GreenChemForCE

GreenChemForCE
Activity 1.1. Analysis of the current state and new strategies for sustainable development
Deliverable D 1.1.1 Analysis report

4th version

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INTRODUCTION

The focus of Activity 1.1 is to analyze current plastic management practices within the industry and develop a collaborative strategy for valorizing plastic waste and promoting sustainable production methods in Central Europe. This initiative will foster cooperation between academic and industrial partners to identify existing challenges, such as the prevalent linear make-use-dispose model, which contributes to plastic waste accumulation. The goal is to devise strategies that transition to closed-loop systems, including chemical recycling technologies, and establish circular economy value chains.

Key objectives include:

1. **Identifying Problems**: Analyze the existing linear plastic production and disposal streams, highlighting issues that lead to waste generation.
2. **Developing Strategies**: Create new approaches for substituting linear processes with closed-loop systems, focusing on sustainable practices.
3. **Valorization of Byproducts**: Investigate and optimize the use of byproducts generated during plastic manufacturing.
4. **Sustainable Product Design**: Emphasize the importance of designing products with sustainability in mind.
5. **Resource Identification**: Identify critical resources for plastic production in the region and explore alternatives to petroleum-based sources.

We (CCIS) will lead this activity, collaborating with UL and CU as academic partners, and the Czech Technology Platform Plastics representing the SCHP CR. The action plans and strategies developed will be integrated into the agendas of participating organizations, with anticipated positive impacts on plastic production within the involved chemical companies after the project's conclusion. Additionally, the hope is that organizations beyond the project consortium will adopt these strategies.

The outcomes of this analysis will serve as a foundation for developing actionable plans and collaboratively crafted strategies to effectively address the outlined challenges.

Table of Contents

Table of Figures

Table of Tables

1. GreenChemForCE: Introduction and aim

The chemical industry in Central Europe faces challenges such as excessive waste, elevated greenhouse gas emissions, and a heavy dependence on petroleum-based materials. The GreenChemForCE project aims to assist companies in transforming their production processes from linear models to circular systems. Partners involved in the project are testing innovative technologies that minimize the use of hazardous solvents and promote the reuse of any remaining solvents. Additionally, they are developing a strategy for producing more environmentally friendly chemicals and providing greener methods that can be implemented by various companies to improve the industry's sustainability.

The aim of the GreenChemForCE project is to help reduce the negative environmental impact of the chemical industry in Central Europe. Chemical production in the region is currently far from sustainable and its significant portion had been relocated to Asia. In addition, the public image of this sector is extremely poor. This project's objective is to tackle the chemistry issues of local producers, including the generation of excessive waste and greenhouse gas emissions, their dependence on petroleum-derived materials, and the use of toxic chemicals and inefficient energy-intensive processes.

Transnational cooperation is crucial to the success of our efforts, as it allows for maximum integration of knowledge, expertise and experience from all the partners and countries involved. In addition, our partner industry support organizations will disseminate the results to a wider group of chemical companies and experts in the field, in order to trigger a change in the whole sector and enhance environmentally conscious chemical production throughout the Central European region. Thus, the project will contribute to the revitalization of the local chemical industry, transforming the current linear economic streams into the closed-loop circular systems, and establishing conditions for the return of chemical production back to Europe thanks to the developed green and cost-effective processes.

Moreover, by raising public awareness of the green chemistry principles and training a new generation of experts, the project aims to improve the perception of the regional chemical industry by the general public and the adoption of sustainable practices by the future employees of regional companies. This may eventually lead to the desired behavioral change in both industry and end consumers. The project will also facilitate stronger connections between the partners, leading to long-term collaboration between universities, chemical companies and other organizations.

2. Plastic management in Central Europe: State of the art

2.1. Legislation

All project partners are member states of the European Union, which means they are committed to complying with the common legislation established by the EU. Although plastic-related legislation may differ in certain aspects among member states—since they have a degree of autonomy when transposing EU directives into national law to reflect their specific environmental, economic, and social contexts—the core principles and objectives are largely aligned. As a result, the legislative framework on plastics is ultimately quite harmonised across the EU, particularly regarding the bans on certain plastic products, the promotion of recycling, and the shift toward sustainable alternatives.

EU Plastics Strategy in the Circular Economy

In 2018, the EU introduced the Plastics Strategy, the first comprehensive EU-level document aimed at transforming the way plastics are produced, used, and recycled.
The main goals include:

- ensuring that by 2030, all single-use plastic products on the EU market are reusable or recyclable,
- reducing the use of microplastics,
- encouraging innovation and investment in more sustainable materials.

Single-Use Plastics Directive (SUP Directive – 2019/904)

This key directive bans or restricts the use of certain single-use plastic products for which more sustainable alternatives are available.
It includes:

- bans on products such as plastic cutlery, plates, straws, cotton buds, etc.,
- labelling requirements (e.g., for tobacco products containing plastic),
- measures to reduce the consumption of specific items (e.g., food containers),
- extended producer responsibility obligations.

Packaging and Packaging Waste Directive

The revised directive sets out:

- recycling targets (e.g., at least 50% of plastic by 2025 and 55% by 2030),
- measures to reduce excessive packaging,
- incentives for the use of recycled plastics,
- extended producer responsibility (EPR).

Regulation on Waste Shipments and the Single Market for Recycled Materials

The EU aims to streamline the secondary raw materials market and improve traceability of plastic waste to ensure high-quality recycling within the EU and reduce waste exports to third countries.

Funding and Research

Through programmes such as Horizon Europe and the LIFE Programme, the EU supports innovation in areas including bioplastics development, advanced recycling methods (e.g., chemical recycling), microplastic reduction, and solutions to plastic pollution in aquatic environments.

Environmental Awareness and Education

The EU encourages Member States to implement awareness campaigns targeting consumers, especially regarding proper waste separation, the environmental impact of plastics, and the importance of reuse.

2.2. Market trends

Plastic technology stands at the forefront of innovation, continually evolving to meet the challenges of a rapidly changing world. In recent years, the industry has witnessed a transformative shift towards sustainability, driven by environmental concerns and regulatory pressures.

1. Biodegradable and Sustainable Plastics
2. Recycling Innovations
3. Smart Plastics
4. Advanced Manufacturing Techniques
5. Nanotechnology in Plastics
6. Anti-Microbial Plastics
7. Circular Economy Initiatives
8. Regulatory Changes

The plastics industry is undergoing a dynamic transformation, marked by a convergence of innovative trends that collectively strive for a more sustainable and responsible future. From the development of biodegradable and sustainable plastics to the integration of smart technologies, the sector is adapting to address pressing environmental concerns and societal needs. Recycling innovations, advanced manufacturing techniques, and the infusion of nanotechnology exemplify the industry's commitment to efficiency, waste reduction, and enhanced material properties. Moreover, the emergence of anti-microbial plastics caters to the heightened focus on hygiene, especially in critical sectors like healthcare.

Crucially, the adoption of circular economy initiatives signifies a paradigm shift, with companies actively designing products for recyclability and championing closed-loop systems. These initiatives, coupled with robust regulatory changes worldwide, underscore a shared commitment by governments and international bodies to curb the environmental impact of plastics. Restricting single-use plastics and promoting recyclability align with a broader vision of a sustainable, circular, and eco-conscious plastics economy.

As these trends continue to evolve, the plastics industry finds itself at the nexus of innovation and responsibility, poised to shape a future where plastics not only serve functional and economic purposes but also contribute positively to global environmental challenges. By navigating this transformative landscape collaboratively, stakeholders can pave the way for a more sustainable and resilient plastics industry that meets the demands of the present without compromising the needs of future generations.

The world of plastics is slowly transitioning to what may be called “Plastics Technology 2. 0.” This change is characterized by the application of fresh materials that have enhanced the sustainability and the performance as well. Therefore, there is enhanced concern towards the use of plastics in the global market because of its impacts on the environment; although the plastics industry is trying to look for ways and means of minimizing the impact of plastic usage in the environment and usefulness of the plastics material (the push for sustainability; advanced materials for enhanced performance; recycling and circular economy; innovative applications of new plastics; challenges and future directions).

2.3. Development trends

The latest developments in polymer and plastic technology focus on reducing the planetary impact of synthetic polymers. Bio-based polymers, for instance, are produced from renewable feedstocks and can also be biodegradable. The market for these products is expected to reach USD 29.7 billion by 2026. With further innovations in this field, bio-based polymers will become more widespread in medicine, industry, agriculture, and beyond.
At the same time, efforts are underway to tackle the problem of plastic waste in marine ecosystems. The Ocean Cleanup, a non-profit that develops and scales technologies to rid the ocean of plastic waste, is a notable example. The organisation engages individuals, corporations, and governments with the target of reducing 90% of floating ocean plastic, and its new System 03 technology is expected to capture plastic 10 times faster than the previous version.
Plastics was widely used because of its flexibility, ability to endure as a material and also due to its cheap nature. Despite this, its uses are now expanding towards exclusive new areas in possibilities created by modern technologies.

Flexible Electronics

Organic electronics or flexible electronics are the new generation inventions which are changing the conventional views on technology. Regular electronics are not flexible or portable but with the help of plastics flexible, lightweight and even foldable gadgets can be produced. Organic light-emitting diodes (OLEDs) employed in displays and the organic photovoltaic cells are perfect examples. Color flexible OLEDs could be another example. It is flexible and pliant in nature for the use in wearables with tiny screens and even in curved screens and extendable screens that are rollable in nature.

3D Printing

Additive manufacturing or more commonly known as 3D printing is revolutionizing many industries including; health care and automobile. Popular materials include PLA that is polylactic acid and ABS that is acrylonitrile butadiene styrene since it is easy to process, and it is cheap.
Some of the creative uses of 3D printing includes making of special artificial limbs, architectural maquettes and even some components for the aerospace industry. The freedom of designing and shaping is very high and enables structural designs and features to be printed through the plastic material.

