combs, cups, squeeze bottles, sneakers and more. The possibilities of plastics appeared endless. Plastics began to replace traditional material like paper and glass in packaging. Even the humble grocery paper bag, preferred by American consumers until the mid-1980s when plastic held just 25% of the market, was replaced by plastic less than ten years later when, in the mid-90s, plastic captured 80% of the market for grocery bags[2].

Today, plastics are a key material not just for consumer goods, but for a wide range of industries, including automotive, aerospace, electronics and healthcare. In healthcare, plastic is indispensable in its ability to maintain sterility. Plastic is used to manufacture medical devices from syringes, surgical gloves and insulin pens, to pacemakers and prosthetics. While plastic will remain popular because of its durability, versatility and cost-effectiveness, there is widespread recognition of our global plastics consumption and waste problem. Consumers, businesses and governments acknowledge that waste reduction cannot be the only solution to a big problem.

To address this challenge, we must reconsider our current model of consumerism and examine the root causes of plastic pollution. This will involve a radical departure from how we currently design products, requiring us to evaluate new materials such as bioplastics and plan for recycling and re-use of plastics through a circular economy.

Bioplastic has re-emerged as a credible alternative. Besides some recent exciting bioplastics innovations, we see encouraging, wider-scale bioplastics' adoption and supportive policies. For example, Seven-Eleven Japan switched to plant-derived bioplastic wrappers for all rice ball offerings at the end of July[3] 2019. Similarly, Germany has supported the use of certified bio-based and compostable biowaste plastic bags since 2015.

# Bioplastics: the landscape today

Global bioplastics production today is just a fraction compared to the more than 359 million tons of plastic produced annually. Global bioplastics production in 2019 was 2.11 million tons, and growth is expected to be modest, reaching 2.43 million tons in 2024 – still less than 1% of annual plastics production[4]. Similar to plastics, packaging (rigid and flexible) dominates bioplastics global production capacity, comprising more than half (53%) of the total bioplastics market last year.

While still a relatively small and nascent market, there have been some exciting bioplastics innovations lately, for example:

- bioplastic containers made from rice starch with a high degree of thermal resistance and mechanical strength,
- edible bioplastic food wrappers made from corn and shellfish byproducts and
- some Lego kits that now contain sugarcane-derived bioplastics[5].

Could these innovations lead to mass market production in the near future, and potentially reduce both our plastics dependency and pressure on the environment? Or are bioplastics too good to be true?

Let's take the plastic bag as an example. Just because it is made of bioplastic doesn't mean that it is biodegradable. Depending on the type of material, it could be compostable, require as much time as traditional plastic to break down, or be biodegradable. Even if it is biodegradable, biodegradable bioplastics today can only break down in the right conditions, necessitating industrial composting facilities that can specifically handle bioplastics waste. However, recycling companies and local authorities are currently not equipped to deal with bioplastics waste. In fact, many recycling and composting facilities today treat bioplastics as a contaminant material[6]. Adequate waste disposal is an area that must be addressed, ideally before widespread adoption of bioplastics.

Then, we must also consider the carbon footprint of bioplastics production. Plastics production consumes approximately 8% of the world's oil production today[7]. Those in favor of bioplastics argue that its production reduces our fossil fuel dependency, thereby conserving natural resources and cutting related emissions. However, there are other environmental considerations when plants are grown for bioplastics.

Bioplastics land usage, just 0.02% of global agriculture's 4.8 billion hectares[8], may not cause much concern at present, but the picture would likely change if bioplastics production is ramped up in the future. If large quantities of compostable bioplastics are composted, there may be higher volumes of methane production at these bioplastics' end-of-life compared to their plastics equivalent.

Significantly, the economics of bioplastics production partially explains bioplastics' relative lack of growth and development compared to its popular counterpart. For instance, PLA (polylactic acid), a type of bioplastic that is typically made from sugars in corn starch, cassava or sugar cane, can be 20% to 50% more costly than comparable materials[9]. This is due to the complex process used to convert the plant-based material into the building blocks for PLA.

Human attitudes towards waste are also a factor in bioplastics' sustainability footprint. Just because a product is made of bioplastic doesn't mean it will not end up as litter in our natural environment. If it does, like petroleum-based plastics, some of it may be unable to degrade and could take hundreds of years to break down into tiny particles, potentially posing a danger to wild and marine life that often mistakenly consume these products. Unless there is meaningful change in human attitudes towards plastics consumption and disposal – and these attitudes still vary dramatically across the world – waste, whether bioplastic or plastic, will still appear in our seas and forests.

Bioplastics may not be the green savior they are touted to be by some, but as the world seeks credible alternatives to plastics, we can expect more innovation and the continued growth of bioplastics. We can also expect to see greater collective efforts to reduce and recycle plastics through the circular economy, promoted at local, regional, national and global levels.

**Bioplastics papers are well-cited, according to Web of Science**

According to Web of Science™, there are 1,200 papers that refer to bioplastics – mostly in the last ten years. The papers are well-cited, with an average of 19 citations per item with a steep recent upswing. Fifteen of the papers are highly cited in their field. They cover a mix of biotech, basic physical science, and environmental science papers. There is a mix of geographical diversity, with authors coming from the United States, Spain, China, Italy, India, Japan and Germany.

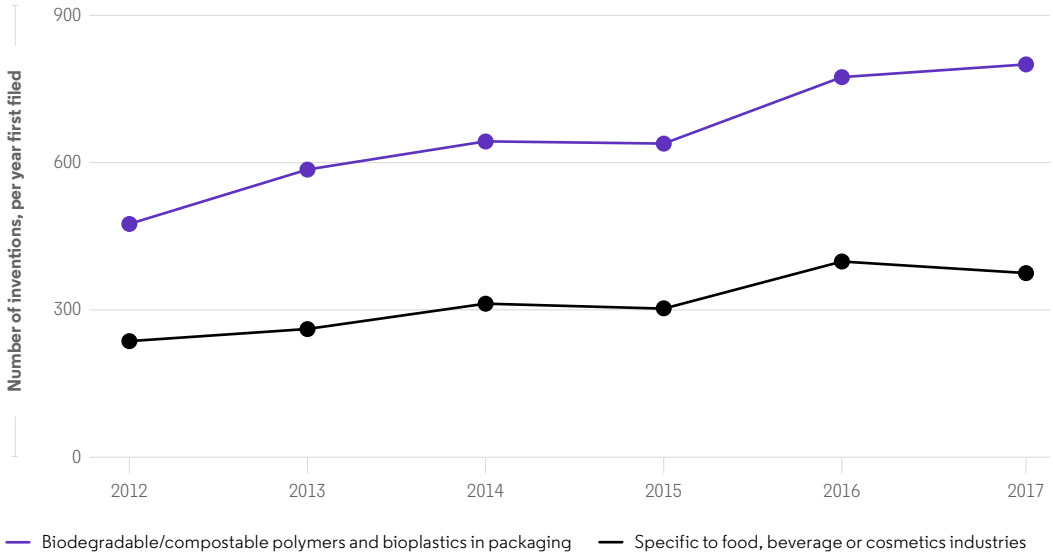
# Defining the innovation landscape, and identifying a gap

**Applying a definition of bioplastics as plant-derived, biodegradable or compostable, we created a patented innovation dataset that looked at packaging solutions generally.**

For a deeper dive into the innovation trends in the bioplastics space, we also focused in detail on packaging solutions specific to the food, beverage or cosmetics industries, i.e. those that are closest to the consumer and the largest contributor to waste streams today in terms of single-use plastics.

