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PROJECT POLREC

EURO CLUSTERS

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Mapping of European plastic waste streams and of European plastic recyclers

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Glossary of terms, abbreviations, and acronyms

Partner short name	Partner	Country
POL	Polymeris	FR
CEN	Centro Tecnológico da Indústria de Moldes, Ferramentas Especiais e Plásticos	PT
MAV	Clúster de Materials Avançats de Catalunya	ES
PCD	Plast Center Danmark	DK
WFG	Wirtschaftsförderung Raum Heilbronn GmbH	DE

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1. Introduction

The POLREC project is a collaborative project between the 4 European clusters and a technological center. It focuses on sustainable development and recycling of high and low value polymers as a contribution to the objectives of the European Green Deal aiming at zero CO_2 emissions in 2050 and to increase the European strategic autonomy on raw materials for polymer production.

During a project period of 3 years the consortium will explore how an intensified cluster and business network collaboration across boarder and across sectors can meet this challenge and exploit the international business opportunities related to this topic.

A number of activities have been lined up to handle this challenge and one of them is a mapping of European waste streams and Europeans plastic recyclers.

This mapping is to be seen as a support tool of the POLREC Innovation Open Call, which can financially support SMEs with an ambition of decreasing the environmental impact of their products. Their practices must be switched from incineration and landfill of polymer waste towards polymer recycling – mechanical as well as chemical. To improve processing of recycled polymers, the open call will finance the implementation of improved moulds and processing aids to support SMEs in switching their practices.

In this report the importance of the European plastic industry is described with the aim of giving a better understanding of this industry. Then a description of the extent of plastic waste and plastic recycling in Europe is given. Plastic recycling is divided into mechanical, dissolution and chemical recycling technologies, where descriptions of the three approaches are given.

The report concludes with an overview of the plastic recyclers in Europe with a focus on the POLREC consortium countries.

This document serves as Deliverable D2.2 of the POLREC project.

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2. Importance of the European Plastic Industry

In 2021, the plastics industry gave direct employment to more than 1.5 million people in the European Union, a small increase compared to 2020. [PLASTICS - THE FACT 2022]

An industry with over 52,000 companies, most of them SME's, distributed across the European Union. The European plastics industry (EU27) had a turnover of approximately 405 billion Euros in 2021, and a positive trade balance of 14.4 billion Euros in 2021.

In 2021, the United States of America, United Kingdom and China were the top trade partners of the EU27 plastics industry. The largest amount of polymers was imported form The United States of America and the largest amount was exported to the United Kingdom. When it comes to manufactured plastic products the largest amount of goods was imported from China and the largest amount was exported to United Kingdom.

After a decrease in 2020 due to the Covid-19 pandemic, the European production of plastic goods increased to 57.2 million tons (Mt) in 2021. Please see Figure 1.

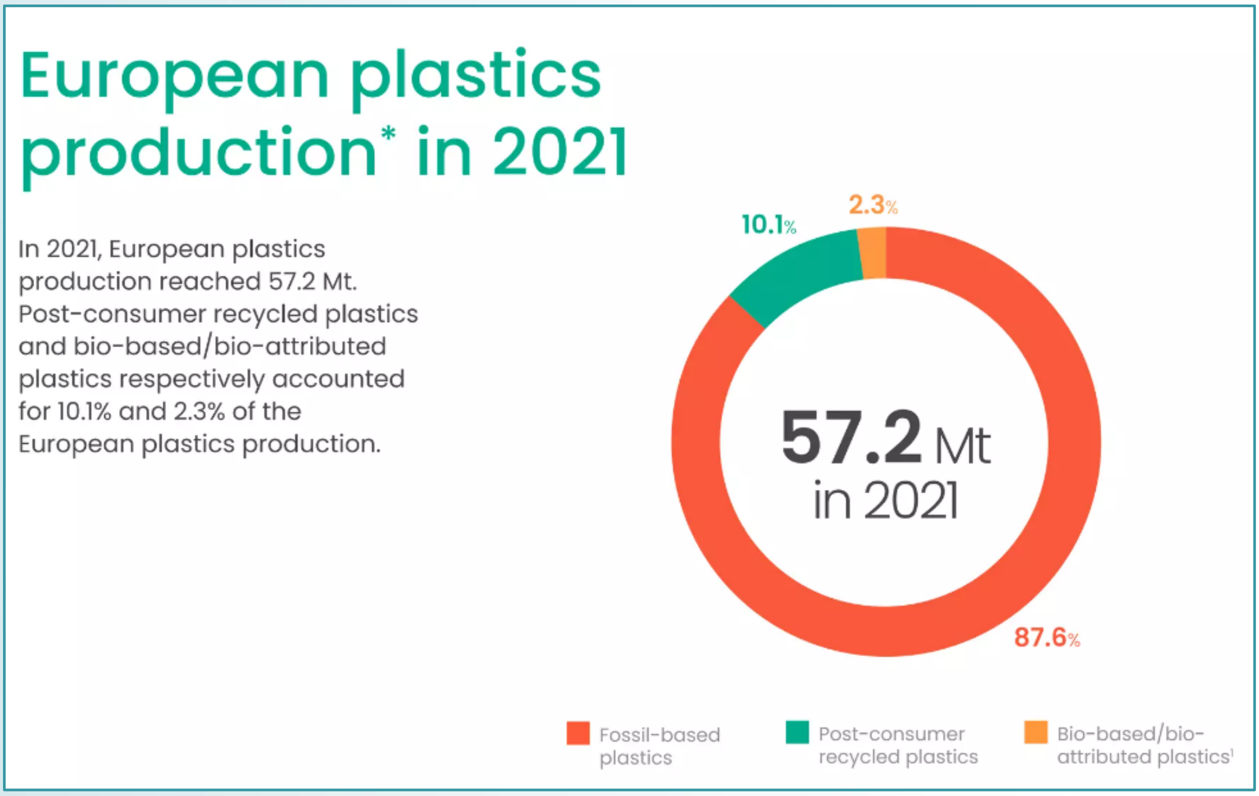

Figure 1 – European Plastics production in 2021 [PLASTICS - THE FACT 2022]

However, there are challenges. Latest data show that China's share of global plastics production continues to grow (reached 32% in 2021) while Europe's share continues to decline (hit 15% in 2021). This confirms a loss of competitiveness. Please see Figure 2. [PLASTICS - THE FACT 2022]

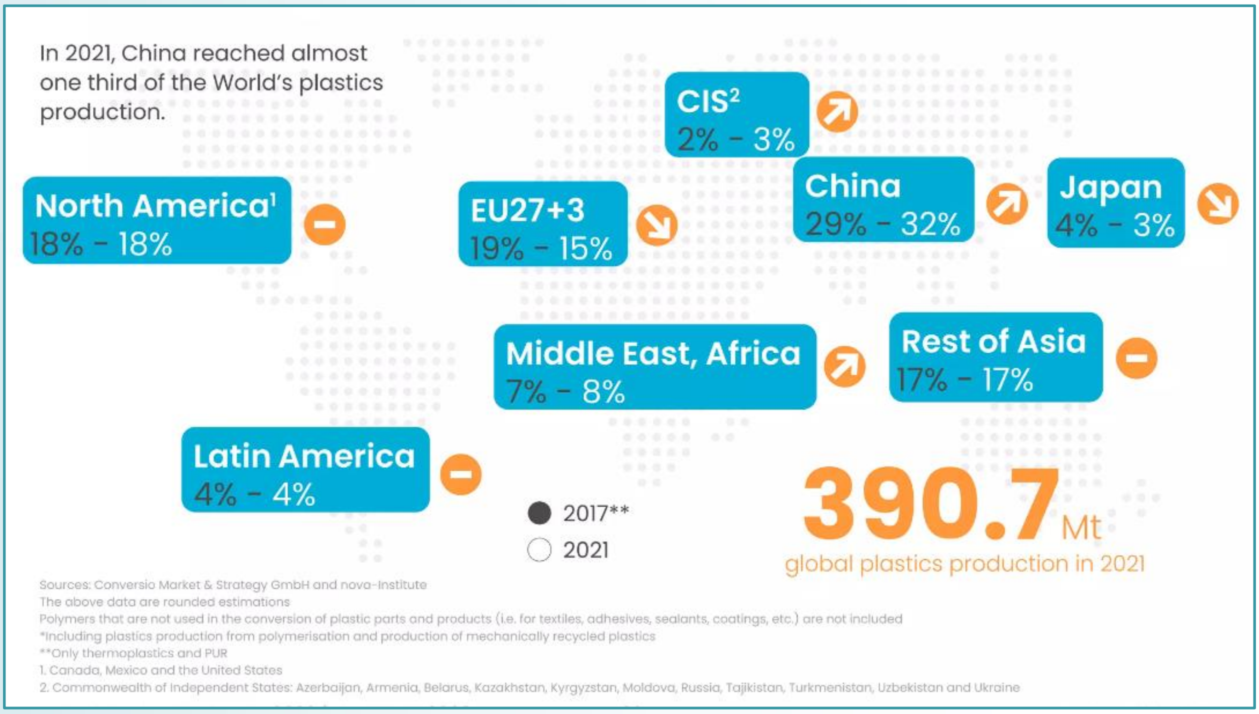

Figure 2 – Distribution of the global plastics production [PLASTICS - THE FACT 2022]

The figures of production of plastics must be transformed into the demand of the plastics converters. Here the fractions of plastics used for textiles, adhesives, sealants, coatings, paints, varnishes, textiles waterproofing, or within the production of cosmetics, medicines or chemical processes are excluded. Data on European converters demand for plastics do not include recycled and bio-based/bio-attributed plastics due to limited data availability. The scope includes thermoplastics and thermosets.