Medical Devices

Medical area has shown significant improvements that are attributed to the improvements in the area of plastics technology. They are presently employed in sutures and implants that disintegrate in the human body without the need for further surgery. Disposable microfluidic systems, represented by elements of lab-on-a-chip, which are extensively used in diagnostics, are made of plastic because of its low cost and possibility to work with polymers. They are also used continuous wearing health monitor devices that are light in weight but comfortable to be worn all the time.

Smart Textiles

Smart textiles refer to clothing items that have electronics incorporated in their production and plastic material is involved here. Conductive polymers are applied on textiles to make them conductive to be able to interface with sensors and electronics. These textiles can include health-monitoring clothing for patients, smart attire that can communicate, and even military uniform that changes with the weather.

Sustainable Packaging

There are certain environmental issues that are now compelling manufacturers to find better solutions such as packaging and here, plastics are playing a major role. Eco friendly and compostable plastics give a chance to use renewable resource instead of petroleum based packaging. These materials also degrade faster and safely than the traditional plastics hence having lesser effects on the environment. Antimicrobial agents or oxygen scavengers as incorporated in the active packaging solutions help prolong the shelf life of foods, and drugs.

Advanced Aerospace Components

In aerospace, weight control is significant in fuel consumption as well as other aspects of the performance. High-performance thermoplastics like thermoplastic composites, polyimides and related products are commonly used in aircrafts and spacecrafts to attain these goals.
These materials possess excellent specific strength and can endure temperature variation and other harsh conditions; the most appropriate use of these materials is on items such as frames, trusses, hinges, and other similar parts found within a given structure.

Energy Storage and Conversion

Currently, plastics are also being incorporated into energy storage and conversion devices. Research is also being carried out in conductive polymers and plastic-based super capacitors to improve energy storage products.
They can be incorporated into bendy and lightweight energy conversion and storing devices that are useful in the development of batteries and capacitors used in electronics and renewable energy.

Consumer Electronics

Incorporation of new plastics as materials in the manufacture of consumer electronics is enabling the producers to come up with more stylish gadgets. Polycarbonate as well as acrylic are favorite materials for smartphone, tablet and laptop housing because of their high impact strength.
Furthermore, plastic based nanomaterials are being researched for the enhancement of electronic devices and at the same time containing the manufacturing cost. The given examples of using plastics in the technologies that are being developed demonstrate the unlimited possibilities of this material. Whether in the creation of electronic papers or high-end aerospace parts, plastic is moving the goalposts and setting the pace in different fields.

2.4. Life cycle stages

The life cycle stages of plastics encompass the entire journey from raw material extraction to disposal or recycling, emphasizing the importance of integrating sustainable practices to align with circular economy principles. A notable example is the collaboration between the Faculty of

Chemistry and Chemical Technology, University of Ljubljana (UL FKKT), and AquafilSlo, a pioneer in sustainable nylon production. This partnership demonstrates a good practice model within the plastic value chain, particularly in the recycling of nylon waste into high-quality ECONYL® yarn.

Key Life Cycle Stages:

Raw Material Extraction and Production: Traditional nylon production relies on petrochemical sources. However, efforts by AquafilSlo have shifted towards sourcing used nylon materials, such as discarded fishing nets and other waste products, as alternative feedstock.
Product Manufacturing: Nylon waste undergoes advanced processing techniques to produce ECONYL® yarn, maintaining the material's quality while significantly reducing the environmental footprint.
Use Phase: ECONYL® yarn is incorporated into diverse applications, such as textiles, fashion, and industrial uses, offering durability and versatility.
End-of-Life Management: Instead of contributing to waste, used nylon is collected globally through strategic partnerships and initiatives. This material is then returned to the production loop, highlighting the circular nature of the process.

Initial efforts between UL FKKT and AquafilSlo have focused on refining the depolymerization process, a critical step in the recycling of nylon. Laboratory-scale research has integrated Process Intensification (PI) techniques to enhance efficiency and sustainability. Current activities aim to optimize mechanisms such as advanced mixing strategies and controlled reaction conditions, ensuring effective depolymerization and alignment with sustainability goals.
By continuously improving and scaling up these methods, the partnership aims to set an example of how plastics, particularly nylon, can be managed responsibly throughout their life cycle. This approach not only reduces waste but also ensures the production of high-quality recycled materials, embodying the principles of the circular economy.

2.5. Value chain

In the intricate web of modern industry, understanding the plastic value chain is paramount. From raw material extraction to manufacturing, distribution, consumption, and eventual waste management, each link plays a crucial role. Understanding the plastic value chain is crucial for informed decision-making, as it enables stakeholders to identify environmental impacts, optimize resource use, and implement sustainable practices. It aids in developing circular economy strategies, mitigating pollution, and fostering innovation for a more environmentally responsible plastic industry.

Stages in the Plastic Value Chain:

Raw Material Extraction

In this initial phase, the industry identifies and assesses potential sources of raw materials, primarily fossil fuels like crude oil and natural gas. Companies explore regions with rich petroleum reservoirs, conducting geological surveys to determine extraction feasibility. Sourcing strategies aim to secure a stable supply chain for the petrochemicals essential for plastic production. Following sourcing, the extraction process begins. Petrochemicals, such as ethylene and propylene, are derived through refining crude oil or cracking natural gas. These building blocks are pivotal for subsequent plastic production stages.This aspect can be improved by using alternative sources, such as bio-based raw materials derived from renewable natural resources, or by using depolymerised materials obtained through the recycling of existing plastics. Such approaches reduce dependence on fossil resources and contribute to greater sustainability of the overall process.

Plastic Production

The extracted petrochemicals undergo polymerization, a chemical process where monomers link to form polymer chains. Catalysts facilitate this transformation, resulting in the creation of plastic resin, the raw material for various plastic products. Polymerization methods vary, including techniques like injection molding and extrusion. Once polymerization is complete, manufacturers employ diverse processes to shape plastic into final products. Injection molding forms intricate shapes, while extrusion creates continuous profiles. Thermoforming molds heated plastic into desired forms, and rotational molding produces hollow items. Understanding these processes is integral to optimizing efficiency and minimizing waste in the plastic value chain.

Distribution and Supply Chain

Plastic products move through extensive distribution networks. Transportation methods include shipping, trucking, and rail. Efficient logistics play a crucial role in minimizing environmental impact and costs. Sustainable practices, such as optimizing routes and utilizing eco-friendly transportation options, are increasingly prioritized. Storage facilities and warehouses serve as key nodes in the distribution network, ensuring timely delivery to manufacturers and retailers. Proper inventory management reduces the risk of overproduction and waste. Implementing sustainable warehousing practices, like energy-efficient facilities and waste reduction measures, contributes to the overall environmental responsibility of the plastic value chain.

Plastic Usage and Consumption:

Packaging

Packaging represents a significant segment of the plastic value chain, providing containment, protection, and marketing for various products. From food packaging to industrial materials, plastics offer versatility, durability, and cost-effectiveness. Balancing functionality with sustainability is crucial in this sector, driving innovations like eco-friendly materials and minimalist designs to reduce environmental impact.

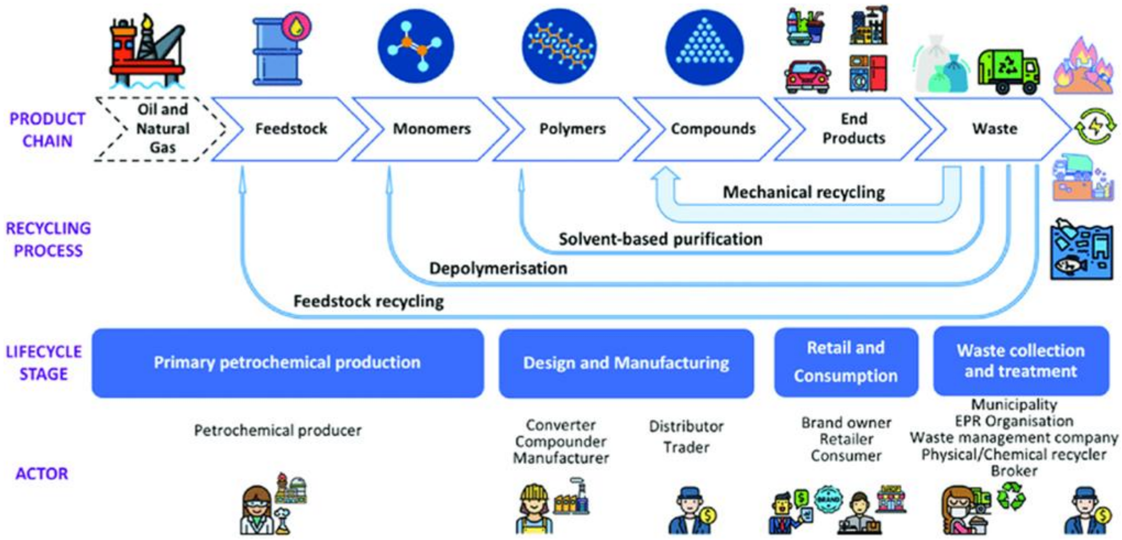
Consumer Goods

In the realm of consumer goods, plastics play a pivotal role in the manufacturing of a diverse range of products, including electronics, appliances, and everyday items. The durability, lightweight nature, and design flexibility of plastics contribute to the creation of efficient and aesthetically pleasing consumer goods. Sustainable practices in this sector involve responsible material.

Construction and Infrastructure

Plastic materials are increasingly utilized in construction and infrastructure projects. From pipes and insulation to architectural elements, plastics offer durability, insulation, and cost-effectiveness. Integrating recycled plastics into construction practices contributes to sustainability, addressing environmental concerns and fostering innovation in the construction industry.

