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THE PLASTIC REVIVAL

The key building block to unearth sustainable materials

CONTENT

400Mt
The annual plastic production per year globally

188kg
The average weight of plastic waste produced per US inhabitant each year

Largest plastic production demand per sector:

Packaging (39.1%)
Construction (21.3%)
Automotive (8.6%)

Most common items found in the Ocean:

Food wrappers
Cigarette butts
Plastic bottle

500 years
The estimated time required for a plastic bottle to decompose

150Mt
The plastic amount cluttering up oceans

9%
The percentage of plastic waste recycled globally

+8Mt
Additional plastic waste is thrown into the ocean per year

On average, a human will ingest the plastic weight equivalent of a credit card (5 grams) every week

x3
The size of France is the immensity of the new continent made of plastic waste in the Pacific

INTRODUCTION

SECTION 1

Plastics are widely used for their manifold benefits, and forecasts indicate that global plastic production and usage is set to quadruple by 2050. However, plastics currently represent around 2 billion tons of CO2- equivalent (greenhouse gas emissions) a year, i.e. around 4% of the global total. In the EU, this represents 9% of the region emissions due to the bloc's position as a leading producer and converter of plastics, even while leveraging a greener renewables energy mix. While plastics are versatile and practical, short lifecycle abuse leads to waste mismanagement as consumption rises, thereby ultimately resulting in a plastic waste challenge.

Currently, only around 10% of global plastic waste is recycled, with 25% of EU plastic waste ending up in the hands of recyclers. These low recycling rates are generally attributed to poor consumer awareness, limited regulations outside the EU and inadequate collection and sorting infrastructure. Indeed, key obstacle to this transition starts with inefficient upstream waste management, which stems from low waste traceability and non-binding (up/re/down)cycling frameworks, before arriving at sub-optimal recycling capacities and recycling pathways, all resulting in limited volumes, low liquidity, and volatile recycled molecule prices.

However, fresh momentum in EU plastics recycling is being driven by tightened and voluntary recycling targets, expanded regulations covering non-packaging plastics as well as progress in digital technologies and recycling processes. With these developments paving the way for a rising share of recyclates in plastic production, from less than 10% in 2019 to over 50% in 2050, recycled feedstock could become the "new oil", ie. offering substantial volume growth and attractive margins for recyclers while pressurising not only traditional brand owners but also textile and O&G players whom benefit from current waste feedstock flows.

Challenges in the recycled plastics market stem from inadequate investments in sorting and recycling capacity by potential suppliers, coupled with limited incentives for manufacturing firms to use recycled plastics due to concerns over availability, quality and price competitiveness. Addressing these issues through policy interventions is crucial. On the demand side, measures should establish distinct demand for recycled plastics and level the playing field between virgin and recycled plastics. On the supply side, efforts are needed to increase the supply of recovered plastics and enhance feedstock quality and thorough lifecycle assessment, including improvements in the sustainability of plastic materials and products during the design phase.

In general terms, companies in the plastics value chain need to seize these opportunities based on shifts in material flows and a temporary pivot in gravity from today's scale-driven asset base. Indeed, plastics players can embrace the revolution and turn feedstock security into maximised downstream profits while consolidating activities, minimising leakages and investing in circularity through advanced recycling technologies, thereby collaborating across the entire value chain.

THE PLASTIC BURDEN

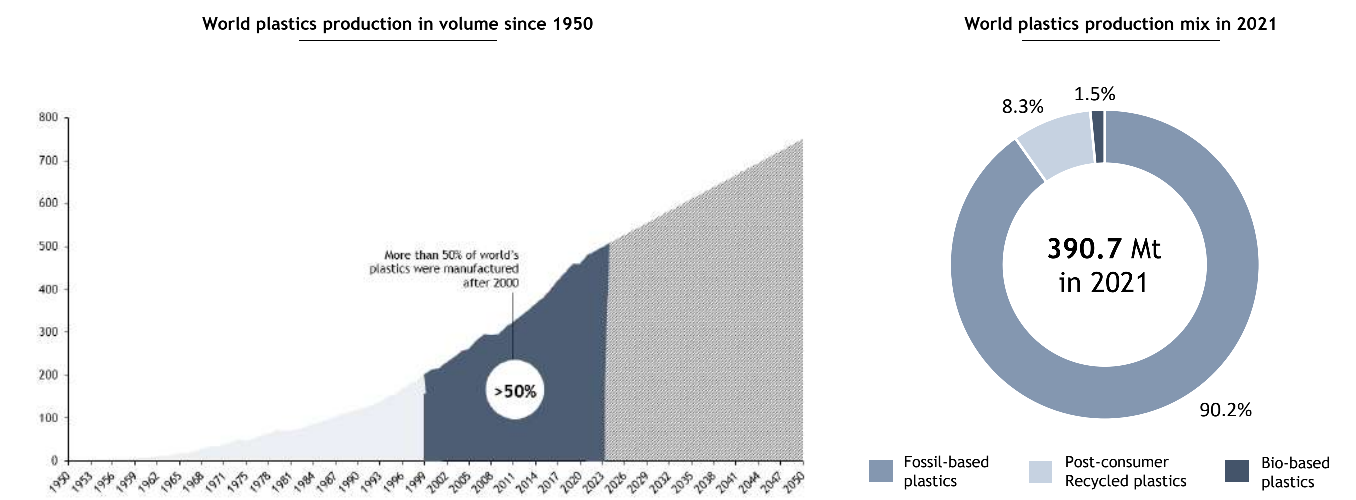
SECTION 2

PLASTIC WAS FANTASTIC, BUT NOW IT HAS BECOME A MAJOR **PROBLEM**

The past two decades have been the scene of a plastic revolution

Plastic has become an indispensable part of modern life, and its use is crucial to many industries. The **(1) convenience** and **(2) cost-effectiveness** of plastic has driven its widespread adoption since the 1950s, as it has gradually replaced paper, glass, metal and other materials. Since 2000, the development of very diverse plastic types has proven very useful in catering to rising needs for packaging, textile production, construction, automotive and electronics – as well as many other applications.

FIG 1: THE REVOLUTION IN PLASTIC USE SINCE THE 1950S HAS STEMMED LARGELY FROM THE USE OF PETROCHEMICALS



Source: PlasticsEurope (PEMRG), Conversio, Nova-Institute, OECD, Stifel IRIS*

More specifically, more than 50% of the world's plastics were manufactured after 2000, incrementally being included into packaging and textiles, but also ubiquitous for home appliances, everything around automotive, logistics as well as building and construction – benefiting from:

- **Progress in material science:** the development of new plastic materials and technologies has expanded the range of applications and improved the performance of plastics. This has made plastics more versatile, durable and suitable for a wide array of industries and products.

- **Consumer demand and lifestyle changes:** the demand for convenience and on-the-go products has increased with changing consumer lifestyles. Plastics provide the necessary flexibility and convenience required for fast-paced and mobile lifestyles, such as single-serve packaging, ready-to-eat meals and portable containers.

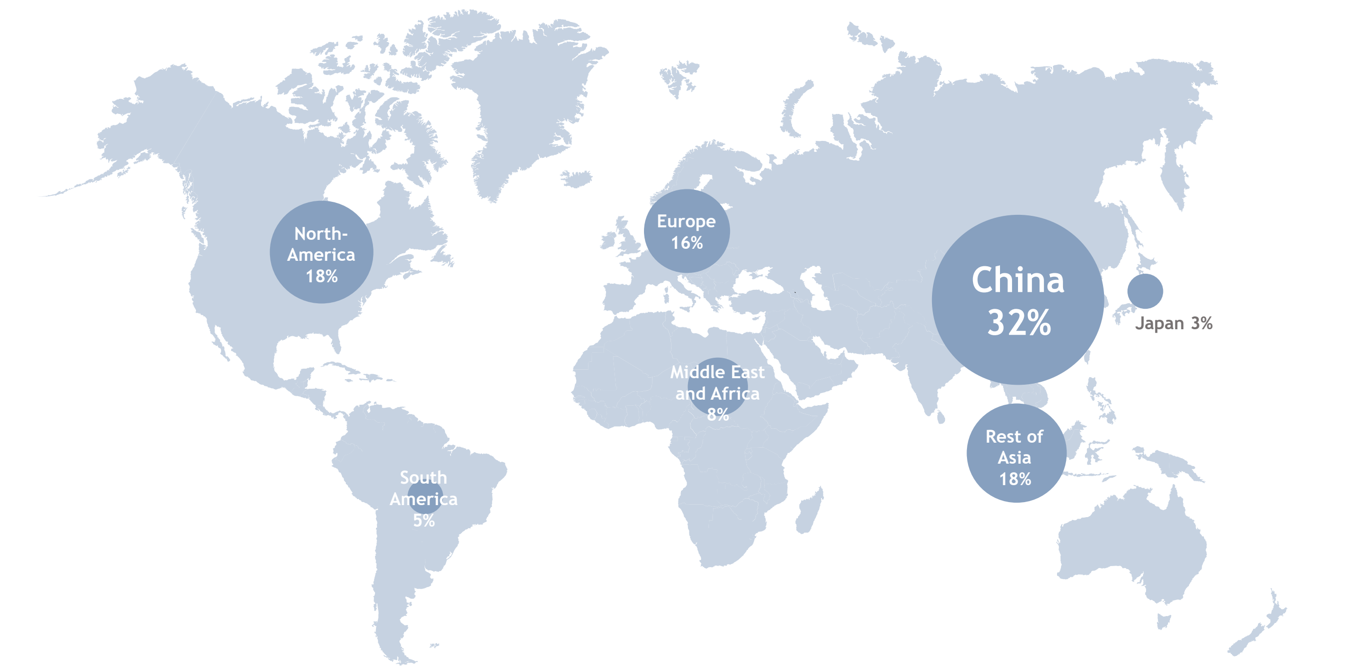
- **Globalisation and market expansion**: growth in global trade and interconnected supply chains has driven demand for plastic packaging. The versatility and durability of plastic make it suitable for long-distance transportation, allowing products to be shipped and stored efficiently.

- **Limited regulatory restrictions:** in some regions, the regulatory framework governing plastic use and disposal has been relatively lenient, which has allowed its widespread adoption without stringent environmental regulations or recycling requirements.

As a result, the annual global production of plastics amounted to 400 million tons in 2022 and is set to reach 750 million tons by 2050. Indeed, the World Economic Forum (WEF) forecasts an annual growth rate in plastic production and usage of 3.8% out to 2030. After 2030, the WEF expects this growth rate to fall back slightly to 3.5% annually until 2050.

Most plastics currently in use are produced from non-renewable resources such as crude oil and natural gas. Despite progress in sustainable alternatives and the growing interest in bio-based and biodegradable plastics, fossil-based plastics continue to dominate the market due to their cost-effectiveness, versatility, and well-established manufacturing infrastructure. Only 8.3% of plastic production in 2021 stemmed from post-consumer sources, while 1.5% was bio-based.

FIG 2: DISTRIBUTION OF GLOBAL PLASTIC MATERIALS PRODUCTION IN 2021



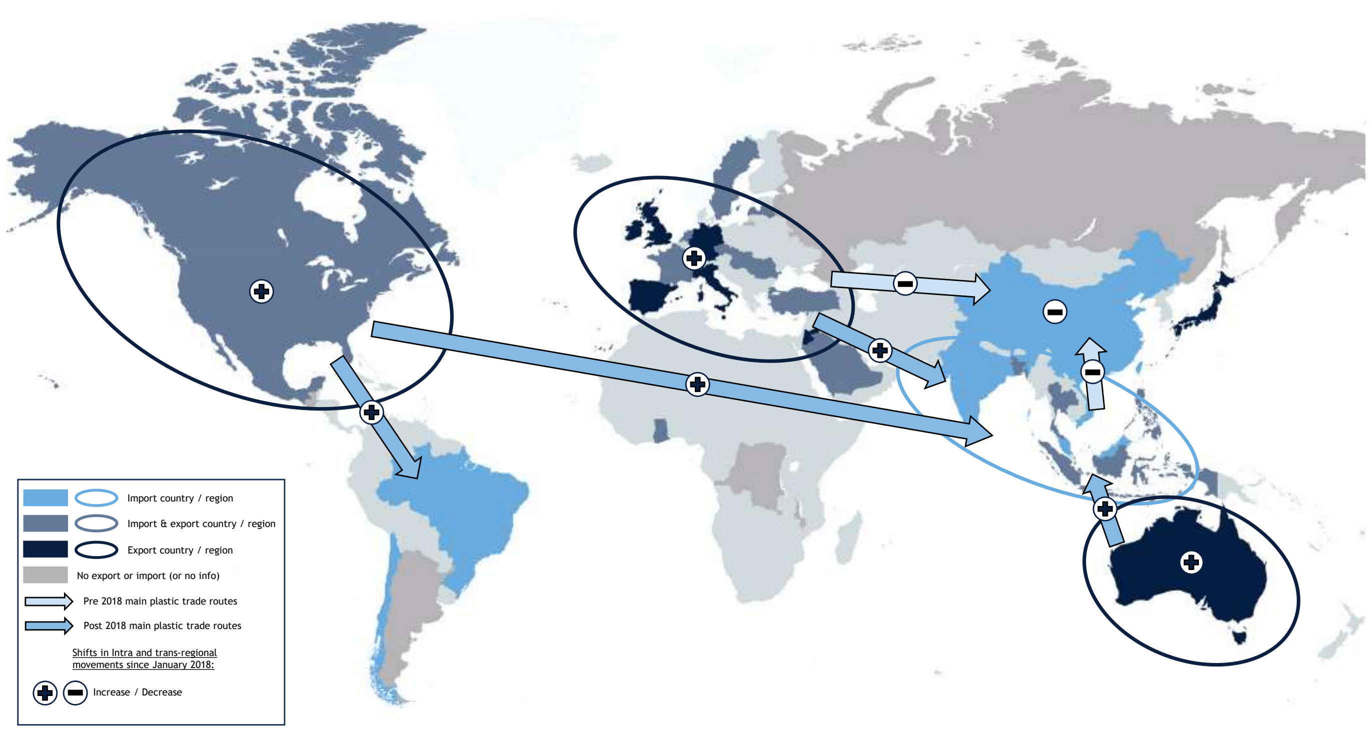
Source: PlasticsEurope (PEMRG), Conversio, nova-Institute, Stifel IRIS*

Global plastic production is unevenly distributed, with certain regions playing significant roles in its manufacturing. Asia is currently the largest producer of plastic globally, accounting for close to 50% of total production in 2021. Countries like China – 32% of global plastic production – India, and Southeast Asian nations have witnessed a surge in plastic production due to their growing industrial sectors and consumer markets, but also because of globalisation.

North America and Europe also have significant presence in the global plastic production landscape, accounting respectively for 18% and 15% of global plastic production capacity. The United States in particular is a major player in plastic manufacturing, driven by its industrial infrastructure and diverse range of industries using plastics.

As such, in view of globalisation and an ever-growing number of containers travelling around the world, collected plastic waste has not always been managed locally in developed countries, but has also tended to be shipped to Asia, and especially China to be "recycled". Although China was not accountable for the bulk of Western plastic waste, it closed its doors as a global dumping ground in 2018/2020, thereby prompting developed countries to rush to structure their own recycling ecosystems, and pressurising its neighbours to host the surplus. Testifying to leakages in the system, piles of post-consumer and post-industrial waste whether plastics or not, continue to be sent to emerging countries and therefore advocate for a significant enforcement of regulations on overall waste and end-of-life traceability.

FIG 3: GLOBAL IMPACT OF IMPORT BANS ON PLASTIC IN 2018

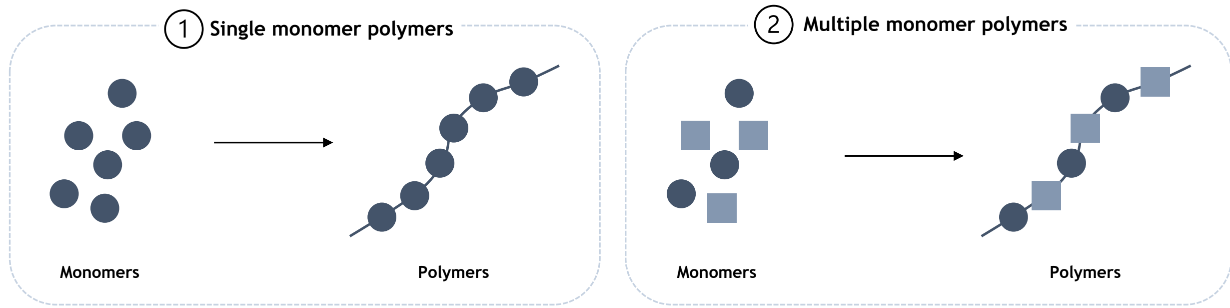


Source: Interpol, Stifel IRIS*

Versatile and durable, plastic has thus become a staple of modern life

All plastics are composed of polymers, which are themselves made up of simpler chemical units called monomers. These monomers are connected through chemical bonds to form long chains. Plastics can be created by (1) linking a single type of monomer, such as those commonly used in packaging, pipes and toys. Alternatively, they can be produced by (2) the reaction between two different types of monomers, as seen in carpets and clothing (e.g., polyethylene terephthalate, nylon).

FIG 4: SCHEMATIC REPRESENTATION OF POLYMER STRUCTURES

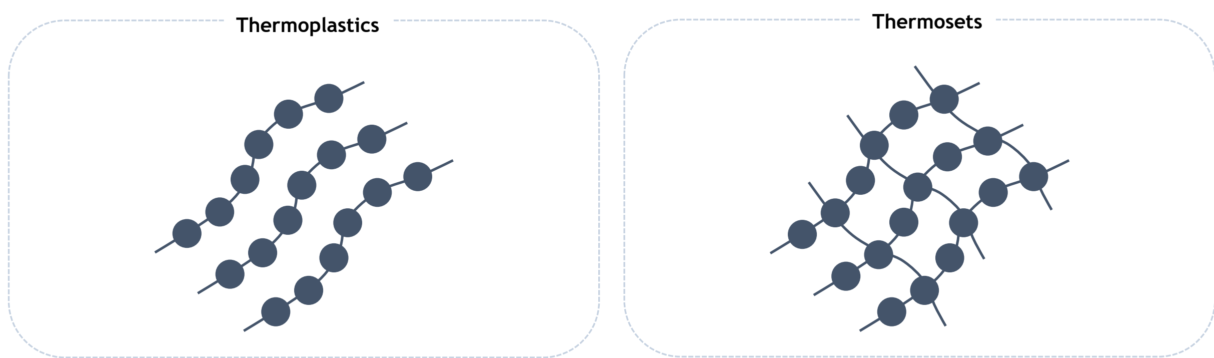


Source: Stifel IRIS*

Plastics can be classified into two categories: thermosets and thermoplastics.

- **Thermoplastics** such as polyethylene (PE), polypropylene (PP), and polystyrene (PS) lack crosslinks and are more flexible. As they can be reshaped when heated and are easily moulded or extruded into films, fibres, and packaging, they can be recycled.
- **Thermoset plastics** such as epoxy, silicone or polyurethane are hard and durable but cannot be recycled into new polymers due to irreversible chemical bonds called crosslinks.

FIG 5: SCHEMATIC REPRESENTATION OF PLASTIC STRUCTURES



Source: Stifel IRIS*

Usage of different plastic types is driven by the various characteristics that make them suitable for specific applications. As a result, they exhibit different lifetimes before they reach the end of their functional lifespan and become waste.

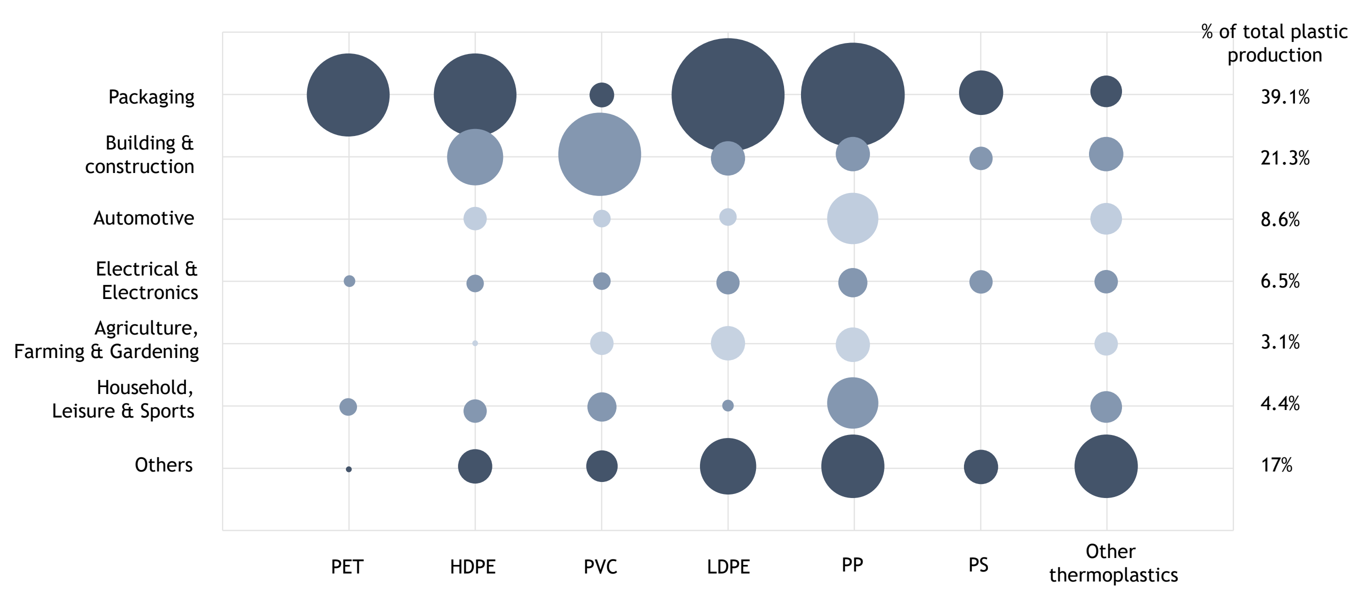
FIG 6: THE INTERNATIONAL CLASSIFICATION SYSTEM BREAKS DOWN PLASTIC TYPES INTO SEVEN DISTINCT CATEGORIES

PLASTIC TYPES	CHARACTERISTICS	APPLICATIONS	LIFETIME TO WASTE
PET *Polyethylene terephthalate*	• Clear, smooth & tough • Correct barrier against O2, water & CO2 • Shatter resistant	Water bottles, jars and caps	●○○○○
HDPE *Polyethylene*	• High chemical resistance • Good tensile strength	Milk & juice bottles, detergent bottles, grocery bags, cereal box liners	●●○○○
PVC *Polyvinyl chloride*	• High impact strength • Resistance to oil & most solvents • Stable electrical properties	Plumbing pipes, plastic toys, table-cloths, vinyl floorings	●●●●○
LDPE *Polyethylene*	• Flexible & transparent • Heat sealing properties • Resistant to most acids & bases	Garbage bags, "paper" milk cartons and hot/cold beverage cups	●○○○○
PP *Polypropylene*	• Tough & flexible • High melting point • Good optical clarity	Yogurt containers, food containers, luggage and clothing insulation	●○○○○
PS *Polystyrene*	• Good moisture barrier • Significant stiffness • Low melting point	Cups, plates, take-out containers, supermarket meat trays	●○○○○
Other *Bisphenol A & others*	• Resin other than the 6 other listed above or made of more than one type	CDs, baby bottles, etc.	●●●○○

Source: ACS Royal Society of Chemistry, Stifel IRIS*

Plastics like PET are commonly used in the production of beverage bottles. Designed for single-use purposes, they have a relatively lower durability as PET bottles have short lifetimes – typically being discarded after a single use. In contrast, plastics such as HDPE are known for their strength and resistance and have longer lifetimes due to their ability to withstand wear and tear, making them suitable for repeated use over an extended period.