Through this lens of the bioplastic innovation ecosystem, we see increasing interest in these materials as a replacement for traditional petrochemical-based polymers in packaging supply chains. Food, beverage and cosmetic uses account for just under half of all bioplastic packaging patent activity, although in the most recent full-year data available (in this case 2017, due to patent applications remaining non-public for up to 18 months) this percentage has reduced slightly to 46%.

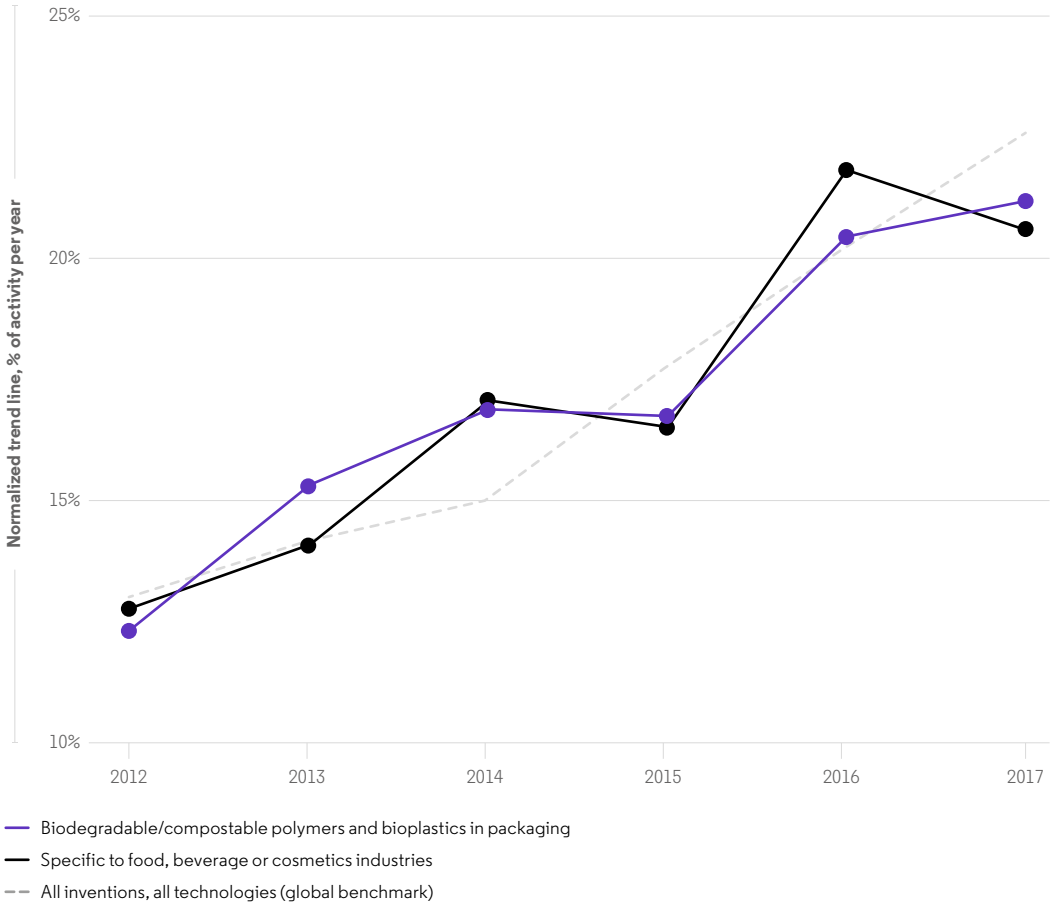
**Figure 1:**
Number of inventions first filed each year according to Derwent World Patents Index across a) biodegradable or compostable polymers or bioplastics, with mention of a packaging use and b) a subset of a) further specific to a food, beverage or cosmetic packaging use. Source: Derwent World Patents Index.




As an overall trend, bioplastic innovation in general packaging and food, beverage and cosmetics packaging are very closely correlated. Further, they closely follow general patent volume increases seen across all geographies, in any technical area.

Patent volumes have risen significantly over the past 15 years, driven largely by increases in Mainland China, Taiwan and South Korea. Since 2012, the general increase has accelerated. However, the effect of this general rise can be seen as one analogous to monetary inflation, economic growth or a baseline of innovation activity. Because of this, interpretation of any technical areas' invention activity growth must be placed alongside the patent growth baseline to assess whether the sector is out-growing the baseline, or under-growing.

**Figure 2:**
Normalized trend line for inventions first filed each year for bioplastics according to DWPI in a) any packaging use, b) specific to food, beverage or cosmetic packaging. Also includes normalized trend line for all inventions, globally, in any technology as a reference for general increase in patented innovation. Normalization based on % of total 2012 to present activity falling in each year. Source: Derwent World Patents Index.




In the case of the bioplastics packaging and food, beverage and cosmetic specific subset, both map very closely to the overall patent activity rise. The conclusion is that while biodegradable and compostable packaging is a key issue for consumers and regulators, it is not exhibiting fast growth – despite percentage increases of between 58% and 70% from 2012 to 2017. This is because patent volumes generally grew 70% over the same period.

Indeed, these growth trajectories show that a focus on the highest consumer impact and sales volumes, and thereby the waste streams that end up in the environment, i.e. food, beverage and cosmetics, are below the baseline. Arguably, this means that real growth is not occurring at all.

This revelation should act as a wake-up call for companies that sell products to retailers, consumers and their supply chain that more focus and investment is desperately needed. At the same time, it means that there is a significant opportunity. While it is true that individual ideas can disrupt or enable significant change in industries, it is very unlikely that a single invention, a single patented idea, would act as a 'silver bullet' (a comprehensive solution) for all requirements of consumer products that may end up in the environment.

As an example, the requirements for biodegradable meat packaging differ hugely from the requirements for toothbrush packaging. There are also multiple vectors of innovation in each packaging use, such as how you manufacture the material; whether the process is economic; its focus on flexibility, material strength or tear resistance; or its biodegrade/compost profile.

Out of our three sectors, food packaging is the most active and is increasing most quickly. Almost 60% of biodegradable/compostable or bio-derived food packaging inventions have been filed since 2015, compared to almost 40% for cosmetics packaging.

If bioplastic packaging for fast-moving consumer products overall is not out-pacing general innovation trends, innovation focused on cosmetics uses is particularly poorly covered.

We found just 137 inventions globally, new filing rates of between 9 and 29 inventions per year and no sign of an uptick or acceleration in inventive output.

**Figure 3:**
Number of bioplastics inventions first filed since 2012 in food packaging, beverage packaging and cosmetics packaging. Source: Derwent World Patents Index.