The total demand for plastics by the European converters is therefore reduced to 50.3 Mt in 2021.

In Figure 3 below the distribution between the countries can be seen.

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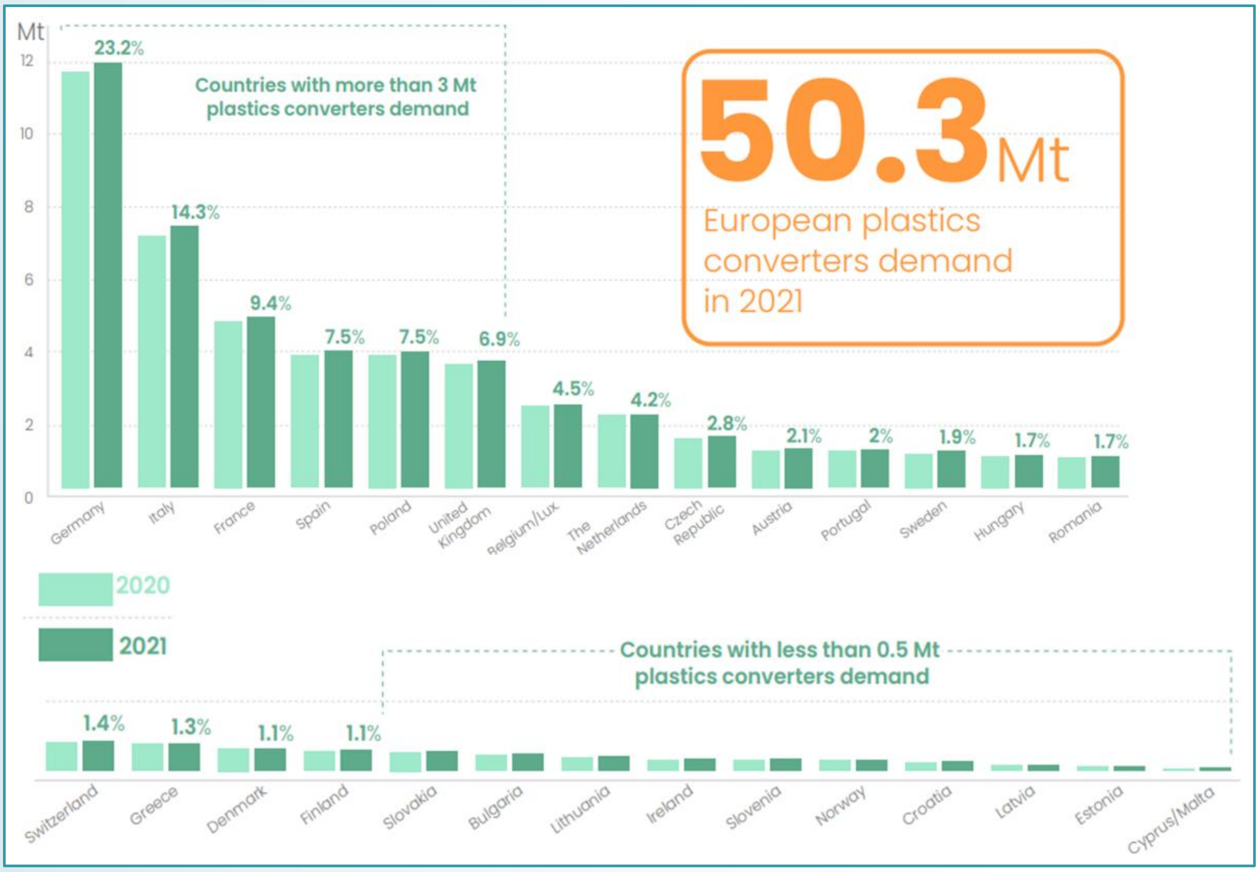

Figure 3 – European plastics converters demand by countries [PLASTICS - THE FACT 2022]

From the above it can be concluded that the POLREC consortium represents 86% of this demand: Germany 23.2%, France 9.4%, Spain 7.5%, Portugal 2% and Denmark 1.1%.

When looking at polymer types the distribution is as follows:

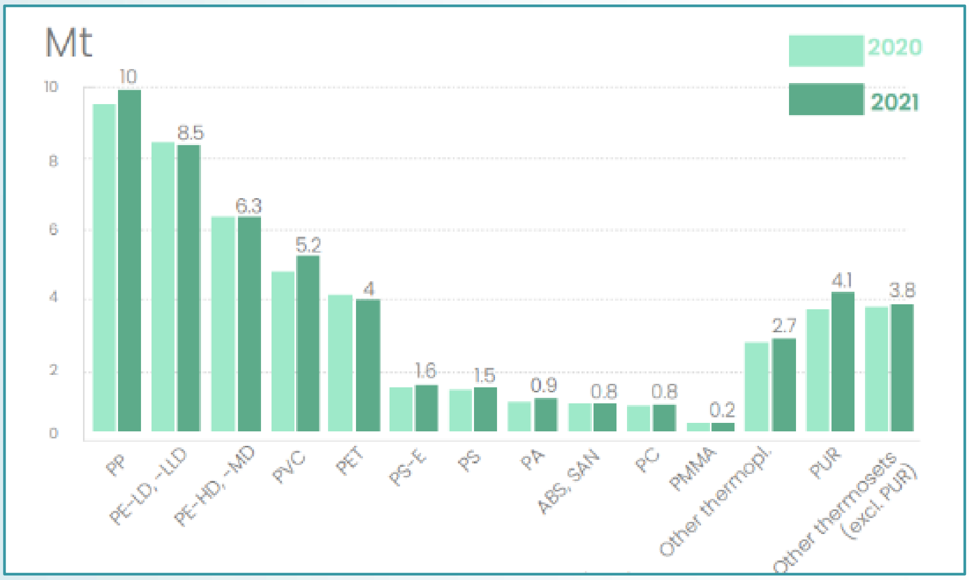

Figure 4 – European plastics converters demand by polymer type [PLASTICS - THE FACT 2022]

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In Figure 4 it can be seen, that the most widely used polymers are the various types of polyolefins – PP, PE-LD, PE-LLD, PE-HD and PE-MD.

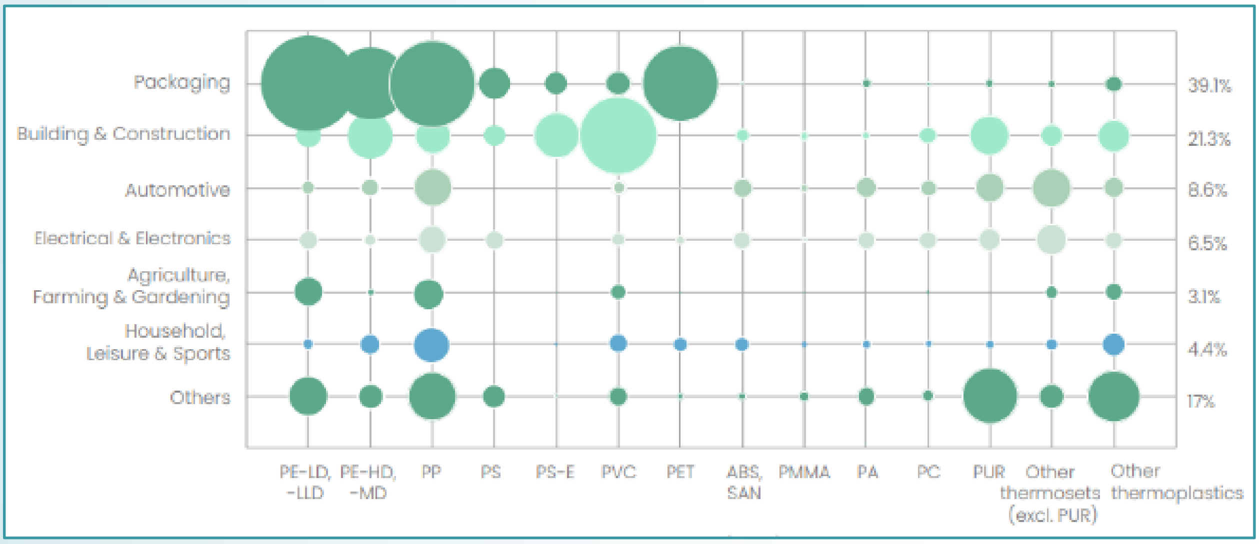

Figure 5 – European plastics converters demand by application and polymer type [PLASTICS - THE FACT 2022]

In Figure 5 it can be seen that the packaging industry is the industry consuming the largest number of plastics – all polyolefins but PET, which is primarily used for drinking bottles. Building & construction industry is consuming the 2nd largest number of plastics – mostly PVC for piping and PS-E for insulation purposes. The third largest industry is automotives using especially PP for car interiors.