FIG 7: MOST DEMAND FROM EUROPEAN PLASTICS CONVERTERS GOES INTO PACKAGING



Source: PlasticsEurope (PEMRG), Conversio, Stifel IRIS*

Packaging stands as the primary end-use application for plastics (39.1% of total plastic production in Europe in 2021), playing a crucial role in preserving and delivering a wide array of products. Among the various plastic materials used for packaging, LDPE, HDPE, PP and PET are the most widely represented. There is no doubt that plastic in all its forms has become a useful party in many aspects of modern life.

FIG 8: KNOW YOUR PLASTIC, AN OVERVIEW OF WIDESPREAD PLASTIC POLYMERS

Source: OECD, Closed Loop Partners, Sustainable Plastics, ACS Review, Stifel IRIS*

The unbridled rise of plastic usage has created major environmental and human health issues

It is paradoxical that the qualities of plastic – namely durability and low cost – have made the material a cause of concern for both developed and emerging societies. Since plastic is relatively cheap compared to other packaging or building materials, it is comparatively less economical to recycle. Additionally, its durability makes its decomposition in natural environments very long.

According to the OECD, approximately 80% of global plastic production currently ends up in a landfill or is incinerated. Trade-off between let be, stand still and expensive measures being taken, these pathways have long favoured non-sustainable models, with many economies now lacking efficient recycling ecosystems – for instance, North American infrastructures (US and Canada) only meet 6% of the region's real recycling demand, either piling/exporting waste or converting carbon to electricity.

Until now, the widespread use of plastic has been built on a "take-make-waste" model optimised for cost-efficiency and overall profitability, ie. raw materials sourced with a primary focus on minimising expenses, as well as products and packaging intentionally created to be disposed of, disregarding any environmental lifecycle assessment. Today still, a large majority of the plastic used is never recovered and constitutes a major source of waste in landfills and oceans, thereby raising concerns about air pollution, groundwater safety and quality of life issues.

Greenhouse gas emissions

Throughout its lifecycle, plastic is a significant contributor to greenhouse gas emissions, primarily through the following processes:

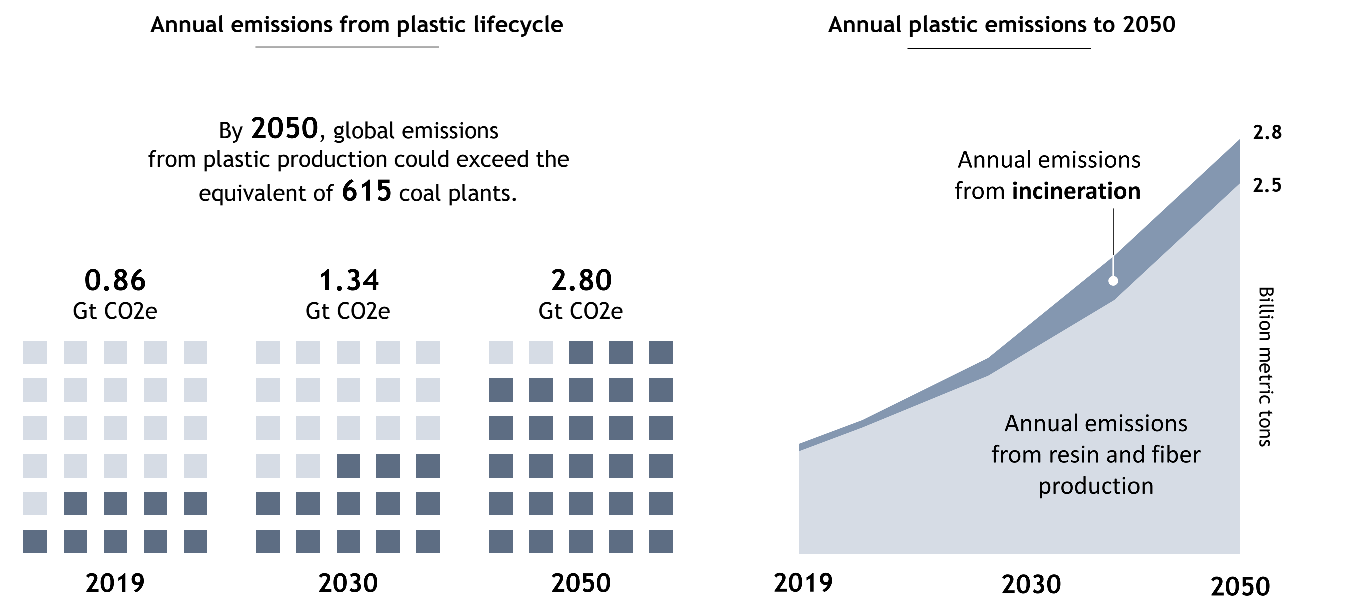
1. **Extraction and transportation:** this phase involves emissions from various sources such as methane leakage and flaring, as well as combustion and energy consumption during the extraction and transportation of raw materials.

2. **Refining and manufacturing:** the production of plastic requires substantial energy, resulting in energy-intensive manufacturing processes. Additionally, the conversion of alkanes into olefins (a crucial step in plastic production) generates emissions.

3. **Waste management:** when it comes to managing plastic waste, different approaches have varying levels of emissions. Landfills, while not ideal, contribute the least to emissions. Recycling has a moderate impact, but then incineration of plastic leads to significantly higher emissions.

4. **Plastic in the environment:** when plastic is not properly managed and ends up in the environment, it undergoes degradation, releasing emissions. It is now proven that microplastics release methane and other gases when decomposing at the surface of the oceans. Additionally, microplastics reduce the ability of plankton to photosynthesise and therefore to absorb carbon dioxide (CO_2) and produce oxygen (O_2). The Center for International Environmental Law (CIEL) estimates that by 2050, 101-103 million tons of methane will be released from ocean surfaces.

FIG 9: ANNUAL EMISSIONS FROM THE PLASTIC LIFESPAN ARE SET TO TRIPLE BY 2050, WITH 11% FROM INCINERATION



Source: Center for International Environmental Law (CIEL), Stifel IRIS*

The continued production, disposal and incineration of plastics is set to hinder global emission reduction efforts to maintain global warming below 1.5°C.

By 2030, plastic-related emissions could reach 1.34 gigatons per year, the equivalent of 296 coal plants. Even with slower growth post-2030, plastic emissions could reach 2.8 gigatons per year by 2050, more than 615 coal plants.

Cabka

Cabka, founded in 1994, is a Dutch company operating globally in the manufacturing of reusable transport packaging (RTP) made of recycled materials, namely plastics. Cabka has set ambitious targets to increase subsequently the proportion of recycled material in its pallets, containers and boxes to the 90% threshold. In 2022 the group had reached a 86% level, of which 46% was processed in-house and 40% was purchased from third-parties.

Cabka is leading the industry with an integrated approach to close the plastic loop, leveraging verticality in its organization with activities ranging from collection to commercialization of plastic waste through recycling, innovation, and manufacturing of recycled goods. Indeed, Cabka's products are then attractive to numerous industries including Food & Beverage, Retail, Chemical, Pharmaceutical and Automotive. The company has installed production locations in Germany, Belgium and the USA while innovation, sales and marketing are based in Spain.

Recycled goods can be made of different materials, however preferring low-cost recycled PO plastic and higher-grade HDPE, to comply with legal requirements regarding clean loading equipment. Beside its main RTP line of business, Cabka also expanded through eco-products made from unsorted mixed plastics which are generated out of 100% post-consumer plastic waste.

worn again technologies

Worn Again Technologies, founded in 2005 and based in the United Kingdom, is a developer of polymer recycling technology designed to create waste-free circular textile materials. The company's technology cleans, decontaminates, extracts and regenerates polymers from non-reusable textiles to turn them back into new textile raw materials (and/or rPET bottles). Worn Again's dual input/dual output process recovers hard-to-recycle blended materials, thereby providing textile manufacturers with clean, high quality renewable raw materials.

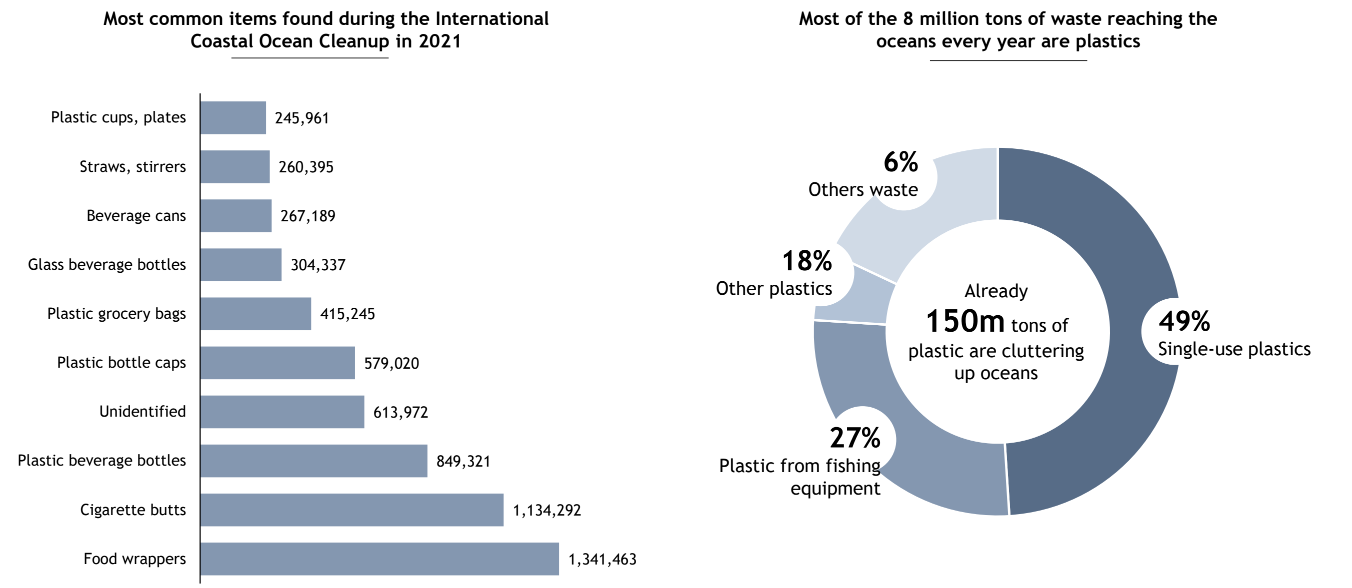
In 2012, the company has successfully tested its dissolution technology at a laboratory scale. Following investments from H&M and Kering, Worn Again Technologies has focused its strategy on accelerating the adoption of its chemical recycling technology within the textile industry. Succeeding the first tests, a first pilot plant has been built in 2019 capable of processing 100x the laboratory trials.

With the help of strategic investor Sulzer, Worn Again Technologies raised an additional GBP27.6m in 2022, and announced the development of a demo plant located in Winterthur, Switzerland expected to be operational in 2025. The plant should prevent the incineration of 1Kt of textiles with the objective of developing larger-scale plants in the future to further expand their closed-loop chemical recycling technology globally.

Marine Pollution

In addition to the overload of landfills, a primary issue related to single-use plastics is the contamination of marine environments. As many plastics – in particular single-use items - are not properly managed by collect systems and leak to natural areas or rivers they eventually end-up spilling into oceans. Although challenging to measure, the European Commission estimates the volume of plastics that are already populating the Earth's oceans at 150 million tons. Among those, half are single-use plastics and 94% are plastics of a kind. Notably, items linked to PET bottle consumption, such as plastic bottle caps, straws and stirrers constitute the items most found in oceans.

FIG 10: OCEANS CLUTTERED WITH PLASTIC WASTE



Source: European Commission, Stifel IRIS*

Among the issues created by this over-accumulation of plastic waste in the maritime environment, we find:

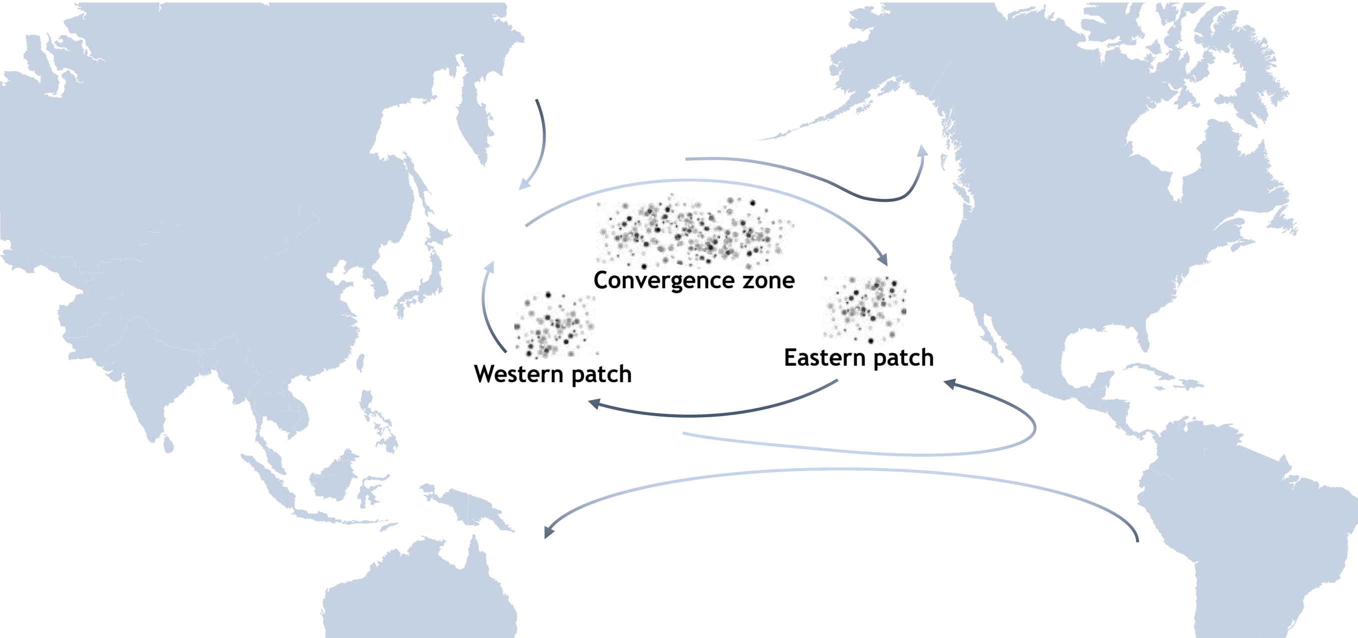
- **Contamination of marine ecosystems** causing harm to marine life through ingestion, entanglement, and release of toxic chemicals. This disrupts natural habitats and threatens the biodiversity of marine ecosystems.

- **Microplastic contamination** through the degradation of larger plastics into smaller microplastics, posing significant risks. Ingested by marine organisms, microplastics enter the food chain and pose threats to both marine life and human health.

- **Economic impacts** on industries dependent on clean oceans, such as tourism, fishing, and recreation – leading to economic losses and affecting the livelihoods of coastal communities.

- **Pollution transport** through the ocean currents carrying plastic waste across long distances, spreading pollution beyond the initial source – thus exacerbating the problem on a global scale.

FIG 11: POLLUTION TRANSPORT HAS CREATED THE GREAT PACIFIC GARBAGE PATCH



Source: Stifel IRIS, National Geographic*

One of the most telling examples of the effects of plastic waste on marine ecosystems is the Great Pacific Garbage Patch composed of two distinct collections of debris bounded by the massive North Pacific Subtropical Gyre. A 2018 study found that synthetic fishing nets made up nearly half the mass of the Great Pacific Garbage Patch, largely due to ocean current dynamics and increased fishing activity in the Pacific Ocean. However, as ocean gears gather plastics and exposure to the sun breaks it down into tiny pieces – through photodegradation – the rest of these patches is predominantly composed of small plastic particles: microplastics.

Damage to human health

Not limited to the environment, the consequences of plastic pollution also affect human health and lifestyles.

- **Microplastic ingestion:** Around 50 years ago, plastic microbeads made their debut in personal care and consumer goods, gradually replacing natural ingredients as plastics gained prominence. Surprisingly, as of 2012, this problem remained relatively unknown, with many products containing microplastics available in the market and consumers largely unaware of the issue. It is now established that microplastics bring: (i) physical damage to the human body caused by particles, (ii) damage caused by chemical additives – such as fabric softeners, endocrine disruptors, and carcinogens – (iii) damage caused by the micro-organisms attached to particles. Some studies even show that the total mass of microplastic ingested by humans corresponds to 50 plastic bags per year, one credit card per week, or a median value of 4.1 µg/week for adults.

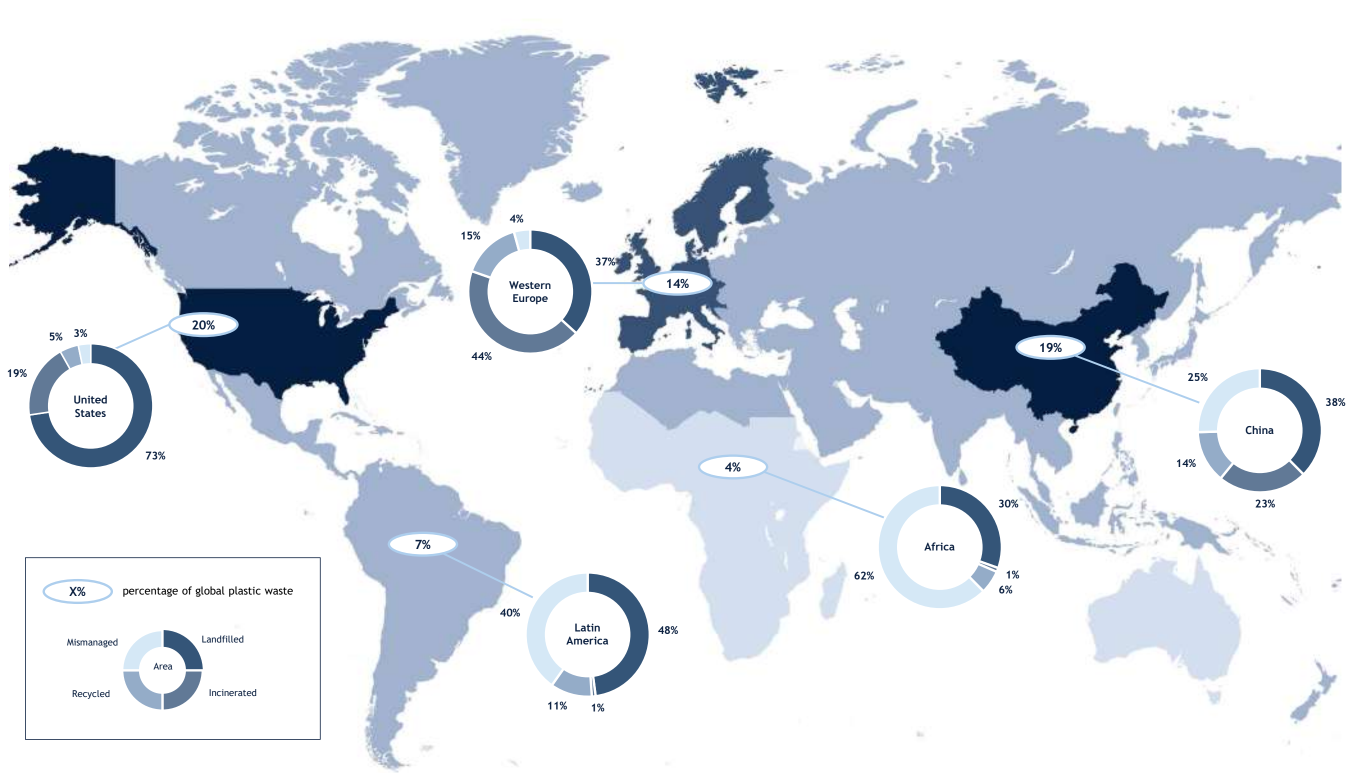
- **Increased risk of natural catastrophes:** plastic waste can also disrupt crucial infrastructure such as irrigation systems and water drain by clogging pipes and canals. Counter-intuitively, given that floods and natural disasters served as a warning as early as in the 1880's, how customary they are and the lack of critical infrastructures in emerging countries, they have been among the first globally to implement bans on certain types of single-use plastics. Bangladesh, for instance, instituted the world's first nationwide ban on plastic bags in 2002 following deadly floods.

- **Spreading of disease:** as plastic bags and discarded bottles are scattered in uncontrolled environments they risk accumulating water and creating breeding ponds, thereby creating favourable conditions for the spread of diseases such as malaria.

Increased awareness of the dangers of plastic mismanagement has led to a growing global movement to reduce single-use plastics, promote recycling, and advocate for sustainable alternatives. Individuals, communities, and organisations are actively working towards minimising plastic pollution and fostering a more sustainable future for the planet.

State of global waste management

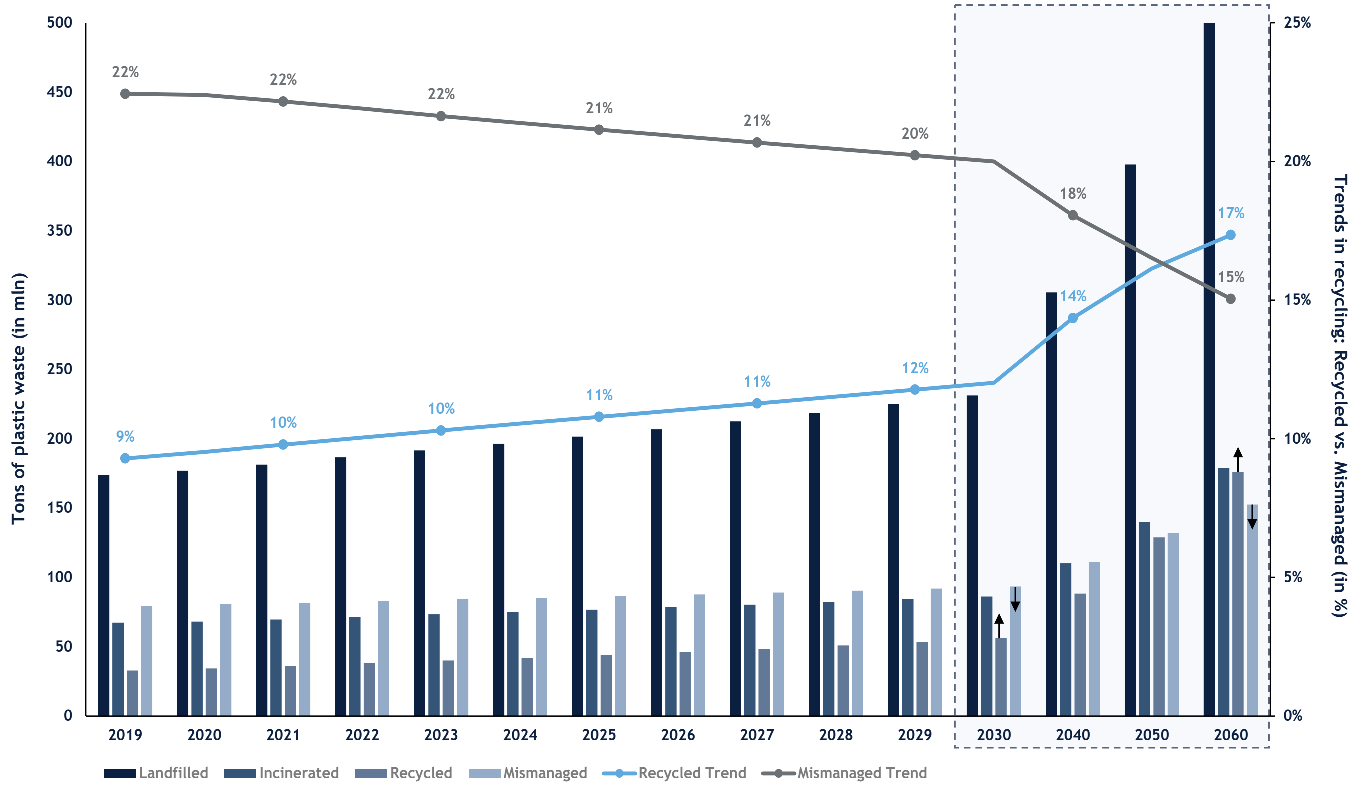
FIG 12: GLOBAL WASTE MANAGEMENT BY REGION



Source: Stifel IRIS, OECD*

Projections simulated for waste management on a regional scale bring hope when aggregated on a global scale. Forecasts for landfill and incineration remain on a stable trend, at respectively 50% and 18% of global plastic waste. As emerging countries gain exposure to multiple recycling techniques, leadership between the mismanaged and recycled proportions tends to reverse over time.