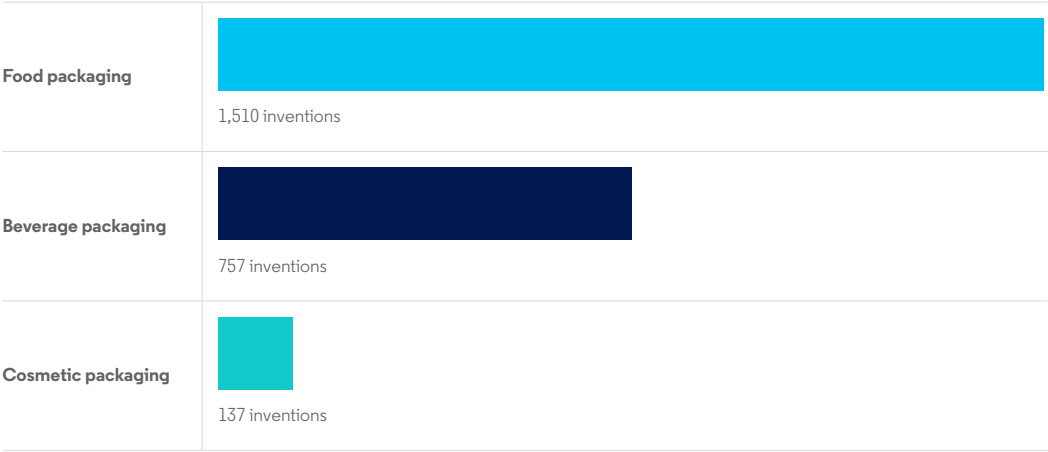



**Figure 4:**
Proportion of invention activity in each packaging use file prior to 2015 (year of first filing) vs 2015 or after. Source: Derwent World Patents Index.

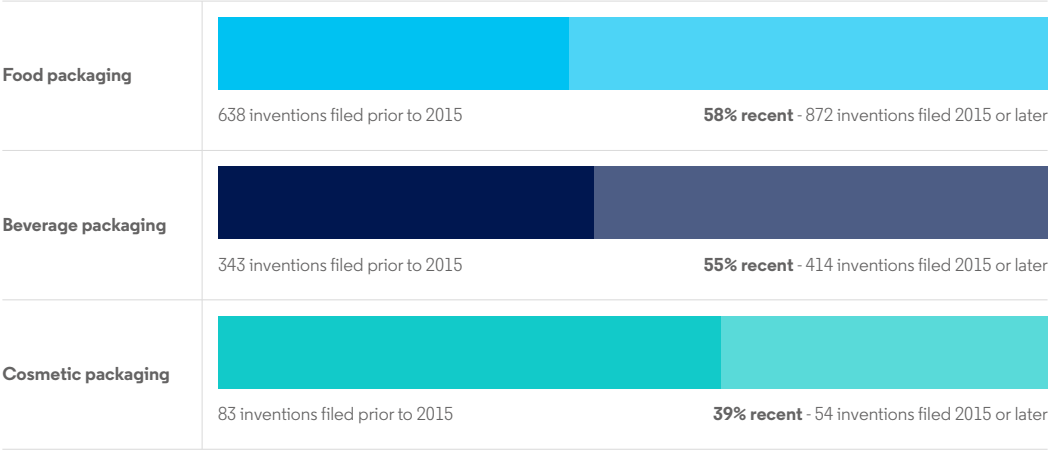
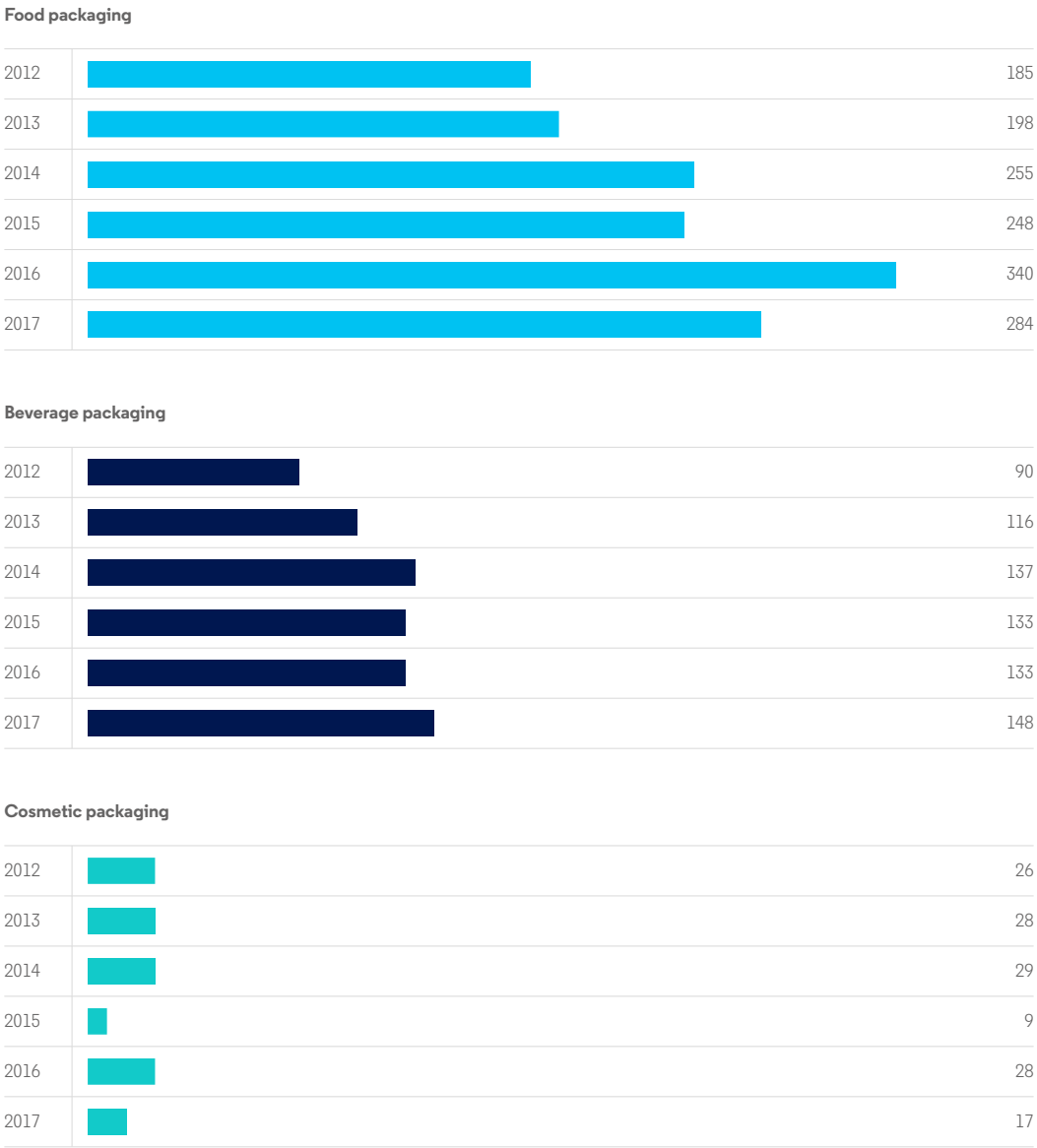


**Figure 5:**
Number of inventions first filed each year according to Derwent World Patents Index in food packaging, beverage packaging and cosmetic packaging. Note that 2017 is the last year of complete data. Source: Derwent World Patents Index.



