

Sustainable Materials

 Technology
Trend Report

 **YTU** TECHNOLOGY
TRANSFER OFFICE

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TECHNOPARK

This report is prepared by the experts of
**YILDIZ TECHNICAL UNIVERSITY
TECHNOLOGY TRANSFER OFFICE**

based on the data generated from scanning patent databases for patent applications filed in a specific date interval. The data, assessments and statistics in this report are prepared inline with the publicly available datasources as well as the documents published at the time of preparation of this report.



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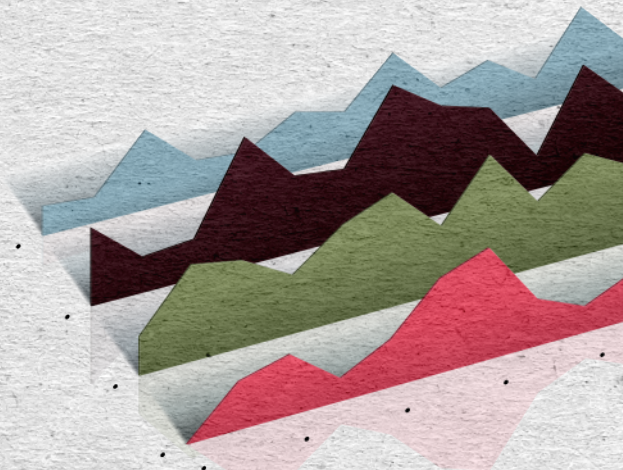
TECHNOLOGY TREND REPORT

WHAT IS A TECHNOLOGY TREND REPORT?

The Technology Trend Report aims to provide information on the inventions, recent developments and market conditions in a specific scientific or technical area as a guide for academic studies, research and development efforts, and innovative business ideas. It aims to determine the technological developments and the state of the market in said specific area, thereby contributing to keeping up with the technology trends.

HOW IS THE TECHNOLOGY TREND REPORT PREPARED?

Technology Trend Report is prepared based on the outputs obtained by filtering the patent document data on the global patent databases with combinations of international patent classifications (IPC) and/or certain keywords. Moreover, import-export figures, global market size and other similar data regarding the products and services in a given technology area are analyzed.



WHAT IS THE INTERNATIONAL PATENT CLASSIFICATION (IPC)?

international patent classification is a hierarchical system for the classification of the patents and utility models of inventions based on the different areas of technology to which they pertain, as well as subgroups and more specific technical areas.

[Source: WIPO Guide to the International Patent Classification (2024)]

The international patent classifications can be accessed using this link
<https://www.wipo.int/classifications/ipc/en/>

WHAT DO PATENT STATISTICS INDICATE?

Patent statistics can be useful for understanding whether the technology in question is current or not, and for drawing conclusions about the market potential of the technology. Patents are considered industrial property, and therefore commercial instruments. Usually, patent protection is requested to have a competitive advantage in the market and to have protection against being copied or imitated by

rival companies in order to make a profit. In this context, the course of patent applications, distribution of the companies that filed patent applications, and the monetary value of the patents can indicate the direction of ongoing innovation efforts in a given technology area and the commercial potential of the innovations.

PREFACE

Sustainable materials technology is increasingly becoming a cornerstone of modern innovation, driven by the need to address environmental challenges such as climate change, resource depletion, and pollution. The trend encompasses a wide range of materials designed to reduce environmental impact throughout their lifecycle, from sourcing and production to use and disposal. Key innovations in this space include biodegradable plastics, plant-based alternatives to conventional materials, and the development of high-performance, durable materials from renewable resources.

These innovations are being fueled by advances in material science, biotechnology, and recycling technologies. Largely, the trend toward sustainable materials technology is characterized by a multidisciplinary approach, integrating advancements in material science, environmental science, and engineering. This trend is not only reshaping traditional industries like construction, packaging, and textiles but is also opening up new opportunities for innovation in fields such as electronics, automotive, and consumer goods.

As regulations around environmental impact tighten and consumer preferences shift toward sustainability, the momentum behind sustainable materials technology is expected to grow, driving further advancements and widespread adoption across industries.

Some most recent trends in sustainable materials:

In a recent innovation within sustainable materials, Eco Materials Technologies (EMT) has introduced groundbreaking advancements in eco-friendly

construction. EMT focuses on transforming fly ash—a byproduct of coal combustion—into a key component of sustainable cement. This innovation not only reduces CO2 emissions but also addresses global cement shortages by promoting circular economy principles. EMT's goal is to significantly cut greenhouse gas emissions by 2030, positioning their sustainable cement solutions as a pivotal development in the green building sector.

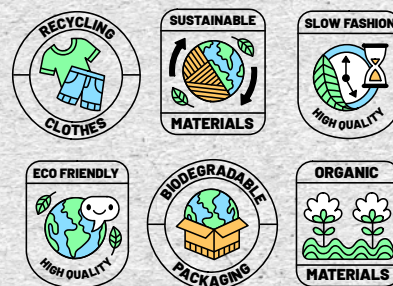
Volkswagen has introduced an innovative and sustainable material for car interiors: leather made from industrial hemp. This eco-friendly alternative to traditional leather reduces environmental impact. Hemp leather is durable, versatile, and significantly reduces resource consumption in the manufacturing process. As part of the company's broader sustainability initiatives, this development aligns with their goal of creating greener, more sustainable vehicles for the future.

Further innovation on sustainable materials includes fluoropolymers gaining attention for their role in eco-friendly manufacturing. Known for their durability and chemical resistance, fluoropolymers are being used across industries like renewable energy, automotive, and construction to enhance sustainability. By reducing environmental impact and supporting greener production processes, fluoropolymers are helping drive the shift toward a more sustainable industrial future.

RESEARCH

1- KEYWORDS

Some of the keywords used in the search and analysis process of the sustainable materials include “sustainable materials,” “sustainability,” “renewable resources,” “biodegradable,” “recycling” and high-level terminologies thereof.