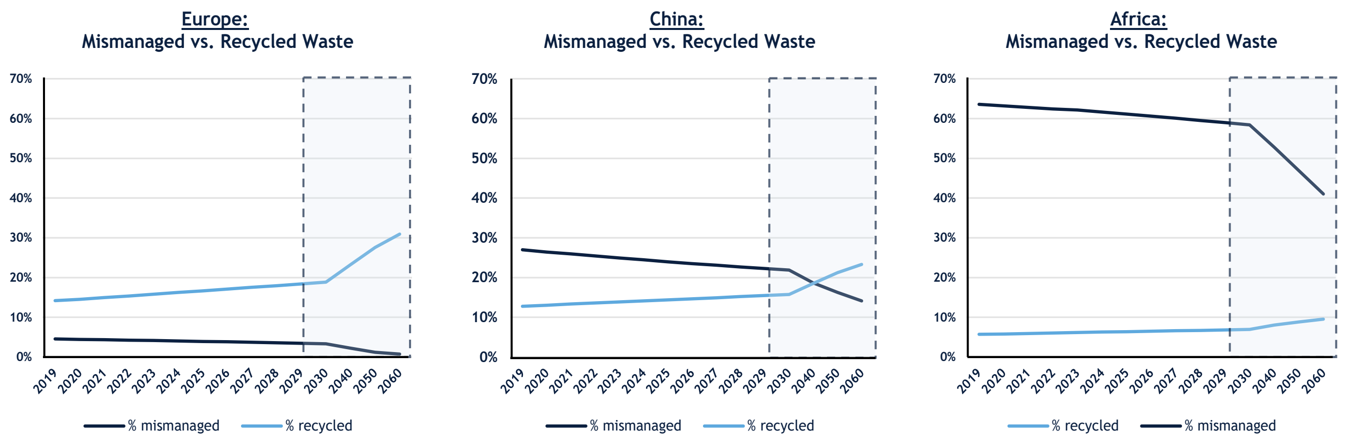
FIG 13: PROJECTIONS FOR GLOBAL WASTE MANAGEMENT AND REVERSAL TRENDS



Source: Stifel IRIS, OECD*

This shift is even clearer when we look at where emerging countries stand in terms of waste management. Region such as Latin America, Middle East and North Africa are in the same bracket as China and India, showing an accelerating trend towards recycling with almost fully asymmetric market share behavior between mismanaged and recycled waste. Those regions are considered to be the main contributors to the global trend expected until 2050. On the other hand, since they are poorer and less structured, African countries (but also South American and Asian countries) lack the incentives and the means to deal with waste management in an environmentally proactive manner, therefore taking more time to shift from one model to another. As such, while the share of mismanaged plastic waste is projected to be lower by 2050-2060, aggregated mismanagement volumes (Mt) should still end up higher by that time, as for landfilling and recycling.

FIG 14: PROJECTIONS FOR MISMANAGED VS. RECYCLED WASTE FOR THE EUROPEAN UNION, CHINA AND AFRICA



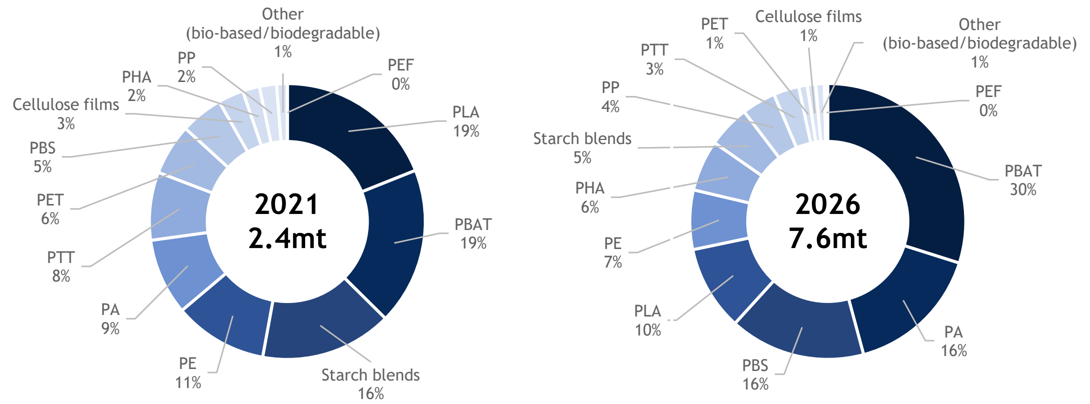
Source: Stifel IRIS, OECD*

Hence the need for renewable/bio plastic

Bioplastics and bio-based plastics are terms used to describe types of plastics that are derived from renewable biological sources, in contrast to traditional plastics that are made from fossil fuels like oil or natural gas. These alternatives aim to address environmental concerns associated with conventional plastics, such as pollution and dependence on non-renewable resources. Not all bioplastics are necessarily biodegradable, and not all bio-based plastics are completely derived from renewable sources. Bioplastics (from biopolymers) are cellulose acetate for example while PEF and PLA are bio-based plastics.

Although bioplastics currently represent less than 1% of total annual plastic production, the market is rapidly expanding. The global production capacities are set to increase from around 2.4 million tons in 2021 to approximately 7.6 million tons in 2026. In other words, bioplastics should represent close to 2% of global plastic production by 2026.

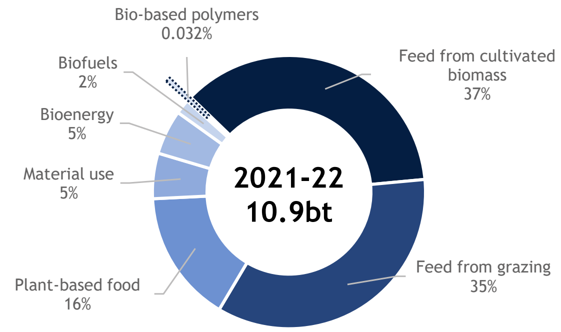
FIG 15: GLOBAL BIOPLASTICS PRODUCTION CAPACITIES BY MATERIAL TYPE IN 2021 AND 2026



Source: European Bioplastics

Often mentioned being in direct competition with the food industry both from land requirements and food resource re-routing perspectives, those fears might be overstated as sustainable practices and strategic planning are being put in place, also leveraging alternative (non-food) feedstock research to minimize the impact, if any in the long-term. Indeed, according to Nova Institute, global bioplastic production in 2021-2022 required close to 0.03% of the 10-12bn ton per year of dry matter steaming from global harvested agricultural and grazed biomass. Moreover, bio-based plastics can be produced from agricultural or food processing waste streams, and a wide range of algae and microorganisms are investigated as potential feedstocks for bio-based plastics to be cultivated in non-arable land or wastewater, therefore reducing the reliance on primary crops and minimizing competition with food production.

FIG 16: GLOBAL HARVESTED AGRICULTURAL AND GRAZED BIOMASS DEMAND BY SECTORS IN 2021-2022



Source: Nova Institute

Avantium is a Dutch green chemistry company specialising in the development of sustainable alternatives to traditional fossil-based polymers. Founded in 2000, Avantium is at the forefront of renewable chemistry, with a focus on creating bio-based and recyclable materials. Leveraging its proprietary YXY technology, Avantium focuses on transforming plant-based sugars into furandicarboxylic acid (FDCA), a chemical building block for the production of a first-of-its-kind plant-based polyester named polyethylene furanoate (PEF). This innovation positions PEF as a plant-derived alternative to conventional plastics like PET, offering a more sustainable option with superior performance properties for packaging and various other applications.

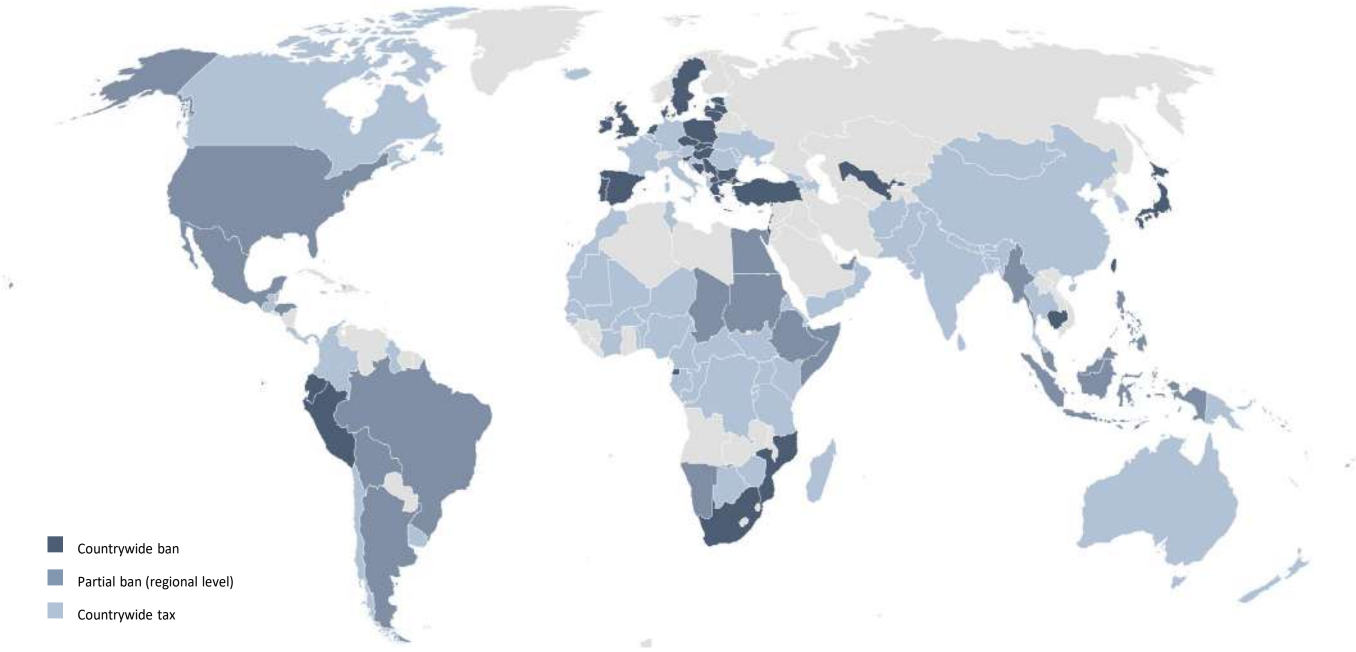
Currently building its industrial-scale 5Kt pilot plant in Delfzijl, Netherlands, Avantium's strategy is to collaborate with leading brands and industrial companies worldwide to create global demand for plant-based products based on FDCA. As such, Avantium is currently involved in partnerships with Mitsui, Toyobo, Alpla, Danone, Carlsberg, Paboco, BillerudKorsnäs, R&F Chemical, Refresco and Albert Heijn for the development of PEF bottles and films. It has also very recently agreed to supply Pangaia with PEF to be used in sustainable fibers, and also continues to develop other innovative plant-based chemicals and materials, leading products stemming from RAY plantMEG and Volta carbon-capture.

EMERGING REGULATIONS SPARK INCENTIVES FOR PLASTIC RECYCLING INITIATIVES

Single-use plastics face long-due global restrictions

To address the plastic issue, regional organisations, countries, regions, and cities have started to adopt mitigating strategies, taking the form of bans or the establishment of discriminating taxes on single-use plastics. A symbol of the legal fight against plastic pollution is the increasingly common ban on plastic bags: as of 2022, more than 100 countries had completely or partially banned their use.

FIG 17: AN INCREASING NUMBER OF COUNTRIES HAVE IMPLEMENTED REGULATIONS ON PLASTICS MANAGEMENT



Source: Stifel IRIS*

No longer confined to plastic bags, these measures are increasingly extended to all disposable and/or difficult-to-recycle plastic types. The European Union has a relatively bold approach to the matter, adopting the European Single-Use Plastics Directive in 2019, which aims to reduce the impact of certain single-use plastic products on the environment. Its legislation targets 10 specific items the most littered on European beaches, including plastic cutlery, plates, straws, and beverage stirrers.

In North America, Canada introduced the Single-use Plastics Prohibition Regulation in 2022, covering items such as plastic bags, straws, cutlery, and six-pack rings.

Perhaps most significantly, many similar incentives were introduced in emerging countries – often very affected by plastic pollution because of (i) the fast adoption of new modes of consumption involving plastics, and (ii) the lack of waste management infrastructures to sustain it. The emblematic "Plastic Waste-Free India" campaign in 2018 targeted the elimination of six major single-use plastic items by 2022. Across the Pacific, several countries in Southeast Asia, such as Thailand or Malaysia, have taken action to fight plastic pollution.

These bans reflect the increasing will of public stakeholders to take action. However, while these bans indeed contribute to reducing plastic consumption and waste, alone they are insufficient to eliminate existing plastic pollution and demand for certain plastic products.

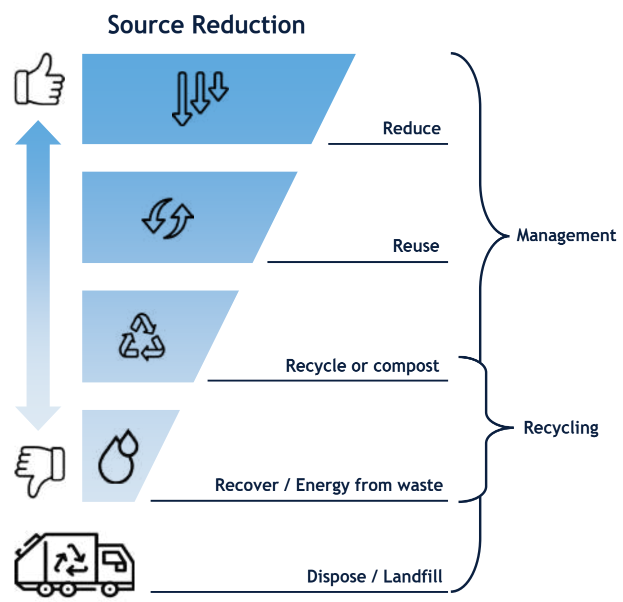
FIG 18: EUROPEAN UNION SINGLE USE PLASTICS DIRECTIVE

Source: Stifel IRIS*

Recycling rates have already increased in Europe, but the RoW needs to catch-up

Recycling plays a vital part in mitigating the environmental impact of plastics by diverting them from landfills and incineration. By transforming discarded plastics into valuable resources, recycling saves energy, reduces greenhouse gas emissions, and preserves natural resources. Improving the recycling rate of plastic waste is critical to tackle the global plastic pollution crisis.

FIG 19: WASTE MANAGEMENT OR WASTE RECYCLING? HERE IS A FRAMEWORK

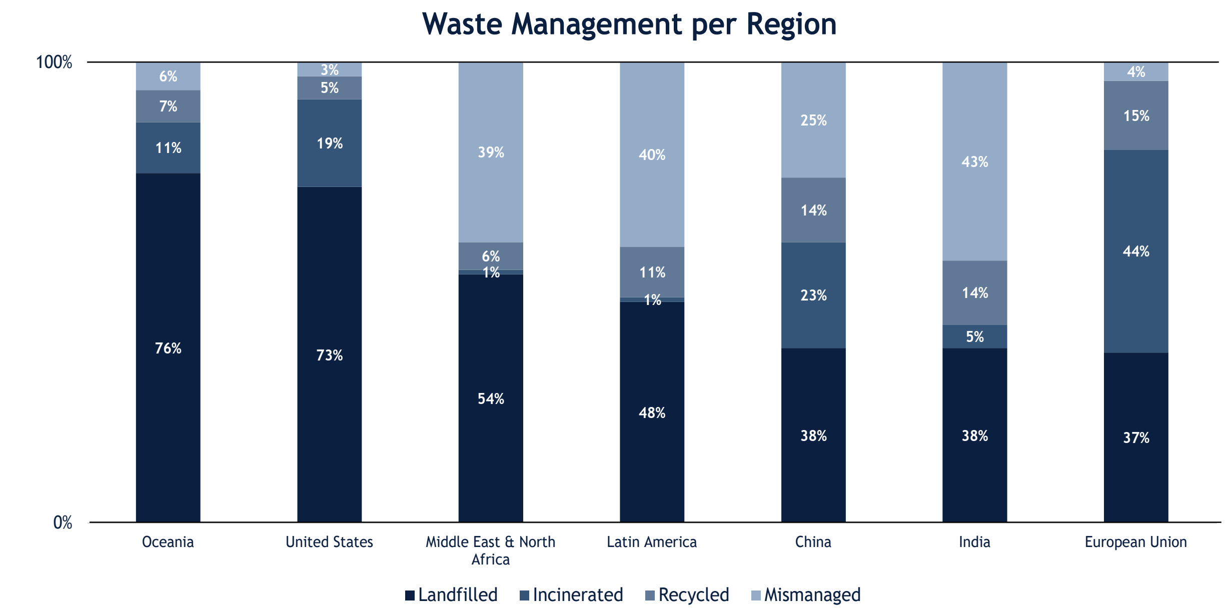


Source: Stifel IRIS*

However, knowing the difference between waste management and waste recycling is making a difference. Recycling is a key component of a broader waste management framework, involving the separation, sorting and processing of waste materials for reuse and/or remanufacture. Recycled materials are no longer considered as waste, thereby highlighting the importance of recycling for sustainability. Waste management encompasses the entire lifecycle of waste, including controlling waste generation, collection, transportation, storage, treatment, and environmentally responsible disposal.

Waste management regulations would therefore ultimately lead to leaner packaging uses, higher recycling rates and lower reliability on energy recovery or waste disposal channels, favouring closed loop channels and higher recyclable material contents.

FIG 20: RECYCLING RATES REMAIN INSUFFICIENT, ESPECIALLY IN CERTAIN PARTS OF THE GLOBE



Source: Stifel IRIS, OECD*

In the United States, various measures have been taken to improve plastic waste recycling, including the implementation of recycling incentive programs, promoting community recycling education, and investing in advanced recycling technologies. The US Environmental Protection Agency (EPA) has launched programs like the America Recycles Initiative, which aims to increase the recycling rate of plastics and other materials to 50% by 2030.

Similarly, Canada has taken steps to improve recycling infrastructure and encourage sustainable packaging design.

On the other side of the Atlantic, the European Union has set ambitious targets for plastic recycling and waste reduction, emphasizing the need for effective collection systems and extended producer responsibility schemes. The 2019 Single-Use Plastics Directive introduced a 77% separate collection target for plastic bottles by 2025, increasing to 90% by 2029. In the 2022 revision of EU legislation on Packaging and Packaging Waste, the commission emphasized its goal “to make packaging fully recyclable by 2030”, by (i) setting design criteria for packaging, (ii) creating mandatory deposit return systems for plastic bottles, and (iii) making it clearer which packaging can be thrown to biowaste.

Circularity will be key

Developing and encouraging the use of recycled materials is considered crucial for the creation of a fully circular value chain. The incorporation of recycled materials into production processes has the potential to significantly reduce the demand for virgin resources, minimize waste generation, and mitigate the environmental impact associated with extracting raw materials. To promote recycling and create a more sustainable approach to plastic management, several countries have implemented notable initiatives.

FIG 21: MAIN REGIONAL AND NATIONAL LEGISLATION INITIATIVES

	EU		Canada	Australia	UK	California, USA	Washington, USA	New Jersey, USA
Adoption date	2019	In progress *(proposed in 2022)*	In progress *(proposed in 2022)*	2021	2022	2020	2023	2022
Regulation	Single-Use Plastics Directive	Revision of the Legislation on Packaging and Packaging Waste	Revision of the Canadian Environmental Protection Act	2021 National Plastics Plan	Plastic Packaging Tax (PPT)	Assembly Bill 793	Washington’s plas tics law	Bills S2515/A4676
Key regulations	PET beverage bottles incorporate at least 25% recycled plastic by 2025 All plastic beverage bottles incorporates at least 30% of recycled plastic by 2030	30% recycled content for contact sensitive packaging made from PET by 2030, 50% by 2040 10% recycled content for contact sensitive packaging made from plastic materials other than PET, 50% by 2040 30% recycled content for single use plastic beverage bottles, 65% by 2040 35% recycled content for other plastic packaging, 65% by 2040	Plastic packaging to contain at least 50% recycled content by 2030	20% average recycled content within plastic packaging by 2025 including 30% for PET packaging	Tax on plastic packaging manufactured in, or imported into the UK, that does not contain at least 30% recycled plastic	Plastic beverage containers: 15% PCR in 2022, 25% in 2025 and 50% in 2030	Plastic bottles: 15% PCR in 2023, 25% in 2026, 50% in 2031 Dairy milk containers: 15% PCR in 2028, 25% in 2031, 50% in 2036 Household cleaning/personal care products in plastic containers: 15% PCR in 2025, 25% in 2028, 50% in 2031 Garbage bags: 10% PCR in 2023, 15% in 2025, 20% in 2027	Rigid plastic containers: 10% PCR in 2024 and increasing incrementally until 50% by 2036 Plastic beverage containers: 15% PCR in 2024 and increasing incrementally until 50% by 2045 Glass containers: 35% PCR in 2024 Paper carryout bags: between 20-40% PCR, depending on size, in 2024.
Current level	9.9% recycled content in post-consumer plastics (2021)		11% recycled plastic content in packaging (2021)	4% recycled plastic content in packaging (2021)	Recycled plastic content has tripled since 2018, from 9% to 27%	U.S. Pact members average about 8% (2020) recycled plastic content in their packaging		

PCR (Post-Consumer Resins): Materials, such as plastics, that have been collected and recycled in resins so they can be (re)utilized in new applications

Source: Stifel IRIS, European Commission, Local regulators, Plastic Europe, Wrap (UK.org), US Plastics Pact, Canada Plastic Pact Partners*

The European Union (EU) has set ambitious targets for plastic recycling and waste reduction, prompting countries in the region to implement significant actions. These also include binding constraints on countries to ensure that PET beverage bottles incorporate minimum recycled content. The Commission has also proposed to broaden this measure to all plastic packaging with the revision of EU legislation on Packaging and Packaging Waste. Meanwhile, in 2022, the United Kingdom introduced a tax of GBP210,82 per ton of plastic packaging that does not contain at least 30% recycled plastic.

