October 2021

Plastics – an obvious problem with no obvious solution

Key innovators in biodegradable alternatives

1950 is not that long ago, it depends on your perspective. Many of the world leaders, top executives and leading thinkers are men and women that were born in the 50s. And over the course of their lives we have produced mega-volumes of plastic to support demand from both consumers and industry. By some estimates at least 8 billion metric tons since 1950, most of which has ended up in landfill or as detritus scattered across the natural world. At current production rates there will be around 12 billion metric tons of plastic circulating in the planet's ecosystem by 2050. That's 35,000 times as heavy as the Empire State building or think of it another way, consider it a time when our oceans may have more plastic than fish.

Challenges associated with reducing the environmental impact include plastic's high resilience, some plastics can take more than 400 years to decompose. Recycling often seen as a solution continues to be wholly ineffective due to a combination of factors including a lack of recycling infrastructure, cost, inaction, social attitudes and competing regulatory priorities to name a few. Of the 8 plus billion tons that has been produced to date, estimates are that no more than 10% has been recycled.

Another phenomenon that goes hand in hand with the plastic problem is the usage of adhesives in industrial production. Just like plastics, adhesives are synthetic polymers and are widely use in assembly of all sorts of products. About 40 kg of adhesive sealants are needed for assembling the typical car and many consumer products we purchase today are put together, in one way or another, with the use of adhesives.

We take a look here at innovation trends across biodegradable plastic and adhesives. Who are the key players? Which countries are leading innovation? And what are the challenges for biodegradable materials in becoming an alternative to their conventional crude oil-based counterparts?

Key Messages:

- Biodegradable plastic & adhesive has not become an alternative to conventional petroleum-based options, representing only about one percent of the 368 million tons produced annually. Innovation in biodegradable alternatives appears to have stagnated since 2014, as measured by the pace of invention from published patent data.

- The German chemical company BASF is the leading innovator in the US and European market for biodegradable plastics & adhesives.

- The majority of plastic waste still finds its way to dumping grounds in Asia. China is acknowledging the importance of biodegradable alternatives and is leading innovation in both biodegradable plastics & adhesives.

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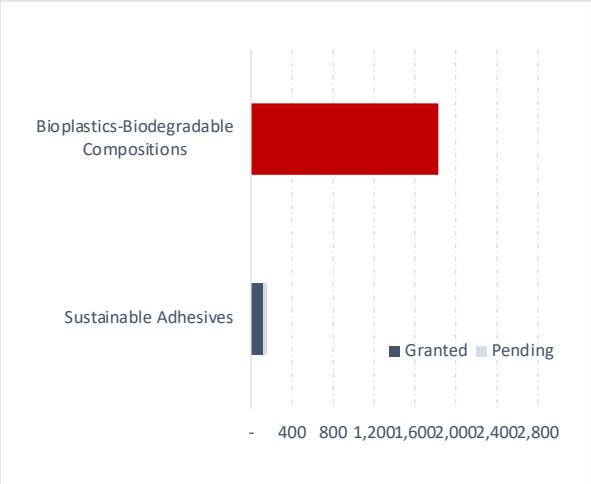
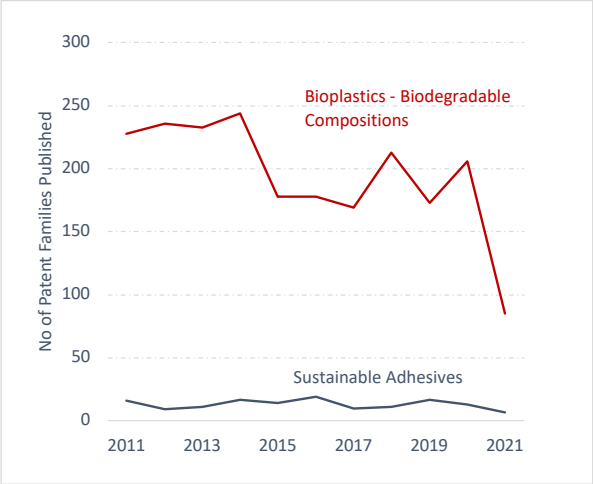
The unsettling trend – biodegradable compositions show a negative invention trend since 2014

Research into alternative biodegradable plastics and adhesives attracted significant interest and investment in the first decade of the 2000s. However, the pace of invention has stagnated over recent years.