2- INTERNATIONAL PATENT CLASSIFICATIONS & COOPERATIVE PATENT CLASSIFICATIONS

Class	Description
B09	DISPOSAL OF SOLID WASTE; RECLAMATION OF CONTAMINATED SOIL
Y02W	Climate change mitigation technologies related to wastewater treatment or waste management
Y02W90/10	Bio-packaging, e.g. Packing containers made from renewable resources or bio-plastics
Y02E	Reduction of greenhouse gas [ghg] emissions, related to energy generation, transmission or distribution
Y02P	Climate change mitigation technologies in the production or processing of goods
Y02P80/10	Efficient use of energy, e.g. Using compressed air or pressurized fluid as energy carrier
Y02A	Technologies for adaptation to climate change
C08L	Compositions of macromolecular compounds
C08L1/02	Cellulose; modified cellulose
C07C	Acyclic or carbocyclic compounds
Y02B	Climate change mitigation technologies related to buildings, e.g. Housing, house appliances or related end-user applications
Y02B10/00	Integration of renewable energy sources in buildings
A61K31/00	Medicinal preparations containing organic active ingredients
B32B	Layered products, i.e. Products built-up of strata of flat or non-flat, e.g. Cellular or honeycomb, form
A23K20/10	Organic substances
B29B	Preparation or pretreatment of the material to be shaped; making granules or preforms; recovery of plastics or other constituents of waste material containing plastics
Y02T	Climate change mitigation technologies related to transportation

PATENT STATISTICS (2013-2024)

1. APPLICATION TRENDS BY YEARS

Chart 1 and 2 below shows the trend of patent applications filed on Sustainable materials that were filed between 2013–2024. It may be observed that the annual average number of patent applications filed per year is 354 and the average number of

patents granted per year is 117. Since the applications filed in 2023 and 2024 may not yet be published, the filing count is seen to be low in respective years.

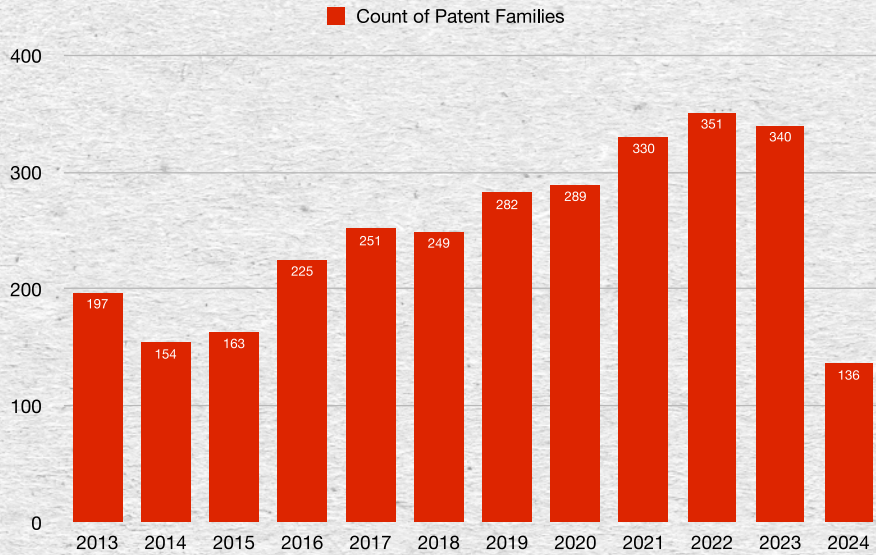


Chart 1: Number of Patent applications filed between 2013 and 2024

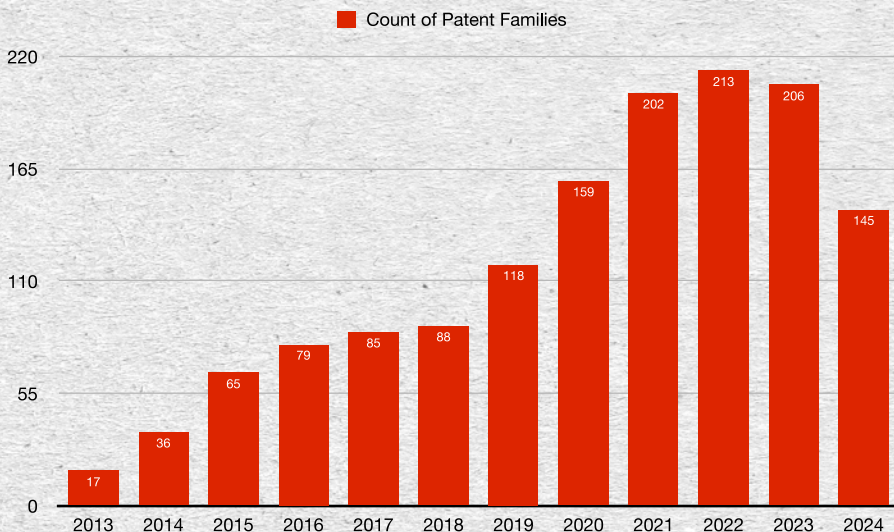


Chart 2: Number of Patents granted between 2013 and 2024

2. APPLICATION TRENDS BY ASSIGNEES AND COUNTRIES

As it can be seen from Chart 3, China has the highest number of patent filings between 2013 and 2024. China is followed by India and the US. Chart 4 shows assignees with large number of filings between 2013 and 2024, where the Saveetha institute of medical &

technical sciences tops the chart. Chart 5 shows the top 10 countries with the number of patent applications by years for the purposes of assessing the innovation capacities of said countries.