3. Plastic use in Europe

The current use of plastic in Europe is primarily a linear economy because material is extracted, produced and used only once before being disposed or ending in the environment. Only a small circular flow of plastic is cycled back into new uses.

Problems with the current plastics economy include:

Structural flaws:

Every year about 26 Mt of plastic waste are generated in the EU. Less than 30% of it is recycled. [A European Strategy for Plastics in a Circular Economy 2018]

In Europe, energy recovery is the most used way to dispose of plastic waste, followed by recycling. About 25% of all the generated plastic waste is landfilled. [www.plasticexpert.co.uk/eu-recycling-statistics-2022/]

Half of the plastic collected for recycling is exported to be treated in countries outside the EU. Reasons for export include the lack of capacity, technology or financial resources to treat the waste locally.

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Previously, a significant share of the exported plastic waste was shipped to China, but recent restrictions on imports of plastic waste in China is likely to further decrease EU exports. This poses the risk of increased incineration and landfilling of plastic waste in Europe. Meanwhile, the EU is trying to find circular and climate-friendly ways of managing its plastic waste.

The low share of plastic recycling in the EU means significant losses for the economy as well as for the environment. It is estimated that 95% of the value of plastic packaging material is lost to the economy after a short first-use cycle. [www.europarl.europa.eu/news]

In addition, many plastic products are placed in markets that lack the capacity to collect and safely dispose of them. A systemic approach can lead to a fundamental transformation of the plastic economy.

Weak waste management systems:
Capacities for the control of transboundary movements, environmentally sound management of plastic waste, including the necessary infrastructure, are often lacking and have not kept pace with the sharp rise in plastic consumption, particularly in low- and middle-income countries. [United Nations Environmental Programme, UNEP, and International Solid Waste Association, ISWA, 2015]

Collection of waste is chronically underfunded and, despite often being the single highest item in the budgets of municipalities, formal collection coverage remains patchy. [UNEP and ISWA 2015]

Scaling this as plastic consumption grows is difficult as the informal sector typically only collects high-value plastics. Even when collection is effective, e.g. in many high-income countries, the rate of plastic waste being recycled back into the economy is very low - approximately 15% for plastics in short-lived products or 10% for all plastics. [UNEP 2021]

Lack of incentives to encourage the adoption of new solutions:
Today's markets are structured around the ubiquitous use of plastic products, particularly in packaging. New business models that meet overall needs with less environmental impacts have been proven effective but have not reached the scale of impact needed. [UNEP 2021a]

There are currently few policy incentives for new business models or to promote the adoption of safe and sustainable alternative materials, or new delivery models such as reusable or refillable packaging. [Potočnik and Teixeira 2022]

Design and packaging choices that do not account for local infrastructure:
Many plastic products are designed for a global market, with marketing and sales as primary drivers of product design. Globalised supply chains of consumer goods fail to account for the realities of the local waste management infrastructure available to deal with them, which can vary greatly from one municipality to another. Fast innovation cycles in product design outpace slower innovation downstream in the waste infrastructure, which exacerbates the problem further. [The Pew Charitable Trusts and Systemiq 2020]

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Insufficient data and reporting:
Consistent definitions and standards for plastic data and metrics are lacking, and there is insufficient transparency regarding the plastic being placed on the global market, including its composition - polymers, chemicals and additives, demand and what drives it, trade flows, waste production, consumption, post-use patterns and impacts on human health and marine life. This lack of data and transparency currently limits effective and safe management of plastics throughout their life cycle.

In spite of the above there has been some progress. Since 2016, the amount of plastics waste sent to recycling across Europe has more than doubled, while the amount sent to landfill has been reduced by almost 50%. Data from 2020 shows that recycling rate increased to nearly 35%. However, 65% of post-consumer plastics waste was still sent for energy recovery or to landfill. Additionally, the data shows that recycled plastics uptake increased by 15% compared to 2018, reaching 4.6 Mt. [The circular Economy for plastics – A European overview]

Despite these encouraging developments, the pace of the progress remains insufficient to meet the various industry targets. Consequently, more needs to be done to increase the circularity of plastics.

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4. Transformation of the European Plastic industry

The shift towards a circular economy for plastics has already begun.

At EU level a European strategy for plastics was adopted in January 2018. It is part of the EU's circular economy action plan and builds on existing measures to reduce plastic waste.

The plastics strategy is a key element of Europe's transition towards a carbon neutral and circular economy. It will contribute to reaching the 2030 Sustainable Development Goals, the Paris Climate Agreement objectives and the EU's industrial policy objectives.

The plastics strategy is supported by the European Green Deal, which is a set of policy initiatives by the European Commission with the overarching aim of making the European Union (EU) climate neutral in 2050. The plan is to review each existing law on its climate merits, and also introduce new legislation on the circular economy, building renovation, biodiversity, farming and innovation. The European Green Deal is dealt with separately in section 5 of this report.

The organisation Plastics Europe, the leading plastic trade association of the European plastic industry, is striving to be a catalyst for enabling a circular and climate neutral economy for plastics and prevent plastics waste ending up into the environment.

In order to achieve this collective ambition, collection, sorting and recycling technologies need to be enhanced to obtain higher quality and quantities of recycled plastics, which will facilitate a circular economy for plastics.

The plastics industry is leading the way in this transition, from improved products designs that enable reuse and recycling, to innovation in new technologies such as bio-based and carbon-captured feedstocks and chemical recycling. Emerging technologies also present the opportunity to recycle mixed plastics waste streams that cannot be processed by mechanical recycling, opening up new possibilities for the plastic circular economy.

The plastics industry supports the European Union's Green Deal and climate-neutrality ambitions, and the Paris Climate Agreement, their collective blueprint for accelerating the transformation to a more sustainable Europe.

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5. The European Green Deal

At European level climate change and environmental degradation are seen as an existential threat to Europe. To overcome these challenges, the European Green Deal will transform the EU into a modern, resource efficient and competitive economy, ensuring:

- No net emissions of greenhouse gases by 2050
- Economic growth decoupled from resource use
- No person and no place left behind

One third of the 1.8 trillion Euro investments from the NextGenerationEU Recovery Plan, and the EU's seven-year budget will finance the European Green Deal.

As part of the Green Deal, 55% of plastic packaging waste should be recycled by 2030. This would imply better design for recyclability, but Members of the European Parliament, MEPs believe measures to stimulate the market for recycled plastic are also needed.

These measures could include:

- Creating quality standards for secondary plastics
- Encouraging certification in order to increase the trust of both industry and consumers
- Introducing mandatory rules on minimum recycled content in certain products
- Encouraging EU countries to consider reducing VAT on recycled products

The Green Deal also includes a proposal for a regulation on eco-design for sustainable products. The proposal addresses product design, which determines up to 80% of a product's lifecycle environmental impact. It sets new requirements to make products more durable, reliable, reusable, upgradable, reparable, easier to maintain, refurbish and recycle, and energy and resource efficient. In addition, product-specific information requirements will ensure consumers know the environmental impacts of their purchases.

All regulated products will have Digital Product Passports. This will make it easier to repair or recycle products and facilitate tracking substances of concern along the supply chain.

The new proposal extends the existing Eco-design framework in two ways: first, to cover the broadest possible range of products; and second, to broaden the scope of the requirements with which products are to comply.

In addition, hereto in January 2023 the EU Parliament voted on its position regarding waste shipment rules which aim to promote reuse and recycling and reduce pollution. MEPs insist that exports of plastic waste to non-OECD countries should be banned and shipments to OECD countries should be phased out within four years.