Figure 1: Plastic value chain



Resource: W.-T. Hsu, T. Domenech and W. McDowall, ResearchGate (2022);The plastic value chain, showing the actors, life-cycle stages, and key routes for secondary materials

3. Plastics

3.1. Type of polymer

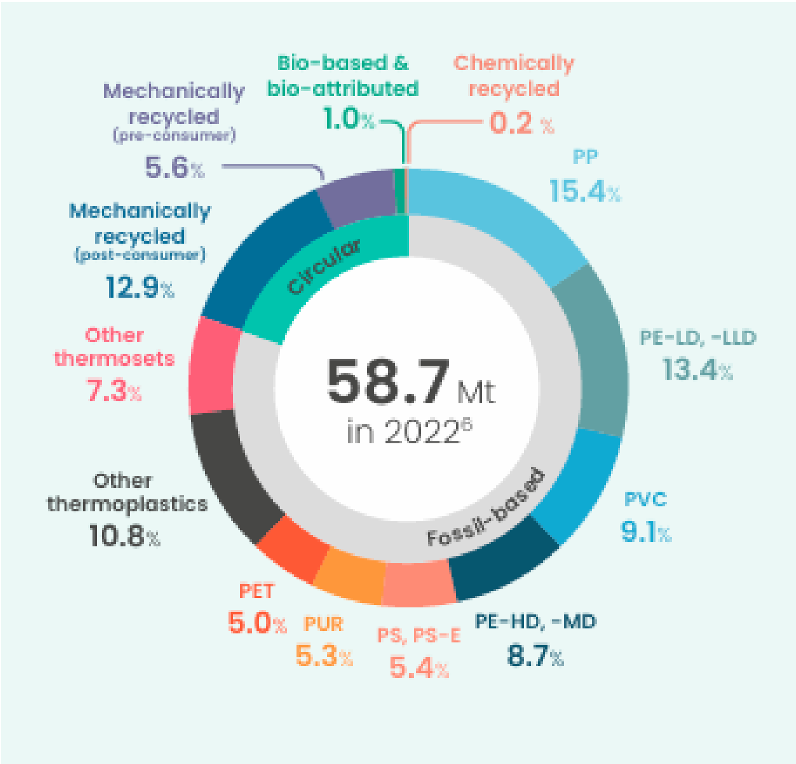
Plastics are an extremely useful and flexible material. Because of this we often use plastics in our daily lives without giving them a second thought. One of the things that is overlooked when it comes to plastic types (although general awareness is growing) is that not all plastics are created equal when it comes to the environment. This means that some plastic types are responsible for more of the environmental damage that is happening in the world than others. Knowing how to identify the different plastic types is important for consumers since it is then possible to either avoid certain types of plastics or be able to recycle them more effectively. A sea change is required when it comes to our relationship with plastic and how we think about the material. Often, we think of plastic as either waste or refuge, but it is in fact a resource that can often be reused time and time again. Thermoplastics, typically can be easily recycled since they can be melted and reshaped into new products.

Plastics are a specific type of synthetic or semi-synthetic polymer. They are made from molecules derived from oil, petroleum, or bio-based sources, which are combined to create different polymers. Plastics are known for their ability to be molded, extruded, or pressed into solid objects of various shapes.

Plastics are a specific type of synthetic polymer with a large molecular mass where the structure is mostly linear. The first synthetic plastic was created in 1909 for telephone and electrical components and was known as Bakelite

There are seven main types of plastic, each suited to certain applications. The three most common types are: polyethylene (PE), which is used to make products like shopping bags, cling film, and hydraulic seals; polypropylene (PP), which can be found in laboratory equipment, automotive parts, and medical devices; and polyvinyl chloride (PVC), a common feature in a wide variety of construction materials. Other types of plastics have applications including glass alternatives, food containers, luggage, protective headgear, and refrigeration devices.

Figure 2: Types of polymer



Resource: PlasticEurope (2023); [Plasticsthefastfacts2023-1.pdf]

Types of plastics:

#1 - PET Polyethylene terephthalate

This is one of the most commonly used plastics. It's lightweight, strong, typically transparent and is often used in food packaging and fabrics (polyester).
Examples: Beverage bottles, Food bottles/jars (salad dressing, peanut butter, honey, etc.) and polyester clothing or rope.

#2 - HDPE - High-density polyethylene

Collectively, Polyethylene is the most common plastics in the world, but it's classified into three types: High-Density, Low-Density and Linear Low-Density. High-Density Polyethylene is strong and resistant to moisture and chemicals, which makes it ideal for cartons, containers, pipes and other building materials.
Examples: Milk cartons, detergent bottles, cereal box liners, toys, buckets, park benches and rigid pipes.

#3 - PVC - Polyvinyl chloride

This hard and rigid plastic is resistant to chemicals and weathering, making it desired for building and construction applications; while the fact that it doesn't conduct electricity makes it common for high-tech applications, such as wires and cable. It's also widely used in medical applications because it's impermeable to germs, is easily disinfected and provides single-use applications that reduce infections in healthcare. On the flip side, we must note that PVC is the most dangerous

plastic to human health, known to leach dangerous toxins throughout its entire lifecycle (eg: lead, dioxins, vinyl chloride).
Examples: Plumbing pipes, credit cards, human and pet toys, rain gutters, teething rings, medical tubing and oxygen masks.

#4 - LDPE - Low-density polyethylene

A softer, clearer, and more flexible version of HDPE. It's often used as a liner inside beverage cartons, and in corrosion-resistant work surfaces and other products.
Examples: Plastic/cling wrap, sandwich and bread bags, bubble wrap, garbage bags, grocery bags and beverage cups.

#5 - PP - Polypropylene

This is one of the most durable types of plastic. It is more heat resistant than some others, which makes it ideal for such things as food packaging and food storage that's made to hold hot items or be heated itself. It's flexible enough to allow for mild bending, but it retains its shape and strength for a long time.
Examples: Straws, bottle caps, prescription bottles, hot food containers, packaging tape, disposable diapers and DVD/CD boxes.

#6 - PS - Polystyrene

Better known as Styrofoam, this rigid plastic is low-cost and insulates very well, which has made it a staple in the food, packaging and construction industries. Like PVC, polystyrene is considered to be a dangerous plastic. It can easily leach harmful toxins such as styrene (a neurotoxin), which can easily then be absorbed by food and thus ingested by humans.
Examples: Cups, takeout food containers, shipping and product packaging, egg cartons, cutlery and building insulation.

#7 - O (Other) All other plastics

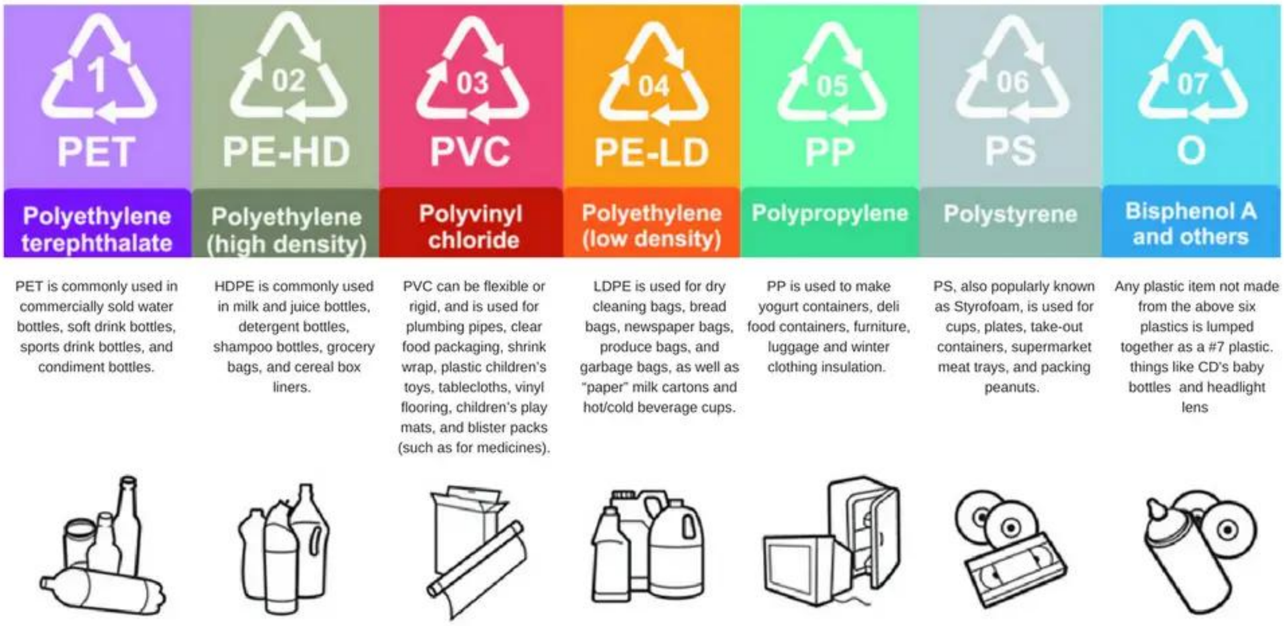
This category is a catch-all for other types of plastic that don't belong in any of the other six categories or are combinations of multiple types

Other Plastics Types:

- Polyphthalamide (PPA)
- Polyurethane (PUR)
- Polytetrafluoroethylene (PTFE or Teflon is a brand name variant)
- Acrylonitrile Butadiene Styrene (ABS)
- Polyamide (PA 66) and (PA 6) commonly referred to as Nylon
- Acrylic (Polymethyl methacrylate or PMMA)
- Polylactic acid (PLA / poly or polylactide)

Examples: Eyeglasses, baby and sports bottles, electronics, CD/DVDs, lighting fixtures and clear plastic cutlery.