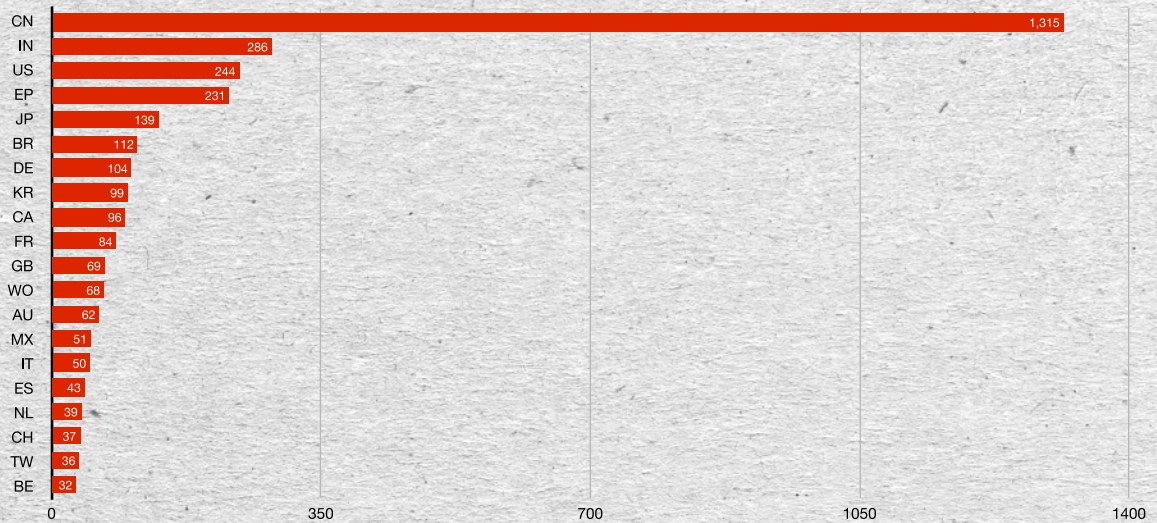


Chart 3: Countries with highest numbers of patent applications filed between 2013 and 2024

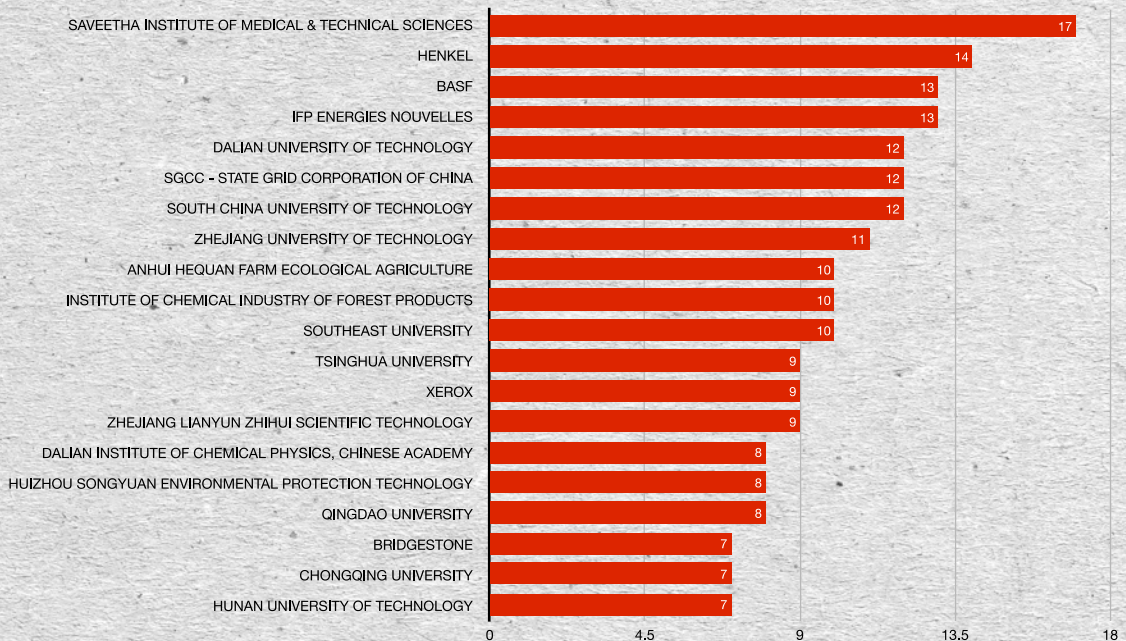


Chart 4: Assignees with highest numbers of patent applications filed between 2013 and 2024

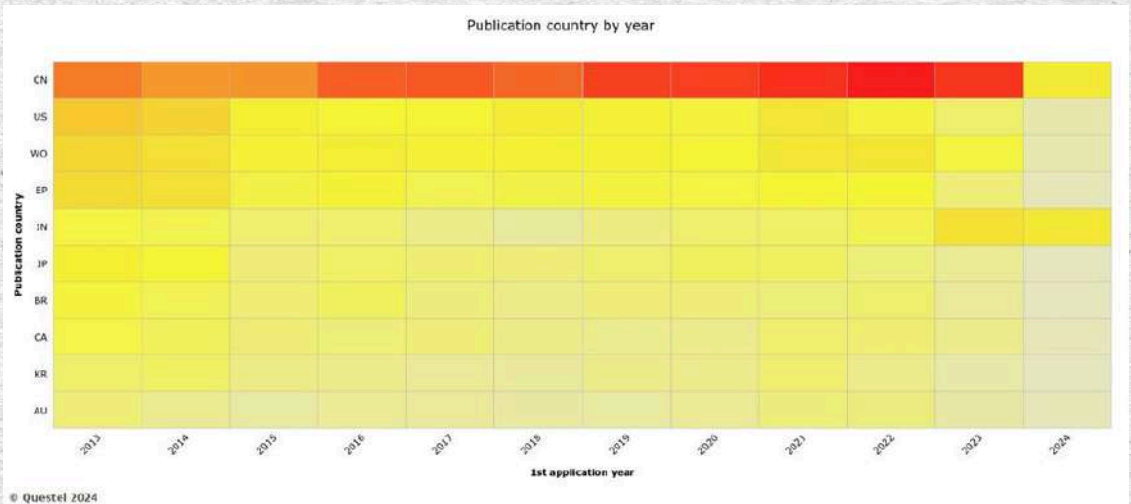


Chart 5: Top 10 countries with the number of patent applications between 2013 and 2024

Chart 6 shows the current legal status of the patent applications of the assignees filed between 2013 and 2024, wherein the legal status include active, pending and dead. Although, the assignee Saveetha

Institute has highest number of filings, the grant rate is seen to be zero. This chart explicitly shows the value of the assignee's patent portfolio.