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6. Plastic waste streams in Europe

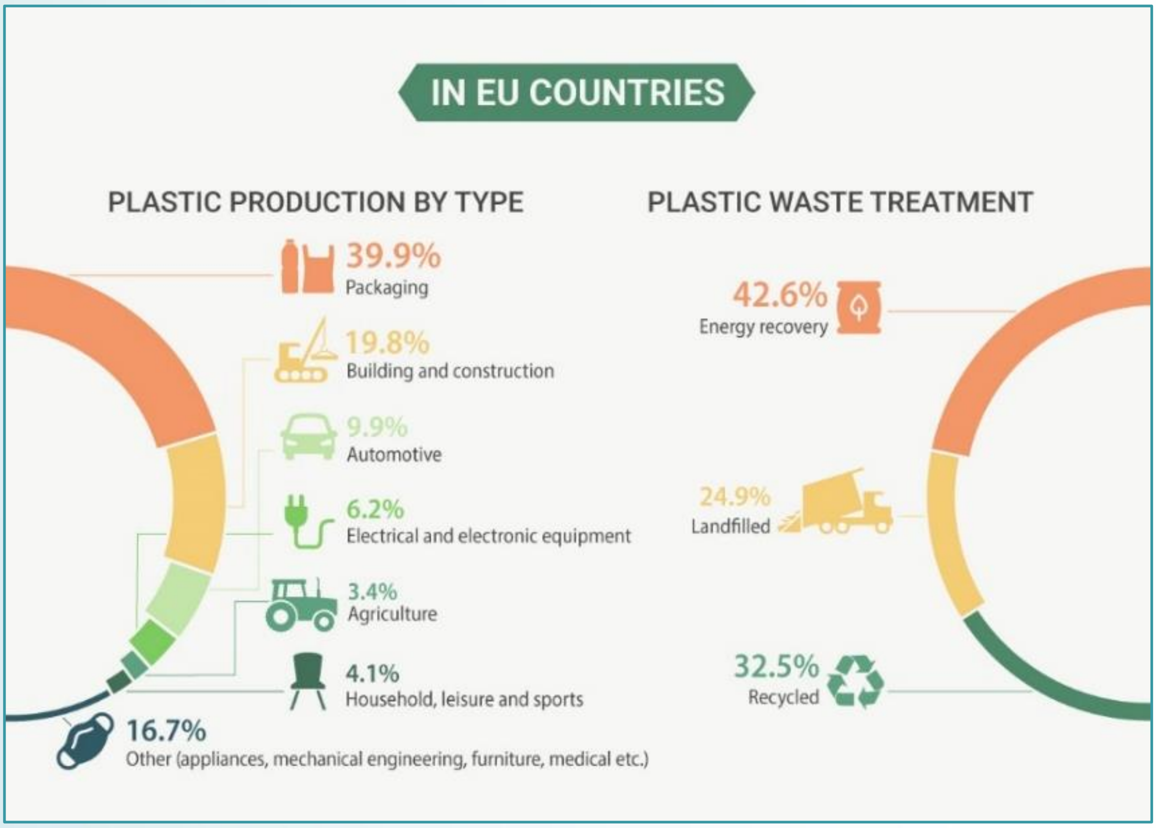

Figure 6 – Overview of European plastic production – [www.europarl.europa.eu/news]

In Figure 6 it can be seen that European plastic production can be divided into: Packaging 39.9%, building and construction 19.8%, automotive 9.9% Electrical and electronic equipment 6.2%, agriculture 3.4%, Other – appliances, mechanical engineering, furniture, medical etc. 16.5%.

After end of life these products will end as plastic waste and is treated as follows: Energy recovery 42.6%, landfill 24.9% and 32.5% is collected for recycling.

Plastic products and parts that enter the market have different life spans. Many of them remain in use for years, e.g. insulation boards, cables, cars, electrical and electronical devices etc. and therefore do not become waste in the same year that they entered the market.

Some plastic products and parts are exported for a second life service, and therefore never become waste in the EU27+3, e.g. exports of used cars. Other products, such as furniture and toys, may be resold and used second hand, and do not become waste for a very long time.

The variable lifespans of different plastic products and parts helps to explain why waste quantities for a given year are considerably smaller than the total plastic products and parts entering the market for the same year.

Similarly, plastic products and parts collected as waste in a given year may have entered the market decades beforehand, e.g. old fridge, used mattress, etc. See Figure 7.

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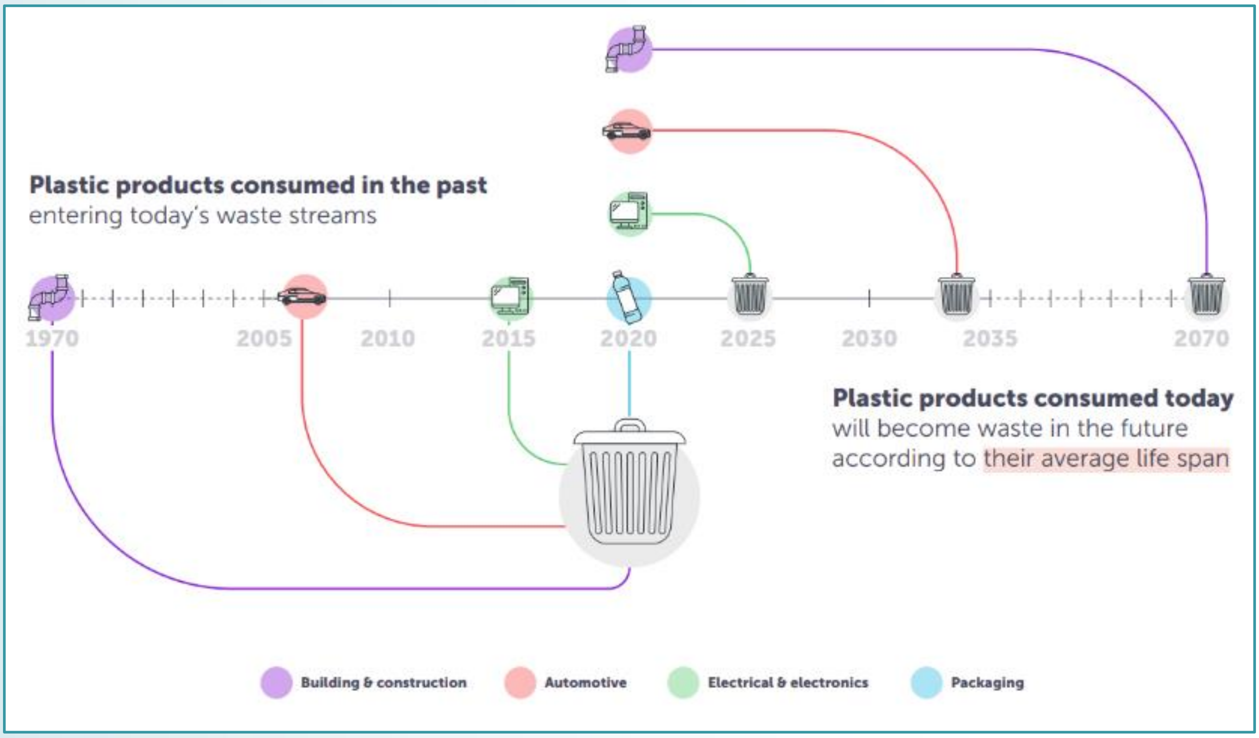

Figure 7 – When do plastic products become waste? [The circular economy for plastics]

6.1 State of affairs in the European plastic recycling industry

In 2022 the European plastic production amounted to 50.3 – 51 Mt. Please see Figure 8. Of this amount approximately 10 Mt were recycled.

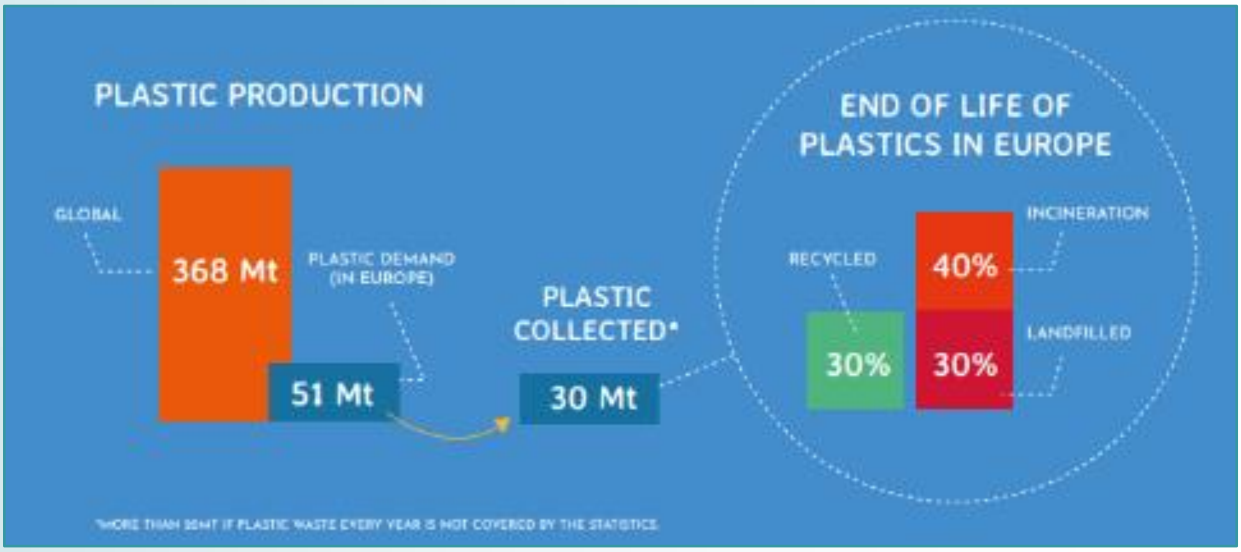

Figure 8 – State of affairs [25 years of making plastic circular]

Most of the recycled plastic waste in Europe originates form plastic packaging. Actually about 80% of all collected plastic waste originates from plastic packaging, as the polymers PET, flexible PE and PP and a large proportion of rigid PP and PE originates from plastic packaging, while only

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about 20% originates from industrial and building components in terms of the polymers PVC, mixed plastics and technical plastics. Please see Figure 9.