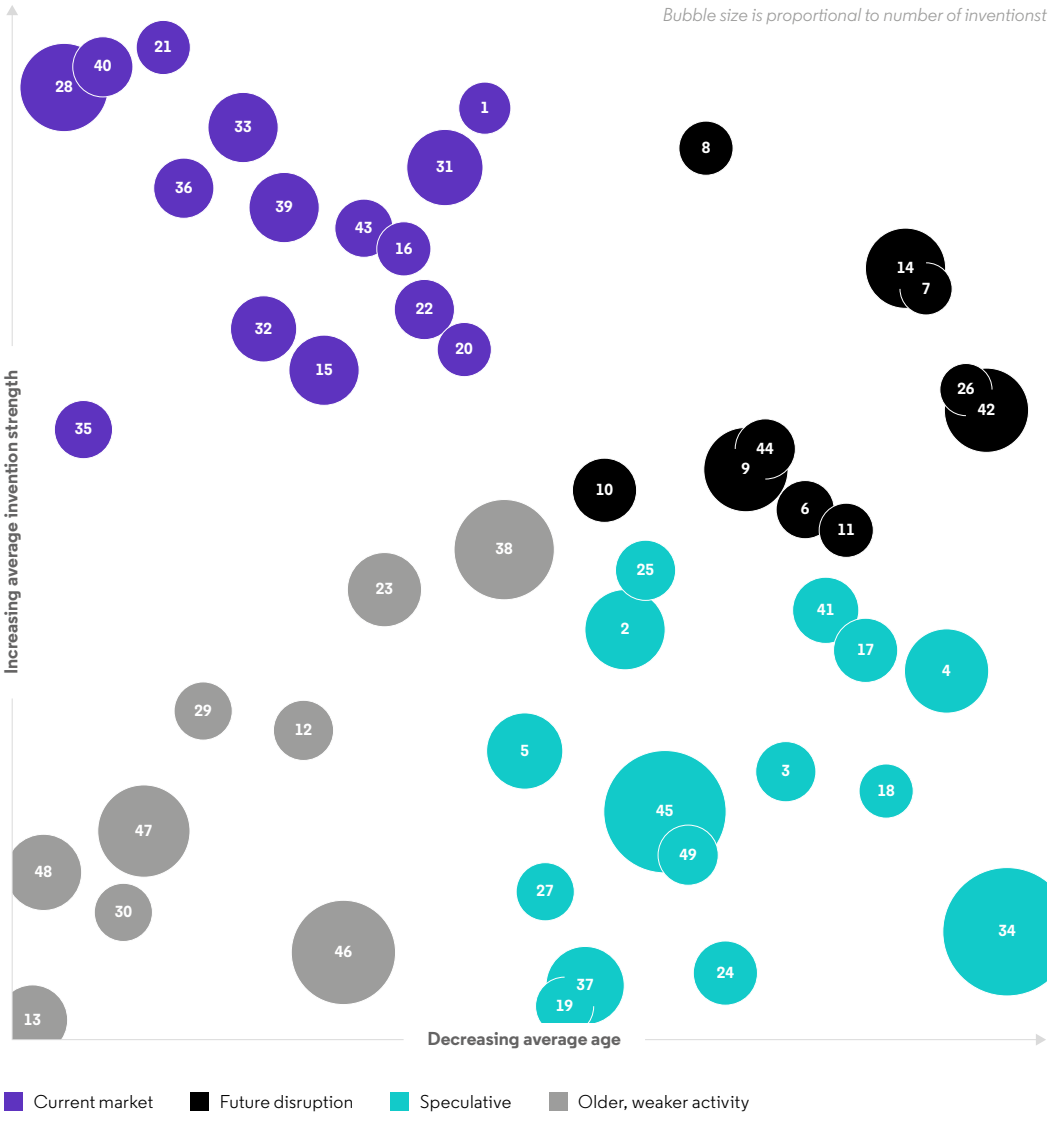

## The importance of coffee

Most patent analyses at some point will show a list of top assignees[10] or organizational applicants as a way of identifying which organizations are expending the most effort or investment into a technical field.

In the case of our food, beverage and cosmetics bioplastics dataset, this approach is not appropriate. First, not all patents or patented inventions are the same. Some are filed in just one country, or filed and not granted, or filed and granted but of limited impact or use. Second, the volumes within our dataset are low, meaning that one or two entities that have filed fifteen or twenty inventions naturally appear at the top.

To understand the commercial dynamics, we must take a more sophisticated and nuanced approach. Instead of a simple ranked list, we review the Top 50 (by volume) entities in the dataset by their rank in terms of average age of activity and by the average invention strength.[11]

**Figure 6:**
Market model for food, beverage or cosmetic bioplastics packaging; average activity invention strength vs average activity age; quadrant analysis based on (from top left, clockwise) stronger-older, stronger-younger, weaker-younger and weaker-older. Source: Derwent World Patents Index.




1. Ahlstrom-Munksjö
2. Anhui Chaohu Nanfang Film
3. Anhui Mengniu Color Printing Pa...
4. Anhui Shuntong Packaging Material
5. BASF
6. Cambridge Scientific Innovations,
7. CHOCAL Aluminumverpackungen
8. CJ CheilJedang
9. Dainippon Printing
10. DIC
11. Ecobag
12. Intellectual Ventures
13. Estee Lauder
14. Footprint
15. GranBio
16. GrupoNabeiro
17. Guanxi University
18. Hefei Zhiyuan Packaging Tech...
19. Hefei Zhonghao New Material
20. Henkel
21. illycaffè
22. Jacobs Douwe Egberts
23. Jiangnan University
24. Jiangsu Daoqin New Materials
25. Jieshou Baojia Packaging Materials
26. Jining Mingsheng New Material
27. Jurong Maoyuan Weaving Factory
28. K-Fee / Kruger Group
29. Kingfa
30. Kunshan Haolida Packing
31. Lavazza
32. MonoSol
33. Nestlé
34. Ningxiang Kaishu Finance Cons...
35. PepsiCo
36. Procter & Gamble
37. Qingdao Baizhong Chemical Tech...
38. South China University of Tech...
39. Starbucks
40. Stora Enso
41. Suzhou Dingli Packaging
42. Taicang Ya'ao Plastic Industry
43. Tetra Laval
44. Tianjin University of Science & Tech...
45. Tongling Founder Plastics Tech...
46. Toppan Printing
47. Toray Industries
48. Wuxi Huangsheng PackingProducts
49. Zhejiang Ocean University
50. Zhuhai Wantong Chemical

This process produces a market model that can be read as a simple 2x2 grid in terms of stronger and weaker, younger and older portfolios.

We have learned over time that these quadrants then map to modes of operation and general dynamics within a technical sector.

Specifically, the top left quadrant (i.e. older, stronger portfolios) maps closely to the way the market is operating at the moment. In other words, entities that have been in the sector for some time and have produced technical intellectual property rights with a good mix of cross-geography, downstream impact and influence, cross-technology applicability and validity/enforcement potential.