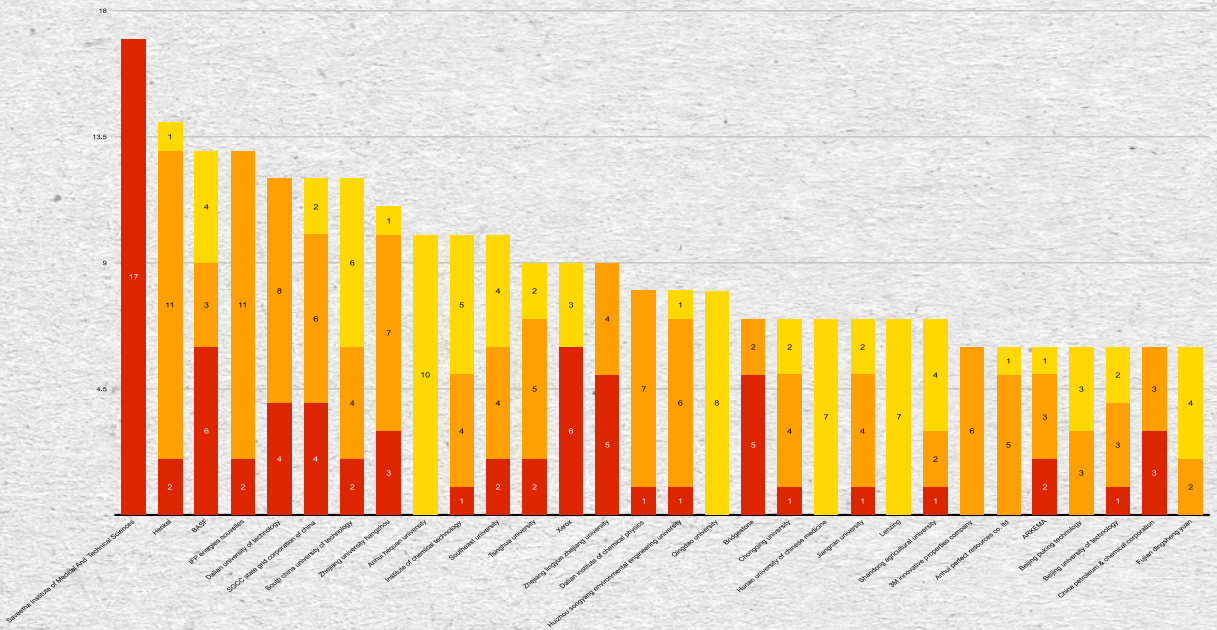


Chart 6: Assignee by legal status between 2013 and 2024

3. APPLICATION TRENDS BY TECHNOLOGY

IPC/CPC are the patent classification codes assigned to every patent application on the basis of their field of technology. This code help identify the scope of the patent application. Each technology class have multiple sub technical domains. Based on the keyword search on the applications filed between 2013 and 2024, it may be observed that the applications are concentrated in the field of

Macromolecular chemistry, polymers, polysaccharides and rubber. Chart 7 shows the sub technical domain of the patent applications filed to better demonstrate the alternative applications of the technology and asses the openings and potential opportunities in terms of commercialization. Chart 8 shows the patent applications about these technologies by years between 2013 and 2024.

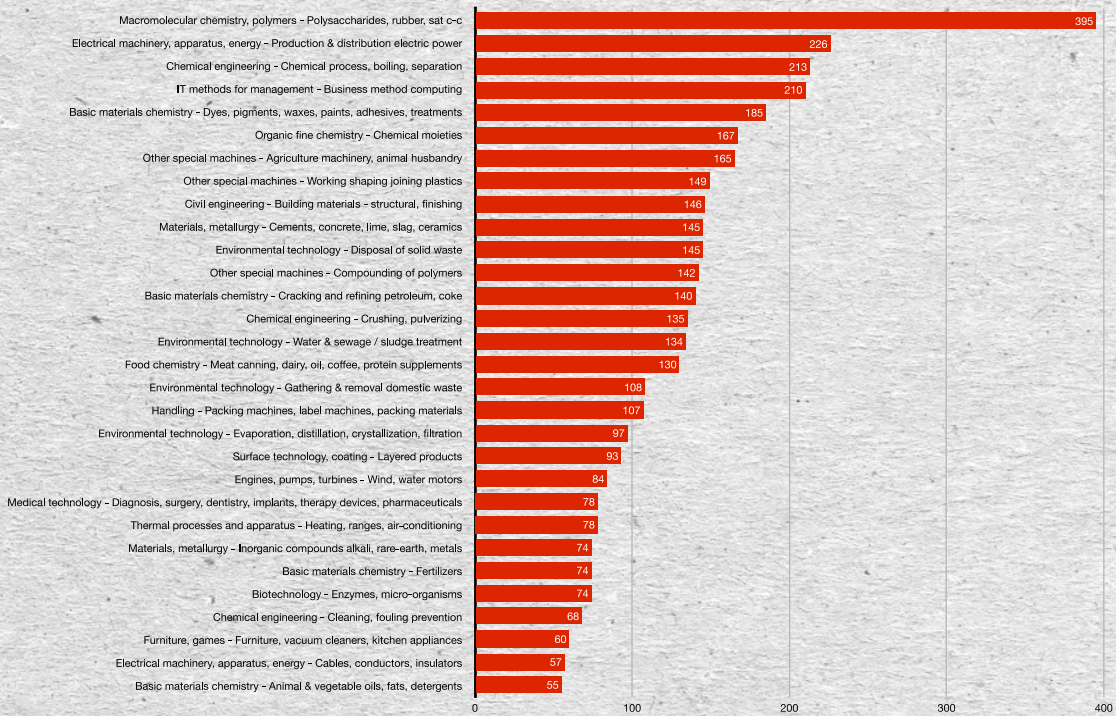


Chart 7: Sub technical domains with highest numbers of patent applications filed between 2013 and 2024