Number of Inventions: *US & Europe*



Pace of Invention: *US & Europe*



As measured by patent families either granted or pending in US and Europe

A general misconception of biodegradable plastics and adhesives is that they are made from materials with natural origins, such as plants, animals, or micro-organisms and can be quickly degradable in natural environment. There are in fact two main different types of biodegradable plastics: petroleum-based and bio-based.

Petroleum-based biodegradable plastics

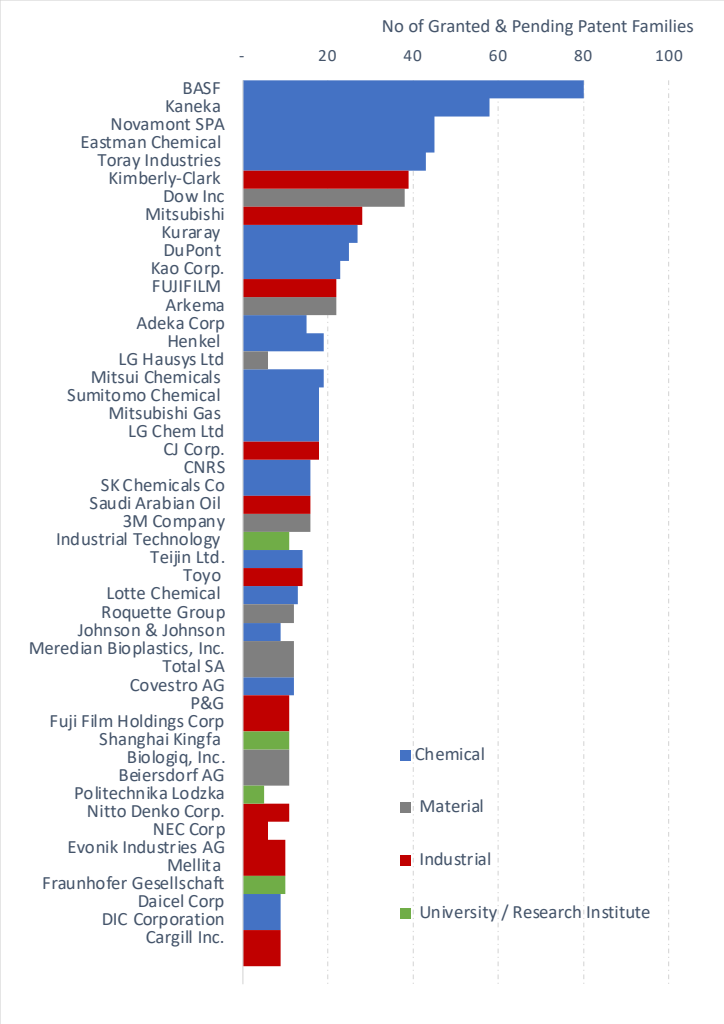
There have been significant efforts in recent decades with developing biodegradable plastics that degrade at speed in the natural environment. For example, oxo-degradable plastics are one of the petroleum-based plastic materials that are commonly promoted as biodegradable. In reality these are conventional plastics such as PE, PP, PET, but that contain additives which accelerate the oxidation process. The major issue with these types of petroleum-based plastics is that they rapidly fragment into huge quantities of microplastics when exposed to sunlight and oxygen. While this speeds-up the degradation process, making large plastic items disappear, the microplastics generated still cause the exact same problem to the ecosystem as conventional plastics. Moreover, not only are these plastics more expensive because they are promoted as biodegradable, the products made from them are also much less durable and have a shorter usable life which has the effect of just generating greater volumes of plastic waste. In consideration of this phenomenon, it is not hard to understand why the market was not so sure about investing in this more expensive, less durable and equally environmentally damaging alternative.