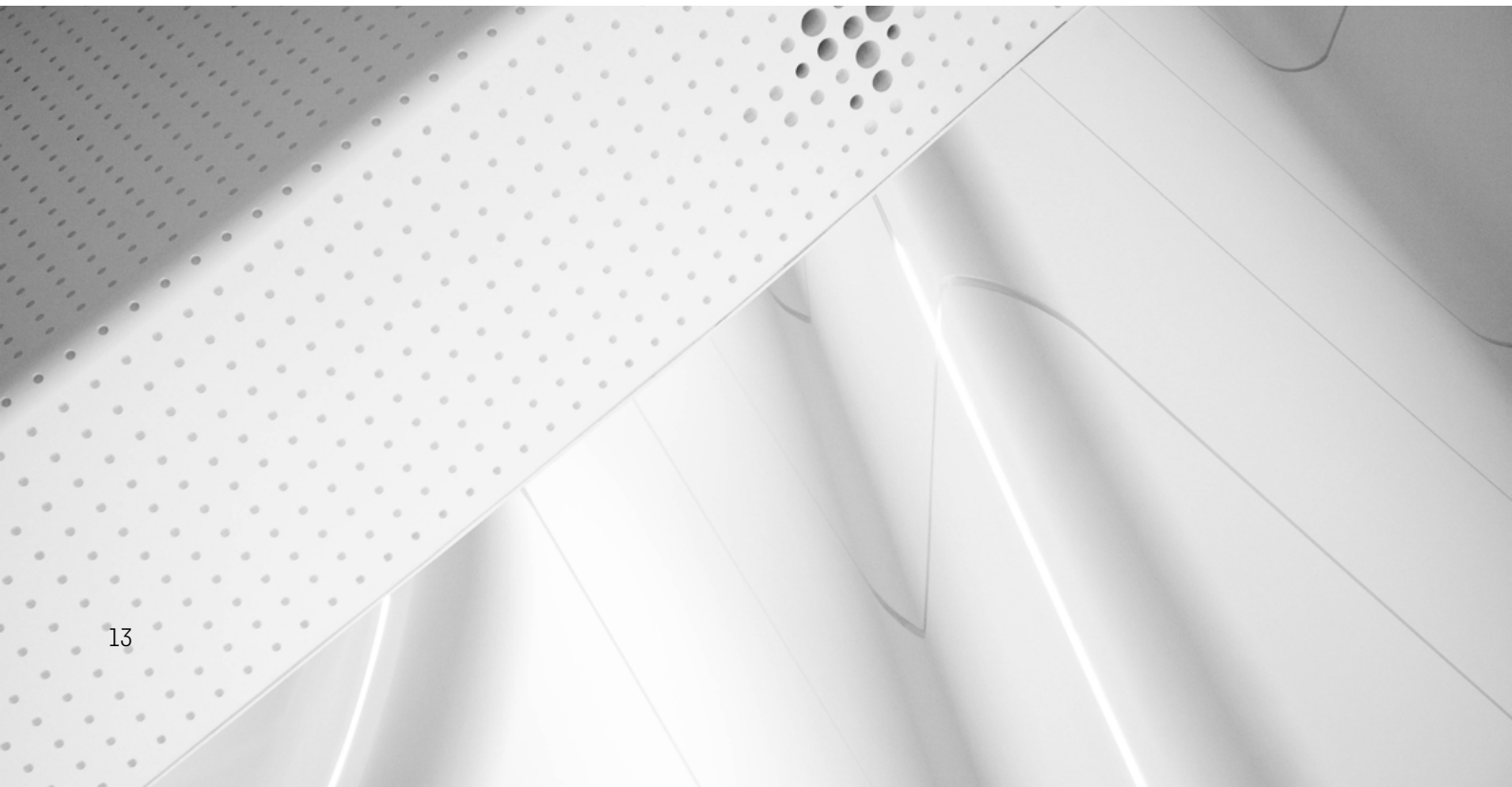
The model provides a clear picture of where bioderived/biodegradable fast-moving consumer goods (FMCG) packaging sits today: coffee. K-Fee, illy, Lavazza, Starbucks, Nestlé and Jacobs Douwe Egberts are all either coffee-specific entities, or have significant coffee businesses. Exploring these companies' activity in more detail via the Derwent World Patents Index™ (DWPI) use field shows that they are specifically focused on inclusion of bioplastics within their single-serving/coffee capsule businesses.

This is logical, as coffee capsules represent a significant waste challenge. They are almost by definition single-use items. Once discharged and used, they are thrown away and unable to be re-used. Further, they are typically mixed-material devices, containing both metal, plastic and potentially paper or adhesive components. The inclusion of many different materials effectively excludes them from recycling waste streams where they act as contaminants[12].

The 'primary active players' quadrant also includes major packaging and materials suppliers within the packaging industry, such as Stora Enso, Tetra Laval and Ahlstrom-Munksjo. We also see other FMCG and more food/cosmetics-oriented firms such as Procter & Gamble, Henkel and Pepsico.

Moving to the top right quadrant (the stronger yet younger portfolios), we profile firms in this space as those that represent potential disruption and change to the current market. Two notable firms here are Footprint, an Arizona, United States start-up founded in 2013 focused on sustainable packaging ($12.4m in funding to date) and CHOCAL Aluminumverpackungen, a family-run firm based near Stuttgart, Germany and traditionally specializing in aluminum foil packaging for chocolate.

Notably, Mainland Chinese and United Kingdom academia are included in the 'potentially disruptive' quadrant, as well as Chinese specialist manufacturing and materials science firms, indicating that these entities are important in the development cycle.



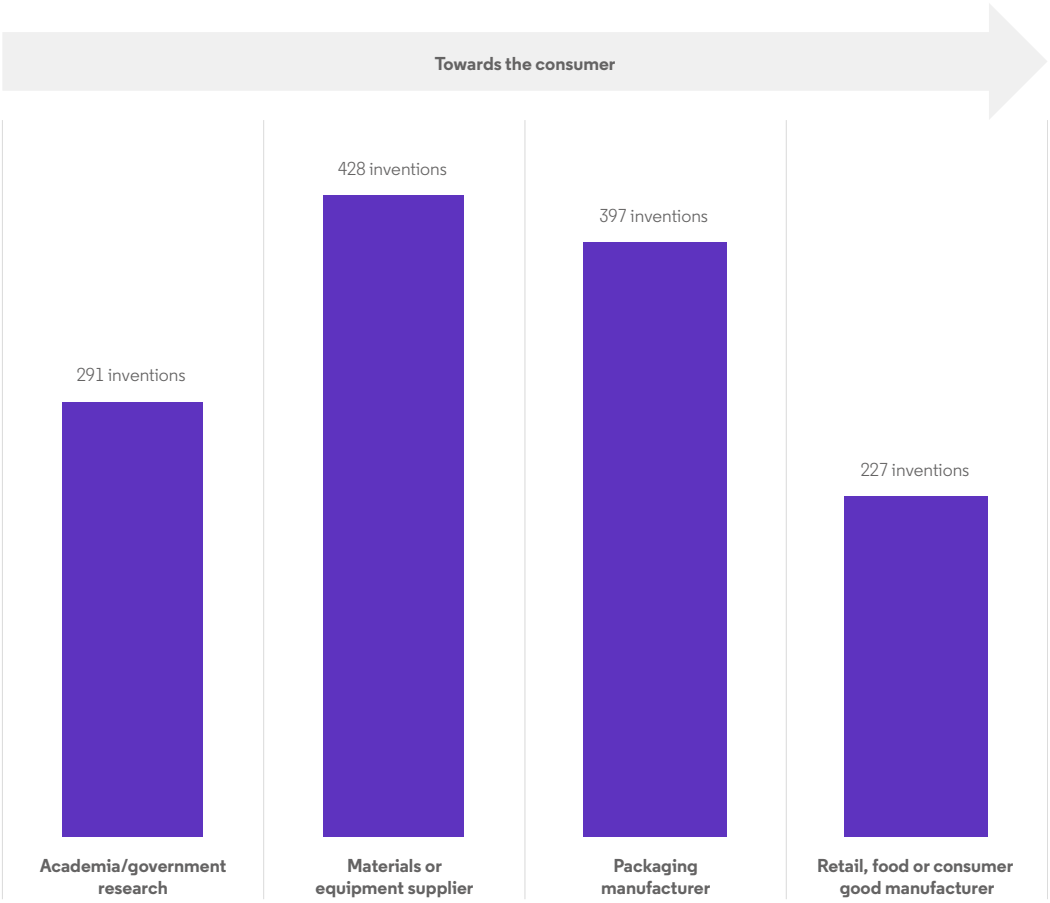
# Immature and ripe for change

The overall dynamic of this innovation profile is spread across the supply chain of packaging – from academia through to FMCG firms performing and patenting research, but selling closest to the consumer and the waste stream that follows.