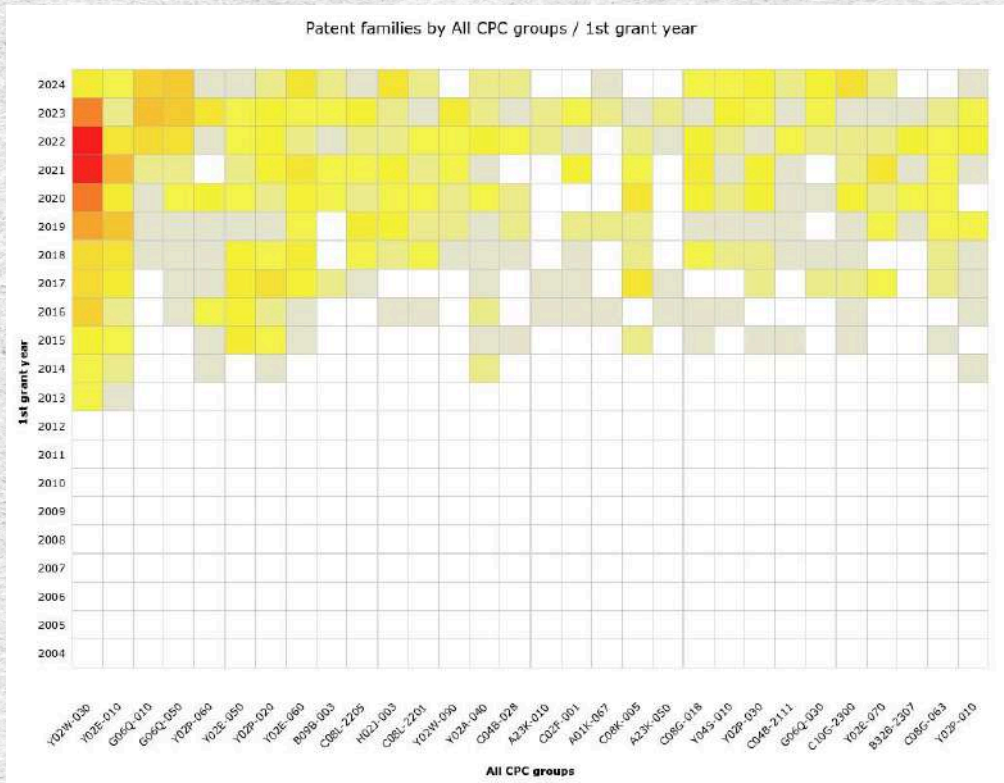


Chart 8: Top most CPCs in which patent applications are filed between 2013 and 2024

Chart 9 illustrates the distribution of the main concepts contained in the analyzed portfolio. This helps visualize the most-used concepts in the study

area. This can be a source of ideation for new developments or identification of protected technologies in a new field.



Chart 9: Frequently concepts in patent applications are filed between 2013 and 2024

Chart 10 identifies areas of high-overlap technology between players and can be particularly useful in acquiring a portfolio. Areas with a strong overlap

show consolidation of the portfolio on the topic. Areas with a low overlap are either opportunities for new development or portfolios to be sold.



Chart 10: Landscape by technology clusters

Charts 1 to 9 only allow quantitative evaluation of the patent data. Accordingly, the figures indicate that China has the highest number of applications filed. However, the charts do not provide any information about the quality of the applications. Therefore,

statistics that exhibit the desired market outputs, as well as innovative inventions with high commercialization potential, are used from this point on.



4. APPLICATION TRENDS BY LEGAL STATUS

Chart 11 shows the distribution of patents or patent applications filed between 2013 AND 2024 that are accessed by the keyword search, based on their legal status as GRANTED, PENDING, LAPSED, REVOKED, EXPIRED. As it can be seen from the chart below, only 37.34 % of 2967 patent applications about sustainable materials remain active between 2014 and 2024. This information makes it possible to distinguish between patent families that have at

least one member with a grant versus families that have not yet received a granted patent. This also makes it possible to measure the proportion of patents that are no longer in-force (whether they are lapsed, revoked or expired). A portfolio in which a very high proportion of patents is no longer in force is an indicator of the disengagement of the stakeholders.

● Pending ● Granted ● Expired ● Revoked ● Lapsed

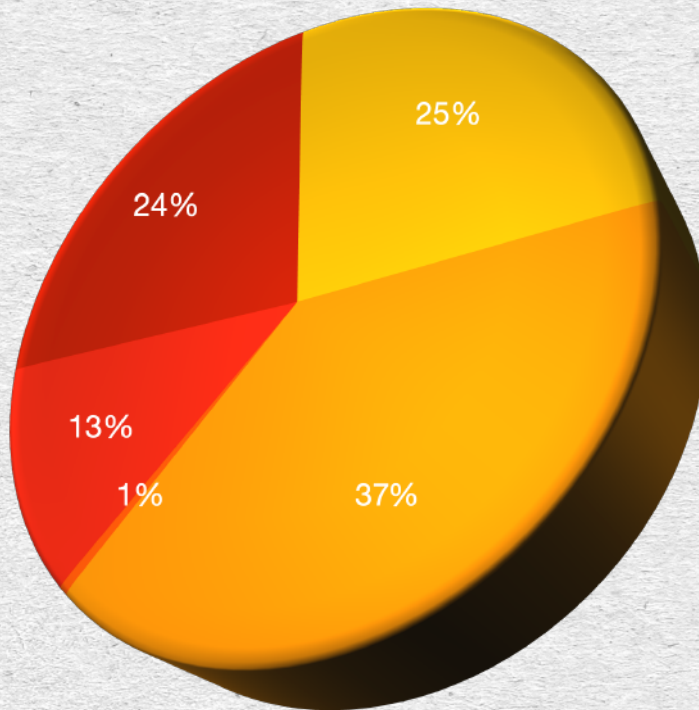


Chart 11: Legal Status of Patents/Patent Applications about Sustainable Materials Between 2014 and 2024