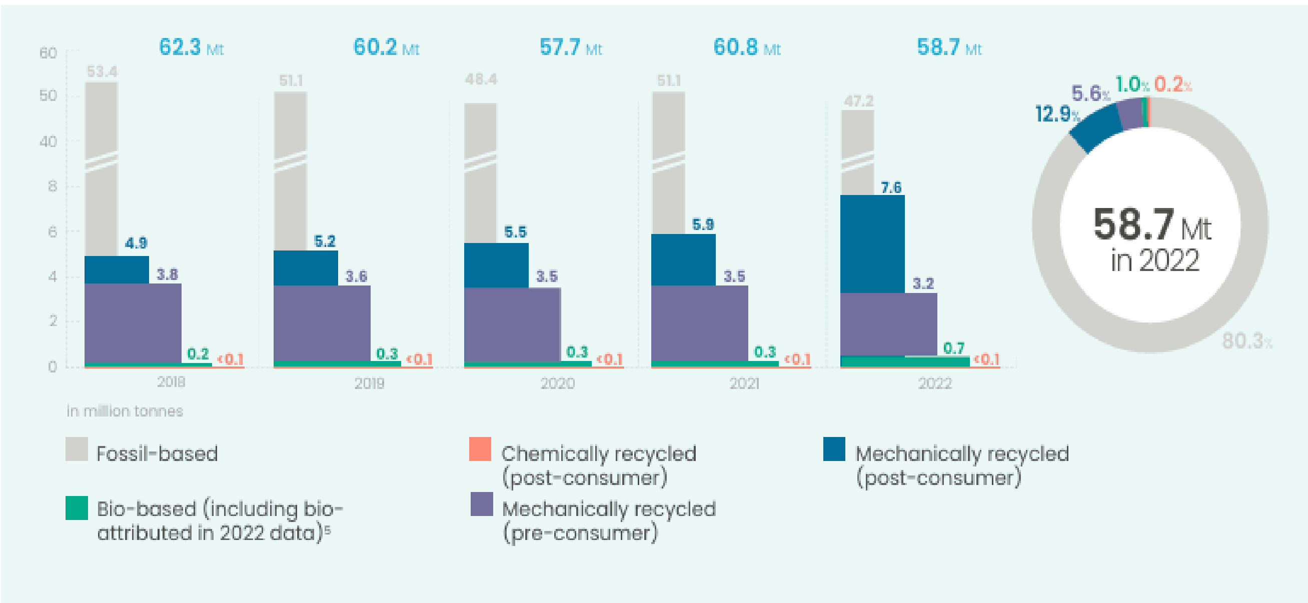
Figure 3: Types of plastic



Resource: PlasticOceans (2022); [7 Types of Plastic That Are Most Common | PlasticOceans.org]

3.2. Production technology

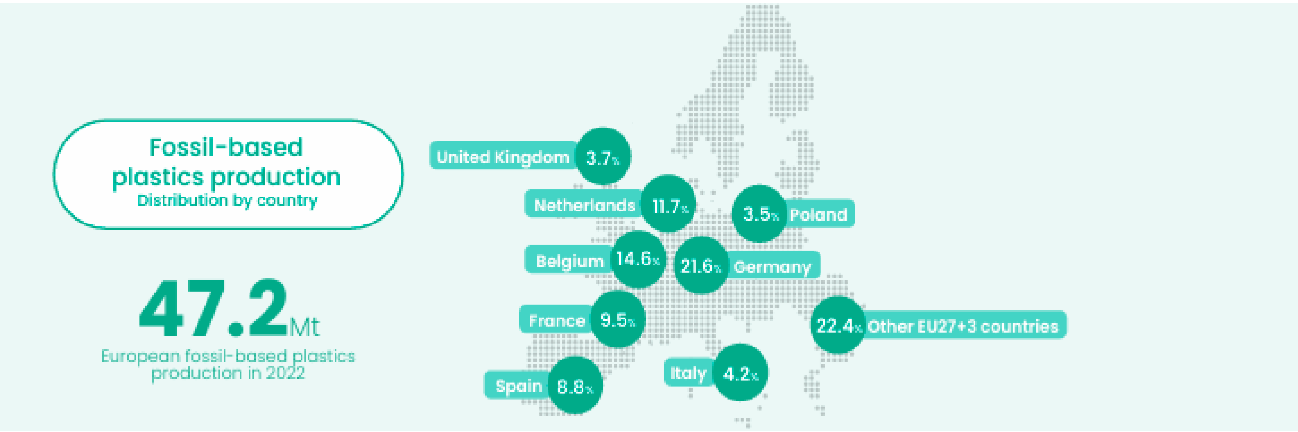
Figure 4: Production technology



Resource: PlasticEurope (2023); [Plasticsthefastfacts2023-1.pdf]

A fossil-based synthetic material made from a diverse range of organic polymers such as polyethylene (PE), polyvinyl chloride (PVC) and polyamide (PA), which can be moulded into shape while soft and then set into a rigid or semi-elastic form. The physical properties of plastic can be precisely determined by its chemical composition – from very stiff to ultra-soft. Plastic is long-lasting, hygienic and cost-effective. The economic growth and widespread accessibility to consumer products that marked the twentieth century would not have been possible without it. As a result of its positive attributes, the material has been used and mis-used for an ever-growing number of applications. In the past years, there has been a significant increase in the production of plastics from 100m tonnes per year in the early 1990s to 390m tonnes in 20211. Plastics are a non-renewable and non-biodegradable material. They can linger in the environment for centuries, breaking down into microplastics and polluting natural habitats.

Figure 5: Fossil-based plastics production



Resource: PlasticEurope (2023); [Plasticsthefastfacts2023-1.pdf]

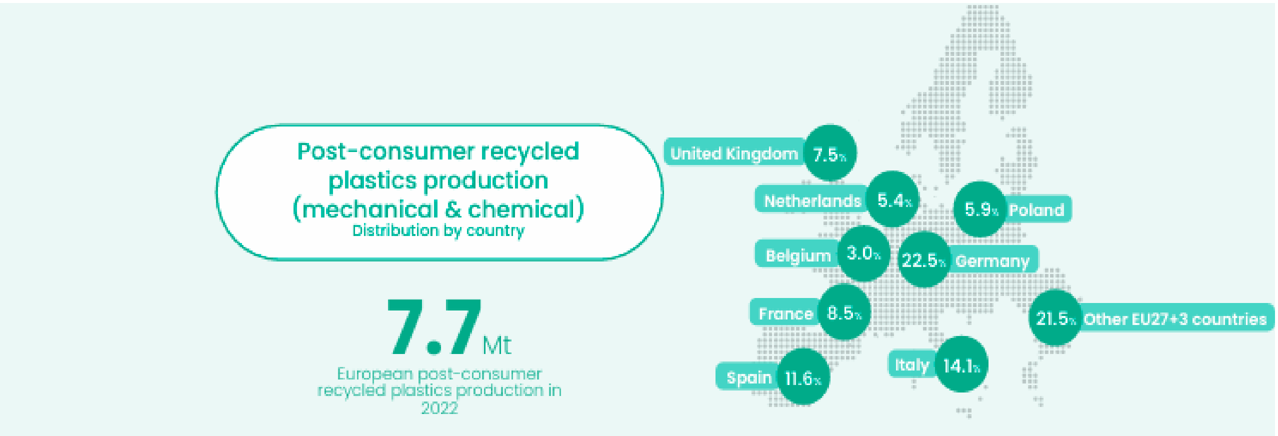
Post-consumer recycled plastic, or PCR, refers to plastic that has been collected, sorted, and processed to be reused after its life as a consumer product. This means the plastic has been used by consumers and then recycled for subsequent use in manufacturing new products. Using post-consumer recycled plastic to manufacture new products helps reduce the amount of plastic waste in landfills and conserves the natural resources used in virgin plastic production.

Chemical recycling is the process of converting polymeric waste by changing its chemical structure and turning it back into substances that can be used as raw materials for the manufacturing of plastics or other products. There are different chemical recycling technologies, e.g. pyrolysis, gasification, hydro-cracking and depolymerisation. Chemical recycling complements other plastic recycling options like mechanical, dissolution and organic recycling. Since it can deal with complex plastic waste streams, like films or laminates, chemical recycling can be used for plastic waste, which would otherwise result in incineration or landfill. With 67.5% of post-consumer plastic waste going to landfill and energy recovery across Europe, there is a clear potential for improvement. Because chemical recycling breaks down polymers into their building blocks, it also allows the production of recycled plastic (recyclate) with virgin plastic properties that can be used in demanding applications, such as food contact.

Mechanical recycling is an essential component of the circular economy. It can be applied to various material classes like plastics, lithium-ion batteries for electric vehicles, or metals. End-of-life materials can be processed via collecting, sorting, shredding, melting and transforming it into secondary raw materials for a new application. Manufactured from recycled material, the article enters its new use-phase before the next end-of-life management. For plastic waste, mechanical recycling is the preferred recycling solution if ecologically most beneficial, technologically possible, and economically attractive. Chemical recycling will complement mechanical recycling.

Post-consumer plastics are plastic waste consumers generate after use, such as packaging, bottles, and containers. This waste is collected through recycling programs and sorted based on the type of plastic. The sorted plastic is then processed into small pellets or flakes and used as a raw material for manufacturing new products. Post-consumer plastics represent a significant portion of the plastic waste stream. According to Ellen MacArthur Foundation, in 2016, only 2% of consumer plastics were collected for closed-loop recycling. Closed-loop recycling is when a product is used to make the same product and is the preferred recycling method to keep the highest utility and value. For example, a food-grade plastic bottle should become a food-grade plastic bottle again. Many manufacturers regard post-consumer plastics as a better material to reuse because it is evident to consumers. Many consumers are aware of the environmental impact of plastic waste and are motivated to recycle. Manufacturers demonstrate their commitment to sustainability and appeal to environmentally conscious consumers by promoting post-consumer plastics as a preferred recycled material. This has made post-consumer plastics more popular to use at the expense of post-industry plastics. But is it the best choice for a sustainable product? That isn't self-evident when we take a closer look. The problem with post-consumer plastics is that there are thousands of different plastics, each with its composition and characteristics. They all include various chemical additives and colourants that cannot be recycled together, making it almost impossible to sort the trillions of pieces of plastics into different types for processing. For example, green PET bottles cannot be recycled with clear PET bottles (which is why South Korea has outlawed coloured PET bottles.) High-density polyethene, polyvinyl chloride, low-density polyethene, polypropylene, and polystyrene must all be separated for recycling.