Categorizing all of the entities in our dataset by their role in this supply chain (academia, materials science, packaging manufacturer, FMCG firm) provides a way of profiling where in the innovation lifecycle bioplastics are in terms of maturity.

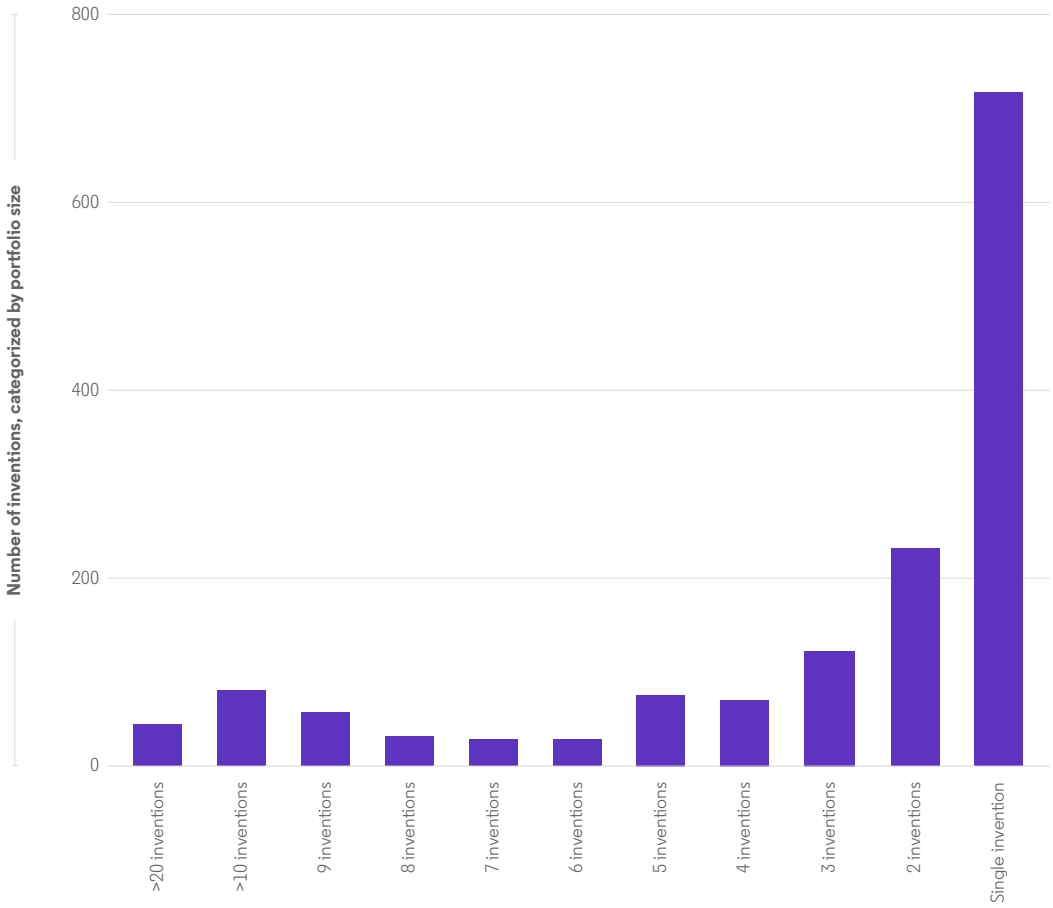
Our analysis shows that the inventive peak is currently occurring within the materials and equipment supply sector – firms such as Toray and BASF – with a secondary peak in the packaging manufacturers. FMCG firms – retailers, food, beverage and cosmetics manufacturers – come last in the volume distribution.

**Figure 7:**
All patent applicants according to Derwent World Patents Index within food, beverage or cosmetics bioplastic packaging categorized by type of entity; excludes those where entity could not be identified by type, or not in supply chain (6.7% of dataset).
Source: Derwent World Patents Index.




Notable all the way through our analysis of the bioplastics packaging dataset is the very high number of entities with just a single invention. Visualizing this brings the bottom-heavy nature of the innovation landscape into clear focus.

**Figure 8:**
Distribution of food, beverage and cosmetics bioplastic packaging by entity portfolio size according to DWPI. Source: Derwent World Patents Index.




40% of all inventions concerning food, beverage or cosmetics bioplastic packaging are held by organizational applicants with just one invention. This is an extreme number, and contrasts to just 7% of the landscape held by entities with 10 or more inventions.

The bottom 854 entities have the same volume of activity as the top 211.

Our conclusion is that this sector is very immature, with no company or entity having a dominant or indeed competitive advantage position over any other. Where immaturity exists, so does opportunity. But if innovation is required on multiple fronts to bring these materials to consumers, what are those fronts and where is the innovation need the greatest?

40% of all inventions concerning food, beverage or cosmetics bioplastic packaging are held by organizational applicants with just one invention.

# The paradox of durability

**A unique aspect of the Derwent World Patents Index database is that every invention is summarized into context-specific text fields, including one that focuses on the benefit or advantage of the invention over previous inventions.**

Applying natural language processing to pre-contextualized information provides a unique analytical entry-point: it tells us where the market is focusing its resources and where it is not. And it does so through the prism of problem solving, rather than generic technical classification.

Within bioplastics, the clear focus is on the mechanical properties of the materials. This is expected. The history of materials such as biodegradable/microbiologically-produced polymers like polyhydroxyalkanoates is typically within very specific use cases, such as dissolving tissue sutures.

Polyhydroxyalkanoates (PHAs) then shifted from industrial use and led to deployment in food waste streams such as municipal composting, where households can dispose of peelings, leftover food or other organic matter. To help collect and dispose of food waste, households needed compostable bags, and PHAs were a good solution. As anyone who has used fully compostable PHA bags will know, possibly from messy experience, they are not very strong. They tear very easily, as the requirement to decompose as easily as possible is in conflict with the need to be durable.

A solution to the 'paradox of durability' – finding materials that do not persist in the natural environment, but are strong enough to work as intended – is one major front of the innovation battle.

**Figure 9:**
Analysis of approaches and benefits mentioned in the DWPI Advantage field for food, beverage or cosmetics bioplastic packaging, mapped as the motivation or benefit behind the invention. Source: Derwent World Patents Index.