5. APPLICATION TRENDS BY CITATIONS

Publication Number	Title	Assignee name	1st app. date	Technology impact	Citations
EP3105255B1	Glucosyltransferase enzymes for production of glucan polymers	NUTRITION & BIOSCIENCES USA 4	9/25/2013	5.83	72
CN103440607A	Service platform and method for classifying and intelligently recycling waste and old materials and garbage	HANGZHOU LANGDUN SCIENCE & TECHNOLOGY	8/9/2013	6	59
CN107472752A	Household garbage classified collection and intelligent supervision method and system	INDIVIDUAL	9/21/2017	6.8	53
CA3101570C	Electrolyser and energy system	HYDROGENICS	5/27/2013	6.31	49
US9774819B2	Reproduction device, reproduction method, and recording medium	SATURN LICENSING	6/6/2014	5.8	46
EP3621933B1	Mineral wool product	ROCKWOOL	5/11/2017	7.45	45
US9850192B2	Renewable acrylic acid production and products made therefrom	CJ CHEILJEDANG	6/7/2013	5.57	33
AU2014388095B2	Artificial turf and production method	POLYTEX SPORTBELÄGE PRODUKTIONS	3/27/2014	6.39	33
US10255629B2	Electronic care and content clothing label	CACOTEC	4/11/2017	6.4	32
US20180127554A1	Biodegradable polymer-based biocomposites with tailored properties and method of making those	UNIVERSITY OF GUELPH	3/4/2016	6.01	32
CN108252137B	Preparation process of high-breakage-resistance environment-friendly kraft liner board paper	DONGGUAN JIANHUI PAPER	12/8/2017	7.17	31
CN106622327B	A kind of catalyst and its preparation method and application of N doping porous carbon carried metal	QINGDAO INSTITUTE OF BIOENERGY & BIOPROCESS TECHNOLOGY - CHINESE ACADEMY OF SCIENCES; INTERNATIONAL CENTRE FOR BAMBOO & RATTAN	12/20/2016	6.55	30
AU2018253649B2	Reusable foldable drinking straw in storage case	FINAL	5/23/2018	7.34	28
WO2021081775A1	Marine energy-island device	SUN YAT-SEN UNIVERSITY	10/29/2019	6.63	25
CA3003580C	Low cost manual expanding-dunnage conversion apparatus	RANPAK	8/16/2016	6.42	25
CA3064955C	TiO2 catalyst in ketonisation reactions to produce RBO	NESTE OIL	6/15/2018	6.28	22
US11772866B2	Single-walled disposable cooler made of disposable, biodegradable and/or recyclable material	IGLOO PRODUCTS	6/19/2019	6.58	16

Table 1: The top 10 most frequently cited patent applications

6. BY PATENT VALUATION

Patent Value - CPC comparison;

The chart 11 below shows the comparison of the estimated patent value in the relevant CPC classification with the estimated average value among all the assignees in the CPC classification.

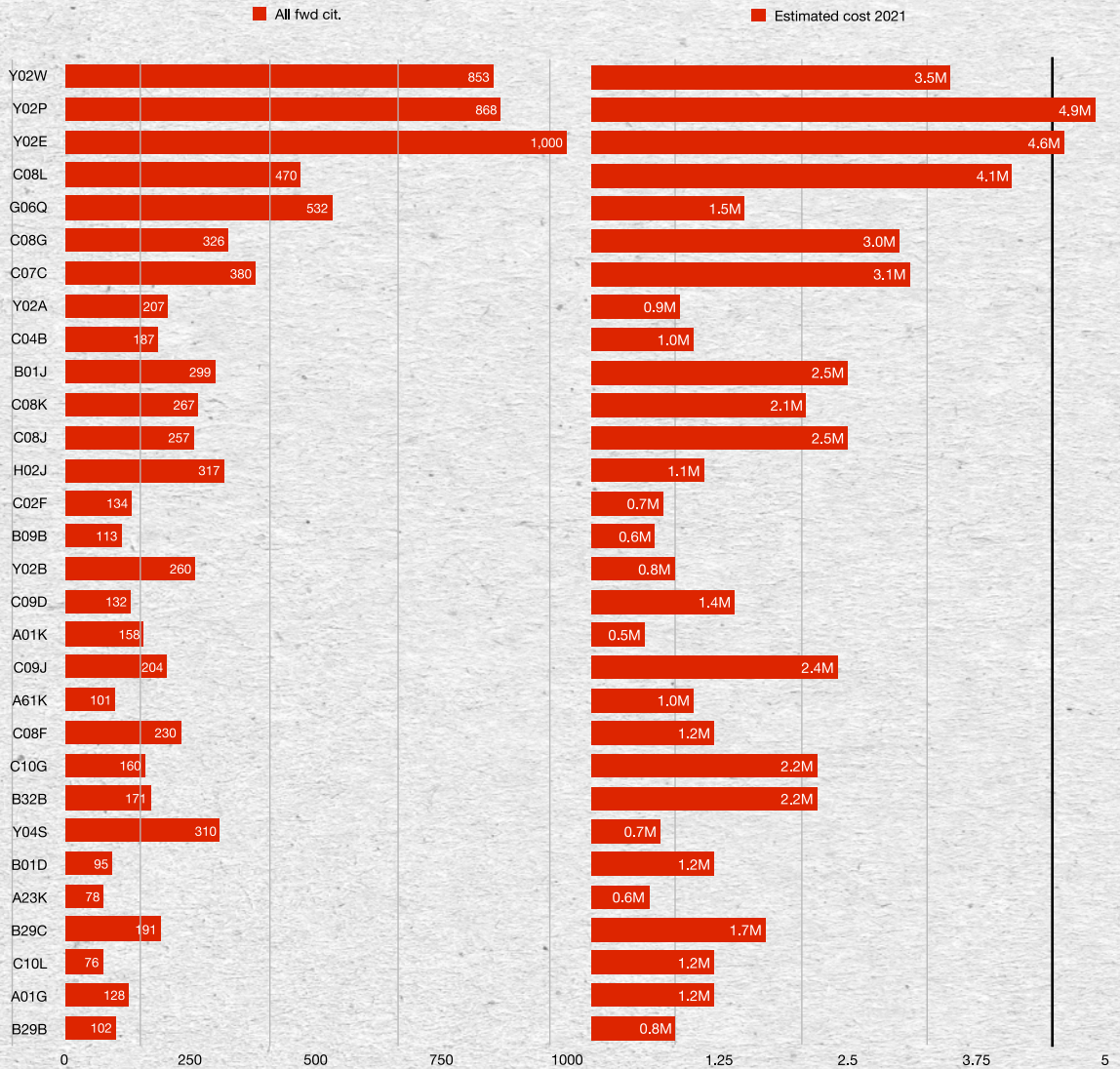


Chart 12: Patent Value by CPC

Ultimately, patents are technical documents and it is essential to evaluate a patent's potential to transform from being an intangible property into a commodity that can generate income. To evaluate where the patents are protected, competitive advantage that

the patent can bring for the relevant technology area, technological preparation necessary for transforming it into an end product, and the size of the market that the end product will be introduced.