Bio- based biodegradable plastics

For those plastics that are considered truly biodegradable, the biodegradability of the final product is not solely determined by the properties of its polymers. It is also determined by additives that are incorporated in the final resins to achieve the desired plastic properties. In addition, due to the expensive and unstable nature of the raw materials which include recycled resins and agricultural byproducts, bio-based biodegradable plastic and adhesive have not gone mainstream. Bioplastics represent only about one percent of the more than 368 million tons of plastic produced annually.

BASF – The leading inventor in biodegradable plastics

The Companies: *Number of Inventions Owned Bioplastic-Biodegradable Compositions.*



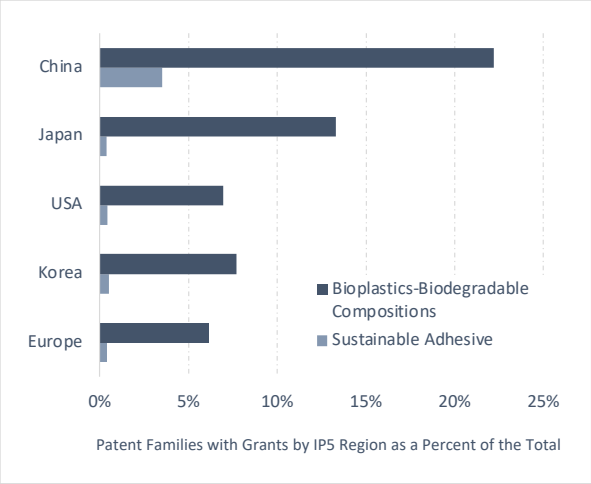
BASF, the German multinational chemical company headquartered out of Ludwigshafen, is one of the largest and oldest chemical producers in the world operating for over 150 years. As one of the industry leaders, BASF recognized early the importance of biodegradable plastic substitutes and invested in research and development across petroleum and bio based biodegradable plastics such as ecoflex® also known as polybutylene adipate terephthalate (PBAT) and polylactic acid (PLA). Today BASF owns the most active patent families in biodegradable compositions with grants covering the core US and European markets. BASF has partnered with a number of companies to develop biodegradable alternatives. This includes a 2019 agreement with French company Lactips and a 2020 agreement with Red Avenue New Materials Group in China.

BASF's strategic decisions on biodegradable research and innovation, which is still divided between bio-based and petroleum-based, is a recognition by this innovation leader of the challenges associated with the bio-based plastic alternative as a single solution.

An expected acceleration of new regulations enforcing the use of truly biodegradable plastics positions BASF in a favorable position to take advantage of changing supply dynamics that are underway.

Global Trends – Asia recognises the importance of innovating and developing biodegradable plastics & adhesive alternatives

Geographies protected



It is a well understood fact that Asian countries generate large quantities of plastic waste, but have also been used as a dumping ground by way of waste imports from the US and Europe in particular.

Asian governments and communities are better recognising the severity that plastic and adhesive waste has on their environment. In addition to pushing back firmly against waste imports to their countries there has been significant investement in alternatives by Asia based organisations. China, Japan, and Korea together account for 43% of the global biodegradable composition inventions, followed by the US, Europe and rest of the world.

Global Efforts: regulatory activity supports and is enforcing the wider adoption of bioplastic and sustainable adhesive alternatives

2019 UN Environment Assembly, Nairobi: 70 nations pledged to "significantly reduce" the use of plastic by 2030. And many have already started by proposing or imposing regulations on single-use plastics.