In the United States, although no country level legislation exists for the moment, some states such as California, New-Jersey and Washington have started to legislate on minimum Post Consumer Resins rates for specific plastic products.

Overall, national initiatives to promote a more circular use of plastics have increased. These initiatives typically focus on three key areas:

1. **Favour recyclable plastics**. This involves promoting the use of materials that are readily recyclable and encouraging eco-design principles that facilitate the recycling of plastic components.

2. **Improve waste collection.** This includes the deployment of smart bins, waste tracking systems, and public awareness campaigns to promote responsible disposal and recycling practices.

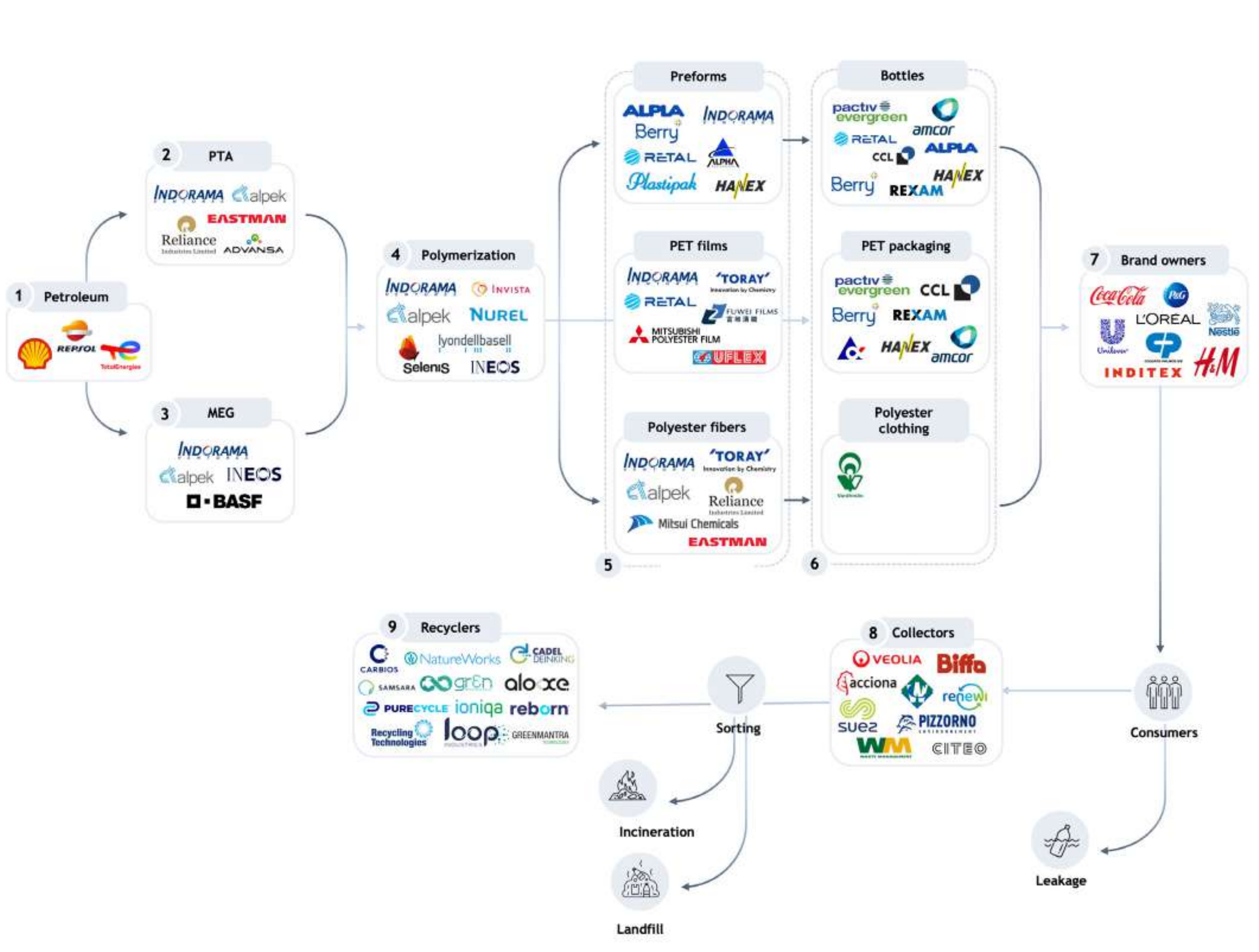
3. **Foster the incorporation of recycled materials as raw materials.** This can take the form of mandatory minimum recycled content requirements, financial incentives, or preferential procurement policies.

UNPACKING THE **PET LIFECYCLE**

The polyethylene terephthalate (PET) value chain as an anchor of plastics' one

PET plastic, also known as polyethylene terephthalate, is a widely used and highly versatile thermoplastic polymer. It is valued for its strength, transparency and lightweight nature. It is commonly employed in the production of various bottle types, packaging and clothing, and plays a pivotal role in numerous industries worldwide. The global market volume for polyethylene terephthalate (PET) and polyesters amounted to 99 million metric tons in 2022. By 2030, those volumes are expected to reach 120 million metric tons, growing at a 2.4% CAGR between 2022 and 2030.

FIG 22: OVERVIEW OF THE CRUCIAL STEPS AND MAIN PLAYERS IN THE PET VALUE-CHAIN



Source: Stifel, IRIS*

We break down the value chain of PET into nine crucial steps, from chemical feedstock reactions to recycling of waste associated with its consumption.

(1) Petroleum extraction
The PET production process begins with petroleum refining. Major players such as Total Energies, Eni, Shell, and others are responsible for the extraction of raw materials which will later be transformed into the prime chemical components of PET: purified terephthalic acid (PTA) and monoethylene glycol (MEG).

(2) Purified terephthalic acid (PTA) and (3) monoethylene glycol (MEG) transformation
The method to produce purified terephthalic acid (PTA) involves converting the hydrocarbons derived from petroleum into a substance known as paraxylene through a catalytic reforming process. Paraxylene, a key intermediate, is then chemically transformed into purified terephthalic acid through oxidation and purification steps.

Monoethylene glycol (MEG) is another important chemical derived from petroleum. It is produced by first reacting ethylene, which is derived from hydrocarbons in petroleum, with oxygen under specific conditions to form ethylene oxide. Further, the ethylene oxide is converted into monoethylene glycol through a process called hydrolysis.

Major global chemical manufacturers, as well as companies specialising in polyester production, are typically key players in the production of PTA and MEG. They may operate as integrated companies, involved in all stages of the production process, from petroleum refining to the final production of PTA.

(4) Polymerisation
The polymerisation process is an essential step in the production of PET. In simple terms, it consists of combining PTA and MEG to form a PET resin. The process results in the formation of long chains of repeating units, which make up the polyester polymer. These polymer chains have high molecular weights and exhibit desirable properties such as strength, durability, and resistance to chemicals.

Some companies responsible for the polymerisation process are integrated and others offer specialised polymerisation services, customised polymer formulations, and tailored solutions to meet specific application requirements. Among these we count groups such as Indorama Ventures, Alpek, or INEOS.

(5) Conversion into preforms, PET films and polyester fibres
Once polymerisation is complete, the resulting PET polymer can be processed further into various forms, such as preforms, PET films and polyester fibres.

- **Preforms** are specially designed intermediate products used in the manufacturing process for plastic bottles taking the form of a small, tubular-shaped piece made of PET. They are moulded into a specific shape that resembles the final bottle, including features such as the neck, thread, and base.

- **PET films** are produced through a process called extrusion, where molten PET polymer is continuously extruded into a thin sheet and rapidly cooled to form a solid film. The film can be manufactured in various thicknesses, ranging from a few micrometres to a few millimetres, depending on the desired application.

- **Polyester fibres** are produced by melting PET which is then extruded into fine filaments,. These are known for their strength, durability and resistance to wrinkles, stretching, and shrinking. Polyester fibres also have excellent colour retention and can be easily dyed, making them suitable for textile applications.

(6) Conversion into bottles, PET packaging and polyester clothing
Once PET is converted into preforms, the resulting items can be further processed into PET bottles, PET packaging and polyester clothing.

- PET bottles: preforms are transformed into PET bottles through a process called stretch blow moulding. The preforms are heated, stretched, and shaped using pressurised air inside a mould cavity. Once cooled, the bottles are ejected and trimmed, resulting in fully formed PET bottles ready for packaging and use.

- Roughly the same process is applied to PET films to create PET packaging.

- Polyester clothing: consists of clothes made out of polyester fibres.

While PET bottles and packaging are often manufactured by the same companies (Amcor, Rexam, Berry, Pactiv Evergreen, Indorama etc.), the transformation of polyester fibres into clothing involves more specialised players such as Vardhman and others.

INDORAMA CORPORATION

Indorama is a global corporation of 12 international companies with diversified interests in petrochemicals and textiles, whether virgin or recycled. Among the largest producers and/or converter of polyolefins (HDPE, LDPE, PP and PET among others), i.e. polymer resins used to make durable consumer and industrial plastic goods, Indorama has also expanded into fertilisers and yarns. With 20,000 people employed worldwide, Indorama has built a plastic empire through multiple acquisitions and developments in emerging countries, especially Indonesia, India, Malaysia, Uzbekistan, Georgia, Nigeria, Senegal and Brazil.

Chasing its sustainability goals, Indorama is set to spend USD8bn over the 2022-2030 period to help scale up chemically recycled and bio-based plastics, eyeing a 25% sustainable feedstock by 2030 (from less than 2% in 2022). As of 2022, the group had invested USD1.5bn in increasing recycled PET (rPET) feedstock, setting a 700Kt target by 2025 (vs 400Kt reached in 2021). According to CEO Aloke Lohia, "mechanical recycling will continue, but the big game changer will be a new chapter of advanced recycling and bio-renewable feedstock".

Consequently, Indorama is actively deploying capital through Indorama Ventures, dedicating a special entity to sustainable chemicals. Through financial investments in chemical recycling projects from companies like Carbios and Loop Industries, it has become a leading player in the recycled PET and polyester ecosystems, now expecting to recycle 100bn bottles per year by 2030.

(7) Brand owners
Major brand owners such as Coca-Cola, P&G, L'Oréal – and many others – buy bottles and containers of various types to converters. Plastic usage by brands can range from small-scale packaging for individual products to large-scale applications in industries such as food and beverage, personal care, consumer goods, automotive, electronics, and more. These industries often rely on plastic packaging, containers, bottles, and components to deliver their products to consumers.

Textile groups such as Inditex and H&M are big buyers of transformed PET and also use many polyester fabrics to create their clothes. Polyester fibres, including those derived from PET, make up a substantial share of the global fibre production, often surpassing other synthetic and natural fibres in terms of volume.

(8) Collectors
Once various plastic containers and polyester textiles are uses and discarded by consumers they are gathered from various sources, such as households, commercial establishments, and public spaces. The collected plastic waste is then sorted according to its type, colour, and potential for recycling. After sorting, the plastic waste is compacted or baled to reduce its volume for easier transportation. It is then transported to recycling facilities or processing centres where it undergoes further processing, such as mechanical or chemical recycling, to transform it into reusable materials or to ensure proper disposal. Effective plastic waste collection is crucial for promoting recycling and responsible waste management practices.

It is worth noting that a significant percentage of worldwide consumed PET ends up leaking out of collection systems and spills into uncontrolled/natural environments.

VEOLIA

Veolia is the world reference in the management of solid or liquid non-hazardous or hazardous waste. A global leader in plastics recycling, Veolia operates some 200 sorting centres, 40 recycling & compounding plants, and delivers almost 500Kt of circular polymers to thousands of customers over the globe.

The company is involved in the entire waste life-cycle, from collection to final treatment, and makes waste recovery a priority for the production of ready-to-use highly performing circular resins. As such, Veolia develops innovative solutions to increase the rate of waste recycling and conversion into matter or energy, whether investing organically or deploying capital on key technologies through PlastiLoop, its dedicated global offer committed to implement efficient and low CO2 recycling processes. Consequently, in 2017 when Veolia was recovering 47Mt of waste, the group had set itself a target of increasing its revenue from recycling plastics (excluding collection and sorting, but including incineration) from EUR200m to EUR1bn by 2025, primarily in Europe and Asia. These revenues had jumped to EUR383m in 2021 with similar volumes of processed waste at the group level. This highlights a fivefold increase in Veolia's plastic recycling capacity since 2016, followed by the creation of PlastiLoop in 2022, (i) quiescently growing through consolidation, (ii) eyeing ~610Kt of recycled polymers in 2023 and (iii) gradually activating feedstock synergies.

(9) Recyclers

Once the plastic waste arrives at the recycling facility, it undergoes a sorting process to separate different types of plastics. Recyclers use a combination of manual and automated methods to identify and segregate specific plastic types, including PET. After sorting, the plastic waste undergoes cleaning and preprocessing steps, where contaminants are removed through washing, shredding and grinding. These initial stages ensure that the plastic waste is prepared for further recycling processes, facilitating the production of high-quality recycled materials.

PAPREC

Paprec is a leading French recycling company with more than 16Mt of waste collected and treated in 2022, more than 50% of of which is recycled. Established in 1995, Paprec is known for its comprehensive recycling services, starting out with waste material recovery and now encompassing a wide range of materials such as paper/board, metals, plastics etc. whether post-consumer, post-commercial or post-industrial. Leveraging 37 sorting plants, Paprec plays a vital role in processing and repurposing this waste, working towards minimising the environmental impact of discarded materials.

Thanks to its industrial expertise in the entire waste management chain (collection, design, construction and operation of recycling and organic material recovery plants), Paprec offers waste collection, sorting and recycling solutions tailored to the needs of territories and customers, industrials and local authorities. As such, the group's diversification into the production of low-carbon energy from non-recyclable waste, as well as its ongoing investments both in innovation to introduce the most effective waste management technologies and industrial improvements, reinforce its strategic position as France's leading recycler and a major player in low-carbon materials production.

suez

SUEZ is a waste management company and global leader in circular solutions for water and waste, therefore specialising in food recycling, renewable energy and plastic recycling services. For plastics packaging, SUEZ develops leading-edge technology solutions to improve the identification, separation and preparation of materials thereby optimising their design to facilitate recycling. However, SUEZ does not stop that high in the value-chain, also engaging in concrete resin recycling initiatives. Indeed, SUEZ created the PLAST'lab in Europe, a laboratory specialised in four resins (PET, LDPE, HPDE, PP) to develop its own and test third party recycling additives/pathways.

Consequently, leveraging wider market access to brand owners and waste flows than smaller technology developers, Suez has been accelerating massively over recent years in the plastic recycling industry, developing partnerships and JVs to deploy infrastructure ahead of demand for recycled polymers. As such, Suez has successfully closed deals with LyondellBasell (QCP), SKGC (Loop) and Pyrum, increasing its plastic processing capacity from the 600Kt expected in 2020 to millions by 2025.

Managing PET end-of-life

Recycling PET is a challenge that can be addressed with existing processes but could accelerate further through innovation. Indeed, recycling PET, compared to other plastics, leads to a number of challenges due to its unique characteristics:

- **Identifying and separating** PET from other plastic types can be difficult. PET is commonly used in packaging for various products, and it may resemble other plastics visually. Proper sorting and separation techniques are crucial to ensure that only PET materials are recycled, as mixing different plastics can compromise the quality of the recycled PET.

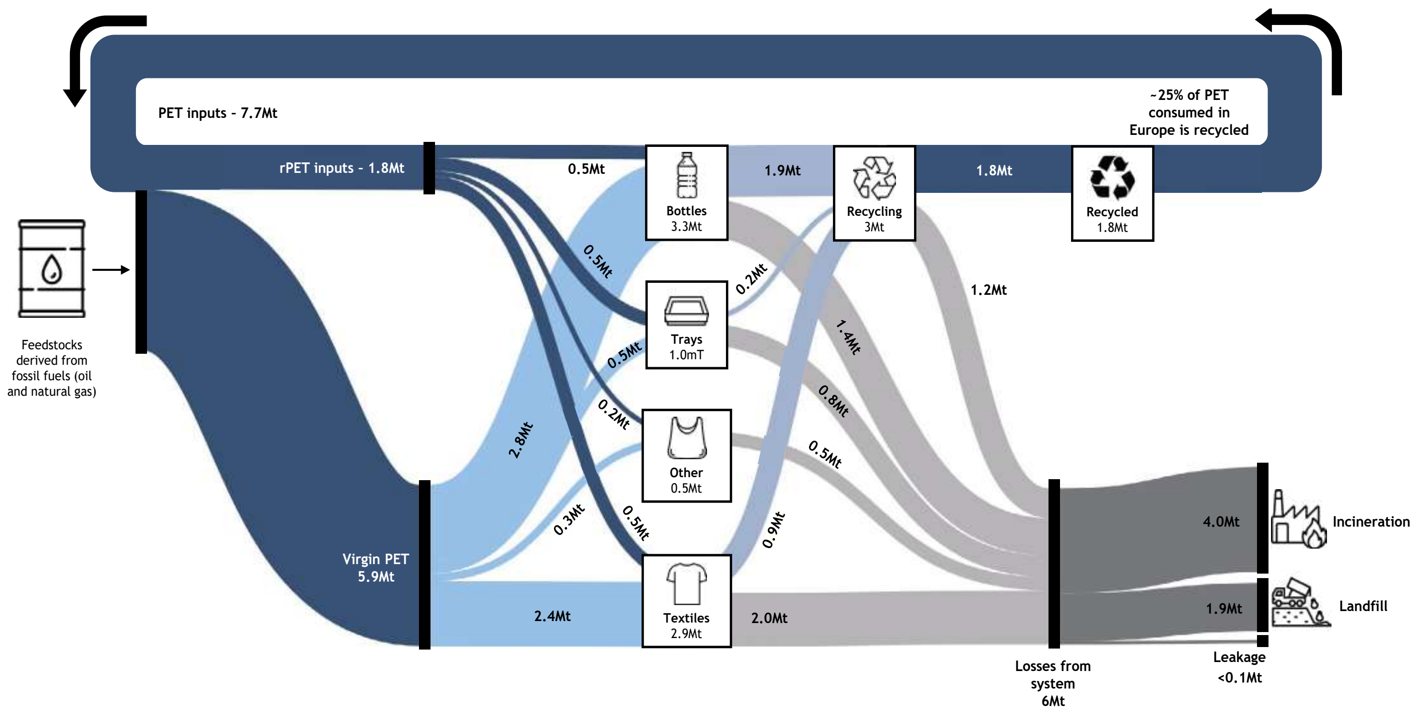
- PET recycling is sensitive to **contamination**. Even small amounts of impurities, such as food residue or non-PET materials, can affect the quality of the recycled PET. Contamination reduces the efficiency of the recycling process and may require additional purification steps to meet the desired standards.

- PET comes in **different colours**, which can complicate the recycling process. Certain colours, especially dark or highly pigmented ones, may require additional processing steps to remove or neutralise the colorants before the PET can be recycled into clear or light-coloured products.

- PET often gets **mixed with other plastics**, such as PVC (polyvinyl chloride) or PLA (polylactic acid). These plastics have different properties and recycling requirements, which can hinder the efficiency of PET recycling processes. Contamination from other plastics can lead to lower-quality recycled PET or even render the recycling process unviable.

- PET has a **lower melting point** compared to most plastics, which can make it challenging to process in recycling facilities. Temperature control and energy requirements during the recycling process need to be carefully managed to avoid degradation or quality issues in the recycled PET.

FIG 23: EUROPEAN PET FLOWS IN 2020



Source: SystemIQ, Eunomia, Zero Waste Europe, Stifel IRIS*

PET RECYCLING IS ONLY THE BEGINNING

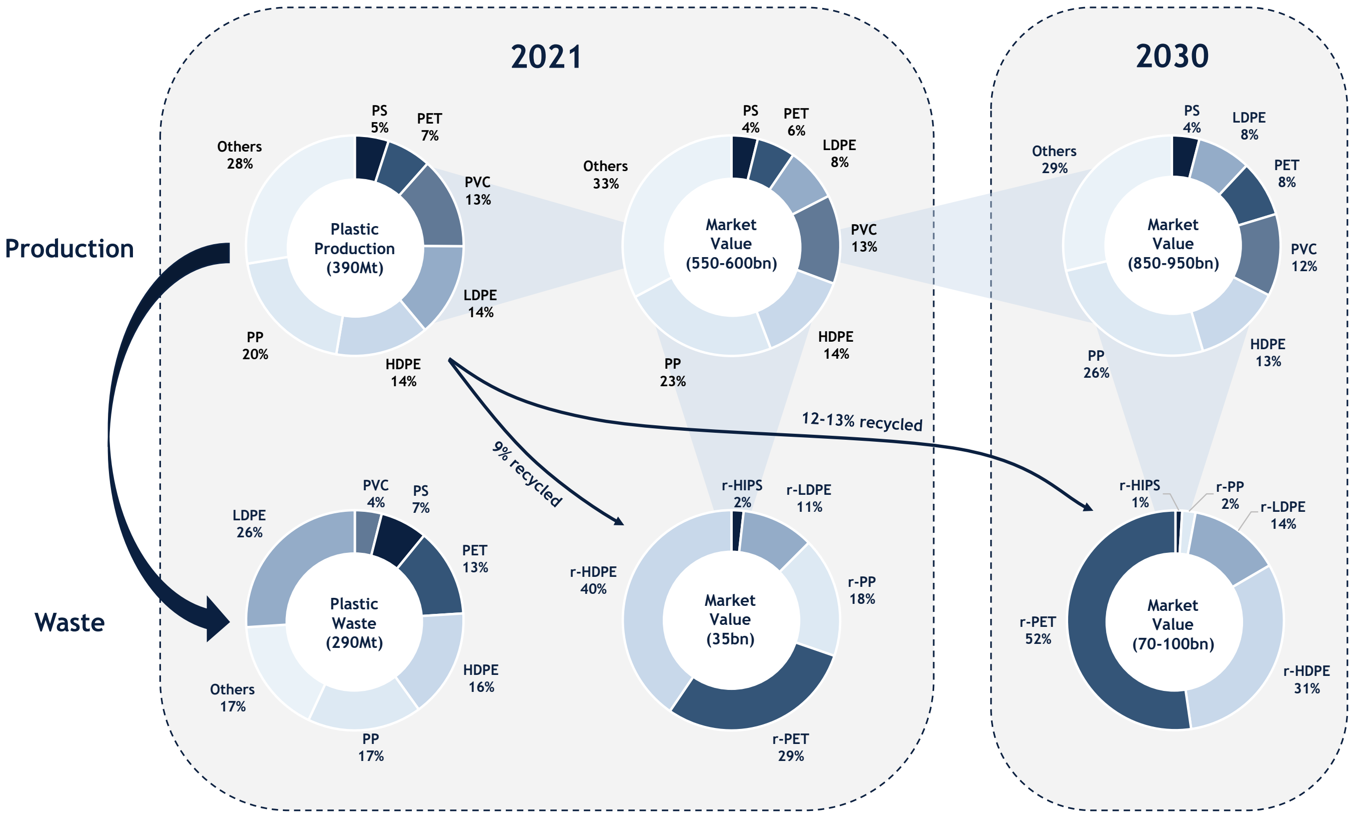
The plastic waste feedstock opportunity

Plastic waste can be collected from two primary sources: post-industrial and post-consumer. The composition of one ton of collected waste varies depending on the batch. On average, the main polymers found in this kind of waste are HDPE, LDPE, PP, and PET.