Publication Number	Title	Assignee	1st app. date	Value (USD)
EP3105255B1	Glucosyltransferase enzymes for production of glucan polymers	NUTRITION & BIOSCIENCES USA 4	2013-09-25	292734
CA3101570C	Electrolyser and energy system	HYDROGENICS	2013-05-27	187159
EP3621933B1	Mineral wool product	ROCKWOOL	2017-05-11	807154
AU2014388095B2	Artificial turf and production method	POLYTEX SPORTBELÄGE PRODUKTIONS	2014-03-27	154285
US10125060B2	Methods of producing para-xylene and terephthalic acid	ORIGIN MATERIALS OPERATING	2013-03-15	119566
CA3064955C	TiO ₂ catalyst in ketonisation reactions to produce RBO	NESTE OIL	2018-06-15	425144
EP2817137B1	High thermal conductivity co-injection molding system	IMFLUX	2013-02-22	158163
CA3036039C	Method for producing polyolefin recyclates	DER GRUENE PUNKT - DUALES SYSTEM DEUTSCHLAND	2016-09-07	143045
CA2980809C	Recyclable material	GIMSA	2015-03-31	119323
US11014280B2	Preform for producing a plastic container, production of the preform and plastic container produced from the preform, as well as its production	ALPLA WERKE ALWIN LEHNER	2015-02-06	116740
CN106635119A	Process for the hydrotreatment of renewable materials, with an optimized gas recycle	IFP ENERGIES NOUVELLES	2015-07-24	120499
US9567311B2	Water dispersible, self-crosslinkable prepolymer composition	LUBRIZOL ADVANCED MATERIALS	2013-01-23	127511
CA2881542C	Removal of organic salts from bio-derived glycol products of polyol hydrogenolysis derived glycol products of polyol hydrogenolysis MIDLAND	ARCHER DANIELS MIDLAND	2013-08-21	119324

Publication Number	Title	Assignee	1st app. date	Value (USD)
US11787885B2	Polyethylene copolymers and products and methods thereof	BRASKEM	2020-10-05	123696
US20230322878A1	Compounds for inducing tissue formation and uses thereof	HISTIDE	2016-08-25	115818
US11001727B2	Renewable, biodegradable marking wax composition	DANIMER BIOPLASTICS; DANIMER IPCO	2017-10-26	110380
US10849306B2	Method for coating cheese products	BEL	2013-04-05	113071
US11724974B2	Methods of producing hydrogen-selective oxygen carrier materials	DOW GLOBAL TECHNOLOGIES	2019-08-27	119968
AU2017284988A1	Method and system for intelligently managing electrochemical batteries of an electrical power supply installation	BLUE SOLUTIONS	2016-06-16	127503
US20170334108A1	Method for producing thin-walled small plastic parts and thin-walled small plastic parts	ALPLA WERKE ALWIN LEHNER	2015-02-06	115011
US11254108B2	Laminate structure for biocompatible barrier packaging	RENOLIT	2017-10-24	109707

Table 2: Top 10 Highest Valued Patent Applications

7. BY COMMERCIALIZATION

7.1 Commercialized Patents by Company and its Revenues:

Besides the patent valuation analysis performed on the basis of Patent classification code, following patent commercialization data help understand the commercialization details including the scope of the potential patents in the sustainable materials technology.

1. Origin Materials' Patented Carbon-Negative Plastics Technology

- Year Commercialized: 2019
- Revenue: \$40-\$60 million expected in 2023
- Patent details: Converts biomass like wood residues into plastics and other materials to provide a sustainable alternative to petroleum-based products.

2. Novamont's MATER-BI Bioplastic

- Year Commercialized: 2014
- Revenue: Over €238 million in 2020.
- Patent details: MATER-BI is a family of biodegradable and compostable bioplastics used in

various industries from agriculture to packaging.

3. BASF's Ecoflex® and Ecovio® Biodegradable Plastics

- Year Commercialized: 2015
- Revenue: Part of BASF's €2 billion Performance Products segment.
- Patent details: Ecoflex® and Ecovio® are biodegradable plastics used in compostable bags, food packaging, and agricultural films.

4. Dow's Recycled Polyethylene Technology

- Year Commercialized: 2017
- Revenue: Integrated into Dow's packaging business, which achieved \$3.5 billion in sales in Q2 2022.
- Patent details: Technology focused on incorporating recycled materials into new polyethylene products, enhancing sustainability.

5. Carbios’ Enzymatic Recycling of PET Plastics

- Year Commercialized: 2021
- Revenue: Licensing agreements and partnerships driving revenue.
- Patent details: This technology uses enzymes to break down PET plastics into their monomers, which can then be recycled into new PET products.

6. LanzaTech’s Gas Fermentation Technology

- Year Commercialized: 2018
- Revenue: Expected to reach \$2 billion by 2030.
- Patent details: Converts industrial waste gases into ethanol and other chemicals for providing a sustainable alternative to fossil fuel-based production.

7. Neste’s Renewable Diesel Technology

- Year Commercialized: 2016
- Revenue: Over €15 billion in 2022.
- Patent details: Technology to produce diesel from renewable sources like waste fats and vegetable oils, reducing the carbon footprint of diesel fuel.