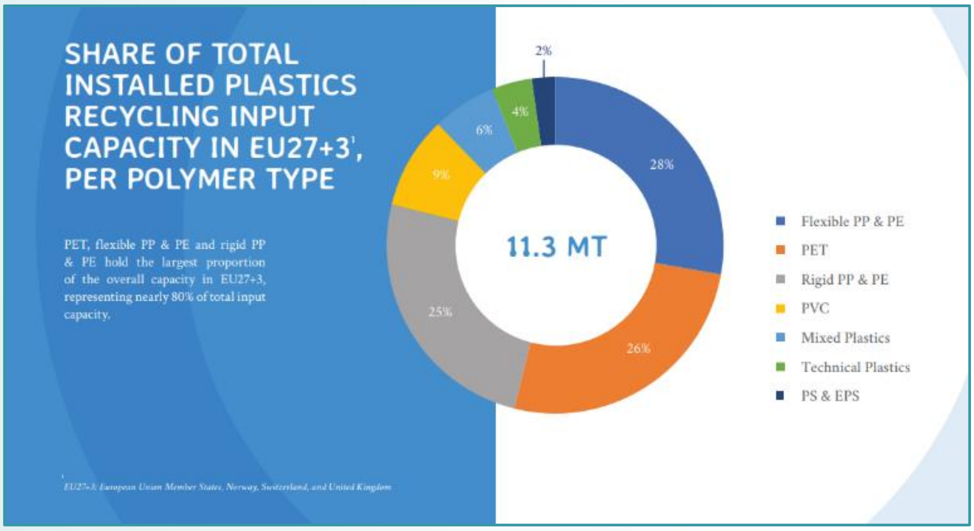

Figure 9 – Types of polymers recycled in Europe [Plastics Recycling Industry in Europe - Mapping of installed plastics recycling capacities - 2021 data]

Recycling rates vary considerably among the European countries. This can be seen in Figure 10.

Figure 10 – Recycling rates [Eurostat (online data codes ENV_WASPACR) European Environment Agency (2018)]

In relation to the POLREC partner countries, it can be seen that Spain recycling-wise is doing the best followed by Germany, Denmark, Portugal and France.

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7. Problems with plastic recycling

The main issues complicating plastic recycling are the quality and price of the recycled product, compared with their unrecycled counterpart. Plastic processors require large quantities of recycled plastic, manufactured to strictly controlled specifications and at a competitive price.

However, since plastics are easily customised to the needs - functional or aesthetic - of each manufacturer, the diversity of the raw material complicates the recycling process, making it costly and affecting the quality of the end product. What quality means depends on what you intend to use the recycled material for.

For instance, if the recycled material is intended for food packaging, the requirements are stricter for safety reasons, but the requirements vary from country to country.

A recycler must comply with REACH by not marketing recycled materials containing banned or hazardous substances, which could come from additives added to the plastic, the waste from the original recycled material or degradation substances. When a recycled material comes from products with a short life, compliance is straightforward. However, this is not the case, when it comes from products with a long life. Even then, recyclers must guarantee compliance.

Among other measures, it is of utmost importance to design plastic products, so they are suitable for recycling and to optimize sorting options, so a satisfactory and uniform quality can be achieved. Also, traceability is an issue.

There are two types of waste, depending on whether it is generated after the use of the product, post-consumer waste, or before its use, post-industrial waste, or pre-consumer waste. Post consumer waste may become contaminated due to different factors, for instance presence of impurities and retained substances, misuse of packaging, degradation due to heat, oxidation light etc., inadequate separation of materials and cross-contamination during waste collection.

The presence of inappropriate materials and contaminants can lead to undesirable odours, dark colouring, surface defects etc., which limits the application and sectors where these recycled materials can be used.

Traditionally, recycled plastics have been used for products with little added value, e.g. rubbish bags, irrigation pipes, and flowerpots.

In spite of the above, the demand for recycled plastics is growing, though in 2018 it accounted for only 6% of plastics demand in Europe. [www.europarl.europa.eu/news]

7.1 Recycling capacity in Europe

Given the wide range of physical, mechanical, and chemical properties of resins, plastics are used in a multitude of formulations and applications, with a demand of 50 Mt per year in the EU. Packaging makes up 40% of this share, followed by building & construction, automotive and electronic & electrical sectors.

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Today, packaging is the only stream for which EU stipulates a specific, mandatory recycling target. Its significant market share and legal obligations can explain why with a rate of recycling 40% of the sector's waste, plastic packaging is still the most widely recycled stream in Europe.

Nevertheless, other plastic recycling streams, such as building & construction or technical plastics, are equally growing.

The most widely recycled polymers in Europe, covering approx. 79% of the recycled plastic market, are polyolefins (PO) and polyethylene terephthalate (PET).

Legislative environment and, most notably, export restrictions have been among the key drivers of increased recycling in Europe since 2016. European plastics recyclers currently produce over 10 MT of recyclates, mainly based on mechanical recycling. As the target is recycling 55% of plastic packaging in 2030 we are far from reaching the goal. Therefore, the European recycling capacity must be heavily extended in the near future.

There are various technologies to be used, the most developed will be described in the following section.

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8. Recycling technologies

Increasing the quantity and the overall quality of recycled plastics are required to accelerate the circularity of plastics. Different technologies are available that maximise the value of plastics at the end of their service life.

Today, mechanical recycling is the recycling process providing the highest quantities of recycled plastics. As a complement, alternative recycling technologies have been developed. These technologies are currently running at smaller scale, however, they will be indispensable, not only to reach higher recycled plastics quantities but also to contribute to the transition to a climate neutral circular economy.

In this section a closer view will be taken on the most common ones, which complements each other.

These are: Mechanical recycling, dissolution and chemical recycling. An overview can be seen in Figure 11.

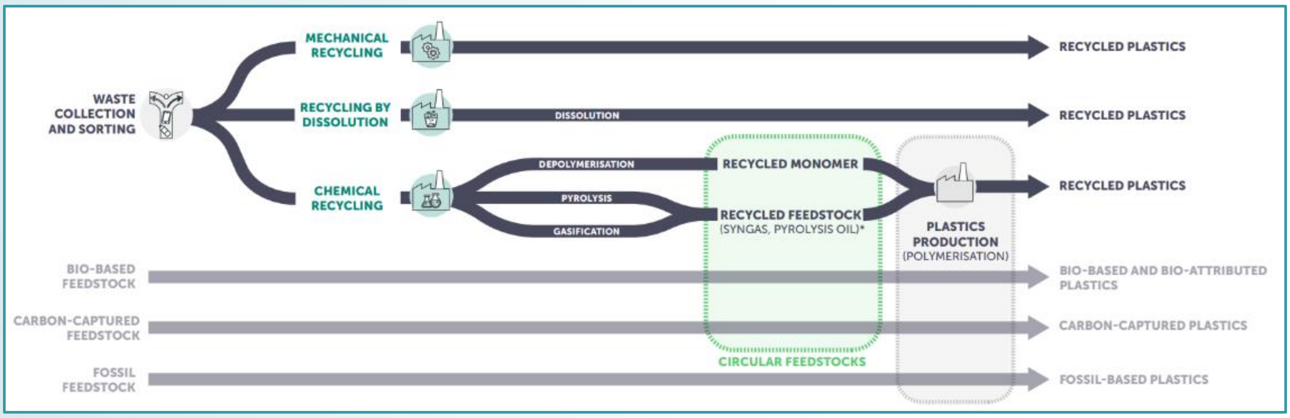

Figure 11 - Main Recycling Technologies [The circular economy for plastics]

8.1 Mechanical recycling

In this process, high temperature is used to melt the plastic, whereby bonds between polymer chains are broken. However, once the temperatures cools again and the plastic solidifies, the broken bonds are re-formed. In this way the polymer chain is generally not broken, and the plastic can, as mentioned above, be reformed to new products. This is the case for thermoplastics.

Thermoset materials cannot be melted, so mechanical recycling with thermoset is limited to shredding and incorporating them as fillers in other materials.

In Figure 12 a simplified schematic diagram of the recycling process can be seen.

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Figure 12 – Simplified schematic diagram of the recycling process [diagram made by PCD]

However, there are difficulties in the mechanical recycling of plastic waste, e.g. cleanliness of the waste, mixtures of different plastics, material degradation, and presence of hazardous substances.

In an attempt to solve these challenges, the plastic waste must be sorted and separated in different plastic types, it must be washed and dried, homogenized and extruded, and very often certain substances must be added.

Plastics are susceptible to degradation, e.g. due to processing, use or exposure to the surrounding environment during use, which leads to deteriorated properties. It is possible to improve the properties by adding certain substances, but it is costly as is also the case with all the other necessary steps.