- **United Kingdom** – introduced a tax on plastic bags in 2015 and banned the sale in 2018 of products containing microbeads, like shower gels and face scrubs. A ban on supplying plastic straws, stirrers and cotton buds recently came into force in England.
- **The European Union** – issued the ban of single-use plastic items such as straws, forks, knives and cotton buds in 2021.
- **United States** – New York, California and Hawaii are among states to have banned single-use plastic bags, though there is no federal ban.
- **China** – has announced a plan to ban non-degradable bags in all cities and towns by 2022. On January 1, 2021, a plastic ban took effect in China that prohibits restaurants throughout the country from providing single-use plastic straws and stores in the major cities from providing plastic shopping bags.
- **India** – instead of a proposed nationwide ban on plastic bags, cups and straws, states are being asked to enforce existing rules on the storage, manufacture and use of some single-use plastics.
- **Kenya** – banned single-use plastic bags in 2017 and, starting June 2019, prohibited visitors from taking single-use plastics into national parks and conservation areas.
- **Zimbabwe** – introduced a ban on polystyrene food containers in 2017, with fines of between $30 to $5,000 for anyone breaking the rules.

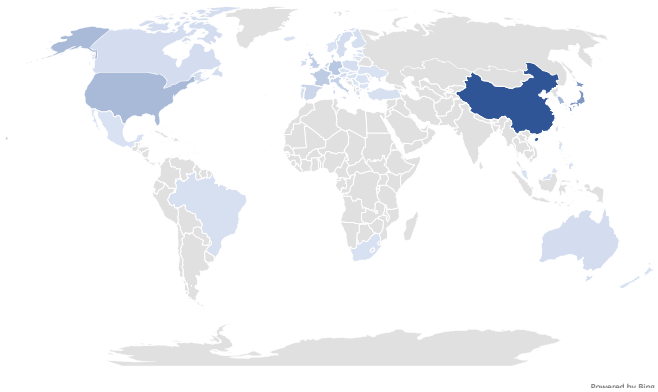
For reference & attached: Innovation Lens Snapshots

- *Technology Screening: Bioplastics-Biodegradable Compositions and Sustainable Adhesives*
- *Company Screening: Bioplastics-Biodegradable Compositions – Top Owners*
- *Company Snapshot: BASF– Bioplastics-Biodegradable Compositions and Sustainable Adhesives*

Technology Screening: *Bioplastics-Biodegradable Compositions & Sustainable Adhesives*

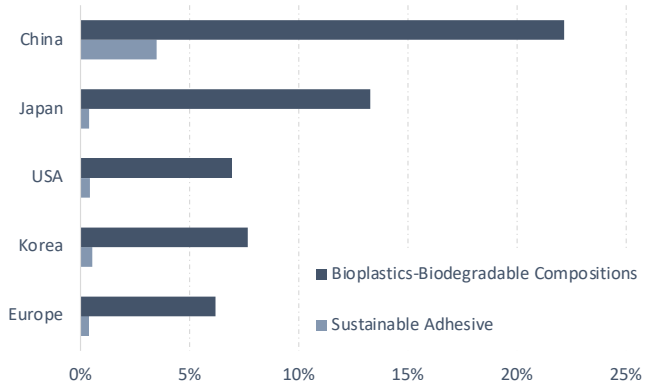
Technology Areas: *Bioplastics-Biodegradable Compositions*
Sustainable Adhesives

Geographies Protected: *By Country across all 2 Tech Areas*



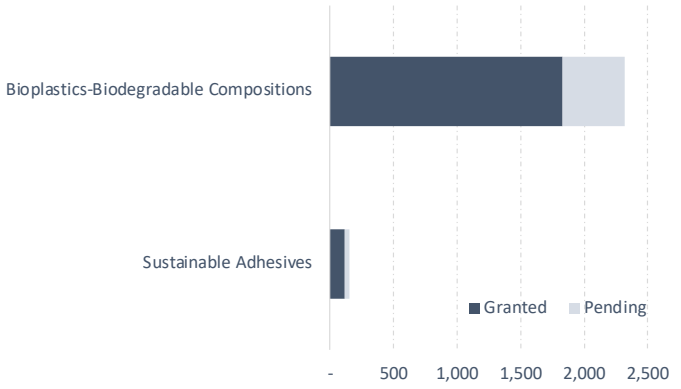
Patent Families with Grants by Country as a Percent of the Total Granted Families