8. PureCycle Technologies’ Polypropylene Recycling

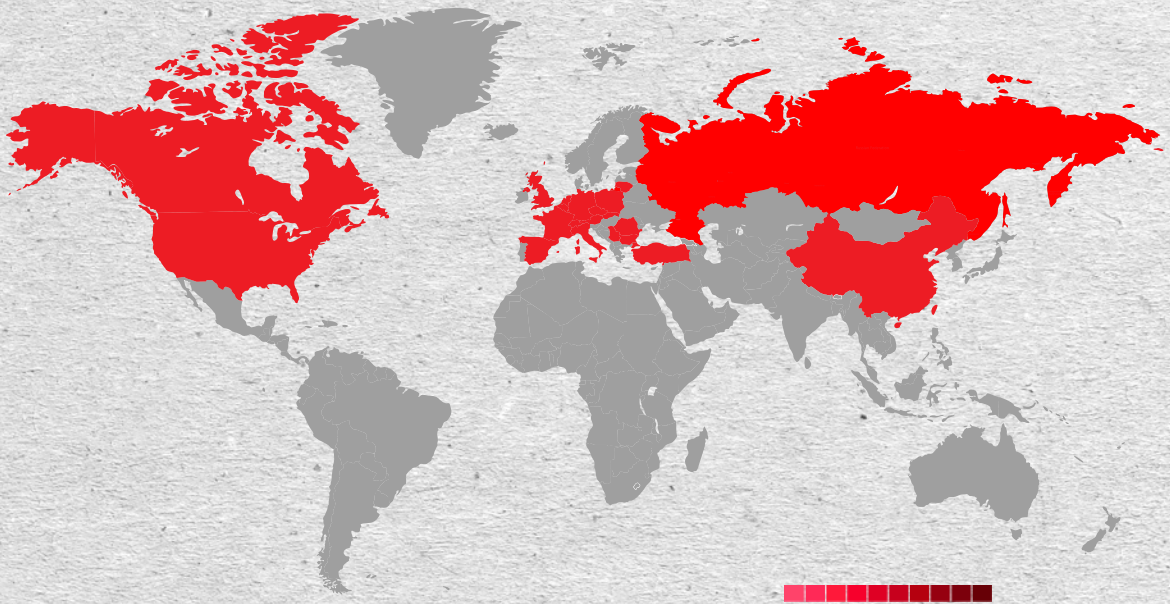
- Year Commercialized: 2021
- Revenue: Expected to exceed \$800 million by 2025.
- Patent details: Uses a patented process to recycle polypropylene, a common plastic, into a near-virgin quality material, that helps close the loop on plastic waste.

7.2 Highest Valued Patent Application Filed Between 2013 And 2024

Rockwool, a maker and supplier of smart and sustainable insulation products for construction and process industries based on innovative stone wool technology has the highest valued patent filed in 2017.

The patent US12070929B2, titled “Mineral wool product” has been granted in 2024, with over 132 Members in the Patent Family, including US, China, Europe, Canada, Denmark, Spain, Russia, Singapore, Finland, Croatia, Lithuania, Poland and Serbia.

Publication No.	Title	Registration Date	Patent Valuation	Number of Citations	Legal Status
US12070929B2	Mineral wool product	2024-08-27	\$807154	45	Active



Patent families by Protection country

8. VALUATION RATES OF THE US REGISTERED APPLICATION NO US12070929B2 AND THE DESCRIPTION THEREOF

Patent valuations given in this report are calculated by a program that uses an indicator-based system. The values are calculated by analyzing simple patent families (for only one of the multiple applications for the same invention filed in different countries/regions) with more than 80 objective value indicators. These indicators include patent family size, geographical scope, patent age, legal status,

etc. It must be noted that the calculated value is a market value -just like real estate valuation- and the actual value of a patent can only be determined upon a real request. In this framework, the table below shows the detailed value rates of Patent No. US12070929B2 filed between the dates specified above with the estimated patent value of \$807,154.

58

Strategic Value

92.6

Market Value

74.5

Technology Value

66.7

Economic Value

92

Legal Value

Strategic value is used to evaluate the purpose of a patent in terms of offensive and defensive capabilities. The impact is determined based on several details including the number of independent claims, invalidation activities, actions of the opposition, and the national order. Market value is the income potential and the competitive market advantages of a patent of the transferee. In this context, the patent's financial contributions are determined based on the market activities including licensing, security, and data transfer. Economic value is the actual realized economic value of a patent. In this context, the patent's financial contributions are determined based on the market activities including licensing, security, and data transfer. Legal value is

used to determine the legal protection of a patent and the stability of patent rights. The factors considered for this purpose include the scope of claims, remaining validity, area of protection, the resilience of a patent against legal challenges, and the scope of protection of patent rights. Technology value is an indicator of the technology of the patent. The background, novelty, technological complexity, and practical uses of the inventions are assessed to determine the technological value. The number of applicants, number of inventors, patents that reflect or refer to the maturity of a technology, and the classifications of the technology are among the factors that are considered for valuation.



The evaluation of sustainable materials and related technologies is increasingly carried out through a patent database, a valuable tool for tracking innovations in this growing field. While there is no single classification system or comprehensive statistical platform dedicated to sustainable materials, patent databases—such as those from the World Intellectual Property Organization (WIPO) and national patent offices—provide an excellent resource for identifying emerging trends and advancements. These databases reveal the dynamic progress being made across industries as they shift towards more eco-friendly solutions.

By analyzing patents, we can gain insights into exciting developments in biodegradable polymers, renewable resource-based materials, advanced recycling processes, and energy-efficient production techniques. Patent filings also reflect the rise of circular economy technologies, including advancements in recyclable multi-layered composites, chemical recycling, and closed-loop systems that are transforming industries like packaging, construction, and textiles. Through these technologies, companies are creating materials and solutions that contribute to a more sustainable and resilient future.

Patents not only highlight the materials themselves but also showcase innovative technologies aimed at improving resource efficiency, reducing environmental impact, and advancing sustainability.

The growing body of patents in this field points to rapid innovation in areas such as bioplastics, nano-enhanced materials, and green chemistry, where materials are developed using environmentally friendly processes.

Although the absence of a unified classification system for sustainable materials can be challenging, patent data offers a clear window into the accelerating pace of innovation. It serves as a strong indicator of the positive momentum in developing technologies that reduce waste, enhance sustainability, and pave the way for greener industries.

Evaluation

USED WEB LINKS

1. <https://www.orbit.com/>
2. <https://www.lexisnexisip.com/resources/a-year-of-ip-insights-2023/>
3. <https://investors.originmaterials.com/news-releases/news-release-details/origin-materials-inc-reports-operating-and-financial-results>
4. <https://constructiondigital.com/sustainability-green-building/eco-materials-technologies-charts-sustainable-construction>
5. <https://www.volkswagen-newsroom.com/en/press-releases/imitation-leather-from-industrial-hemp-innovative-and-sustainable-material-for-future-car-interiors-18665>
6. <https://www.fmiblog.com/2024/09/02/the-future-of-eco-friendly-manufacturing-leveraging-fluoropolymers-for-a-sustainable-industry/>



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Technology Trend Report

This report is prepared by the experts of TECHNOLOGY TRANSFER OFFICE based on the data generated from scanning patent databases for patent applications filed in a specific date interval. The data, assessments and statistics in this report are prepared in line with the publicly available data sources as well as the documents published at the time of preparation of this report.

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