Plastic recycling is a dysfunctional market but is full of potential. Indeed, despite recent efforts, plastic recycling remains a marginal activity. Europe, which is no latecomer when it comes to plastic recycling, still lacks the capacity to recycle the full volume of plastic it produces. In 2019, the European Commission estimated that among the 35kg of plastic generated per capita, only 15kg or 43% was recycled. According to the OECD, in 2022 only 9% of plastic waste was recycled globally, the bulk of it through mechanical recycling, while 22% was mismanaged. This underlines how much of an empty space remains to close the plastic loop.

Those only 9% of recycled plastic waste had an estimated market value slightly above EUR35bn in 2021. By 2030, considering increasing recycling rate globally and growing competition to secure recycled polymers as a feedstock, the accessible pool to recyclers could more than double compared to 2021.

FIG 24: PLASTIC PRODUCTION, WASTE, AND RECYCLING MARKETS IN 2021 VS DYNAMICS BY 2030



Source: OECD, WFF, Closed Loop Partners, ACS Chem., Sustainable Plastics, Stifel IRIS*

REPEATS
RECYCLING PE AT SCALE

Repeats is a pan-European platform that invests and operates recycled PE facilities in key European markets. The company specialised in high-quality recycled low-density polyethylene (LDPE) and expanded its reach by acquiring a stake in Polimero, a recycled LDPE producer in northern Italy. Repeats uses a best-in-class mechanical process to transform post-commercial plastic waste into high-quality resin suitable for commercial and industrial applications. The company is scaling LDPE recycling capacity throughout Europe to address the shortage of supply compared to growing demand required to meet industry sustainability and net zero targets, increasing consumer preferences for low-carbon products and stricter regulatory requirements around decarbonisation.

As such, operations are and will remain focused on core European markets characterised by dense populations and under-served LDPE recycling capacity, aiming for a significant LDPE recycling capacity roll-out, focused on greenfield developments, acquisitions and strategic partnerships.

reborn

French company Reborn, formerly known as ExcelRise, focuses on transparent LDPE films used in food and beverages packaging, but also the logistics and construction industries. The group was created from the merger between CEISA Packaging and Semoflex, two French PE plastic packaging producers, now forming an integrated recycling group and a major player in Europe's circular economy. With less than a quarter of the 8-10Mt of LDPE produced in Europe recycled annually, usually ending up as rubbish bags, Reborn proposes co-design, collection and recycling services.

Adding to well-knowned mechanical recycling methods, Reborn has developed a chemical process, first implemented in its Semoflex factory, that removes ink from plastic waste and enables the creation of new entirely transparent thin films. Already leveraging nine LDPE production and recycling sites, most of which across Europe, in France particularly, Reborn is able to organise waste collection while ensuring 100% traceability for collected waste end-of-life, with around 10Kt reprocessed annually. Moreover, Reborn is actively engaged in packaging design together with its customers, therefore creating a virtuous circle by enhancing future waste recyclability and gaining confidence from industrial sites and distribution platforms related to Cristalline, InBev or Coca Cola for example. With growing traction, the group is now eyeing 50Kt of reprocessed waste by the end of 2027.

Shark Solutions is the market leader in the production of upcycled polyvinyl butyral (rPVB), a sustainable, non-toxic, recycled material, with a variety of attractive technical properties including binding, adhesion, flexibility and sound damping performance.

Traditional approaches to the recycling of end-of-life laminated glass (including windshields, architectural glass but also solar panels in the medium- to long-term) are unable to capture this valuable, performance improving, polymer interlayer. Therefore, Shark Solutions has developed a cost-effective process to separate glass from PVB films and then reuse it in a wide range of industries, adding paints, coatings, adhesives to flooring products, ie. recycling PVB for use in several Cradle-to-Cradle Certified® products. This unique ability to provide not only a patented upstream system that separated PVB from post-consumer glass, but also the midstream recycling process technology is what really makes industrial scale laminated glass recycling a reality.

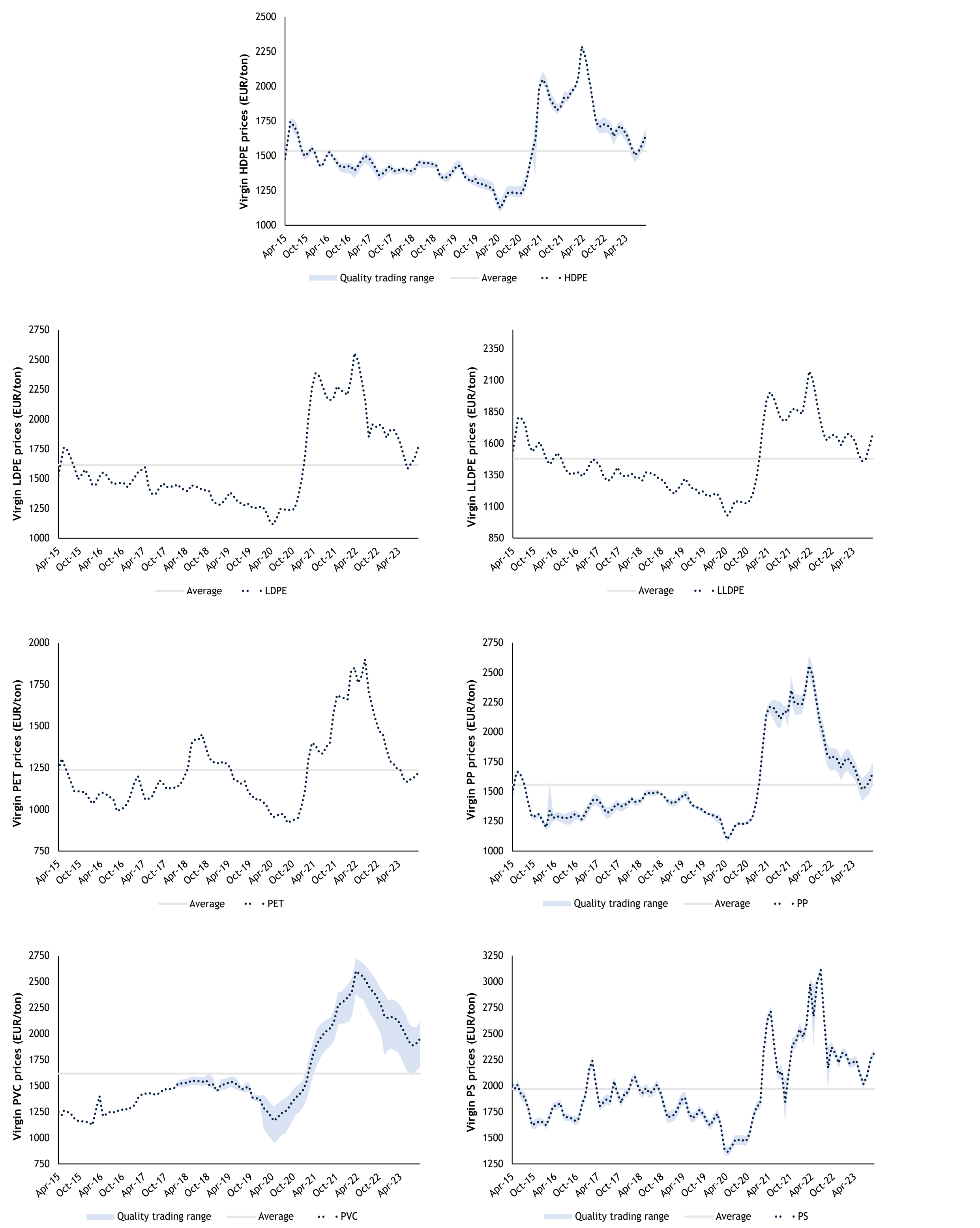
Having secured EUR20m growth capital in October 2022, Shark Solutions shall further expand its capacities from existing manufacturing facilities in Europe and the United States, currently processing tens of thousands of tons of PVB and laminated glass per year (more than one windshield every 3.8 seconds in 2023). In this roll-out, the group will definitively leverage significant feedstock partnerships like Carglass/Safelite, but also the support from other strong consumer brands like Tarkett, Interface and many paint manufacturers using rPVB in their applications.

Founded in 2010 and based in Germany, Saperatec is the developer of a recycling technology designed to recycle multi-layer materials into secondary raw materials. The company's technology uses physical and chemical principles to produce innovated secondary raw materials and generates a considerable added value in the conversion of waste into recyclable materials

Separatec helps in the separation of bonded and coated structures by crushing then immersing the structures into a proprietary separation liquid. The process involves warming up and stirring up the structures into individual fractions enabling a more efficient sorting process afterward. The process is at use for a wide range of materials from used beverage cartons to packaging material through PV modules, batteries or car glasses. The company has planned to build the first integrated recycling plant around the Saperatec technology as a core component of the recycling chain. The plant construction has started in 2021 and is expected to start its operations in 2023, processing 17-18Kt of waste per year and allowing to recover up to 16Kt of secondary raw materials including rLDPE granules and rPET agglomerates.

Saperatec also operated as a licensor of its separation process enabling customers to use a technology that provides dedicated recycling alternatives for products.

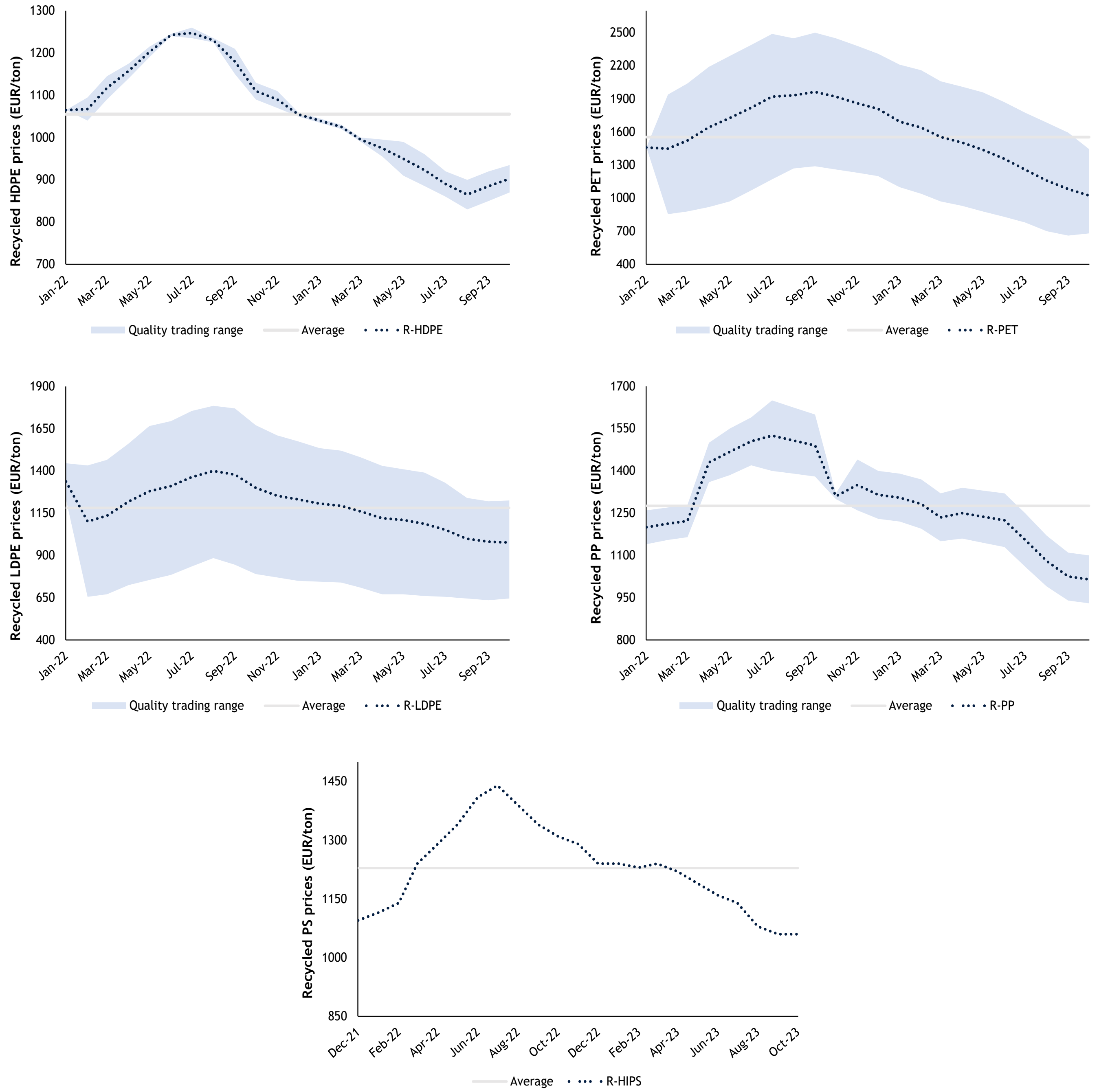
FIG 25: VOLATILE VIRGIN POLYMER PRICES OVER THE PAST EIGHT YEARS



Source: Sustainable Plastics, Stifel IRIS*

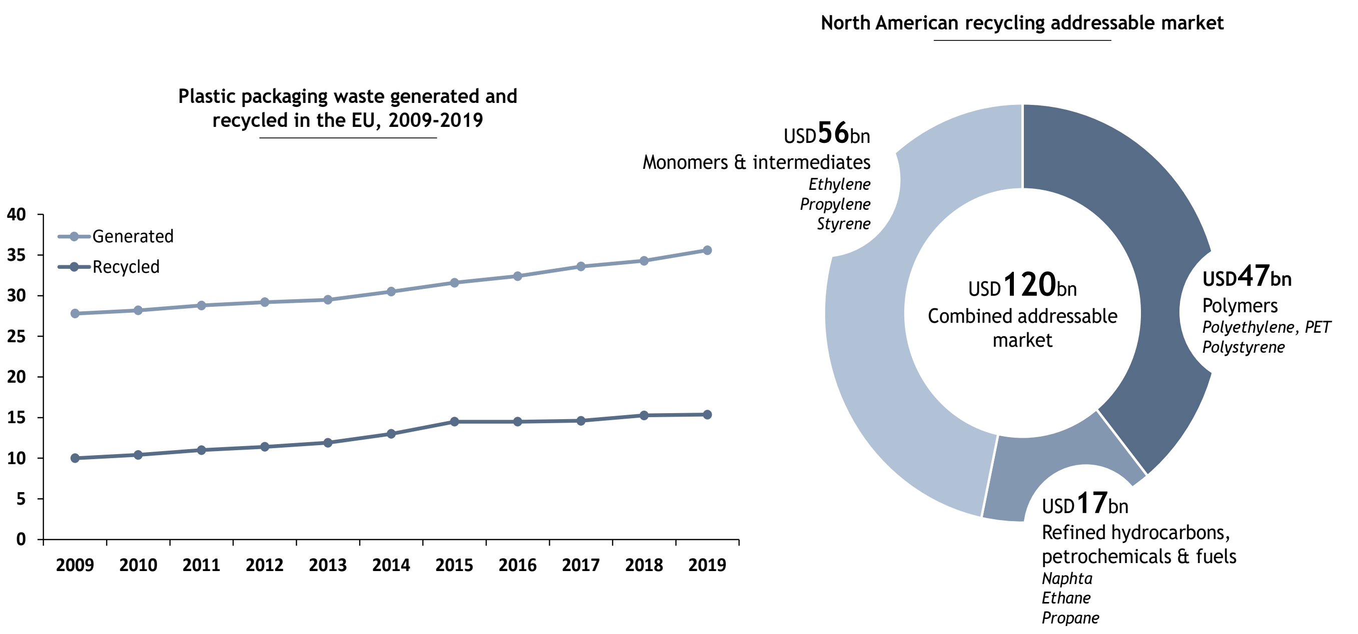
However, demand for recycled polymers is heavily correlated with virgin polymer prices, the higher the better as an incentive to increase polymers' lifetime, also allowing recyclers to derisk their recycling margin with recycled trading at a premium to virgin polymers. Indeed, over 2020-2022, virgin polymer prices increased significantly, boosted by a massive spike in demand for single-use plastics related to protective equipments and a shift in consumer buying habits (stockpiling, grocery vs restaurant, home improvements etc) while supply chain were globally disrupted. This allowed recyclers to live with better margins, supported by tightening regulation and growing interest from brand owners and converters. But in 2023, decreasing virgin prices coupled with higher energy bills and inflation rates have been pressurizing the recycled plastic market, zeroing recyclers' margin with virgin polymers trading so low that they were unattractive to recycle, even with plastic packaging taxes and packaging recovery support (GBP300/ton in the UK for example). This should change with a usual shift in seasonal demand moving into spring/summer, also supported by reinforced waste shipment regulation in Europe.

FIG 26: ... AND WIDE RECYCLED POLYMER PRICES, HEAVILY DEPENDENT ON QUALITY AND END-USES



Source: Sustainable Plastics, Stifel IRIS*

FIG 27: THE EUROPEAN AND NORTH AMERICAN PLASTIC RECYCLING MARKETS REMAIN LARGELY UNTAPPED



Source: Closed Loop Partners, Stifel IRIS*

As of today, the addressable North American recycling market currently represents approximately USD120bn, split into the three principal outputs of modern recycling methods: (i) polymers, (ii) refined hydrocarbons, petrochemicals, and fuels, and (iii) monomers & intermediates.

Mechanical recycling comes as an incomplete starter

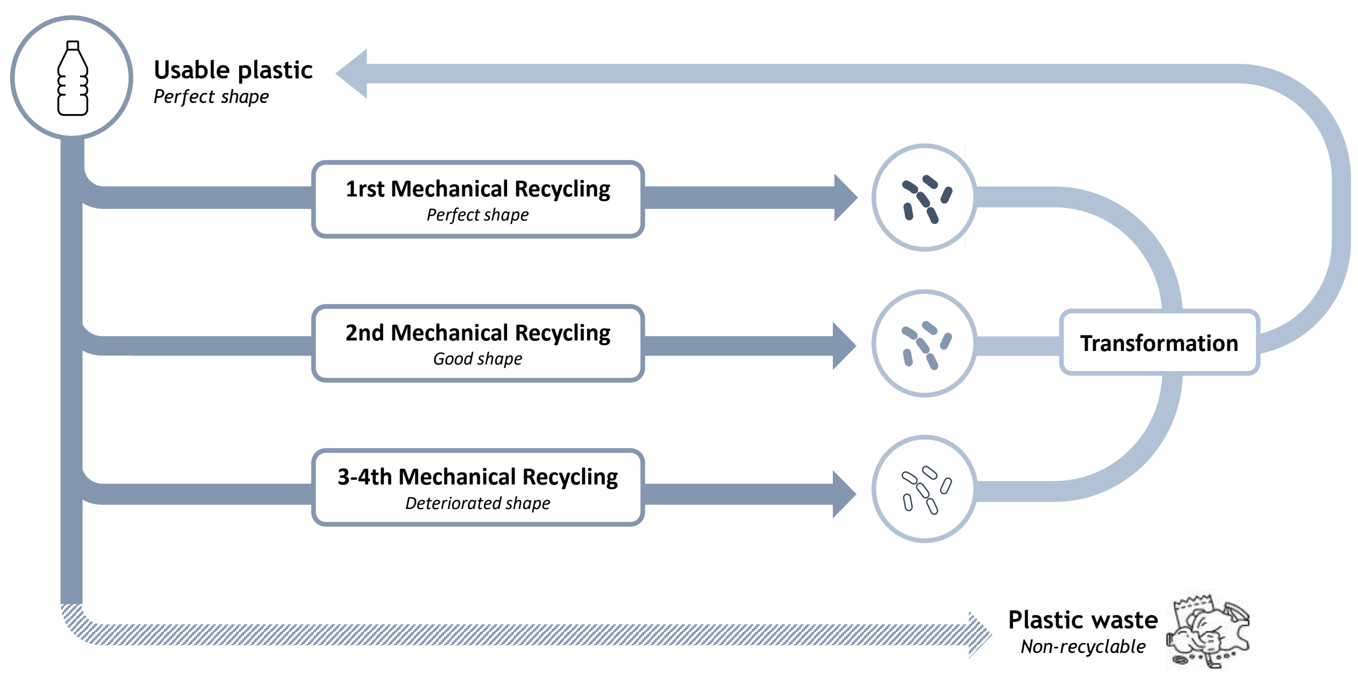
The mechanical recycling process

Mechanical recycling is the physical processing of plastic waste, whereby collected plastics are sorted, cleaned, shredded, and melted to create plastic pellets or flakes. These recycled materials can then be used to manufacture new plastic products.

Mechanical recycling involves using physical processes like grinding, washing, separating, drying, re-granulating, and compounding to recover plastics. This process produces recycles that can be converted into new plastic products, reducing the need for virgin plastics. It is also referred to as material recycling, material recovery, or back-to-plastics recycling.

The resulting plastic flakes can be used directly or processed into granulates before being transformed into new materials. This is the dominant method for recycling post-consumer plastic waste in Europe, focusing on thermoplastic materials like PP, PE, and PET that can be melted and reprocessed through techniques such as injection moulding or extrusion.

FIG 28: MECHANICAL RECYCLING CAN ONLY BE USED A LIMITED NUMBER OF TIMES



Source: Stifel IRIS*

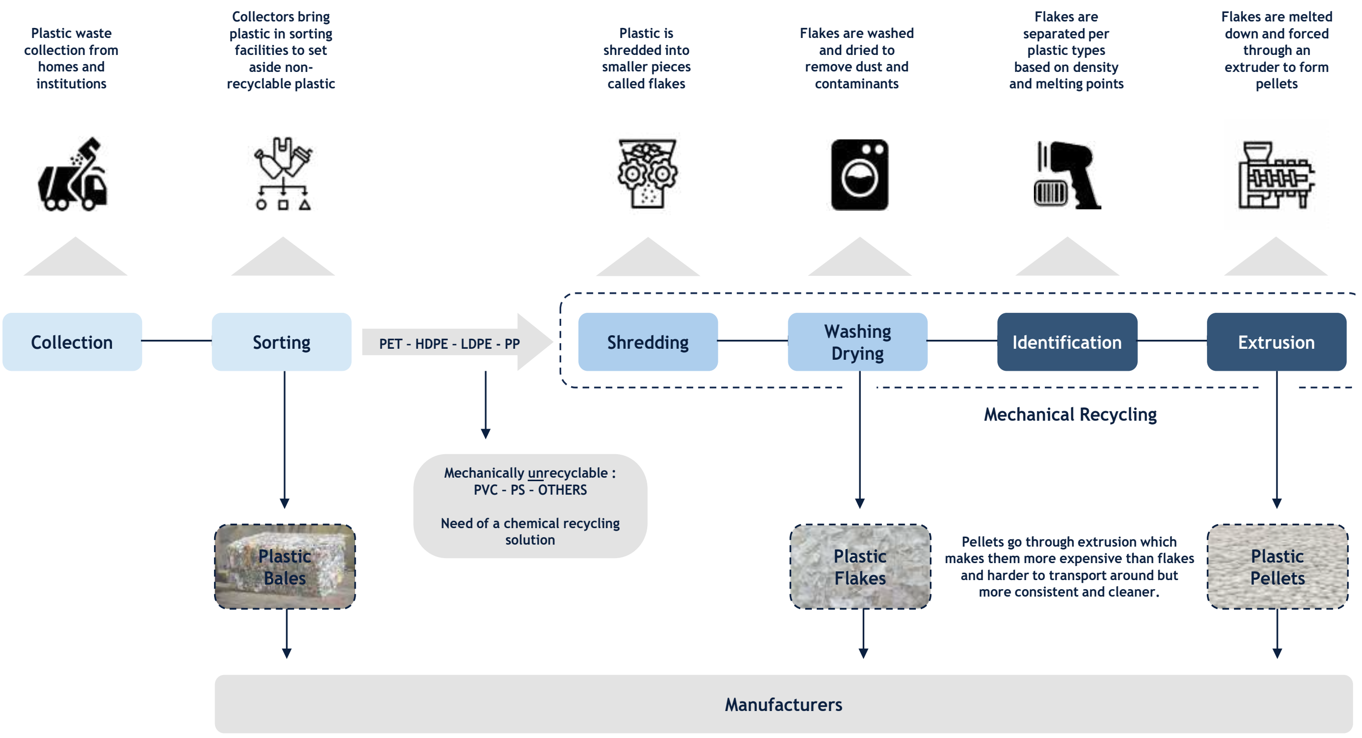
While mechanical recycling plays a vital role in tackling the plastic waste crisis, it is crucial to acknowledge and address the challenges it poses. The process subjects materials to multiple rounds of heating, cooling and mechanical stress, causing a gradual deterioration in their quality and durability. As a result, the recycled plastic may not be suitable for certain high-value applications, limiting its potential for extended use. Furthermore, the energy-intensive nature of mechanical recycling is a significant concern. The various steps involved demand substantial amounts of energy.