There can also be hazardous substances left within the plastics, and they are complex to remove, if possible at all.

The hazardous substances can be present in the plastic due to two causes: They have been intentionally added to the initial composition of the plastic, or the plastics have been in contact with the substances during its life. It is important to stress, that a recycler must comply with REACH by not marketing materials containing banned substances.

All these challenges and a limited number of supply streams of good quality with consistent homogeneous properties makes it difficult to achieve a sufficiently high and uniform quality of the recycled material.

Usually, a lower quality than the original is obtained, and the use of the recycled material depends on the properties of the recycled material in relation to the intended use.

The recycler must establish and hand over a technical data sheet to the customers. A technical data sheet is a summary document containing a detailed description of the characteristics of the

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material. It usually contains data such as name, physical characteristics, method of use or preparation, distinguishing properties, and technical specifications.

There are different standards for recycled materials. They are mainly based on “required data” and “optional data” the parameters of which are usually agreed upon between the supplier and buyer by establishing specifications and specifying test/analysis methods.

Technical data sheets for recycled plastic materials are based on measuring different properties and aspects, which are more or less critical depending on the plastic in question. General description of color, size, shape etc. and test properties like tensile strength, elongation, bending etc., and recycling properties like melt flow index, density etc. and content of contaminants. The data sheets must be drafted in accordance with standards, so the values obtained are comparable.

Despite all efforts done to sort and homogenize, there will be more variation in measured properties of recycled plastics than for virgin plastic material, and some plastics are not possible to recycle mechanically. This applies e.g., to packaging of laminates that contain several different types of plastic, that cannot be separated, and contaminated waste streams.

8.2 Dissolution

Solvent-based Purification (dissolution) is based on physical and not on chemical reactions or changes and only the physical state of the polymer changes from solid to liquid and then back to solid. The polymer chains remain unchanged in contrary to chemical recycling and can be re-used in the original or similar applications.

Only thermoplastic materials are sensitive to organic solvents. Consequently, dissolution technologies are only applicable for thermoplastics.

The main challenges of dissolution technologies are relatively high technical requirements, high costs of solvents, feedstock impurities and the subsequent separations of recycled products are time consuming.

8.3 Chemical recycling

Chemical recycling complements mechanical and dissolution recycling and comes into consideration when plastic waste streams cannot be recycled mechanically for various reasons.

The technologies within chemical recycling are relatively immature, but they are expected to mature in the near coming years due to the advantage of them. The most important advantage of them is that they can contribute to the goal of making the linear consumption of plastic circular, since it is possible to recycle plastics, that are not suitable for mechanical or dissolution recycling, and get high-quality products out of it. The output can thus be used for plastic in food contact and other critical applications.

The U.S. Food and Drug Administration, the European Food Safety Authority and similar authorities around the globe have given approval for PET bottles to be recycled mechanically back into food contact applications, given certain requirements are met. For other resins and applications,

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like non-bottle applications, particularly films, there are no current good options for circularity into high-value and food contact applications without some form of chemical recycling.

The biggest disadvantage for the chemical recycling technologies is their cost versus mechanical recycling and the need for extra sorting and pretreatment to make sure to have the process work properly and to ensure the quality of the output product.

There are three primary types of chemical recycling: pyrolysis, gasification, and depolymerization - solvolysis.

Pyrolysis

Pyrolysis is a thermal treatment process, which can handle relatively mixed waste streams. The pyrolysis process heats up the collected plastic waste stream in a reactor without oxygen, and this rips apart the molecules. Usually, the process is carried out between 350 and 650°C.

There are many different configurations and types of reactors, but most of them involve a catalyst that helps speed up the reaction, reduce the necessary temperature and provide the desired output.

The aim of pyrolysis is to obtain a predominantly liquid faction, a pyrolysis oil. The yields obtained are highly dependent on the feedstock and are reported as high as up to 90%. The remaining output consists of tars and gas which can be used to power the process.

The process is preferably suitable for polymers from polyaddition e.g., polyolefins, PS and PMMA. Some resins such as PVC, PET or PU should previously be removed from the feedstock. Indeed, PVC can release hydrochloric acid, which is highly corrosive and causes harmful toxic fumes. As for PET, it increases the solid residue rate and consequently reduces the final oil yield. PET also contains oxygen, which is released in the reactor and interferes with the reaction media.

Depending on the nature of the process and feedstock used, the refining of pyrolysis oils can either lead to monomers or to a hydrocarbon mix. The hydrocarbon mix can be reprocessed and refined to obtain a petrochemical base of naphtha type or more generally polyolefins with C5-C10 chains. Depending on the process, C20 to C50 chains can be present in this phase. This fraction can afterwards be separated in a petroleum-type steam cracker. The final outputs obtained consist of products such as crude oil, olefins, naphtha, kerosene, BTX and styrene. These products can be used for new polymers, and in this way make the use of plastic circular, it can be used for other chemicals or for fuel.

The main advantage is that the plastic that can be produced from pyrolysis output is essentially virgin.

Because the process breaks down the waste plastic into monomers and then regenerates the plastic, it can be used in any application, especially food contact, cosmetics, or even medical packaging.

Pyrolysis is a very energy intensive process compared to other recycling technologies, but some technology developers assert that by incinerating the gas fraction produced during the process, it can be self-sustaining.

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Gasification
Gasification is a thermal treatment cracking process, which can handle relatively mixed waste streams. The gasification process heats up the collected plastic waste stream in a reactor in the presence of limited quantities of oxygen, causing the waste to break down and partially oxidize.

There are different types of gasification, which happen at different temperatures and under different operating conditions. The gasification process usually occurs at temperatures of 700 - 1200°C, depending on which gasifying agent is used. The main gasifying agents used are air, steam, and oxygen.

The gasifying agents determine the final composition of the output produced and its suitability for different applications.

Gasification converts the waste into a synthesis gas, a syngas, which is a gaseous mixture of carbon dioxide, carbon monoxide, hydrogen, methane, water, and other light hydrocarbons. The output of the process often contains impurities such as char, NH3, H2S, NOx, alkali metals and tars. The quantity of impurities and by-products produced depend on the input used and operating conditions. It is preferable to have a stable waste composition.

The aim of the gasification is to achieve a high proportion of syngas, low char yields and low tar formation.

Different types of syngas are suitable for diverse purposes e.g., energy, fuels, chemicals, or plastics. Output obtained via low temperature gasification is only suitable for energy applications, while that obtained via medium temperature gasification can be used for plastic applications.

Turning syngas into final products requires a phase of catalytic conversion and distillation. There are at least 4 different paths to close the loop with plastic production: 1. Direct conversion of syngas to produce olefins; 2. Syngas used to produce methanol which is converted into olefins (Methanol-to-Olefins process, MTO); 3. Syngas used to produce ethanol, which is converted into ethylene; 4. Syngas used to produce hydrocarbons, obtained via Fischer Tropsch, which are converted into olefins in a steam cracker.

The major advantage of gasification is less sorting and a wide availability of feedstocks. If sufficient plastic waste is not available, food waste, wood or almost any carbon source can be used instead.

Gasification is a very energy intensive process compared to other recycling technologies, but non-condensable light fractions can be used to have an autothermal process.

Depolymerisation - solvolysis
Depolymerisation also called solvolysis is a solvent-based process, that can be used for the types of plastics produced by condensation polymerization. That is e.g., PET, PA, and PU. The current main focus of solvolysis-based plastic recycling is PET. This is what comprises today’s water and soda bottles as well as many disposables and much clear plastic packaging. It’s also called glycolysis, methanolysis or hydrolysis depending on depending on what kind of solvents are used.

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The polymer waste must very often be pretreated before the process and purified after the process, to make new plastics.

In the process the solvents break down the polymer waste at elevated temperatures and pressure and thus go back to smaller molecules in the form of monomers or oligomers that can be used to produce new plastics.

The process usually occurs at temperatures of 100 - 350°C, and pressures in the interval 0 - 40 Bars depending on which solvent is used.

The process is energy-intensive and there are also costs for the solvents.

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9. Recyclers in Europe

Due to the importance of plastic recycling the recyclers have established various networks to support the plastic industry. The most important ones will be described in the following.

9.1 Plastics Recyclers Europe

Plastics Recyclers Europe (PRE) is an organization representing the voice of the European Plastic Recyclers who reprocess plastic waste into high-quality material destines for the production of new articles.

PRE was established in 1996 with the purpose of developing and promoting plastics recycling in Europe and have since then been working relentlessly to put plastics recycling in the spotlight of the public debate. For over 25 years, PRE has promoted recyclates use and high-quality recycling across Europe, and beyond.

Through its many years of presence in Brussels and an extensive membership, PRE acquired considerable knowledge and expertise on policy measures to improve the circularity of plastics. PRE is thus a key stakeholder in the process of formulating, monitoring and evaluating the EU policies that impact plastics recyclers.

PRE represents mainly recycling companies reprocessing plastics from various waste streams including post-consumer and post-industrial streams. Reprocessing includes operations such as sorting, shredding, grinding, washing and extrusion. The companies transform plastic waste into high quality materials that can be used by converters in the production of new articles.