Geographies Protected: *By Key Region / Countries*



Patent Families with Grants by IP5 Region as a Percent of the Total Granted Families

Number of Inventions: *US & Europe*



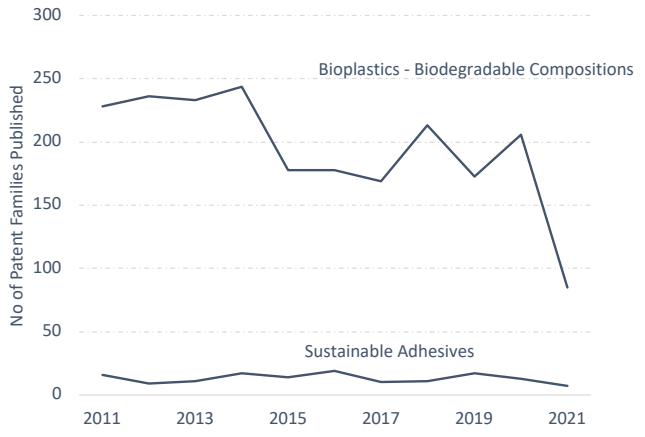
No. of Patent Families with grants / applications in the US / Europe

Companies: *Top ranked by Inventions owned, US & Europe*

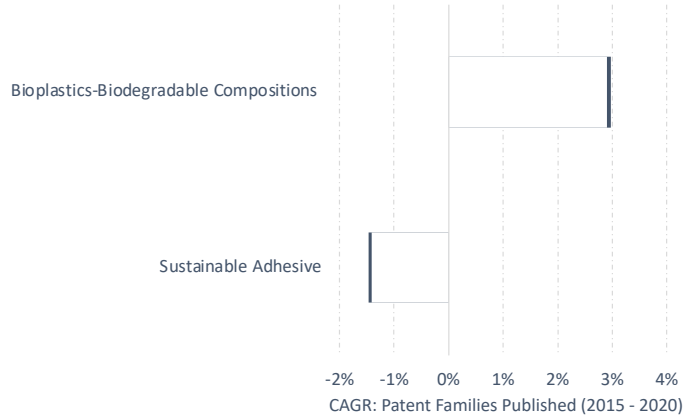
Rank	Sustainable Adhesive	Biodegradable Plastic
1	Novamont SPA	Novamont SPA
2	BASF	BASF
3	Eastman Chemical	Eastman Chemical
4	Kaneka	Kaneka
5	Mitsubishi	Mitsubishi
6	Dow Inc	Dow Inc
7	Kuraray	Kuraray
8	Toray Industries	Toray Industries
9	Mellita	Mellita
10	Kimberly-Clark	Kimberly-Clark
11	Henkel	Henkel
12	SK Chemicals Co	SK Chemicals Co
13	Arkema	Arkema
14	Shanghai Kingfa	Shanghai Kingfa
15	DuPont	DuPont