Figure 6: Post-consumer recycled plastic production

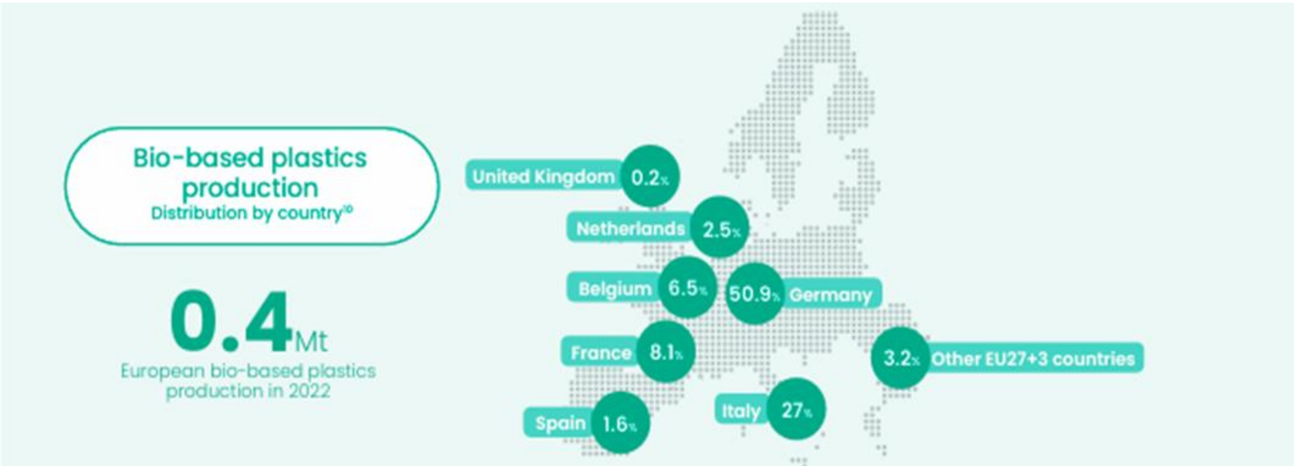


Resource: PlasticEurope (2023); [Plasticsthefastfacts2023-1.pdf]

Bio-based plastics is a way to switch to alternative feedstocks, thereby reducing dependence of fossil fuels and GHG emissions. Bio-based plastics are produced from renewable biomass sources. The biomass mainly originates from plants such as sugarcane, cereal crops, oil crops or non-food sources like wood, organic waste and by-products, such as used cooking oil, bagasse and tall oil. The benefit of bio-based plastics is that they potentially have a lower climate impact (GHG emissions along the life span) than plastics made from fossil sources. This depends on the raw material and production process. They help reduce dependence on (foreign) fossil fuels. However, they may have higher environmental impacts (on land use, water use, biodiversity etc.)

Some bio-based plastics are chemically identical to fossil-based polymers, but just made from a different (bio-based) feedstock. These are referred to as drop-in bio-based plastics and include bio-PET and bio-PE. They can be collected and recycled together with their fossil-based counterparts. Other bio-based polymers such as PLA, PHA, starch blends are bio-based and biodegradable (EEA brief...). Biodegradable plastics are designed to decompose at the end of their life under suitable conditions. These are typically not compatible with waste management systems for conventional plastics, but instead need their own systems such as industrial composting facilities. Global bio-based plastics production capacity has more than doubled since 2010, although it only experienced a slight increase of 10 % during the past 5 years. Today, about 2.2 Mt or 0.5 % of plastics on the global market are bio-based, i.e., produced from a bio-based feedstock. The share of bio-based in total plastics production is only slightly increasing year by year (from 0.54 % in 2013 to 0.56 % in 2022). This is due to the fact that the production of fossil-based plastics is increasing as well. So, although the capacity for bioplastics production is rising, the share of biobased plastics of the total plastics production volume remains quite stable.

Figure 7: Bio-based plastics production



Resource: PlasticEurope (2023); [Plasticsthefastfacts2023-1.pdf]

3.3. Application area

Areas which applications of plastics can be found:

Construction:

Plastics are used increasingly in the construction industry. They offer great versatility and combine excellent strength-to-weight ratio, durability, cost-effectiveness, low maintenance, and corrosion resistance, making plastics an economically attractive choice throughout the construction sector. They are used for insulation and protection materials (films, facade styrofoam, insulation foams, sealing tapes), fitting and finishing materials (cladding, floor panels, PVC carpets, composite terrace boards), and water supply and sewage pipes, as well as protective pipes and pipes for underfloor heating. Plastics are also used to make accessories and tools commonly found on construction sites, such as buckets, paint trays, handles, connectors, and fasteners.

Electrical and Electronic Applications:

Electricity powers almost every aspect of our lives, at home and at work, in both professional and leisure activities. And wherever there is electricity, there is also plastic.

Packaging and Covering Applications:

Plastic is the perfect material for use in packaging goods. It is versatile, hygienic, lightweight, flexible, and extremely durable. It accounts for the largest consumption of plastics worldwide and is used in numerous packaging applications, including containers, bottles, drums, trays, boxes, cups, vending packaging, baby products, and protective packaging. The benefits of using plastic packaging include extended shelf life and child-resistant packaging.

Fashion Industry / Textiles:

The fashion industry is now one of the fastest-growing industries in the world. It uses various types of plastics that have revolutionized clothing production, including:

- Polyester, which is a flexible, water-resistant synthetic fiber used for making blouses, sweaters, jackets, underwear, and home textiles.
- Polyamide, an extremely lightweight, flexible, and soft synthetic fiber, ideal for making sportswear, swimwear, hosiery, and tights.

Chemically and heat-resistant plastics are also used by manufacturers of protective workwear, such as overalls, jackets, and aprons. Interestingly, these materials are largely made from recycled plastic.

Food and Catering Industry:

Plastic also plays an important role in other industries related to food production or distribution. They can primarily be used to make bottles, containers, cutlery, accessories, and disposable dishes. This includes, for example, PET bottles, polystyrene containers, heat-sealable polypropylene trays, and polyethylene drinking straws. The food and catering industry also has a constant demand for plastic waste bags and food storage bags, which are most often made from LDPE, polyamide, and polypropylene. Plastics (polyethylene, PVC, Teflon, silicones) are also useful for making kitchen accessories, household appliances, dishes, trays, and even furniture.

Components for Creating Advertising and Commercial Information Media:
These can include posters, stands, plaques, wall panels, signs, and souvenirs (pens, keychains, scrapers, etc.). The most commonly used materials for making such items include polycarbonate, polypropylene, and polyethylene, as well as PVC.

Other Areas:
- Consumer products
- Industrial machinery
- Automotive industry (bumpers, dashboards, engine parts, seats, and doors)
- Furniture (bedding, upholstery, and household furniture)
- Medicine (syringes, blood bags, tubes, dialysis machines, heart valves, artificial limbs, and wound dressings)
- Sports
- Toy industry
- Agriculture and horticulture
- Aerospace
- Energy generation (wind turbines, solar panels, and wave energy)
- Marine industry (boat hulls and sails)
- Military (helmets, ballistic protection, tanks, military vessels, aircraft, and communication equipment)
- Transportation
- Decorations
- Safety
- Packaging production

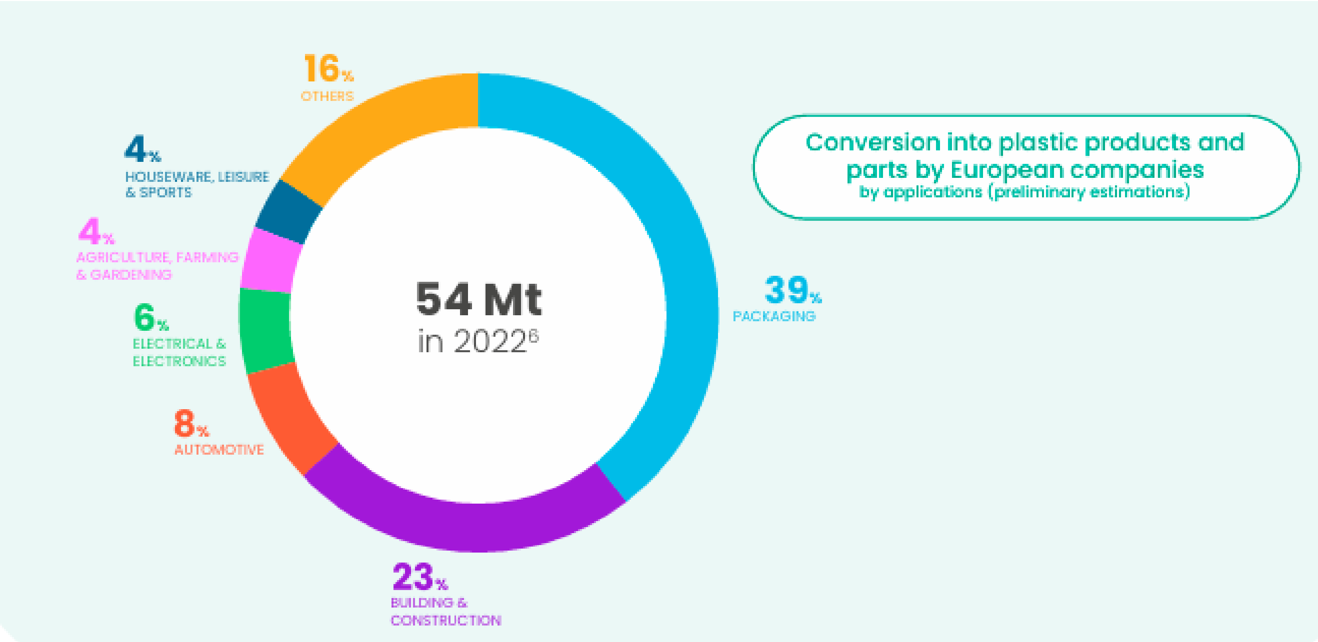
Plastic products are present in virtually every branch of industry and are important both as everyday products and as materials for special purposes.

Plastic has numerous applications in almost every area of life and continues to discover new uses. Unfortunately, as the amount of plastic increases, so does the amount of plastic waste. One of the most effective ways to combat plastic pollution is to reuse plastics or, in other words, to recycle. Polypropylene, PVC, LDPE, or PET plastic can be recycled to make:

- Bags and pouches, packaging, shopping bags
- Components for household appliances or consumer electronics
- Automotive parts
- Disposable tableware.