Nonetheless, until now the preferred recycling technique has been mechanical recycling, even if its efficiency varies depending on the characteristics of the plastic being treated. Mechanical recycling entails the physical processing of plastic waste, involving several steps such as sorting, cleaning, shredding, and melting to produce plastic pellets or flakes. These recycled materials can then be used to manufacture new plastic products.

The process of mechanical recycling includes grinding, washing, separating, drying, re-granulating, and compounding to recover plastics. This approach generates recyclable materials that can be converted into new plastic products, thereby reducing the dependency on virgin plastics. It is also known as material recycling, material recovery, or back-to-plastics recycling.

The resulting plastic flakes can be directly used or further processed into granules/pellets before being transformed into new materials. This method is widely used for recycling post-consumer plastic waste in Europe, with a focus on thermoplastic materials like PP, PE, and PET, which can be melted and reprocessed through techniques such as injection moulding or extrusion.

FIG 29: MECHANICAL RECYCLING FOR BEGINNERS



Source: Stifel IRIS*

Although a significant portion of plastic undergoes mechanical recycling, most of the plastic waste remains unrecyclable due to the limitations of the mechanical recycling process. The process exposes materials to multiple rounds of heating, cooling, and mechanical stress, causing a gradual deterioration in their quality and durability. As a result, recycled plastic may not be suitable for certain high-value applications, thereby limiting its potential for extended use. Furthermore, the energy-intensive nature of mechanical recycling is a significant concern. The various steps involved demand substantial amounts of energy.

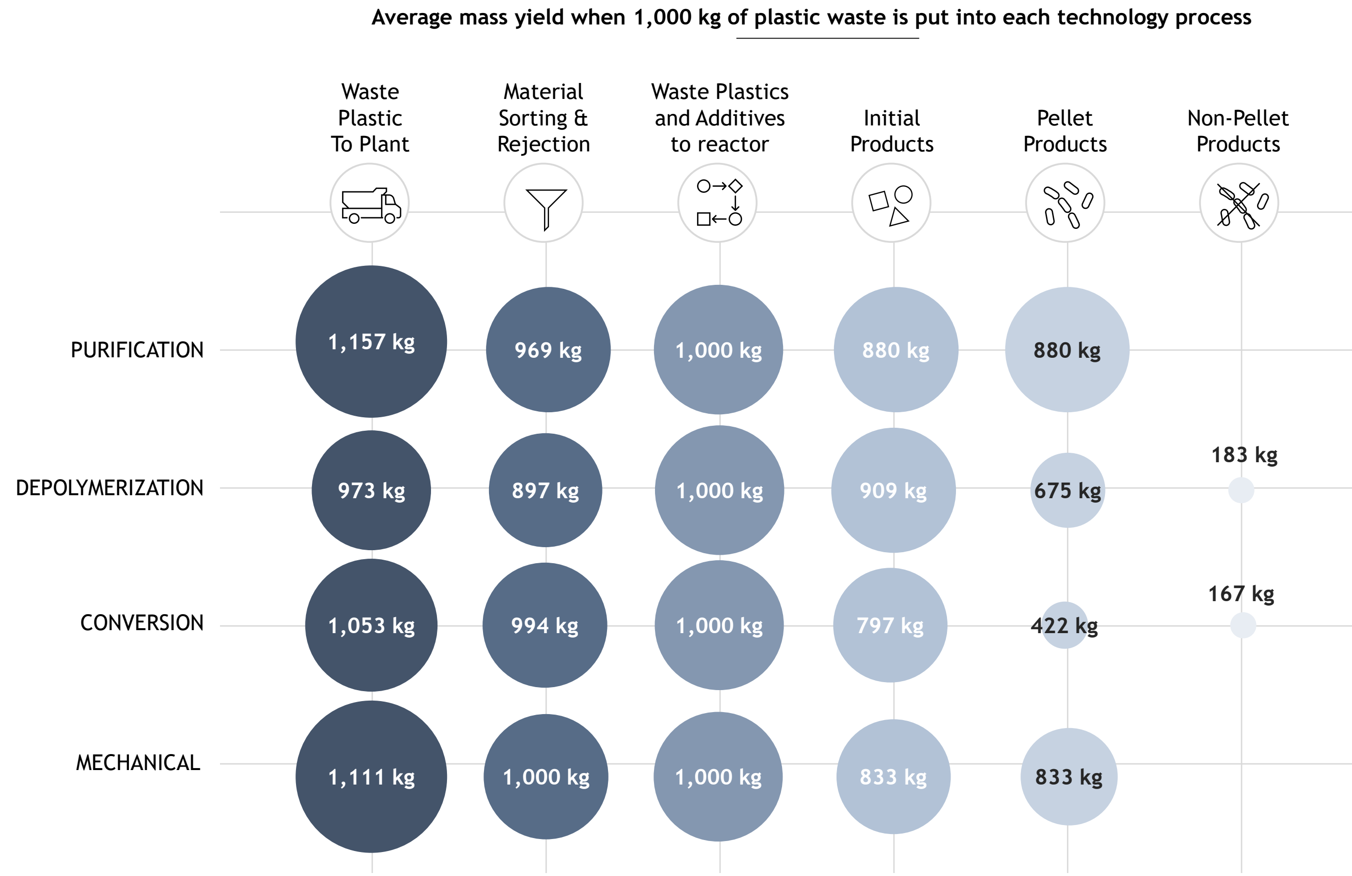
Various technologies are required to recycle the very diverse types of plastics

Due to the limitations of mechanical recycling in its inability to handle all types of plastic effectively, a diversified landscape of plastic recycling has emerged as a response to the unique properties and composition of various plastic types. Each type of plastic possesses distinct characteristics, such as different melting points, chemical compositions and structural properties. These variations pose obstacles to implementing a singular recycling process for all plastics, also adding that some plastics may not be suitable for the mechanical recycling process due to contamination, degradation or a lack of proper sorting facility. In order to avoid a situation where those plastics end up being disposed of in landfills or incinerated, chemical recycling techniques have gained significant traction over the past 25 years (see the following timeline).

FIG 30: CHEMICAL RECYCLING DEVELOPMENTS, GROWING INDUSTRIAL INTEREST ALONG A STEEP LEARNING CURVE

Source: Stifel IRIS, Sustainable Plastics*

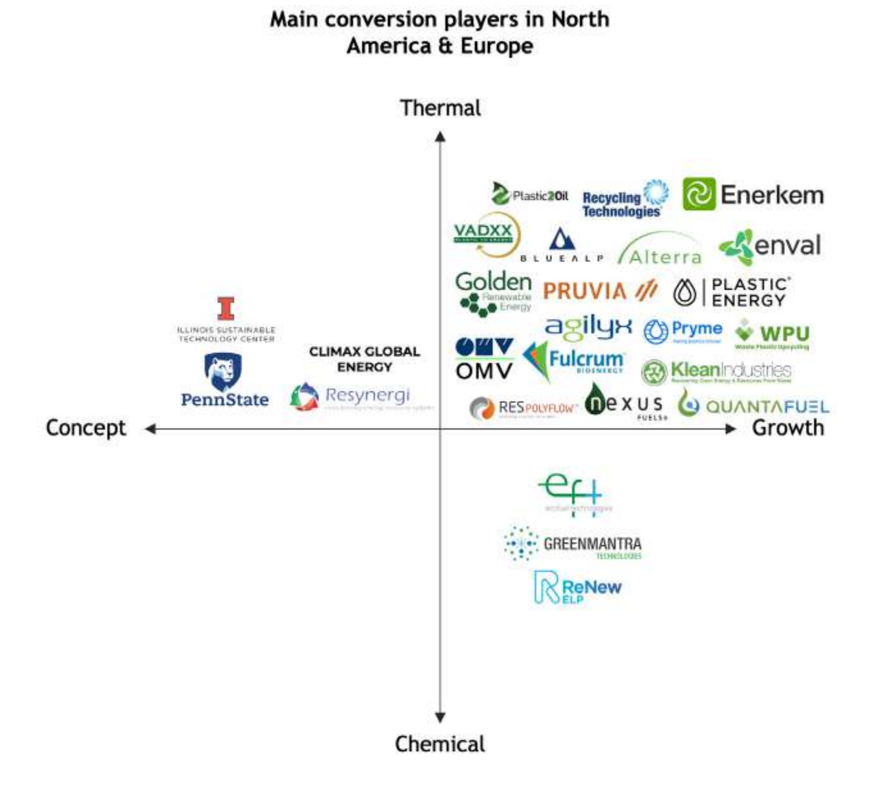
FIG 31: AVERAGE MASS YIELD WHEN 1,000 KG OF PLASTIC WASTE IS PUT INTO EACH TECHNOLOGY PROCESS



Source: Closed Loop Partners, Stifel IRIS*

While mechanical recycling remains a valuable tool in the effort to reduce/reuse/recycle plastic waste, it is essential to explore and invest in other recycling methods such as chemical recycling: conversion, decomposition and purification. However, each of these ends up with a specific output and feedstock position in the value chain, therefore calling for reasoned management/recycling frameworks in terms of energy and carbon uses.

FIG 32: MAIN CONVERSION PLAYERS IN NORTH AMERICA & EUROPE



Source: Stifel IRIS*

Conversion involves converting plastic waste into alternative forms of energy or other valuable products through thermal or chemical processes.

This technology aims to harness the energy content of plastic waste or transform it into useful materials like fuels, chemicals, or even construction materials.

Plastics recycling through conversion involves a specialised process that transforms post-consumer plastic waste into different forms, such as monomers or other chemicals, which can then be used to create new plastics or other plastic-based products. Through conversion, the chemical structure of plastics is modified, enabling the recovery of their building blocks for further utilisation. This innovative approach offers an alternative to traditional mechanical recycling, providing opportunities to maximise the value and resource efficiency of plastic waste.

Nevertheless, the most mature angle of plastic conversion goes through pyrolysis, for which there are ongoing discussions to establish unified European standards on end-of-waste criteria for plastics (expected by 2025), eyeing upcycling rather than downcycling.

WPU
Waste Plastic Upcycling

WPU (Waste Plastic Upcycling) is a cleantech company founded in 2019 backed by global commodity trading group Vitol. WPU is applying a robust batch pyrolysis process which upcycles waste plastic, transforming it into valuable products usable in the production of sustainable plastic oil for plastic production, with end-users like Braskem involved through Vitol as an offtaker. Currently benefiting from the ramp-up of its first plant in Fårevejle, Denmark, with a facility consisting of six separate but standardised reactors for cumulated capacity of (42Kt) 30Kt (in)output per year, WPU should already be in a great position to self-finance other upcoming projects from Q4 2023 onwards. Indeed, based on modular and scalable technology, WPU expects to deploy four additional plants, starting with Nakskov and Esbjerg, both converting 84Kt of plastic waste into valuable feedstocks by 2025 and 2026, before engaging in a JV licensing model beyond the first five plants.

Pryme
making plastics circular

Pryme is an innovative cleantech company founded in 2008 and focused on converting plastic waste into valuable products through chemical recycling on an industrial scale. Being a pure pyrolysis play, Pryme focuses on the production of crude pyrolysis oil from a broad spectrum of plastic waste, whilst removing contaminants like chlorine and metals, therefore requiring its petrochemical partners to further process the naphta output. Currently building its first plant in the Port of Rotterdam with an initial annual intake capacity of 40Kt, and first oil expected by the end of January 2024, Pryme's solution is suitable for >10Mt of waste per year in Europe. As such, with funding in place, this first commissioning should be followed by a wide technology roll-out benefiting from the collaboration with strategic partners like strategic partners like Shell and investors like LyondellBasell & Infinity Recycling, launching construction works for two additional plants early in 2025 and eyeing a broad portfolio of owned-operated plants in the long-run.

PLASTIC ENERGY

Founded in 2012, Plastic Energy has developed and commercialised a proprietary thermal anaerobic technology known as «TAC,» which enables the conversion of mixed plastic waste into high-quality recycled oils. These pyrolysis oils can then be used as feedstocks to produce new plastics or in the wider petrochemicals/fuelling industry, therefore contributing to a more circular economy. As such, under the European REACH regulation, Plastic Energy is the lead registrant of pyrolysis oils from plastic waste, with operating plants in Almeria and Seville, JV agreements with SABIC and TotalEnergies, and advanced licensing discussions with ExxonMobil, SKGC, Nova Chemical, INEOS and Petronas, cumulating hundreds of thousands of tons of potential plastic waste processing network capabilities.

Plastic Energy focuses on transforming end-of-life plastic, including multilayer and difficult-to-recycle materials, into valuable resources. The company's technology aims to complement traditional mechanical recycling methods by addressing the challenges associated with certain types of plastics, focusing on otherwise incinerated or landfilled plastics to close the plastic loop and align itself with growing demand for effective solutions to tackle environmental pollution. Conclusively, Plastic Energy's TACOIL is used in more than 10 consumer products ranging from Unilever's Magnum ice cream tubs, to Mondelez Philadelphia cream cheese packaging and Kraft Heinz snap pots.

PRUVIA

Pruvia, founded in 2016 and headquartered in Germany, has developed a groundbreaking pyrolysis technology with high-energy efficiency to recycle mixed plastic bales (polyolefins) into high-quality oil derivatives through a naptha conversion process. After a first capital increase of EUR3m in 2019, the company has begun its technology verification process, with the commissioning of its first pilot plant in Campania (Italy), able to undertake 100kg/h of plastic waste. This allowed Pruvia to start a licensing pathway throughout Europe, USA, Canada and India back in 2021. In 2022, the company has built a 4ton/h (~30-33Kt/year) industrial-scale demo plant near Leipzig (Germany), in collaboration with partners such as Fraunhofer and the support of a EUR25m fundraising.

This plant helped in scaling further future commercial plants with the engineering of a 8-10ton/h facility which is under construction in Denmark and has been co-developed through a JV with Combineering, an international recycling solution provider. Pruvia therefore parallely started its plant licensing operation in Q2 2023, and expects the commissioning of its first commercial-scale plant by Q3 2024.

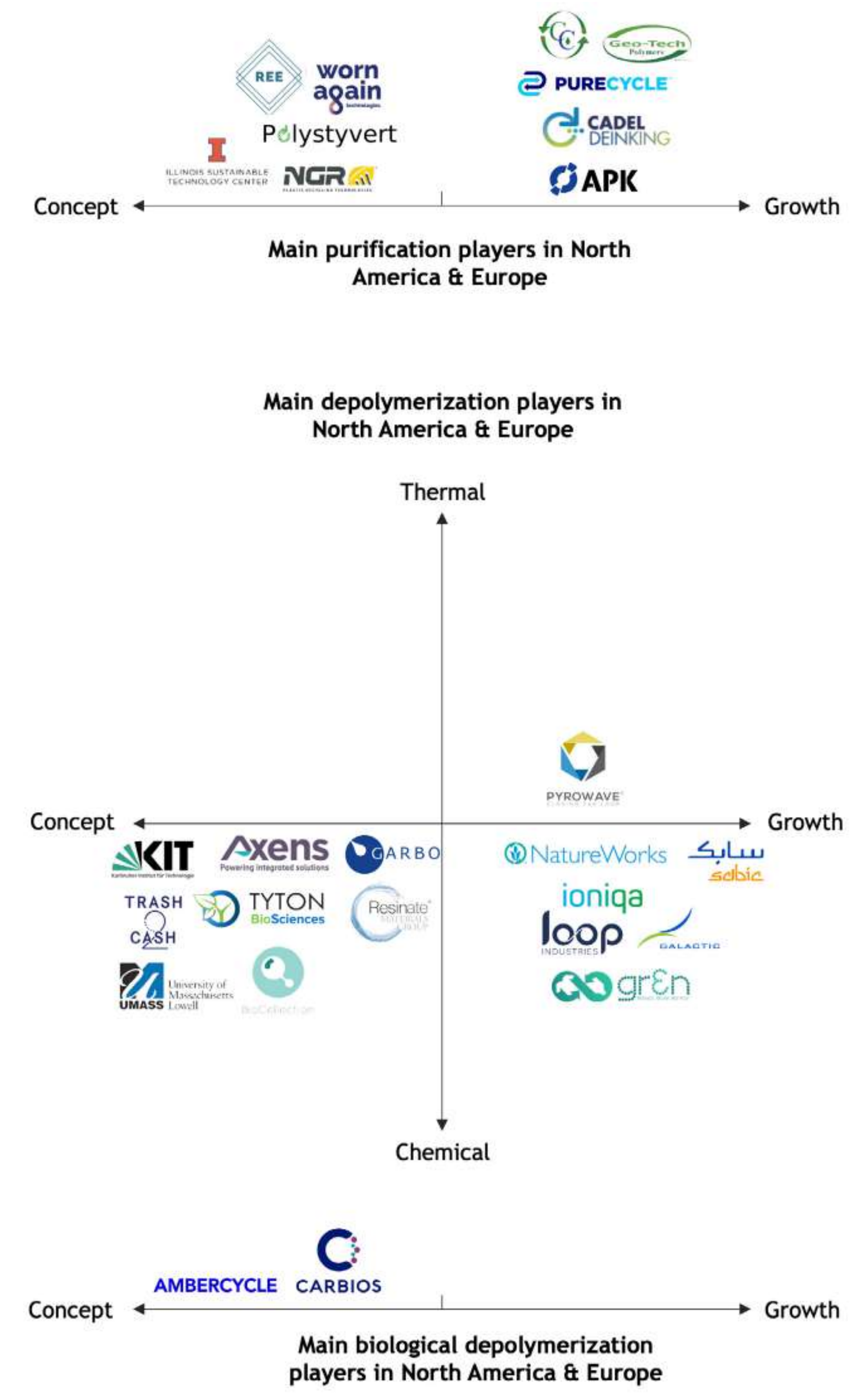
Purification focuses on removing contaminants and impurities from plastic waste to obtain high-quality recycled materials. This technology employs various purification processes such as filtration, washing, and separation techniques to eliminate foreign substances and enhance the purity of the recycled plastic.

Depolymerization focuses on breaking down plastic waste into its basic components through various chemical or biological processes. It aims to transform plastic waste into valuable feedstocks that can be used to produce new plastics or other useful products, reducing the reliance on virgin plastic production.

This process involves subjecting plastic waste to controlled decomposition under specific conditions, such as high temperatures or chemical reactions, to break down the polymer chains and produce valuable monomers or other chemical intermediates.

Through depolymerization (also called decomposition), plastic waste can be transformed into its original constituent components, which can then be used to produce new plastics or other materials.

FIG 33: PURIFICATION AND DEPOLYMERIZATION PLAYERS IN NORTH AMERICA & EUROPE

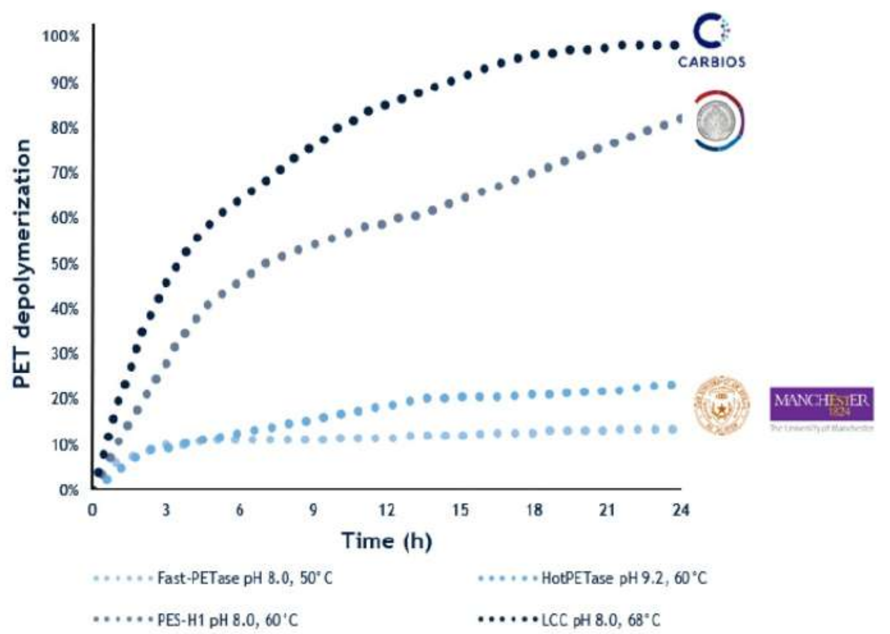


Source: Stifel IRIS*

Founded in 2011 and headquartered in Clermont-Ferrand, France, Carbios is a pioneering green chemistry company specialising in sustainable solutions for the plastics industry. With a primary focus on PET plastic recycling, Carbios has developed a ground-breaking enzymatic recycling process that uses enzymes to break down PET plastics and polyester fibers into their original building blocks, promoting a circular approach and reducing the environmental impact of PET plastic waste. Carbios has also developed an enzymatic biodegradation technology for PLA-based (a bio sourced polymer) single-use plastics.

This technology can create a new generation of plastics that are 100% compostable at ambient temperatures, even in domestic conditions, integrating enzymes at the heart of the plastic product. Among its major achievements, Carbios is currently building a 50Kt enzymatic recycling plant in Longlaville together with Indorama and has secured a mutually exclusive agreement for the supply of its proprietary enzymes by Novozymes to its future licensee. The group is therefore ready for a large-scale roll-out of its enzymatic recycling solutions in the near future.

FIG 34: PET CONVERSION IN % MEASURED BY THE NAOH CONSUMPTION, CONSIDERING AN EXCLUSIVE PRODUCTION OF PTA AND MEG



Source: ACS Catalysis 2023, 13, 13156-13166

Ioniqa is a clean-tech waste-to-value spin-off from the Dutch University of Eindhoven, specialised in chemical recycling solutions using smart ionised fluids. Focused on creating a circular economy for plastics, Ioniqa has developed a proprietary technology facilitating the upcycling of low quality/ unsorted PET waste into new virgin-like food-grade PET resin. The current scaling up of Ioniqa's novel depolymerisation technology is focused on PET plastics only but could be applied to other plastics and organic materials as well in the future.