Top Owners of Patent Families with grants / applications in the US / Europe

Pace of Invention: *Trendlines, US & Europe*



Pace of Invention: *CAGR 2015-2020, US & Europe*

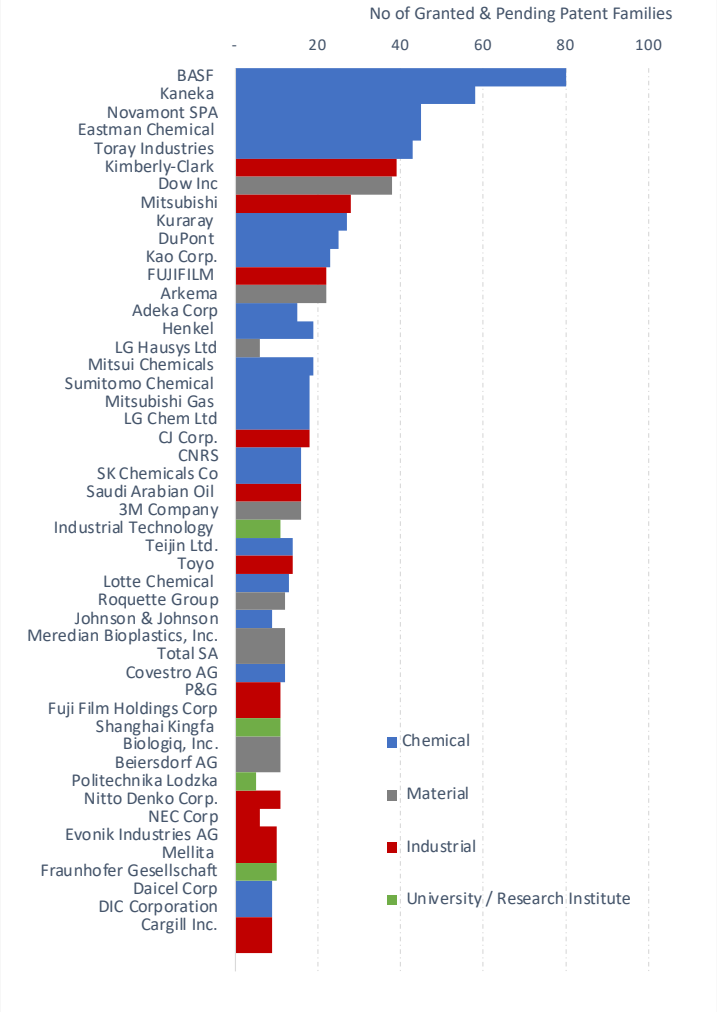


CAGR: Patent Families Published (2015 - 2020)

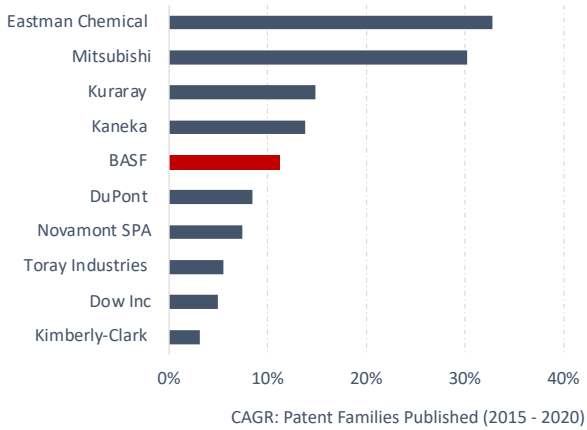
Company Screening: *Bioplastics-Biodegradable Compositions*

Technology Area: *Bioplastics-Biodegradable Compositions*
Region: **US & Europe** *granted/pending patent families (inventions)*

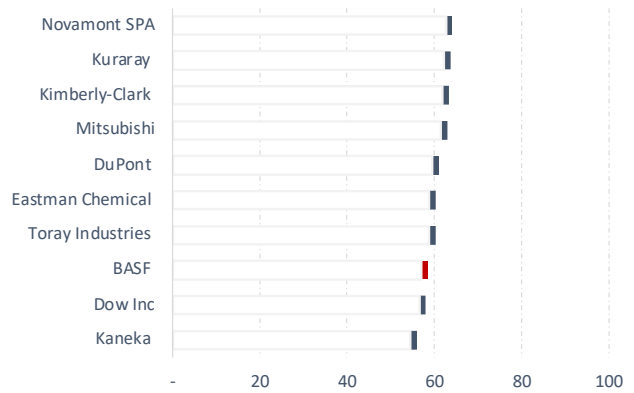
Companies: *No of Inventions Owned, Biodegradable Compositions*