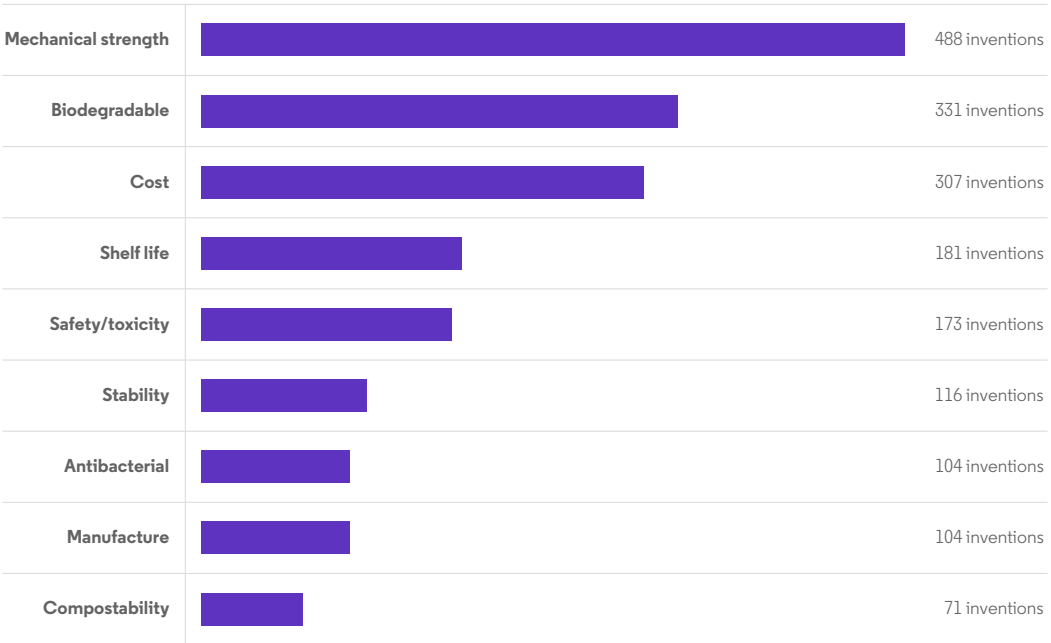


**Figure 10:**
Technical development model for food, beverage or cosmetic bioplastics packaging; average activity invention strength vs average activity age; quadrant analysis based on (from top left, clockwise) stronger-older, stronger-younger, weaker-younger and weaker-older. Source: Derwent World Patents Index.


Another front is cost – these materials need to be producible via economics that are competitive to existing petroleum-based materials, at prices that consumers are willing to pay or ripe for governments to regulate and let the market bear.

The economics of bioplastics production are complex. Not so simple as the cost of manufacture or raw materials, cost planning must include how long the materials will last, what protective benefits they provide to foodstuffs, how they deal with liquids and whether further logistics or expense are needed to maintain FMCG supply chains.

Using the same market model as earlier in this report, but this time focused on the problem/solution categories, provides a way of modelling the technical development phases that have occurred so far in the landscape, and predicting what is likely to occur next.

As seen in Figure 10, the foundational development surrounds the biodegradable nature of the materials themselves and explicit cost factors (lower left quadrant). The first wave of strong IP rights (upper left quadrant) surrounds compostability, manufacture solutions and ensuring stability (mostly around oxidation and water stability).

The current focus of FMCG bioplastic innovation is the mechanical properties of the materials. Notably, it is these solutions that will enable much wider use in consumer applications.

Finally, more nascent technologies are related to specialization of bioplastic packaging as they are deployed to specific applications and uses. For example, how and whether the materials degrade when exposed to moist or short-shelf life foods like meat or fish, how long and whether they change in terms of food safety, and whether it is possible to incorporate aseptic or anti-bacterial properties, or deal with other microbiological factors.

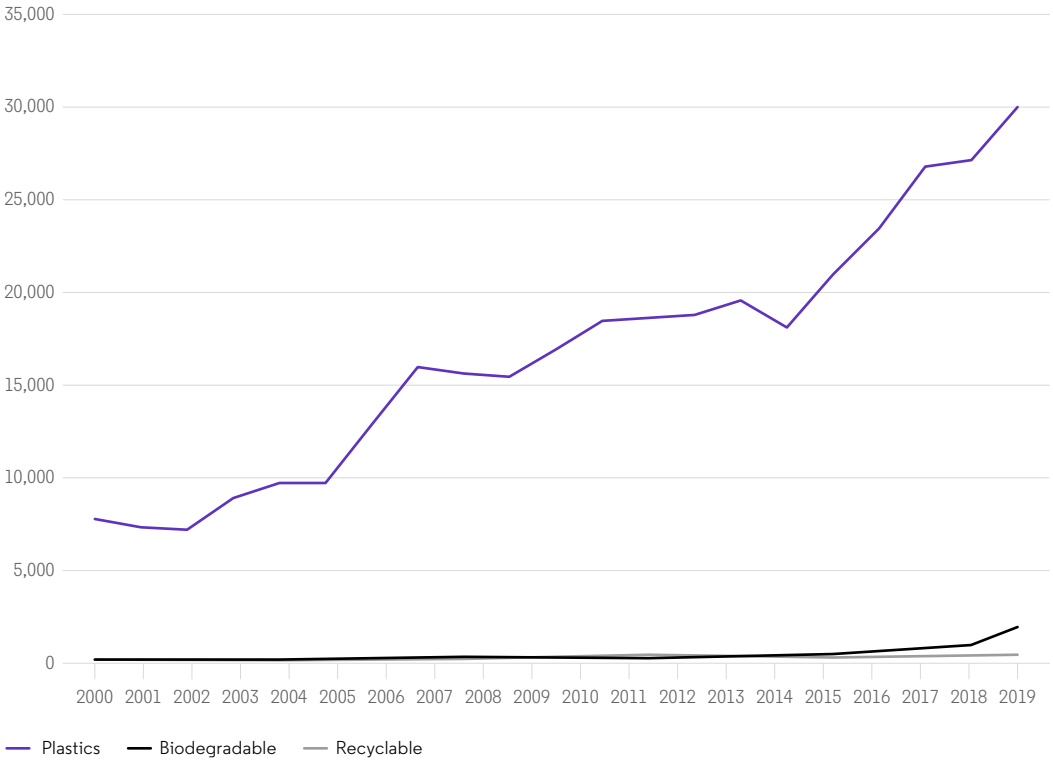
# Trademarks and domains: the commercial aspect

**Since the invention of Bakelite in 1907 (still an active U.S. trademark), synthetic plastics have become a fact of life.**

While consumers have become increasingly aware of the negatives of traditional plastics in recent years, trademark data suggests that companies are still slow to commit to switching to recyclable and biodegradable products.

Looking at trademark applications filed each year at the United States Patent and Trademark Office (USPTO) and the European Union Intellectual Property Office (EUIPO), the term 'plastics' has appeared in ever increasing numbers, while only a very small number of applications describe their product as biodegradable or recyclable.

**Figure 11:** Trademark applications from 2000 to 2019 at the USPTO and EUIPO based on CompuMark's SAEGIS. Source: SAEGIS.



Since 2018, we've seen some positive signs that recyclable/biodegradable products are becoming more important, but the trend is still only a very small part of the overall plastics sector. While consumer sentiment is important in providing visibility to an issue, in our commercial world, money talks. Until bioplastics have a price advantage over traditional plastics, or government incentives (such as deposit schemes, surcharges or taxes on non-recyclable products) are applied, uptake is likely to continue to be slow.