Currently running a 10Kt industrial scale pilot in Geleen, Ioniqa is continuously improving its process to demonstrate how cost-effective it could become based on fluids selectively extracting colorants and impurities from plastic waste before its dissolution into monomers. Together with KTS, Ioniqa is working on scaling up and commercialising its advanced recycling technology in the plastics industry, thereafter partnering across the wider value chain, with brand owners like Coca Cola and Unilever and converters like Indorama, eyeing a worldwide network of 50Kt licensees going forward.

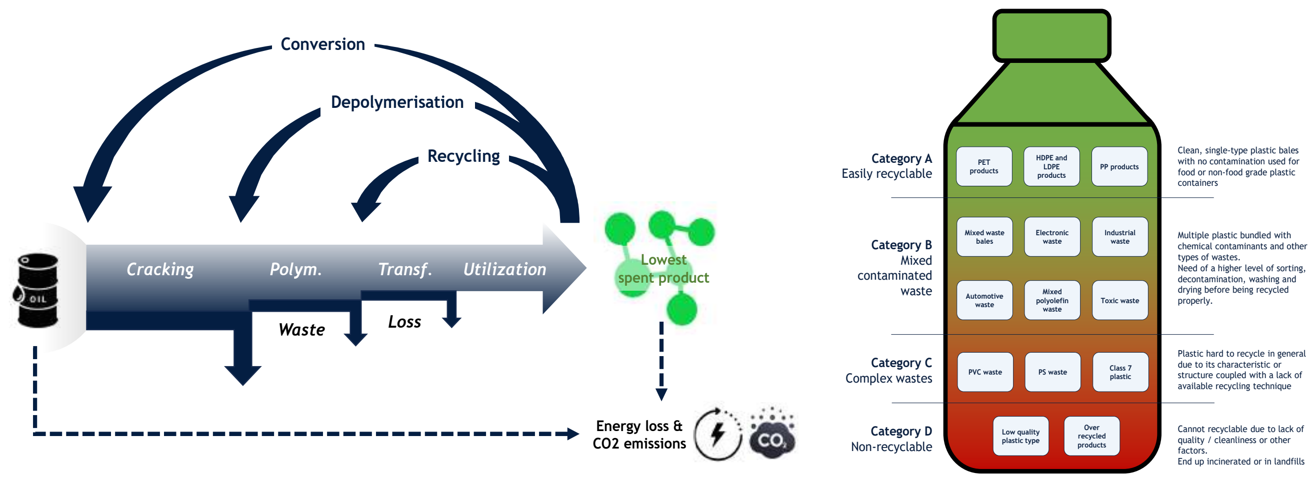
Founded in 2011 and headquartered in Switzerland, Gr3n Recycling is a pioneer in the chemical recycling of PET with the development of microwave-assisted alkaline hydrolysis. This technology allows the plastic to be depolymerised at a temperature below 200°C forming terephthalic acid (PTA) and monoethylene glycol (MEG) in less than 10 minutes. Hydrolysis recycling promises unlimited closed-loop recycling and is also economically viable and eco-friendly.

After building its pilot plant the company has completed its new demo plant in December 2023 with commissioning expected in Q1 2024. After this step and in partnership with Intecsa Industrial, by Q4 2024, Gr3n is expected to build a first-of-a-kind manufacturing plant in Spain for microwave-assisted depolymerisation of PET to produce 40Kt of virgin-like PET per year. This plant should be at full capacity by Q4 2027.

The company is closely following the 2030 Agenda for Sustainable Development adopted by all United Nations members in 2015 by contributing to the reach of responsible consumption and production, climate change and life below water objectives.

Consequently, unlike chemical recycling which aims to achieve upcycling circularity by creating high-quality and value materials from plastic waste, mechanical recycling often leads to downcycling. This downcycling means that the recycled plastic generally is of lower quality compared to the original material, limiting its recyclability and potential for multiple reuse cycles (about 3 – 7 times).

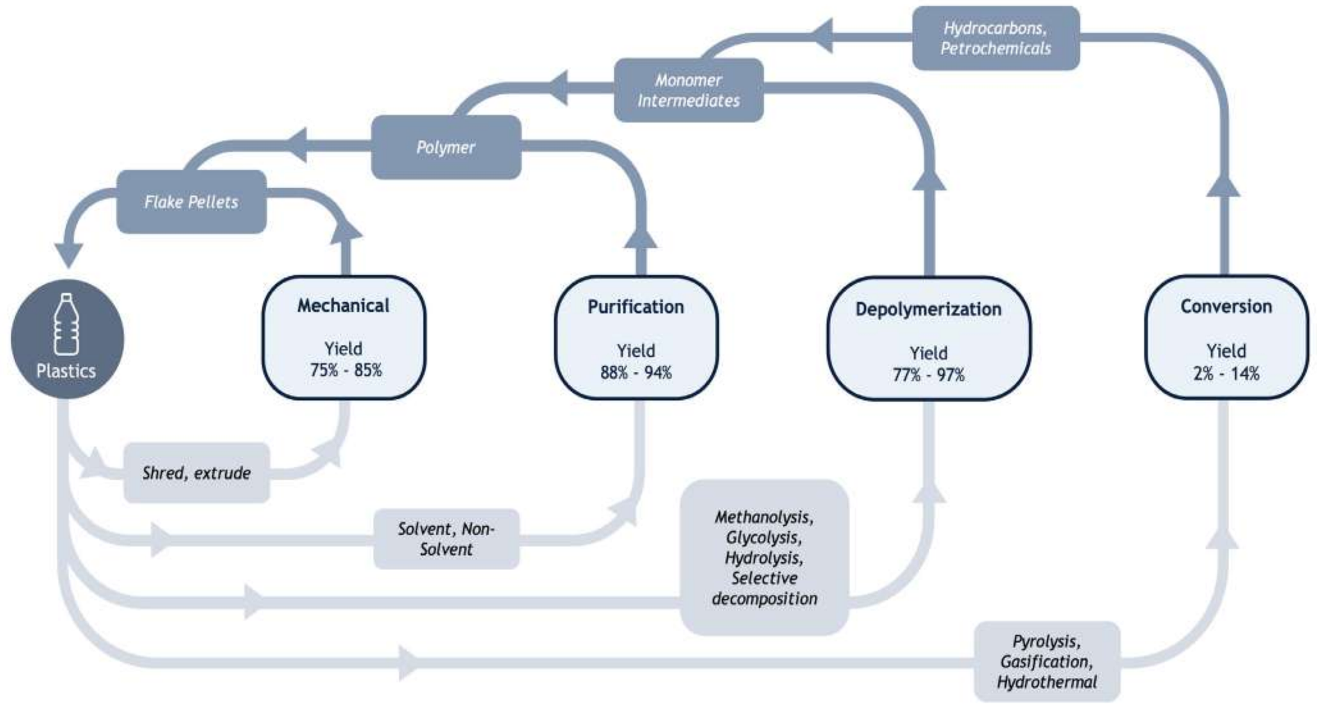
FIG 35: DIFFERENT OPTIONS FOR PLASTIC WASTE RECYCLING, FROM RETRANSFORMATION (MECHANICAL RECYCLING), REPOLYMERISATION (CHEMICAL RECYCLING TO MONOMER), TO RECRACKING (CHEMICAL RECYCLING TO FEEDSTOCK)



Source: ACS Sustainable Chemistry & Engineering, Royal Society of Chemistry, Stifel IRIS*

Nevertheless significant debate around closed-loop yield for conversion compared to other alternatives as pyrolysis oil might need to be highly diluted with virgin petroleum naphtha and only yields less than 15% plastic-to-plastic. However, choosing between one or another recycling alternative depends very much on each project's end-uses. Doing so, conversion could yield significant advantages as a carbon source for RFNBO and RCF compliant projects, thus taking part in fuelling hard-to-abate mobility sectors such as aviation or marine industries. However, as the feedstock quality increases, the focus should be on achieving high closed-loop recycling yields. However, as waste quality deteriorates and becomes unsortable or uneconomical to sort, a broader scheme for reuse becomes necessary.

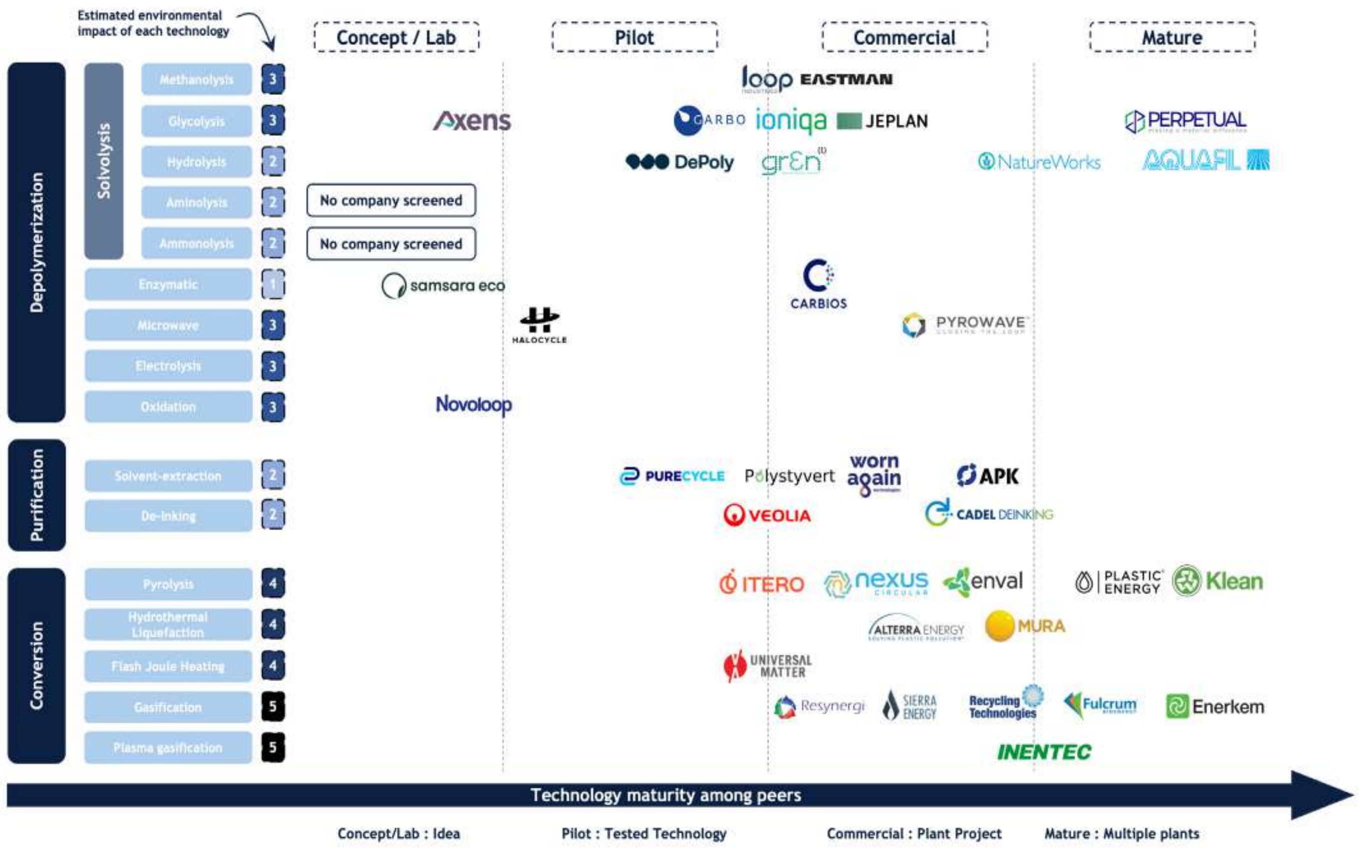
FIG 36: DIFFERENT TECHNIQUES, BUT A COMMON PLASTIC-TO-PLASTIC YIELD CONSTRAINT



Source: Sustainable Plastics, Closed Loop Partners, Stifel IRIS*

Each recycling technique comes with its own development cycle and timing to industrialisation. While mechanical recycling and pioneering leaders from the plastic conversion industry generally leverage mature infrastructure, a wide number of players have been or are entering the commercial phase. However, each of those potential pathways to increase virgin material recoverability (design, use etc) and recovery (recycling techniques) are subject to regulatory push and incentive frameworks, being one of the various cards at play as in the proposed amendments to the Packaging and Packaging Waste Regulation (EU PPWR). Indeed, the EU PPWR points towards overall packaging reduction targets of 5% by 2030, 10% by 2035 and 15% by 2040, being even tighter for plastic packaging with 10% by 2030, 15% by 2035, and 20% by 2040.

FIG 37: DISTRIBUTION OF COMPANIES BASED ON CHEMICAL RECYCLING TECHNIQUES

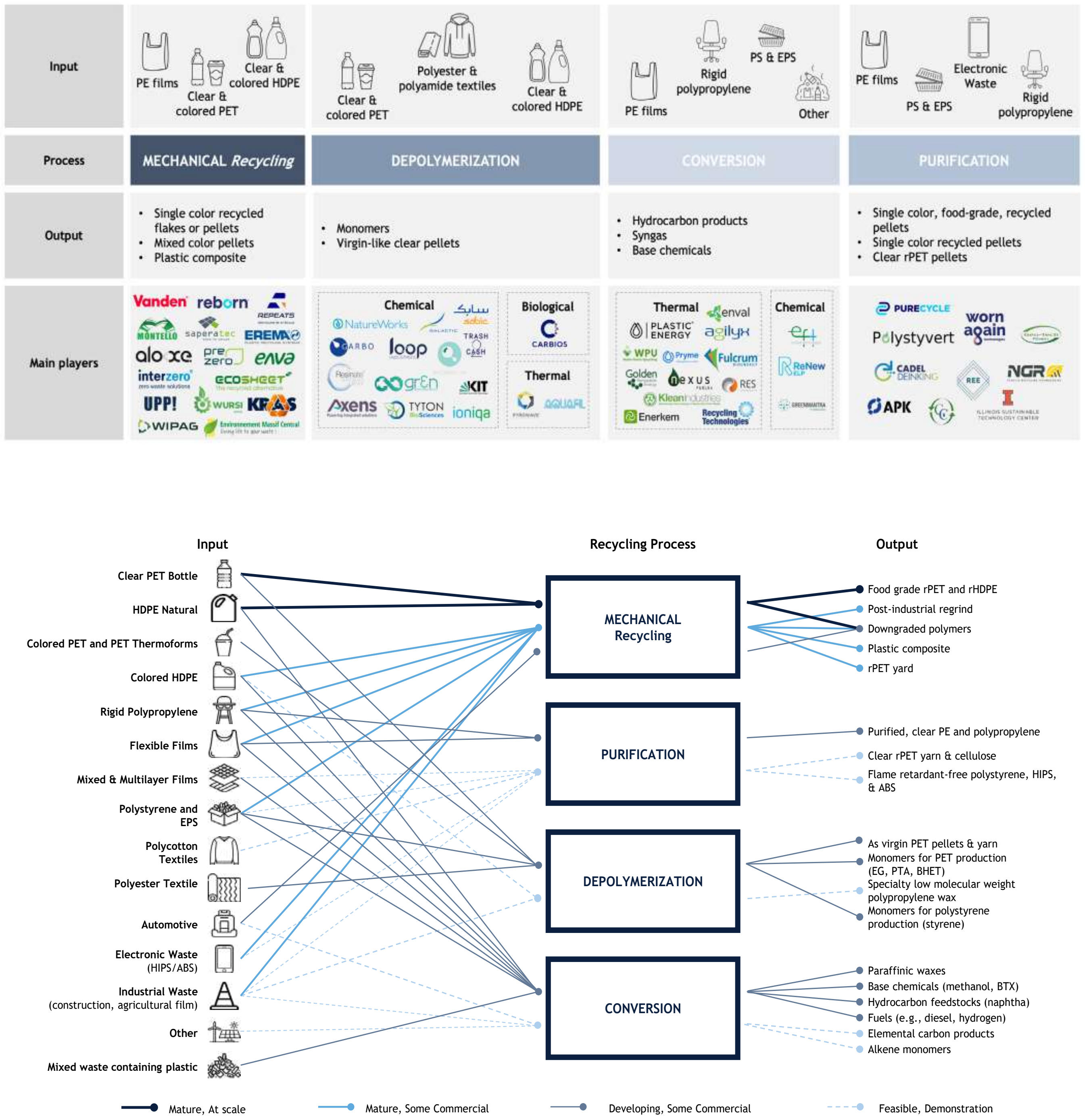


(1)Gr3n does hydrolysis as depolymerization reaction. The use of microwave is to speed-up the reaction and the electrolysis is used to produce the chemicals from the by-products. In the end microwave and electrolysis are ancillary systems to the hydrolytic main process.

Source: Stifel IRIS*

Nevertheless, considering (i) current volumes of plastic waste not only to be correctly managed but also properly recycled and (ii) worldwide plastics consumption trend, there should be enough room for different quality of recycled plastic to be used going forward, paving the way for stringent waste classification, traceability, and acceptability as a feedstock. Those revamped EU packaging rules on "reduce, reuse, and recycle" only favor more reasonable packaging consumption and highlight growing circularity needs, in the end fuelling potential growth prospects for chemical recycling players.

FIG 38: FOUR DISTINCT TECHNOLOGIES TO ADDRESS MOST OF THE PLASTIC POLYMER RECYCLING SPECTRUM



Source: Stifel IRIS, Closed Loop Partners*

The below table summarises the key benefits and drawbacks of the main chemical recycling techniques from a timing to market perspective, alongside their energy requirements and capital intensity.

FIG 39: DESCRIPTION OF THE MAIN CHEMICAL RECYCLING TECHNIQUES FOR PLASTIC WASTE

	Gasification	Pyrolysis	Hydrothermal Liquefaction	Methanolysis	Glycolysis
Description	• Decomposition at very high temperature in the presence of a gasification agent to produce diesel, paraffin and naphtha • Conversion into monomers and then into polymers	• Decomposition at high temperature in the absence of oxygen to produce pyrolysis oil • Conversion of the oil into monomers and then into polymers	• Decomposition held at high temperature and high pressure. • Water is involved in the process to break down the plastic into crude-oil like substance	• Treatment of PET with methanol to produce two monomers: DMT and MEG • The two monomers are used to produce virgin quality r-PET of virgin quality	• Treatment of PET with glycol to produce an oligomer: BHET • BHET combined with PTA and MEG to produce virgin quality PET
Benefits	✓ Technology adapted to flows of organic materials(wood by-products, organic waste) and rubber and plastic (e.g. tires)	✓ Possibility of producing "virgin plastic" from pyrolysis oil ✓ Technology suitable for polyolefins ✓ Tolerance to waste (excl. PVC)	✓ Process of various plastic types (incl. mixed and contaminated) ✓ Achieve high conversion rate into valuable products	✓ Product of monomers registered for food contact applications ✓ Accepts blends of PET and other polymers	✓ Single component to isolate: BHET
Drawbacks	× Very energy-intensive × A small fraction of the gases can be converted into materials such as polymers × Significant emissions	× Energy-intensive × Not suitable for oxygenated compounds such as PET × Processing of pyrolysis must be mixed with virgin oil (mass balance)	× Energy-intensive to heat the feedstock and maintain the high pressure required × Process generates GHG and requires careful residue management	× Does not accept certain organic compounds × Few of world's PET production capacity uses DMT + MEG × Industrial constraints on the use of DMT	× Only works with PET waste with a high purity (clear or slightly lightly coloured) × BHET is not an input for PET production × BHET isn't registered in Europe to make food-grade plastics
Level of development	**Industrial**	**Industrial**	**Pre-Industrial**	**Pre-Industrial**	**Industrial**

	Hydrolysis	Electrolysis	Microwave	Solvent-Extraction	Enzymatic Hydrolysis
Description	• Chemical reaction with water insertion into the functional units of the monomers either replacing an ester (PET) or an amide bond (PA) • Temperature is usually around 200°C and pressure around 1.7mPA	• Decomposition of plastic using an electric current in an electrolyte solution leading to a chemical reaction	• Decomposition at lower temperature than traditional methods and performed at atmospheric pressure • Microwave can also be used as a catalyst for other reaction	• Dissolution of the polymer at low temperature in a suitable solvent. • Aim is to remove impurities on the plastic to lead to further recycling process if needed	• PET depolymerization in an aqueous solution catalyzed by an enzyme to produce PTA and MEG • The two monomers are used to produce virgin quality r-PET
Benefits	✓ Temperature is not as high as other technology which prevent any alteration of chemical compounds. ✓ For PET recycling, produces PTA instead of DMT.	✓ Applicable to a wide range of plastic types including contaminated plastics. ✓ Main use of the technique to remove chlorine component of PVC of plastics to recycle it properly	✓ Low carbon chemical process compared to thermal methods ✓ About 15 times less energy-intensive than other thermal methods	✓ Capital cost is low ✓ Results in low volatile organic compound ✓ Suitable for most plastic types	✓ Accepts all plastic and PET ✓ Operates at low temperature and at atmospheric pressure ✓ Produces monomers for food contacts application ✓ Most of world PET production uses PTA + MEG
Drawbacks	× May require a long-time to process the plastic and require a catalyst that is, rarely recoverable (not the case for alkaline hydrolysis, ie. short and no catalyst) × Process requires a careful humidity control	× Scalability issue may arise × Tight control is required on the electrolyte solution and the electrodes.	× Scalability issue may arise × Microwaves may accelerate the release of harmful chemicals (e.g., BPA and phthalates) × Not effective on all plastics types	× Processing time can be considerably high × Process may reduce the plastic lifetime by reducing the stabilizer × Efficiency varies depending on the plastic type	× Pre-treatment of PET plastics and polyester fibers requires to accelerate catalysis × Purification of PTA is complex
Level of development	**Industrial**	**Pre-Industrial**	**Pre-Industrial**	**Industrial**	**Pre-Industrial**

+ Energy Requirement → **Energy Requirement -**

- Capital Intensity → **Capital Intensity +**

Source: Stifel IRIS, Closed Loop Partners, Carbios*

Usually related to the overall technology maturity, capital intensity should gradually decrease for chemical recycling as opposed to established mechanical recycling techniques. However, another key area of focus to differentiate those innovative recycling pathways is related to the use of solvents and additives. Whereas some can be solvent-free, others rely on water or methanol; same goes with stabilizers etc. Unnecessarily harmful for the environment or for humans, those chemicals (i) impact recyclers' expected margin and margin volatility and (ii) require to be correctly processed, potentially impacting recycled polymer LCAs (ie. the overall carbon emission reduction and environmental impact compared to virgin polymer production).

Loop Industries

Founded in 2015 and headquartered in Montreal, Quebec, Loop Industries has developed an innovative and patented technology called «Infinite Loop,» which enables the recycling of plastic waste into high-quality PET plastic resin. Loop Industries aims to address the global plastic pollution crisis by creating a closed-loop system for the production and recycling of PET plastic. Indeed, Loop's innovative depolymerisation technology upcycles highest purity plastic from waste feedstocks, such as polyester fibres from carpets and clothing, coloured plastic and opaque plastic. Its patented low-energy process breaks down this would-be waste into its base monomers, which are then purified using low heat and no pressure, thus removing all solid waste and contaminants such as colouring, additives and organic or inorganic impurities. The purified DMT and MEG are then polymerised into Loop™ branded virgin-quality PET resin with one of the leanest recycling footprints for the environment.