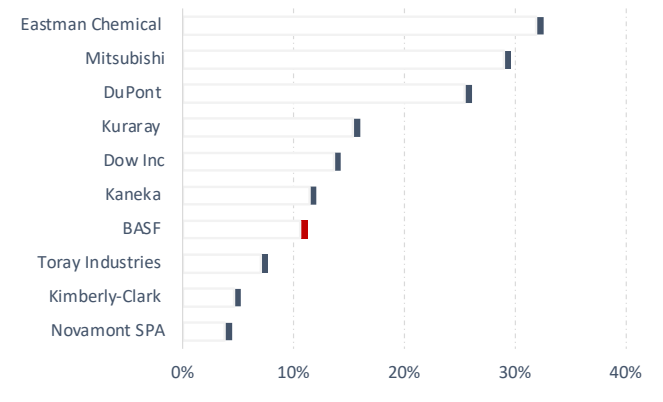
Pace of Invention: *CAGR 2015-2020, Biodegradable Compositions*



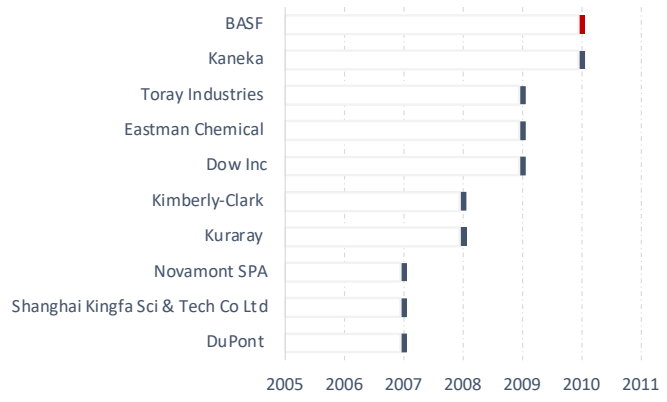
Quality of Invention: *Biodegradable Compositions*



Invention Pipeline: *Biodegradable Compositions*



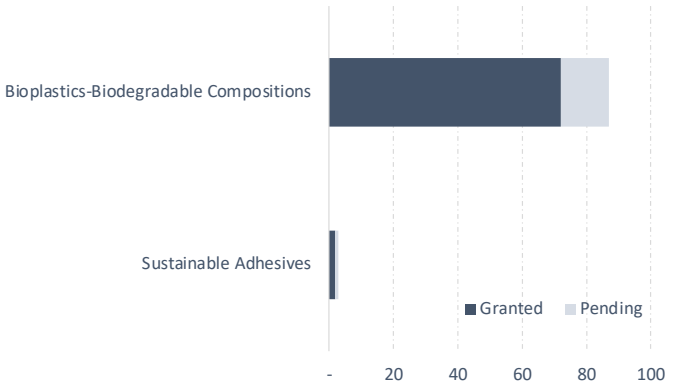
Invention Age: *Biodegradable Compositions (First Filing Date)*



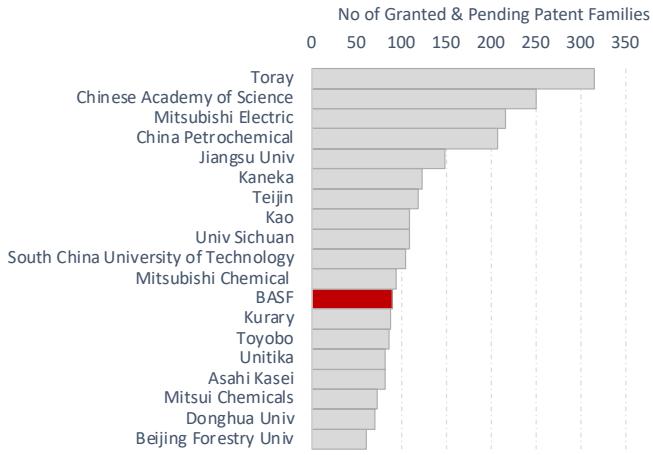
Company Snapshot: BASF Bioplastics & Sustainable Adhesives