Recycled plastics are considered a valuable raw material used for making furniture, decorations, toys, and clothing. Efforts are underway around the world to build the first houses made entirely from recycled plastic. As you can see, plastic is a versatile material that we rediscover time and time again.

Figure 8: Application area of plastic



Resource: PlasticEurope (2023); Plasticsthefastfacts2023-1.pdf

4. Mapping of key industrial players (each country)

4.1. Slovenia

Table 1: Mapping of key industrial players for Slovenia

	NAME OF THE COMPANY	WEBSITE	KEY WORDS
1.	PLASTIKA SKAZA d.o.o.	https://www.skaza.com/	Plastic, production, optimization, plastic manufacturing, waste
2.	KOVINOPLASTIKA BENDA d.o.o.	https://kovinoplastika-benda.si/o-podjetju/	Metal, plastic, digital production, electro industry
3.	AERO-POLYPLAST, d.o.o.	https://www.aero-polyplast.si/	Technology, food packaging, health and cosmetic packaging
4.	AHIL PLASTIKA, d.o.o	https://www.plastika.ahil.si/	Plastic, production, industry,
5.	BIOPLAST, d.o.o.	https://www.bioplast.si/	Bioplastic, PVC, PP, PET,
6.	ELKIM d.o.o.	https://elkim.si/	Cosmetic packaging pharmaceutical packaging
7.	ECOPACK, d.o.o.	http://www.ecopack.si/	Food packaging, ecopack packaging
8.	JUTEKS d.o.o	https://www.juteks.si/	Plastic, floor coverings, PVC
9.	KOVINOPLAST LAHARNAR d.o.o.	https://www.kovinoplast.si/	Metal plastics
10.	AJM OKNA-VRATA-SENČILA d.o.o.	https://www.ajm.si/	Windows production, doors production, blinds production
11.	ACRYFORM d.o.o.	https://www.acryform.com/	Plastic materials, industry, technology, windows production
12.	ALPRO STORITVE d.o.o.	https://www.alpro.si/	Pipes, plastics, plastic pipes
13.	ALU-K KOVINOPLASTIKA d.o.o.	https://www.alu-k.si/podjetje	Windows production, doors production, blinds production
14.	AM Plastics d.o.o.	https://www.am-plastics.com/	Plastic, thermoplastic products, plastic injection molding

15.	PLASTX d.o.o.	https://plastx.si/o-nas/	Plastics, plastic processing, plastic products
16.	ISOKON, d.o.o.	http://www.isokon.si/en/	Technical plastics
17.	Planet Care d.o.o.	https://planetcare.org/	Microfibers, plastics
18.	ANIS TREND d.o.o.	https://www.anis-trend.com/sl/	Waste, baling, waste baling
19.	PLASTIKA BEVC d.o.o	https://plastika-bevc.com/	Injection molding of plastic, plastic elements
20.	AVANTPACK d.o.o.	https://avantpack.com/	Production, green packaging, waste bags

4.2. Austria

Table 2: Mapping of key industrial players for Austria

	NAME OF THE COMPANY	WEBSITE	KEY WORDS
1.	Alpla Holding GmbH	https://www.alpla.com/de	Packaging manufacturing
2.	Greiner AG	https://www.greiner.com	Plastics and foams
3.	Semperit AG Holding	https://www.semperitgroup.com/	Heavy-duty components
4.	adapa Holding GmbH	https://www.adapa-group.com/	Plastics and foils for packaging
5.	Agru Kunsttofftechnik GmbH	https://www.agru.at/	Plastics, piplines
6.	Sunpor Kunststoff Gmbh	https://www.sunpor.at/	Insultation, foams
7.	Senoplast Kletch & Co GmbH	https://www.senoplast.com/	Plastics, Sheets and plates
8.	APSYS modern Baustoffsysteme GmbH	http://www.apsys.at/	Polyols and Polyurethanes
9.	asota GmbH	http://www.asota.com/	PP, PE, PA
10.	Banner Kunststoffwerk GmbH	http://www.bannerkunststoff.com/	Thermoplastics
11.	BASF Österreich GmbH	http://www.basf.at/	Constructionmaterials and coatings
12.	Binder Kunstofftechnik GmbH	http://www.binder-gfk.at/	Packaging and pipelines
13.	Borealis AG / Borealis Polyolefine GmbH	http://www.borealisgroup.com/schwechat	Polyolefines
14.	Ensinger Sintimid GmbH	http://www.ensinger-sintimid.at/	Plastics
15.	Eurofoam GmbH	http://www.eurofoam.at/	Polyurethan foams
16.	EUROPLAST Kunstoffbehälter GmbH	http://www.europlast.at/	Low-energy and low-waste plastic production
17.	Faigle Kunststoffe GmbH	http://www.faigle.com/	Plastics and new compound developmemnt
18.	G. Coreth Kunstoffverarbeitung	http://www.coreth.at/	Recycable plastics
19.	Praher Plastics Austria GmbH	http://www.praher-plastics.com/	Plastics, development of manufacturing systems

20.	Thermoplastics Profil&Rohr GmbH	http://www.akalit.at/	Specialized plastics, extrusion

4.3. Czech Republic

Table 3: Mapping of key industrial players for Czech Republic

	NAME OF THE COMPANY	WEBSITE	KEY WORDS
1.	ORLEN Unipetrol RPA s.r.o.	https://www.orlenunipetrolrpa.cz	Plastics production, industry, polyolefins
2.	Synthos a.s.	https://www.synthosgroup.com	Plastics production, recycling, industry, Polystarene
3.	Silon s.r.o.	https://silon.eu	Plastics production, compounding, thermoplastics
4.	Polymer Institute Brno	https://www.orlenpolymer.cz	compounding, thermoplastics,
5.	Lificolor	https://www.lifocolor.de/cz	compounding, thermoplastics,
6.	TIU Plast a.s.	https://www.tiu.cz	compounding, thermoplastics,
7.	Magna	https://www.magna.com	Automotive parts, termoplastics
8.	Sigmaplast	http://www.sigmaplast.cz	Automotive parts, termoplastics
9.	Witte Automotive	https://www.witte-automotive.com	Automotive parts, termoplastics
10.	PD Plast	https://pdplast.com	Technical parts, construction materials, automotive parts
11.	Plasty Zálesí	https://plasty.zalesi.cz	Technical parts, construction materials
12.	Fatra a.s.	https://www.fatra.cz	Vinyl floor coverings, technical foils
13.	D PLAST a.s.	https://www.dplast.cz	Technical parts, tubes
14.	Hranipex	https://www.hranipex.cz	Furniture Edges
15.	Greiner Packaging	https://www.greiner-gpi.com	Packaking material, foils
16.	Pebal s.r.o.	https://www.pebal.cz/	Packaging material, foils
17.	Remiva group.	https://www.remivagroup.cz	Plastic recycling, compounding

18.	Mateo Packing	https://mateopacking.cz	Plastic recycling, technical foil
19.	Transform	https://www.recyklace.cz	Plastic recycling, construction parts
20.	Petka	http://petkacz.cz	PET recycling, construction part

4.4. Hungary

Table 4: Mapping of key industrial players for Hungary

	NAME OF THE COMPANY	WEBSITE	KEY WORDS
1.	MOL Group	molgroup.info	Integrated oil, gas, petrochemicals, and consumer retail services Produces polyethylene (PE) and polypropylene (PP)
2.	BorsodChem	borsodchem.eu	Produces MDI, TDI, and PVC
3.	Jász-Plasztik	jasz-plasztik.hu	Automotive and electronics plastic parts Internal recycling via Jász-Plasztik Recycling Kft.
4.	Pannonplast	pannonplast.hu	PET bottles and containers for food and beverage
5.	Masterplast	masterplastgroup.com	Plastic-based insulation and roofing materials
6.	Karsai	karsai.hu	Recycled packaging, component production, injection molding
7.	Plastic Material Recovery Facilities (~60)	Source: https://www.enfplastic.com	Companies working on communal and industrial type plastic recovery
8.	Plastic Recycling Plants in Hungary (~30)	Source: https://www.enfplastic.com	Companies coverting different types of plastic waste into raw materials for plastic production

5. SWOT ANALYSIS

5.1. EU

SWOT ANALYSIS

STRENGTHS:

-Developed infrastructure and industry

-Strong legislative support

-Research and innovation

-High recycling rate

-Sustainability and circular economy as core strategic principles

-Consumer awareness

WEAKNESSES:

-Dependence on fossil resources

-Environmental challenges (pollution, microplastics)

-Overburdened waste management systems

-Low practical recycling rate

-Fragmented practices across countries

-Economics of recycling

OPPORTUNITIES:

-New technological trends (digitalization and material traceability)

-Production of high value-added materials

-Chemical recycling

-Development of bioplastics and compostable materials

-Education and awareness

-Circular economy

-Green transition and funding

THREATS:

-Change in consumer habits

-Pressures to reduce plastic use

-Competition from alternative materials

-Stricter legislation, regulations, and policies

-Geopolitical and market instability

-Health risks (microplastics)

-Environmental pressure and pollution

-Negative consumer trends

6. Other projects mapping - synergies

6.1. Slovenia

LIFE CEPLAFIB: Implementation of a new Circular Economy through the valorisation of postconsumer PLAstic waste and reclaimed pulp FIBer

An European project will valorise post-consumer plastic waste and newsprint paper for new construction, packaging and automotive parts. This project, entitled as CEPLAFIB, will transform two post-consumer wastes: plastic waste and newsprint paper, into novel primary resources for high added value applications through their combination in novel recycled fibre reinforced composite materials. In this sense CEPLAFIB aims to orchestrate a new circular economy in which recycled postconsumer plastic will be reinforced with re-claimed pulp fibres to improve their end performance characteristics and to stabilize the recyclates flows for their direct use in mass application sectors, i.e. automotive, caravanning, packaging and construction.