In terms of domains, the internet name space expansion in 2012 saw a number of 'green' or 'eco' top-level domain names (TLDs) become available, such as .BIO, .GREEN, .ORGANIC, .ECO and .SOLAR. These TLDs aim to support companies, industries and individuals working to develop more eco-friendly activities and products, including bioplastics. On the website AllThings.Bio, for example, there is a webpage devoted to articles, videos and educational information on bioplastic product innovation. News briefs feature items such as bioplastic diapers, toys and tableware.

In addition, websites for .GREEN and .ORGANIC showcase other forms of ground-breaking and innovative green technologies. Growing use of these new TLDs shows the expanding market for green and eco-friendly products and technologies that improve the health of our planet.

# Bioplastics: the future

Plastics permeate every aspect of our lives. We cannot deny that the diverse applications of plastics have brought enormous consumer and societal benefits, and will continue to do so. Plastic is also a material that is currently un-matched in its adaptability, malleability and cost-effectiveness. Rather, we must focus on responsible usage and disposal of plastics, while investigating other viable options including bioplastics and a circular plastics economy.

As our report has revealed, bioplastics development and market growth are still nascent. The current innovation focus on bioplastics' mechanical properties is not surprising. The paradox of durability means that bioplastics' mechanical strength will continue to be a focus of inventions. Infrastructural issues, such as the lack of appropriate recycling options and composting facilities for bioplastics, mean that bioplastics are currently as much of a waste problem as plastics. Tellingly, our trademark data underscores how the commercial proposition of bioplastics is not yet attractive. With no dominant player at present, the bioplastics market is still very much up for grabs.

We find that the volume of bioplastics innovation is still lacking in response to the scale of the problem we face.

In 2017, bioplastics packaging only constituted 0.02% of all patent output according to DWPI, compared with 5% for pharmaceuticals (not including bio-tech).

Along with governments, academia and corporations, at Clarivate we can help to provide solutions to the plastic problem by empowering trailblazers in the field of bioplastics to accelerate their pace of innovation.

We must focus on responsible usage and disposal of plastics, while investigating other viable options including bioplastics and a circular plastics economy.

# Plastics and us

## Consumer awakening

In a recent Ipsos global survey[13], almost three quarters (71%) of global consumers want to see single-use plastic banned, and 63% say they were prepared to change where they shop if it meant they would use less packaging.

In South Korea, Gen-Xers and millennials are turning their backs on the country's infamous 10-step beauty routine in favor of buying only the essentials[14]. In the United Kingdom, the broadcast of *Blue Planet II*'s final episode, which included a segment on plastic's impact on marine life, led to an outpouring as people flooded their local Members of Parliament (MPs) and the BBC with calls and emails on how they could play a part in stemming the plastics tide[15].

Environmental organizations too have dedicated resources to address the plastics issue. Greenpeace created a plastics team in 2015. Friends of the Earth's plastic program started in 2016. The Ellen MacArthur Foundation launched the New Plastics Economy initiative in conjunction with a diverse group of stakeholders, embracing a shared vision of a circular economy for plastic[16].

When exactly public opinion towards plastics turned is a source of debate. Some point to the moment when microbeads were brought to consumers' attention in 2015. The following year, a Greenpeace petition, the largest ever environmental petition presented to the United Kingdom government, calling for a nation-wide plastic microbead ban garnered 365,000 signatures in four months. Consumer outrage that plastics were not just a source of litter, but a contaminant in our personal hygiene products, eventually led to countries including France, Sweden, the United States and the United Kingdom banning microplastics in cosmetics and cleansing products.

Suddenly, consumers recognized that plastics, specifically microplastics, were woven into their everyday lives and could inflict significant environmental damage. Plastic, once viewed as a modern convenience, now provoked consumers' ire, leading them to question their plastics consumption habits and the uncomfortable question of disposal.

## Governments' plastics clampdown

Governments are driving change at global, national and regional levels. The Oceans Plastic Charter, spearheaded by Canada with support from the E.U., France, Germany, Italy and the United Kingdom at the G7 summit in June 2018, aims to reduce plastic pollution and support a sustainable approach to plastics management. Today, more than 20 countries and over 50 businesses have signed the Charter[17].

Single-use plastic bags, visible waste scourges to our natural landscape, were the first to be tackled through legislation. Since Bangladesh first banned single-use plastic bags in 2002, albeit with limited success, more than 60 countries around the world have introduced bans and levies to reduce single-use plastic waste. The E.U. has gone a step further, stipulating that all plastic packaging should be reusable or recyclable by 2030[18].

At a national level, governments continue to make progress. Germany's Environment Ministry unveiled a five-point plan to reduce plastic waste. One of the points encourages companies to make packaging and other products more environmentally friendly through new licensing rules, as less environmentally friendly packaging will incur larger fees[19].

The Italian government is also considering a proposed tax on single-use plastic, levying plastic manufacturers €1 for any kilo of plastic product produced, while offering incentives for those who adapt their equipment to incorporate biodegradable materials in production[20].

Japan may be lagging behind in curbing single-use plastic, only requiring supermarkets from July this year to charge shoppers for single-use plastic bags. But a key feature of the Japanese government's plan to tackle the country's plastic waste involves promoting the use of bioplastics. Plastic bags made of at least 25% bioplastic material or marine biodegradable plastic are exempt from the new rule[21].

Reducing waste is only one piece to solving the plastics conundrum. Creating greater opportunities for re-use of existing plastics is another, and global discussions surrounding the circular economy for plastics have gathered steam. Beside the Ellen MacArthur Foundation's New Plastics Economy initiative that aims to ensure plastic never becomes waste, in 2018 the EC adopted a European Strategy for Plastics in a Circular Economy, and bioplastics innovation is included as part of the approach towards a climate neutral economy. According to the World Economic Forum, plastics' short first-use cycle means a $80 to $120 billion loss – equivalent to 95% of plastic packaging's material value – to the global economy[22]. More can certainly be done, not simply by governments, but also with businesses' support to grow the circular economy.

## What next for plastics?

How have businesses responded to public and government pressure on plastics? In 2018, the New Plastics Economy Global Commitment was signed by more than 250 organizations, and this has since grown to over 450. A diverse group that included well-known consumer brand names such as clothing company H&M, food and beverage giant Nestle, major packaging producer Amcor and plastic packaging producer Novamont. They committed to working towards 100% reusable, recyclable or compostable plastic packaging by 2025, with targets to be reviewed every 18 months[23].

As Dame MacArthur, whose foundation leads the Global Commitment, succinctly put,

**"We know that cleaning up plastics from our beaches and oceans is vital, but this does not stop the tide of plastic entering the oceans each year. We need to move upstream to the source of the flow."**

With commitment, action and collaboration, consumers, governments, businesses and non-governmental organizations can work towards a sustainable future, where plastics – both synthetic and bio-based – remain an important societal and economic contributor.

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    i. Frequency of citation, referencing impact of the technical invention

    ii. The breadth of geographic filing, correlating to variation in cost and investment in patent protection

    iii. Existence and location of granted, issued patent rights, a proxy for validity as well as commitment

    iv. The invention's technical breadth, correlating to the range of industry which the invention maps on In addition, the Strength Index also models the value of inventions over time as well as weighting for factors that accrue over time, e.g. existence granted patent rights.

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Contact our experts today:

**+1 215 386 0100 (U.S.)**
**+44 (0) 20 7433 4000 (Europe)**

**clarivate.com**