Back in 1996 the organization only represented a handful of plastics recyclers, but today PRE is the voice of 150 companies, and an European association of plastic recyclers.

PRE offers concrete advice on how to develop innovative products and packaging designed for recycling. High quality plastic recycling is dependent on good design, quality collection and sor-ting.

Also, transparency is important when it comes to the characterization and assessment of recyclers' output. It ultimately boosts confidence in the quality of materials among the industry. To boost transparency & promote the standardisation of sorting practices, PRE developed the "Recycling Input - Characterisation Guiding Requirements". These documents aim to set industry-wide standards for the benchmarking of high-quality recycling practices.

To facilitate the quality and traceability of waste, PRE encourage recyclers to undergo certification of their recycling processes. This step would be equally important in subsequent certification of the use of recycled plastic in new products.

PRE has been promoting the harmonization and development of a pan-European standard for plastics recyclates by the implementation of EuCertPlast.

PRE's actions have facilitated the creation of a Green Paper on Plastic Waste which identified public policy challenges induced by plastic waste, that were not specifically addressed in EU waste legislation.

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PRE has supported the Circular Economy Package and stands behind an increase of the recycling targets to 55% by 2030. Through its various activities, PRE has raised awareness on and advocated against waste exports to developing countries. It has enabled the recognition of incompatibilities between the waste legislation and REACH. Via various projects and research, PRE has encouraged the growth of the plastics recycling market.

PRE has also developed a voluntary industry standard, PRE 1000, for the screening of substances. This standard enables recyclers to analyze the recycled material in a cost-effective manner & thereby prove compliance to the relevant product legislation, such as REACH, RoHS or POP.

9.2 EuCertPlast

Belgium based EuCertPlast scheme is founded by four European organisations: European Association Of Plastics Recycling, PLASTICE RECYCLERS EUROPE, European Plastics Converters and Recovinyl which areorganisations with an interest in recycled plastics. The objective of EuCertPlast is to encourage environmentally friendly plastics recycling processes by standardizing them.

The scheme focuses on traceability of plastic materials throughout the entire recycling process and supply chain, plus on the quality of recycled content in the end-product.

It seeks to increase the transparency of the European plastics industry, as well as to integrate the varying auditing schemes into a common one. At the same time, it is aiming to determine the best recycling and trading practices.

Combining all these aspects will allow recyclers to fulfill REACH requirements and food contact compliance.

The scheme addresses issues of varying standards across EU countries and the lack of trans-parency and traceability of plastic materials.

It was created with the aim to recognize recyclers operating according to high standards and implementing best practices.

The certification scheme itself works according to the European Standard EN 15343:2007.

With EuCertPlast, recyclers and auditors can work towards integrating different auditing schemes and creating an efficient, harmonized and transparent system.

A recycler, with the EuCertPlast certification, can give an assurance that the post-consumer plastics processed in their plant are treated according to best practices and with respect towards the environment. [eucertplast.eu/certified-recyclers]

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10. Overview of the plastic recyclers in POLREC consortium countries

In order to ease the work of the SMEs applying for POLREC grants, the POLREC partners have prepared lists of recyclers placed in their respective countries. These are to be seen in this section.

10.1 Denmark – Mechanical recyclers

Table 1 – Mechanical recyclers in Denmark are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
Aage Vestergaard Larsen	Mechanical recycling	X		POM, PA, PC, ABS, PS, PP, PE, PEEK, PSU, PC/ABS, PET, PMMA, PBT	15,000 t/year
A.V. Pehrsson	Mechanical recycling	X		PA & PA with glass	
Bewi Circular Denmark	Mechanical recycling	X	X	Recycling of EPS	
Dansk Affaldsminimering	Mechanical recycling	X	X	Recycling of household plastic waste: PE & PP granula and flakes	
Dansk regranulat	Mechanical recycling			Recycling of PE from used agricultural PE films	20,000 t/year
CemeCon Scandinavia A/S	PVD-coating of tools			coating of moulds	
Compsoil	Mechanical recycling	X			
DKK Plastics ApS	Mechanical recycling, hard plastic	X		PET, PE/PP mix, PVC hard, PVC mix	
Genan A/S	Mechanical recycling	X		rubber granula from tires	
Genplast	Mechanical recycling	X	X	PP, PE, PVC	
IMDEX A/S	Mechanical recycling	X		rubber granula from tires	
Letbek Plast A/S	Mechanical recycling	X		PE, PP	
Plastix	Mechanical recycling	X		Recycling of fishing nets PE-HD and PP	
RC Plast	Mechanical recycling	X		PE, PP	
Redivivus Polymers ApS	Mechanical recycling & compounding	X		PA unfilled, recycled PA filled with glass	
Re-Match	Mechanical recycling	X		Recycling of rubber from football fields	
Trebo ApS	Separation technology	X		2K polymers	

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10.2 Denmark – Dissolution and Chemical recyclers

Table 2 – Dissolution and chemical recyclers in Denmark are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
Circular Plastic Systems	Pyrolysis		X	PE, PP	Not ready
Plastcon Makeen Energy	Pyrolysis		X	PE, PP	Pilot
Polytech	Solvolysis	X		PUR	Pilot
Quantafuel	Pyrolysis		X	PE, PP	Full-scale
Textile Change	Dissolution	X	X	PET, Cotton	Pilot
Waste Plastic Upcycling	Pyrolysis	X	X	PE, PP	Expected capacity 42,000 t/year
Waste2Value	Pyrolysis w/processing agents	X	X	PE, PP	Pilot

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10.3 France – Mechanical recyclers

Table 3 – Mechanical recyclers in France are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
Broyages industriels vacher	Mechanical recycling - crushed and resold. Grinding on delivery.	X		PP, PE, ABS, PA, PVC, PC, PS	2,000 t/year
NPV Recyclage	Mechanical recycling	X		PVC flexible and hard	2,000 t/year
Recnorec	Mechanical recycling - Thermomechanical	X	X	Plastics traditionally non-recyclable: Flexible plastic, polystyrene, food packaging, yogurts, coffee cup etc.	5 t in 2024
Atmos	Mechanical recycling	X		PE-HD, PP, PS	
CIFRA	Mechanical recycling			PVC - plastic film	
Groupe Barbier	Internal mechanical recycling of plastic films	X		Agriculture plastics	
PAPREC	Mechanical recycling		X	PET (plastics bottle)	45,000 t/year
IPC	Pilot lines for sorting & mechanical recycling	X	X	All types of thermoplastics rigid and flexible	
Suez	Mechanical recycling	X	X	PET plastics bottle to rPET (bottle to bottle)	45,000 t/year
Granuplast	Mechanical recycling	X	X	PE-HD, PP	40,000 t/year
Mob-e-scrap	Delaminating and mechanical recycling	X		WEEE and plastic composites materials (e.g.: laminate aluminium/plastics, multi-layers plastics, sports equipment)	1 t/hour
Indco	Mechanical recycling, technopolymeres	X		Thermoplastics, composites	
MTB recycling	Mechanical recycling	X		All types of thermoplastics	150kg for feasibility study 1tonnes or more for recycling testing
Séché	Mechanical recycling	X	X	All types of thermoplastics	
Sedem	Mechanical recycling	X	X	All types of thermoplastics	600 t/year
Environnement recycling	Mechanical recycling	X		WEEE	
Reviplast	Mechanical recycling	X		PP, PE	

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10.4 France – Dissolution and Chemical recylers

Table 4 – Dissolution and chemical recyclers in France are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
Recyc-elit	Patented formulation, separation & purification of plastics waste	X		All types of difficult PET (Polyethylene Terephthalate), for e.g.: food tray, plastic waste (colored, opaque, trays), simple or complex blended polyester textiles	
Polyloop	Batch dissolution	X		PVC / composites	
Earthwake	Pyrolyse to tranform plastic waste into fuel/gas	X		PP/ PE	
Axens	Rewind PET - Depolymerisation by glycolyse	X	X	PET	Not yet at demonstrator scale
Orrion Chemicals Orgaform	Glycose - aminolyse for mattress foam		X	Mattress foam (special partnership with DOW)	
Carbios	Depolymerisation of PET by an enzyme			All kind of PET (including complex or soiles plastics)	Demonstrator
CEA	Depolymerisation, dissolution, c02 sc			rPE, rPET	MERLIN - Demonstrator
CRYMIROTECH	Liquid catalysts in the form of novel ionic mixtures	X			
EXTRACT HIVE	Solvolysis	X			

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10.5 Germany – Mechanical recyclers