Technology Areas: **Bioplastics-Biodegradable Compositions**
Sustainable Adhesives
Region: **Global** *all granted/pending patent families (inventions)*

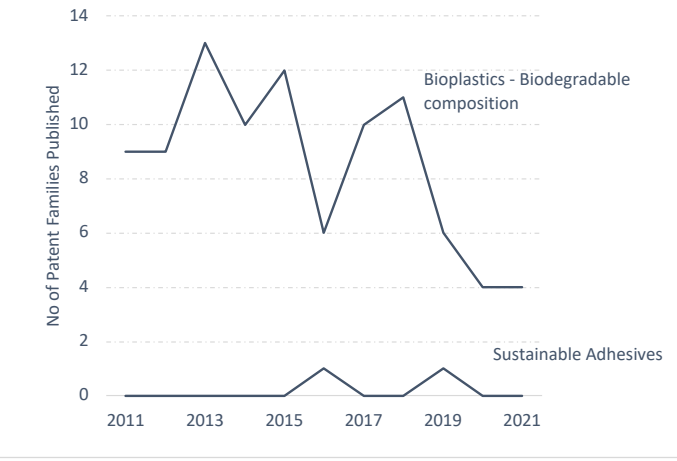
Number of Inventions: *BASF*



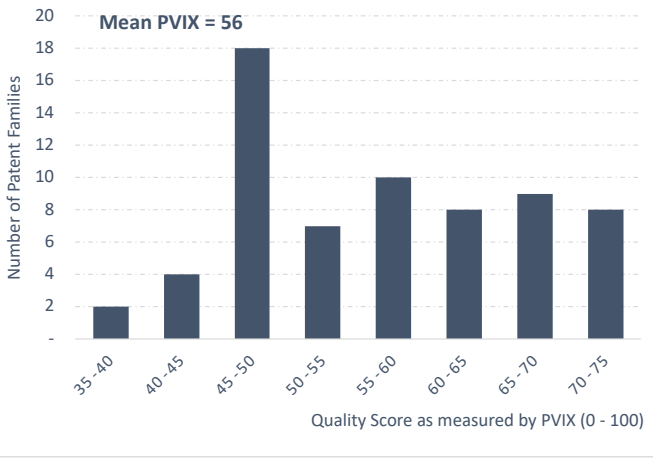
Companies: *Number of Inventions Owned*



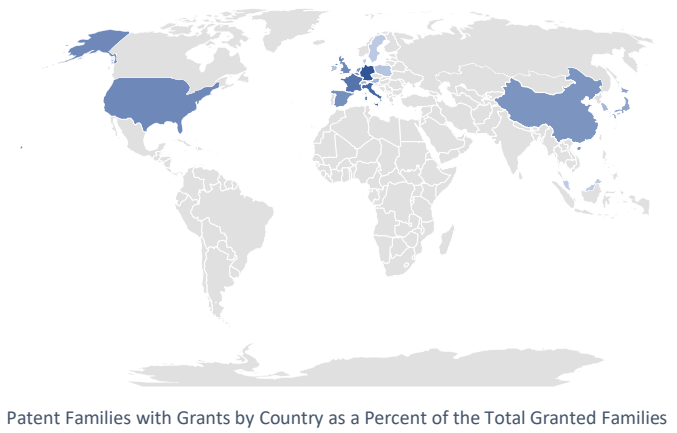
Pace of Invention: *BASF*



Quality of the Inventions: *BASF*



Geographies Protected: *BASF*



Invention Age: *BASF (Expiry Date)*