LIFE BioTHOP: BioTwine HOP waste transformation into novel product assortments for Packaging and Horticulture Sector

BioTHOP project indorses a new circular economy for improved hop waste management, that combines alternative bioplastic twine materials based on poly(lactic acid) (PLA), with ability to be converted into novel feedstock for 100% biodegradable, compostable and recyclable packaging & horticulture product accessories. Hop training systems in Europe are based on wire or polypropylene (PP) twine trellises, usually pinched for about 6-7 meters above the ground on a regular arrangement of wooden or concrete poles. Roughly 5 dt/ha of steel cord and 5.5 dt/ha of steel barbed wire are consumed for wire netting, or 45 km of PP twines/ha for twining, each season. Both of the mentioned practices are far from EU's environmental policy objectives, since the after-harvest biomass cannot be properly composted, recycled or landfilled. Unfortunately, for hop agro-waste, which yields up to 15 tons/ha (fresh matter) per season, the most frequent practice is still uncontrollable burning. In response to the problem described, BioTHOP project indorses a new circular economy for improved hop waste management, that combines alternative bioplastic twine materials based on poly (lactic acid) (PLA), with ability to be converted into novel feedstock for 100% biodegradable, compostable and recyclable packaging & horticulture product accessories.

INCIRCULAR: Promoting sustainable regional development through additive manufacturing: A cross-border initiative for a resilient and circular economy.

Unlocking the innovation potential of European regions in circular plastics. Plastics production and end-of-life seriously damage the environment. Innovative solutions are needed to produce new types of plastics that are environmentally friendly while offering technical properties and a cost line similar petroleum-plastics currently on the market. The goal: reaching second-life raw materials from 100% recycled plastics. In addition, new technologies are needed to be able to use this second-life raw material in the traditional production chains of the plastics production sector. Producing plastics that have less impact on the environment will support a sector that is currently receiving particularly critical perceptions from end users.

Industrial Symbiosis: scaling INCIRCULAR. INCIRCULAR brings together three regional ecosystems involving complementary capabilities in a holistic demonstration project meant to scale up a unique process technology implemented in Slovenia while sourcing technologies from Spanish and French regions (process/digital twinning). INCIRCULAR thus enables cross-regional tech transfer through TRL6 to 9, in support to the setup of an interregional circular ecosystem that will scale at EU level. From a technological standpoint:

- Demonstrate the production of bioplastic sourced 100% from recycled plastic, 100% recyclable and presenting technical properties similar or better to current petro-plastics. This is based on the demonstration (TRL6 to TRL9) of a R&D process developed by TECOS (SI), in collaboration with an innovative SME (ES) and meant to be installed and deployed at the industrial site of Gorenje (SI).
- Integrate this new second-life material directly into the production chain of the Gorenje site by collaborating with Omaplast (SI) which will collect, sort, and recycle on site. The innovative integration of the digital twinning of plastic injection moulding developed by two SMEs (FR) is necessary to ensure the production.

AMT2P: The use of advanced manufacturing techniques in vocational education and training – A case study of the plastics sector

While the latest technologies, methods, and techniques brought about by the Fourth Industrial Revolution simplify daily workflows, a significant drawback that needs to be addressed is the lack of knowledge and practical skills necessary to manage, maintain, and create value using Advanced Manufacturing Techniques (AMT). This is precisely the focus of the AMT2P project. By identifying the existing gap between the skills needed to successfully manage these technologies and the current level of expertise in AMT within the plastics sector, AMT2P aims to bridge this gap by providing a common framework through which the sector can train employees on the use of AMTs.

The main objectives of the project are:

- To develop a training methodology and supporting tools to address the skills gap (with a particular focus on the expertise of staff, access to advanced manufacturing techniques, and gaps in "green" skills);
- To develop educational material content supported by the use of information tools provided by project partners with high expertise in this field;
- To conduct pilot workshops to validate the training methodology and gather feedback from trainers and trainees;
- To assess the results of the pilot workshops and adjust the training methodology and content based on the current needs of the sector.

LFIA-REC: Recycling of rapid antigen LFIA tests (COVID-19)

The Covid-19 pandemic has resulted in huge amounts of waste from single-use medical devices, including rapid tests that work based on nanogold. Large quantities of these tests are discarded and incinerated. When burning one million rapid tests, we throw away 0.1 gram of gold and 5,000 kg of plastic, with a total value of €15,000. In the project, we will recycle rapid tests and separate individual high-quality components (gold, plastic) and use them as a secondary resource. With the project, we want to reduce greenhouse gas emissions that would occur during incineration and achieve a transition to a circular economy through the efficient use of secondary sources. The aim is also to set an example of good practice on how to tackle more complex recycling. The project content follows the long-term goal of the EU Action Plan for the Circular Economy, which includes reducing waste disposal in landfills and increasing the reuse and recycling of waste. The goals of the project are to develop a process and innovative technology for the dismantling and recycling of rapid tests to high-quality secondary raw materials (gold and plastic) for independent processing or incorporation into new products.

I3-DEREMCO: De & Remanufacturing for circular economy investments in the composite industry

Fiber-reinforced plastic is a structural material used in many consumer and industrial products, but the recycling or reuse of composite products after the use in accordance with the principles of the circular economy is still a serious challenge. The goal of the DeremCo project is to establish a systemic, cross-sectoral demand-driven circular economy solution that will enable the cost-effective reuse of composite materials and components after the use in new products with high added value. Fiber-reinforced plastics are the structural components of a wide range of consumer and industrial goods, but managing composite products after use in accordance with the principles of the circular economy remains a significant challenge.

The DeremCo project aims to create a systemic, cross-sectoral, demand-driven circular economy solution that will enable the cost-effective reuse of post-use composite materials and components in new high-added value products. This solution will be based on the interaction between the technical and social eco-systems at the local and interregional level and will benefit the environment, industry, consumers, and the European society.

To satisfy consumer demands, two circular pilot procedures will be used:

- Mechanical demanufacturing and hybrid reprocessing.
- Thermo-chemical demanufacturing and textile reprocessing.

The circular value-chain will be changed into a “pull” system, in line with the new DeremCo Demand-Driven vision, where the demands and specifications on the materials and components to be reused are transferred directly from the demand side in terms of the qualities and functions of the high added-value products reusing them. The major objectives will be to encourage industrial uptake within local eco-systems, to de-risk future industrial uptake through private investments, and to raise awareness for more conscientious consumer behavior to assure sustainability and continuity.

RISE I3: Accelerate innovation and sustainable investments

The overall objective of the Project RISE is to accelerate the deployment of innovation, promoting the drivers and investment needed for sustainable and successful interregional cooperation.

RISE will increase the capacity of less developed regions through successful interregional cooperations. The project supports the birth and development of innovative and resilient projects in 3 less developed regions: Bulgaria, Slovenia and Portugal.
RISE envisions achieving the following objectives:

- Conducting a comprehensive assessment of local innovation ecosystems in underdeveloped regions, benchmarking them against European standards. This involves identifying opportunities for development and the implementation of diverse innovations, accompanied by insightful recommendations for enhancement.

- Crafting localized roadmaps that facilitate the interconnection of companies, fostering collaboration between local and regional businesses and international/European stakeholders.
- Hosting a dynamic event where Small and Medium Enterprises (SMEs) from diverse regions converge, providing an invaluable platform for networking and collaboration.
- Establishing consortia comprising various companies to present innovative ideas, encouraging a collaborative approach to problem-solving.
- Meticulously selecting projects poised for financing, coupled with strategic investment planning.
- Developing a comprehensive plan and roadmap for financing, complete with a sophisticated model for mixed financing approaches.
- Facilitating a seminar to discuss project outcomes, proposing policy measures, with special considerations for less developed regions.

6.2. Austria

Senat für Kreisslaufwirtschaft: The Senate for circular economy ('Senat für Kreislaufwirtschaft') is a cooperation of 8 of the largest companies in Austria to increase the potential for a circular economy. These include the 2 largest supermarket chains (Billa AG, Spar Österreich), the Brewer Union, NÖM AG (Austrias largest dairy producer), as well as plastic and packaging manufacturers, all under the patronage of ARA (Altstoffrecycling Austria AG). The cooperation was initiated as the result of a study on the potential of circular economy for Austria by PwC. The study highlighted the growth potential and strategic relevance for an increased recycling system in terms of economic growth and resource independence.
This 'Senate for circular economy' advice 4 main points:

- The senate advices the government for a rigorous strategy to fulfill the guideline of the European Union. A governmental strategy will give Austrian companies the trust for investments.
- Transport of waste and recyclable material across boarders inside the European Union are laborious and require substantial amounts of documentation. The Senate encourages an agreement for the transport of recyclable material across borders, similar to the 'Schengen Area'.
- The founding of a coordinating body between different ministries. Recycling and a circular economy sit in between the responsibilities of several governmental bodies, from economy, sustainability, finance to agriculture and more. A coordinating body could facilitate the communication between all stakeholders and prevent time and money consuming processes.
- Expanding the responsibility of manufacturer of textiles. This should be done analogues to the Packaging and Packaging Waste Regulation (PPWR) of the European union. A similar directive for textile will increase the potential for a circular economy and recycling in this area.

Zero Pellet loss: An initiative from the Austrian association of the chemical industry (FCIO) to reduce and minimize the loss of plastic during production and logistics. The prevention of plastics ending up in the oceans of the world is attacked by a campaign for information distribution. The initiative is supported by the largest producers of plastics in Austria. Additional to awareness, they include 10 points for proactive reduction of plastic loss:

1) Baskets at all loading stations to collect stray pellets
2) Strategic placement of waste baskets for granulates
3) Equipping all drains with sieves
4) Carefully seal container before shipment
5) Control of container after emptying
6) Check ceiling of transport-cars for pellets
7) Suction-systems for pellet removal, where possible
8) Careful removal of stray pellets
9) Training and education for personal
10) Information for logistics partner

Greiner Zeroplast GmbH: The start-up Zeroplast develops plastic alternatives based on cellulose fibres, wax (mainly from rice) and chalk. The company was incorporated into the Greiner AG, Austrias second largest plastic manufacturer, in 2022 and are now part of Greiners attempt at reducing fossil-fuel based plastics.