Table 5 – Mechanical recyclers in Germany are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
ALBA Recycling GmbH				PE, PP, PS	
APK AG				PE-LD, PA	20,000 t/year
Aurora Kunststoffe GmbH				PBT, ABS, PA, PC	
Cypol GmbH				PE-HD, PP	
DSD – Duales System Holding GmbH & Co. KG				PE-HD, PE-LD, PP	
ELM Recycling GmbH & Co. KG				Mixed plastics into PO, PE-LD, EBS	70,000 t/year
Green Plastic Recycling GmbH				Waste Plastic	
Interseroh Dienstleistungs GmbH				PE-LD, PE-HD, PP, PET und EPS	
Korn Recycling GmbH					
Krall Kunststoff-Recycling GmbH				ABS, ASA, PE-HD, HIPS, PE-MD, PA, PC, PE, PET, PP, PS, PVC, Waste Plastic, PMMA, POM, SAN	
KVS Plastics GmbH				ABS, AS, ASA, BAK, EPP, EPS, E/VA, PE, PE-HD, PE-LD, Masterbatch, NAS, Noryl, PA, PBT, PBTP, PC, PET, PMMA, POM, PP, PPO, PPS, PS, PU, PUR, PVB, PVC, SAN, SMMA, TPE, TPU	
Naftex GmbH				PE, PP, PVC, WPC	
PB Solutions GmbH				PBT, ABS, PE-HD, PA, PC, PE, PET, PP, PS, PVC, POM, SAN, TPE	70,000 t/year
Plastic-Partner Bralten & Evers GmbH				PBT, ABS, PA, PC, PE, PET, PP, PS, PMMA, POM, SAN, TPE	
PreZero Recycling Deutschland GmbH & Co. KG				Post-consumer and industrial waste	95,000 t/year
Remondis Recycling GmbH & Co. KG				PE-HD, PET	20,000 t/year
Rubber Recycling GmbH				Rubber	6,000 t/year
Steinbeis PolyVert Fulda GmbH				PE-HD, PET, PP, PO	
Veolia PET Germany GmbH				PET	32,000 t/year

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10.6 Germany – Dissolution and Chemical recyclers

Table 6 – Dissolution and chemical recyclers in Germany are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
Covestro AG	Chemolysis	X		PC	
BASF SE	Pyrolysis	X	X		
RECENSO GmbH	Catalytic Tribochemical Conversion				
Pyrum Innovations AG®	Thermolysis			Bitumen mats and insulation, Waste tires, EPDM and other elastomers, Rubber, PE/PET, Oil shale and oil sands	
Fraunhofer Umsicht					
Fraunhofer CCPE					
Fraunhofer Institute for Ceramic Technologies and Systems IKTS	CARBOLIQ, Pyrolysis	X	X		
APK AG	"Newcycling"	X		PE-LD	20.000 t/year

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10.7 Portugal – Mechanical recyclers

Table 7 – Mechanical recyclers in Portugal are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
AMBIENTE – RECUPERAÇÃO DE MATERIAIS PLÁSTICOS, S.A.	Mechanical	X	X	PE-LD, PE-HD	N/A
Ecoibéria - Reciclados Ibéricos, S.A.	Mechanical		X	PET, PE	45,600 t/year PET 960 t/year PE
Evertis Reciclagem, Lda	Mechanical	X	X	PET, PE-HD	10,000 ton/year
Interecycling - Sociedade de Reciclagem, S.A.	Mechanical	X	X	PP, PE, PS, ABS	N/A
Micronipol - Micronizaçao e Reciclagem de Polímeros, S.A.	Mechanical	X	X	PE-LD	N/A
RCDPLAS - Recidubai - Reciclagem de Plásticos LDA	Mechanical	X	X	PE-LD, PE-HD, PP	N/A
Serviplast - Indústria de Reciclagem, S.A.	Mechanical	X	X	PE	N/A
SIRPLASTE - Sociedade Industrial de Recyperados de Plásticos, S.A.	Mechanical	X	X	PE-LD, PE-HD, PP	36,000 t/year

10.8 Portugal – Dissolution and Chemical recyclers

Portugal has no known chemical recyclers on industrial scale.

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10.9 Spain – Mechanical recyclers

Table 8 – Mechanical recyclers in Spain are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
GCR Group - Gestora Catalana de Residuos S.L.U.	Crushing, rental, sorting, extrusion and filtration, deodorization	X	X	PP, PE-HD, PE-LD, LPE-LD	50,000 t/year
REALPLAST - Recyclaje y Almacenaje de Materias Plasticas, S.L.	Recycling, Compounding and Trading	X	X	PS, PE-HD, PE-LD, PP, ABS, PA	
PreZero Gestión de Residuos SA		X	X	PET	
Cadel Deinking S.L. (Cadel Recycling Lab)	Innovative plastic recycling process that can remove printed ink from plastic surfaces (Deinking technology). Grinding, Deinking, Rinsing, Drying, Extrusion	X		PE-LD, PE-HD, PP, PET	Demonstration plant with a treatment capacity of 100 kg/h
CLEAR PET S.L.		X	X	PET	70,000 t/year
MANUFACTURAS PAULOWSKY, S.L.		X		PP, PE-HD, PE-LD, ABS	
Vielpa S.A.	Crushing, washing, extrusion	X	X	PE-HD	10,000 t/year
Baidal Plastic, S.L. (BPL)		X		PVC, PE-HD, LPE-LD, POM, PS, PP, PET, ABS, PA, PC	
Levantina Industrial de Plasticos S.A.		X		PE-HD, PE-LD, PP	10,000 t/year
FYCH TECHNOLOGIES	Dissolution, Delamination	X		Multi-layered plastics	
ACTECO PRODUCTOS Y SERVICIOS S.L.		X		Rubber and plastics	
REPETCO Innovations, SL		X		multilayered PET/PE packages	
Eslava Plásticos S.A.				PE-LD, PE-HD, PP, PS	
Extremadura Torrepet, S.L. (Veolia)		X		PET food grade	60,000 t/year
SULAYR		X	X	PET, PE, PET/PE	
Cordoplas, S.A. - Córdoba		X		PE-LD, PE-HD, PP	

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Table 9 – Mechanical recyclers in Spain are listed - Continued.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
Condaplast, S.A.		X		PE-LD	
NIVAPLAST RECICLADOS S.L.		X		PET	
General de Polimeros S.L.		X		PE Films	12,000 t/year
Sevelar SA		X		PP, PE, PS, ABS, PC, PA, PET	10,000 t/year
Elastómeros del Cinca S.L.	Devulcanization	X		Rubber, elastomers	
OMT Recycling Project, S.L.		X		PET	
Reyuplas S.L.		X		PE-LD, PE-HD	
Plasticos Riaza, S.L.		X	X	PE-HD, PE-LD	
Tecnologia y Reciclaje de Materials S.L. (Tyrma grupo POLYMERLOOP)		X	X	PE, film	20,000 t/year
SOGAPOL – Sociedad Gallega de Polímeros S.A. (Grupo Valtalia)		X		PE-LD	
Plascan, S.A.		X		PET, PE-HD, PE-LD	
Green World Compounding, S.L.		X		PE-LD, PE-MD	
Plásticos Reciplast, S.L.		X		PE-LD, PE-HD, PP, PS	
Egutegui Reciclados S.L.U.		X	X	PE-LD	

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10.10 Spain – Dissolution and Chemical recyclers

Table 10 – Dissolution and chemical recyclers in Spain are listed.

Company	Technology provided	Waste accepted		Polymer types	Plant capacity
		Industrial	Household		
B-CIRCULAR	Pyrolysis. Thermolysis.	X		Carbon fibre and glass fibre reinforced polymers, composites, pre-preg.	
ONYRIQ	Fully recyclable epoxy resins, Chemical upcycling of polyolefins.	X		Synthetic polymers (acrylates, PU, epoxy, silicones...) and biopolymers.	
EURECAT		X		Composites, synthetic and biopolymers.	
LEITAT		X		Composites, synthetic and biopolymers.	
UNIVERSITAT POLITÈCNICA DE CATALUNYA (UPC)		X		Composites, synthetic and biopolymers.	
CAMPUS COMPÒSITS - UNIVERSITAT DE GIRONA (UdG)		X		Composites and synthetic polymers	
AIMPLAS	Thermolysis, Pyrolysis. Solvolysis. Enzymatic/biological degradation.	X		Synthetic polymers.	
GSF UPCYCLING	Thermal cracking. Molecular Recycling & Chemical De-polymerization at Room Temperature.	X	X	Mixed end-of-life plastics, multi-layered plastics, discarded mechanically recyclable plastics, ocean plastics degraded by salt and sun.	
SULAYR	Dissolution	X	X	PET	
PLASTIC ENERGY	Pyrolysis.	X		Plastics that are mixed, contaminated, multi-layered, as well as plastics that can no longer be mechanically recycled. PE-HD, PE-LD, PP, PS.	
RECICLALIA	Unique/Patented procedure	X		Composites.	
POLYKEY POLYMERS SL	Solvolysis.	X		Pure cyclic carbonates from polycarbonate wastes, tailor made processes.	
ACTECO PRODUCTOS Y SERVICIOS S.L.	Catalytic hydrogasification plasma (CHGP)	X	X	Transformation of non-recyclable plastic garbage to methylal product	

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PROJECT

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PROJECT INFO

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PROJECT CONSORTIUM

PROJECT

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