Green Tech Valley Cluster GmbH: The cluster provides a network and connects different companies, start-ups and research facilities to develop sustainable products, services or reduce current carbon and waste footprint. It resides in the south of Austria and hosts over 300 companies and research groups under the umbrella of 'green technologies' focusing on mobility, electricity, heating, construction, digital and circular economy. Its goal is to make Austria the central European hub for sustainable technologies.
In terms of renewable plastics and recycling, companies such as KRM Kunststoff-Recycling-Maschinen GmbH and Binder+Co AG, are forerunners.

FolienKreislauf2030: The Austrian Research Promotion Agency (FFG.at) is financing a project which focuses on the recycling of plastic packaging, especially foils. The project started in November 2021 and will finish in 2025. The goal is to evaluate possibilities to increase the recycling of plastic films in Austria to fulfill the goal of the European union to recycle at least 50% of plastic waste by 2030.
The cooperation of research institutes, such as universities, and industry partners is one of the main points of the FFG, and the project here is no exception. The coordinator is the competence center CHASE GmbH, which facilitates the communication between the Energy Institute at the Johannes Kepler University Linz with the industry partners EREMA, Walter Kunststoffe GmbH, the Abfallverwertungsunternehmen of Upper Austria and the Energie AG Oberösterreich Umwelt Service AG GmbH.
The University Linz published the article 'Identification of the recyclable content of polyethylene films in the Upper Austrian waste streams' in 2024 (https://doi.org/10.1080/19397038.2024.2373225), identifying PE films in Austrian waste streams and highlighting the potential for enhancing the recycling rate.

Plastic Pirates - Go Europe: The citizen-science project Plastic Pirates - Go Europe, evolved from the German 'Plastikpiraten' in 2021. The goal is to have a precise map of environmental waste across Europe. This will help to identify hot spots of plastic accumulation, locate potential risk factors and ultimately find solutions and points of attack to prevent waste from ending up in the environment. In total, 26 research institutes across Europe analyze samples taken from 350 rivers and coasts, collected by more then 16000 people, mostly students aged 10-16 years. The project is funded with 2 million € in total by the European Union.

Optimize2Recycle: A cooperation of 3 plastics manufacturer and the research institute OFI Technologie & Innovation GmbH. The companies, namely JODL Verpackungen, Lenzing Plastics and Dannemann Global Extrusion, search for alternatives in plastic packaging, to increase the potential for recycling. First, the identification of insufficiently recyclable materials in packaging is done, followed by finding and production of alternatives.
The project started in February 2024 and ends in July 2025. It receives additional funding from the state of Upper Austria.

6.3. Czech Republic

Circular Czechia 2040 Action Plan: supports the transition of the Czech Republic to a circular economy with the goal of sustainable material and waste management. The main objectives include extending product lifecycles, increasing recycling and reuse of materials, promoting circular design, and fostering innovation in materials.
(https://www.mzp.cz/C1257458002F0DC7/cz/akcni_plan_cirkularni_cesko_2040/$FILE/OCEO-Akcni_plan_Cirkularni_Cesko_2040_2022_2027-01092023.pdf)

The plan focuses on:
1. Products and design – designing products for easy repair and recycling.
2. Consumption – changing consumer habits toward sustainability.
3. Waste management – improving collection, sorting, and recycling.
4. Innovation and research – supporting the development of new recycling technologies.
5. Sector collaboration – connecting the public and private sectors.

The goal is to reduce landfill waste, increase recycling, and promote circular principles in industry. The plan includes legislative changes, financial support, and public awareness efforts.

PolyEnvi21: The PolyEnvi21 project focuses on research into polymer systems to ensure sustainability and circularity in chemical production and plastic processing. Activities include improving the efficiency of automated plastic waste sorting, developing technologies for effective waste utilization, and creating new materials for the automotive industry (PolyEnvi21).
The aim of the PolyEnvi21 project is to research and develop new solutions that meet the requirements of sustainable development and the circular economy. The new materials should be recyclable, biodegradable and energy efficient. Key areas of research and development include mechanical and chemical recycling of polymer materials. The projects also address the issue of biodegradable systems and polymers with the aim of their possible use as a replacement for plastics that are not biodegradable in nature. The PolyEnvi21 project also focuses on the identification and optimization of microorganisms that are able to decompose specific types of polymers, as well as on the development of biotechnologies that enable these processes.

MIRACLES: Multifunctional fibre-reinforced plastic composites with MXene layers. The MIRACLES project focuses on the research of fiber-reinforced plastic composites (FRPC), which are used in aviation, shipbuilding, wind energy, and other advanced fields. The aim of the project is to develop FRPC with added functionalities such as damage monitoring, de-icing, self-detection, and moisture protection.(Multifunctional fibre-reinforced plastic composites with MXene layers | MIRACLES | Project | Fact sheet | HORIZON | CORDIS | European Commission).

BioSys: Proposal for a Technologically Feasible Process for Chemical Recycling of Biopolymers. Biopolymers appear to be an environmentally viable alternative to polymers produced from fossil sources, especially when they are made from secondary agricultural products. However, their mechanical recycling and subsequent biodegradation are technically highly problematic. Chemical recycling leading to the production of bio-solvents allows for post-consumer processing of waste biopolymers within a circular economy system. (Synpo | Projekty).

Plastr: The Plastics Cluster provides a platform for development, collaboration and innovation in plastics, connects professionals and enhances the competitiveness of its members. The company focuses on innovation, development, and collaboration in the field of plastics. It provides a platform for growth and connects experts, thereby increasing the competitiveness of its members.(Inovace a Rozvoj | Plastikářský klastr)
The main activities of Plastr include:
- Support for research and development: Plastr supports the research and development of new technologies and sustainable solutions in the plastics industry.
- Collaboration and innovation: The company connects experts and firms to work together on innovative projects.
- Education and development: Plastr organizes educational programs and develops professional networks for effective collaboration.

Obaly 21platform: project that brings together representatives of major manufacturers, primarily of food packaging, in the Czech Republic. It focuses on improving the recycling of plastic packaging. One of its goals is the rapid detection of the quality of plastic recyclate, which enables more efficient sorting and processing of plastics. The platform aims to present facts and realities regarding packaging, emphasizing their role in preventing food waste and ensuring hygiene. It also conducts surveys and analyses public attitudes toward packaging, waste, and recycling, and offers space for public opinions. The platform includes a section dedicated to packaging design and current trends in the packaging industry.(O platformě - Obaly 21) .

Czech Technological Platform PLASTY (ČTPP): is an association focused on supporting the plastics industry in the Czech Republic. It promotes collaboration, research, and innovation in plastics manufacturing. (https://www.tp-plasty.cz).

Key activities include:

- Industry Collaboration: Encouraging cooperation among companies to advance technological innovations.
- Research and Development:Engaging in R&D projects for sustainability and efficiency.
- Events:Organizing workshops and conferences, such as one on EPS and circular economy.
- Action Plan:Developing a plan for the digital and green transformation of the industry.

Cyrkl: Czech-based company specializing in circular waste management. It operates Europe's largest digital platform for industrial waste and green procurement, connecting waste producers with recyclers. Cyrkl offers consulting services to optimize material flows, reduce costs, and help businesses achieve sustainability goals (https://www.cyrkl.com).
Key activities of Cyrkl include:
Circular Waste Scans: Analyzing waste streams to identify potential CO_2 and cost savings.
Consulting Services: Providing market analyses, transferring recycling technologies, and ensuring compliance with regulations.
Digital Marketplace: Connecting companies with recycling partners and facilitating the trade of recyclable materials.

EPIC-I3: The "Enhancing Packaging Innovation Ecosystems for Interregional Collaboration" project, acronym EPIC, aims to build capacity in innovation ecosystems in less developed regions, enabling the opportunity for innovation actors to drive the transition towards sustainable packaging in response to environmental and regulative challenges outlined by the EU Packaging and Packaging Waste Regulation.
The consortium coordinated by Nanoprogress (Czechia) includes 10 partners from 8 European countries representing the clusters: BalticNet-PlasmaTec (Germany), DBH InnoHub (Hungary), Clust-ER MECH (Italy), Clust-ER HEALTH (Italy), LitMEA- Smart Food Cluster (Lithuania), Bydgoszcz Industrial Cluster Tool Valley (Poland), Association Packaging Cluster (Spain), Feeling Innovation by Stanpa (Spain) and research&technology competence centre: INEGI – Institute of Science and Innovation in Mechanical and Industrial Engineering (Portugal) committed to tackling the upcoming fundamental transition towards a more sustainable packaging sector. More at https://toolvalley.eu/epic-i3-instrument/.

6.4. Hungary

Several national and international initiatives and research projects support plastic management in Hungary. These collaborations drive innovation, circular infrastructure, and regulatory alignment with EU policies.

Research & Innovation Centers

- Bay Zoltán Research Institute: Engaged in research and development, the institute focuses on sustainable materials and recycling technologies, contributing to advancements in plastic waste management practices.
- Eötvös Loránd University (ELTE): Participating in projects like **GreenChemForCE**, ELTE is involved in developing strategies for sustainable plastic management in Central Europe.

Key Projects

PLASTICS CIRCULARITY MULTIPLIER (EU project)

- Partner: Bay Zoltán Nonprofit Ltd.
- Focus: Circular plastic innovation, H2020 project synergies
- Website: plasticscircularitymultiplier.eu

National Waste Management Plan 2021-2027

- Governmental strategy
- Scope:
    - ❖ *Improve plastic collection infrastructure*
    - ❖ *Strengthen EPR (Extended Producer Responsibility)*
    - ❖ *Promote reuse & recycling*
- Website: kormany.hu

PET Cup (PET Kupa)

- Organized by: Civil society, NGOs, local authorities
- Activity: Tisza River plastic cleanups & awareness campaigns
- Impact: Thousands of PET bottles collected annually
- Website: petkupa.hu

Humusz Szövetség

An NGO advocating for waste prevention and the reduction of plastic usage, promoting sustainable consumption patterns among the public.

Greenpeace Hungary

Actively campaigning against plastic pollution, Greenpeace Hungary works to influence policy changes and raise awareness about environmental issues related to plastics.

Blue Planet Foundation

Supports educational and R&D initiatives related to sustainability, including plastic waste reduction and innovation.