Led by Founder and CEO Daniel Solomita, Loop Industries collaborates with industry partners to integrate its technology into existing manufacturing processes, therefore continuously improving its recycling technology to reduce DMT-related integration challenges and contributing to a more sustainable/eco-friendly approach to plastic production. With an industrial pilot already running in Terreborne, Canada, Loop eyes a viral licensing ramp-up backed by 70Kt facilities' design, a commercialisation agreement with SKGC in Asia and a first industrial-scale plant for Suez/SKGC under development in France.

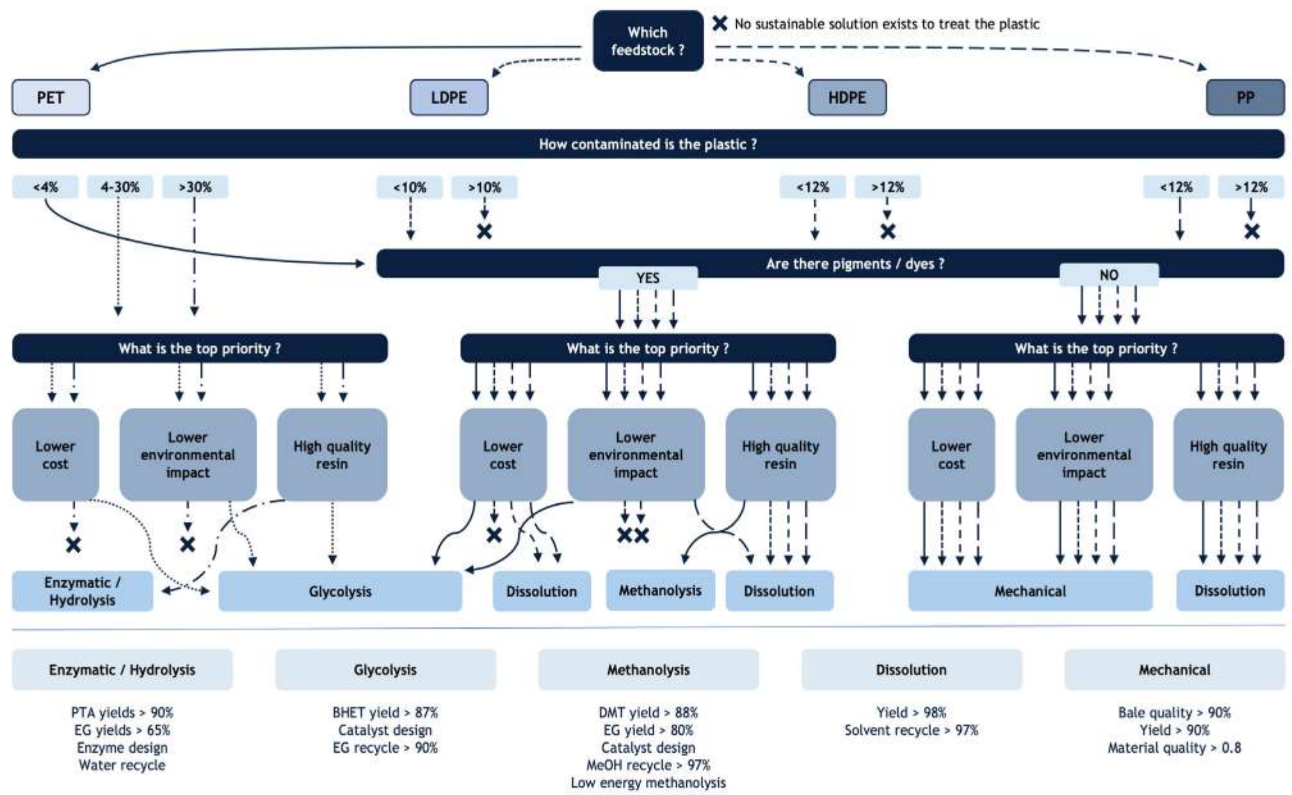
EASTMAN

Eastman is a global specialty chemical company with notable presence in the plastic recycling industry as a technology provider. Known for its innovation towards greener chemicals, Eastman is committed to the circular economy and reducing the environmental impact of plastics, developing technologies for molecular recycling (depolymerization) and transforming waste plastics into high-quality, circular resins. Indeed, addressing mechanical recycling shortcomings, Eastman is a pioneer in advanced recycling, often referred to as chemical recycling, but one of the first to have coined methanolysis among others in molecular recycling as opposed to conversion techniques. The principle is that "not all advanced recycling methods are created equally" and many approaches have been lumped together with other chemical recycling methods, some of which some might be less sustainable from an LCA perspective. As such, Eastman's proven polyester renewal technology provides circularity for hard-to-recycle plastic waste that remains in a linear economy today.

Consequently, Eastman is pursuing significant investments worldwide, having committed up to USD1bn to build the world's largest molecular plastics recycling facility in France. The facility is destined to use Eastman's polyester renewal technology to recycle up to 160Kt a year of hard-to-recycle plastic waste that is currently being incinerated, therefore generating interest from LVMH, Danone, L'Oréal, Procter & Gamble, Clarins and Estée Lauder for multiyear supply of renewable polyester feedstocks.

Therefore, out of these different recycling pathways, some only focus on one specific kind of plastic waste while others would end up being more agnostic and require fewer sorting efforts. Nonetheless, the arbitrage to convert this into margin ultimately lies in a mix between ease of feedstock sourcing, sorting needs and required end-product quality, but also energy (and other intrants costs) or infrastructure investments and integration into existing B2B processes. Consequently, leaving conversion aside as it generally eyes the last lifecycle upgrade out of the monomer/polymer framework, from mechanical recycling to enzymatic hydrolysis, different kinds of polymer and quality can be taken over but require a wide variety of energy and sorting inputs.

FIG 40: PREFERRED TECHNIQUE PER FEEDSTOCK, DISREGARDING CHEMICALS CONSUMPTION AND RECOVERY



Source: Stifel IRIS, ACS Sustainable Chem*

Waste collection and waste sorting challenges remain common denominators

Sorting plastic clearly plays an essential role in enhancing the efficiency of the recycling process, ultimately dictating the ease with which recyclers can handle waste. When plastic becomes contaminated with other types of waste, a sorting process becomes essential. The choice of sorting technique varies based on the composition of waste, each technique having its distinct limitations and accuracy-related requirements. In recent times, there has been a growing trend in the development of image-based identification techniques aimed at mitigating the limitations of more traditional methods.

FIG 41: A WIDE RANGE OF SORTING TOOLS

Sorting Techniques

Techniques	Limitations (color / density)	Required size of plastic	Accuracy level	Used in the industry
Manual sorting	X	X	70%	X
Centrifugal sorting	Same density plastics	10-20mm	99.9%	
Sink float sorting	Water density to be controlled	10-20mm	87%	X
Flotation sorting	Same density plastics	10-20mm	87%	X
Triboelectric sorting	X	1-13mm	98%	
Image based sorting	X	X	99.9%	
Digital watermark	X	X	97%	
Standard near infrared	Dark plastics	X	97.5%	X
Hyperspectral imaging	Dark plastics	X	99%	
Tracer based sorting	X	X	99.9%	

Image - based identification: Image based sorting, Digital watermark, Standard near infrared, Hyperspectral imaging, Tracer based sorting

Level of sophistication ↓

Sink float sorting

Plastic type	Density
HDPE	0.91 - 0.97
LDPE	0.94 - 0.97
PP	0.90 - 0.94
PE	0.91 - 0.97
PET	1.35 - 1.40
PS	1.05 - 1.08
PVC	1.34 - 1.43

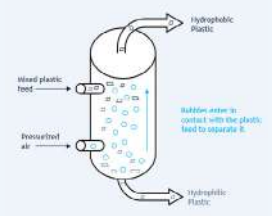
Sorting based on plastic density which separate once immersed in water with specific density
Low density will float while higher density will sink

Plastics with same density are hard to separate

Flotation sorting

Technique taking advantage of the wettability characteristics of the plastic

Gaseous bubbles force hydrophobic flakes to the top of the cylinder

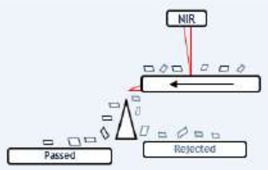


Standard Near Infra-Red

NIR is the most effective automated sorting technique to sort plastic

Use of wavelength signature of specific resins to distinguish them from one another and separate them with an air blower

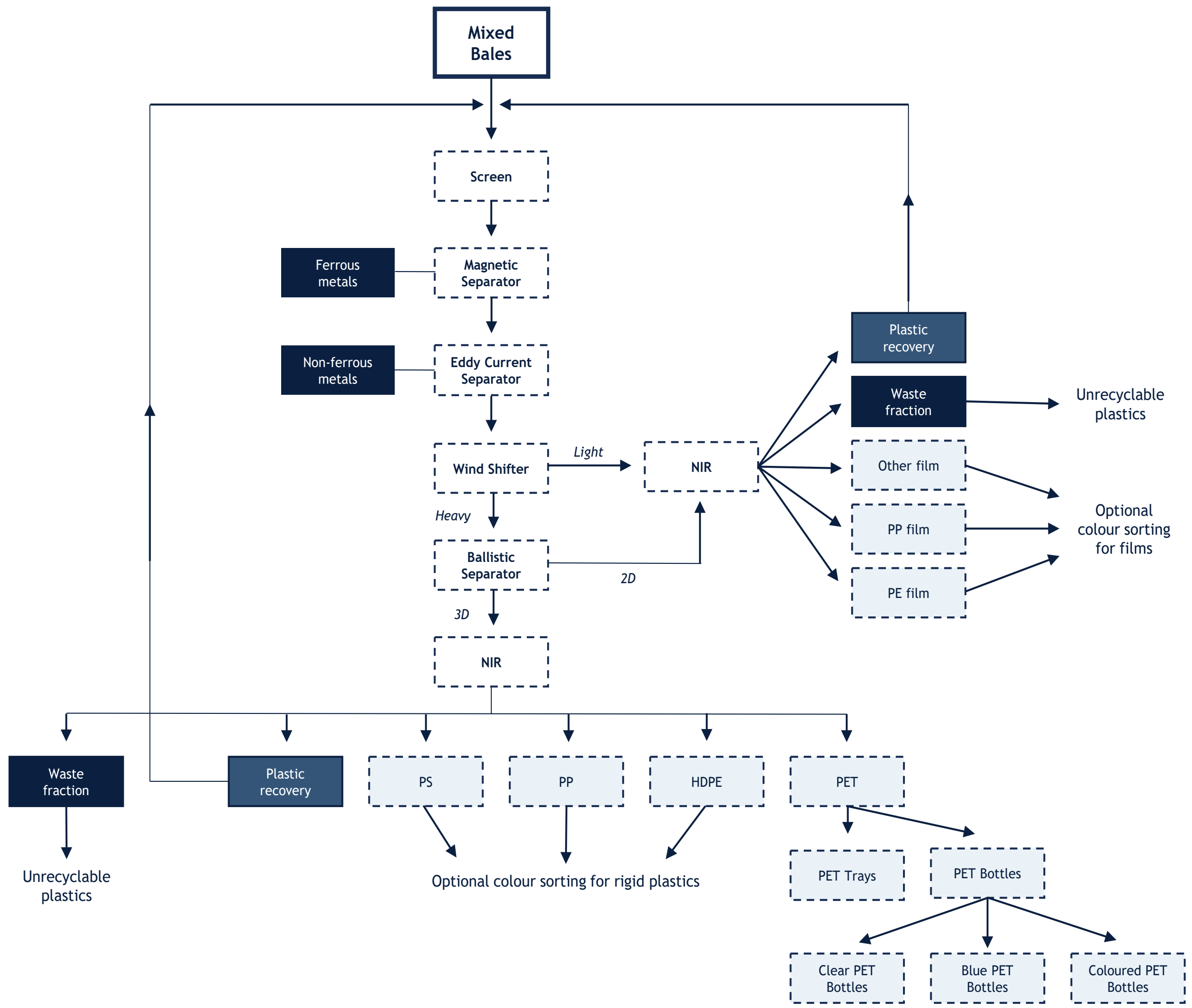
Cannot distinguish black plastics



Source: Frontiers Sustainable, Stifel IRIS*

Nonetheless, to the same extent that recycling depends on accurate sorting, sorting heavily relies on an efficient ecosystem for waste collection. As such, multiple collection systems exist worldwide to deal with the huge quantities of waste produced every year. The whole dilemma is who should bear the fiduciary responsibility of waste management, i.e., who produces waste, the end-users, the brand owner, or the initial producer? This has resulted in different responsibility frameworks, within which extended producer responsibilities (EPR) now also include the electronics and batteries manufacturing ecosystems.

FIG 42: VISUALISING HIGH QUALITY SORTING PRACTICES



Source: Plastic Recyclers Europe, Stifel IRIS*

TOMRA

Tomra is a leading Norwegian company with three business streams, ranging from waste collection, sorting and recycling to food processing machineries. Leveraging its most advanced sensor-based sorting solutions for metal and waste recycling Tomra delivers full-service sorting systems with software-driven intelligence to maximize the recovery yield across numerous waste streams. With more than 105,000 systems installed in 100 countries worldwide, of which about 82,000 reverse vending machines, 14,000 food sorters and 9,000 automated recycling systems, Tomra captures over 45bn used bottles and cans a year, while enabling more effective recovery and recycling.

Fully abiding by Deposit Return Schemes, collection services account for the lion's share of Tomra's revenues (50%), having committed to collecting 40% of plastic packaging produced globally each year for recycling by 2030, with 30% then redirected to favour closed-loop recycling initiatives. Nevertheless, since it is directly exposed not only to mechanical but skyrocketing collection and sorting requirements across the entire recycling value chain, with both policy pressures and increasing market prices for recyclable materials, Tomra should capitalise on its market-leading position for additional growth legs going forward.

greyparrot

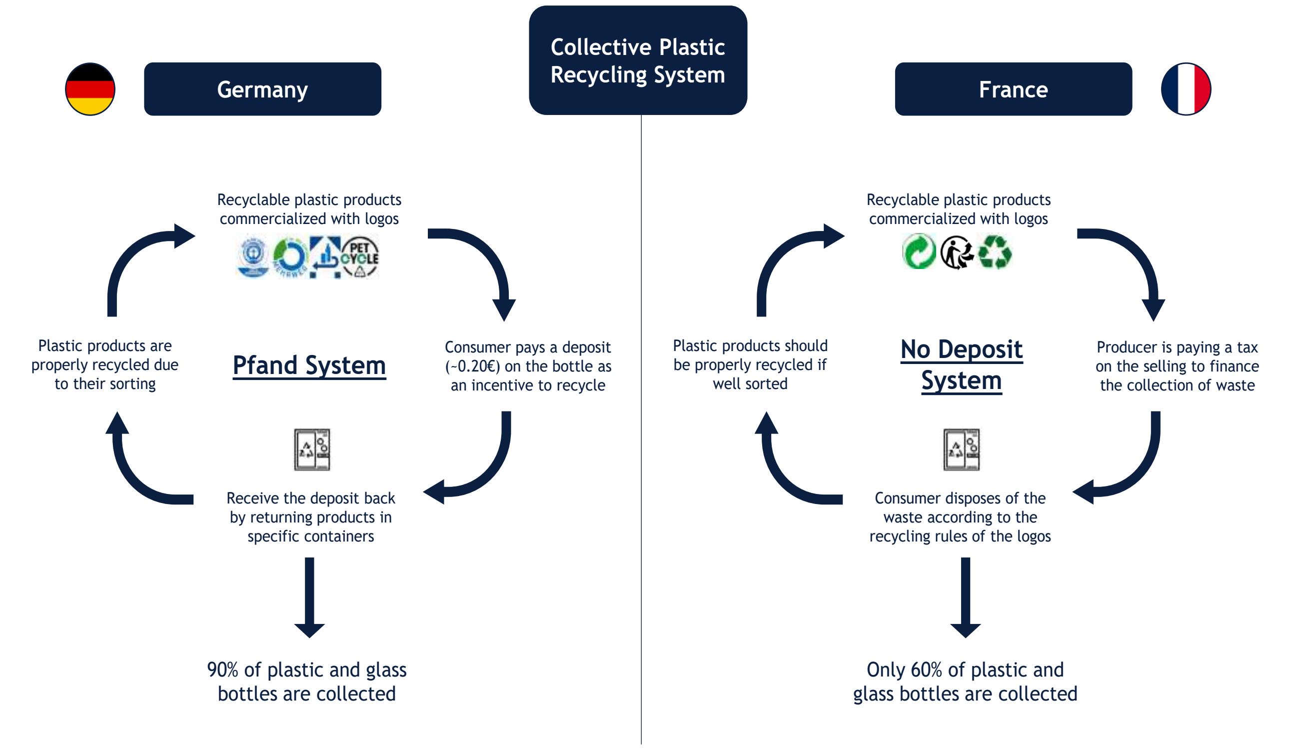
Grey Parrot, founded in 2019 and based in London, is the developer of an artificial intelligence computer vision software designed to be deployed in recycling plants to measure waste flows and provide analytics to increase recycling rates and efficiency. Grey Parrot software leverages intelligent waste recognition while adopting low-cost hardware to ensure its solution can be deployed at scale, enabling a wide range of industrial scale companies to automate and improve their recycling process.

In the process, the Analyser Unit sits above conveyor belts in sorting facilities, using cameras to capture real-time images of wastes flows. Its unique technology can identify characteristics such as composition, financial value, mass, brand, food-grade, function and emissions reduction potential across 67 categories of material at +95% accuracy.

Thanks to their global development, Grey Parrot's software solution is analyzing over 50 billion waste objects every year across 13 countries which has created a large trained database to constantly gain in efficiency.

After securing USD2.7m investments and grants in 2020, the company deployed its first operating unit in a UK recovery facility, thereby stepping a stone to deploy this innovative block across more sorting players. This has been followed by an additional funding of USD11m in 2022, capitalizing on partnerships with global companies such as Veolia, Suez, Viridor, Roydon Recycling or Biffa. Now able to cover the entire waste materials spectrum (hard/flexible plastics, fibers, metals, composite, electronics etc.), this paves the way for a viral adoption of Grey Parrot's solution.

FIG 43: COLLECTIVE PLASTIC RECYCLING SYSTEM



Source: Stifel IRIS*

France and Germany have different viewpoints and systems:

- In Germany, the responsibility for the proper collection of waste is placed on consumers through the Pfand system, which involves the consumer paying a deposit fee when purchasing a product. Consumers are reimbursed this deposit when they dispose of the item correctly. Under this system, the liability is placed on the consumer and there is little incentive for producers to reduce the circulation of plastic.

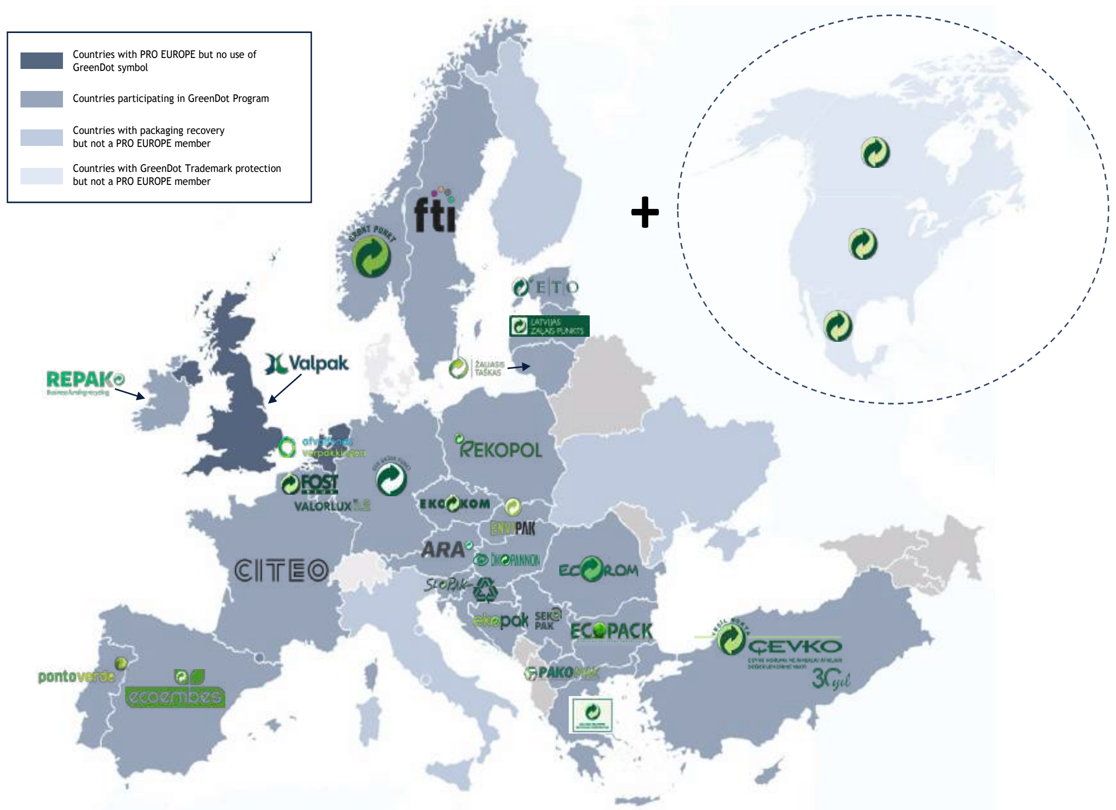
- France's recycling collectives generally oppose this approach because it fails to encourage producers to proactively limit the amount of plastic they produce. Consequently, France supports this system through the Green Dot programme established by PRO Europe, with funding coming from government taxes.

While Germany is well in line with Europe guidance in terms of the percentage of waste collected compared to France, the latter aims to reduce the amount of waste produced, and private companies like B:bot also flourish in the country to incentivize customers' plastic bottles voluntary return options. As such, B:bot favors environmental awareness and reduces the number of steps from consumers to recyclers, thereby reducing leakages and closing the loop to 100% recycled bottles (from around 50% in 2023).

Beside the Pfand system, PRO (Packaging Recovery Organisation) Europe and its 31 member countries is the general licensor of the Green Dot Trademark®. The trademark acts as a licensing symbol paid by producers to co-finance packaging waste recovery and recycling schemes in member countries with end-users. Each member country has a company ruling over the general organisation of the collection and recycling system (e.g., CITEO in France, EcoEmbes in Spain, Repak in Ireland…).

Countries can be users of the Green Dot Trademark without necessarily being PRO Europe members such as Canada, the United States and Mexico.

FIG 44: GREENDOT TRADEMARK ADOPTION



Source: PRO EUROPE, Stifel IRIS*

Brand owners and waste producers pay a licensing fee to the non-profit organisation overseeing the collection and recycling of products in the country where they distribute their goods. This fee grants producers the right to add the Green Dot symbol to their product packaging. Each PRO Europe company receives financial support from licensing fees and taxpayers to facilitate the collection, sorting, recycling, and proper disposal of plastic waste in the country where the fee is paid.

Public and integrated private collectors, or independent sorting and recycling entities operations are partly being financed by PRO organisations with the money collected from licensing fees as an incentive to recycle consumer waste properly.

Danone, a global food-products corporation, has demonstrated a commitment to sustainability by actively addressing environmental concerns, particularly in the realm of plastic packaging. While not directly involved as a plastic recycler, Danone is a powerful brand owner and has undertaken initiatives to enhance the recyclability of its products, therefore acting as a pioneer, bending its emissions and reducing its environmental footprint in the medium to long-term to satisfy secular trends towards better extended producers' responsibility monitoring.

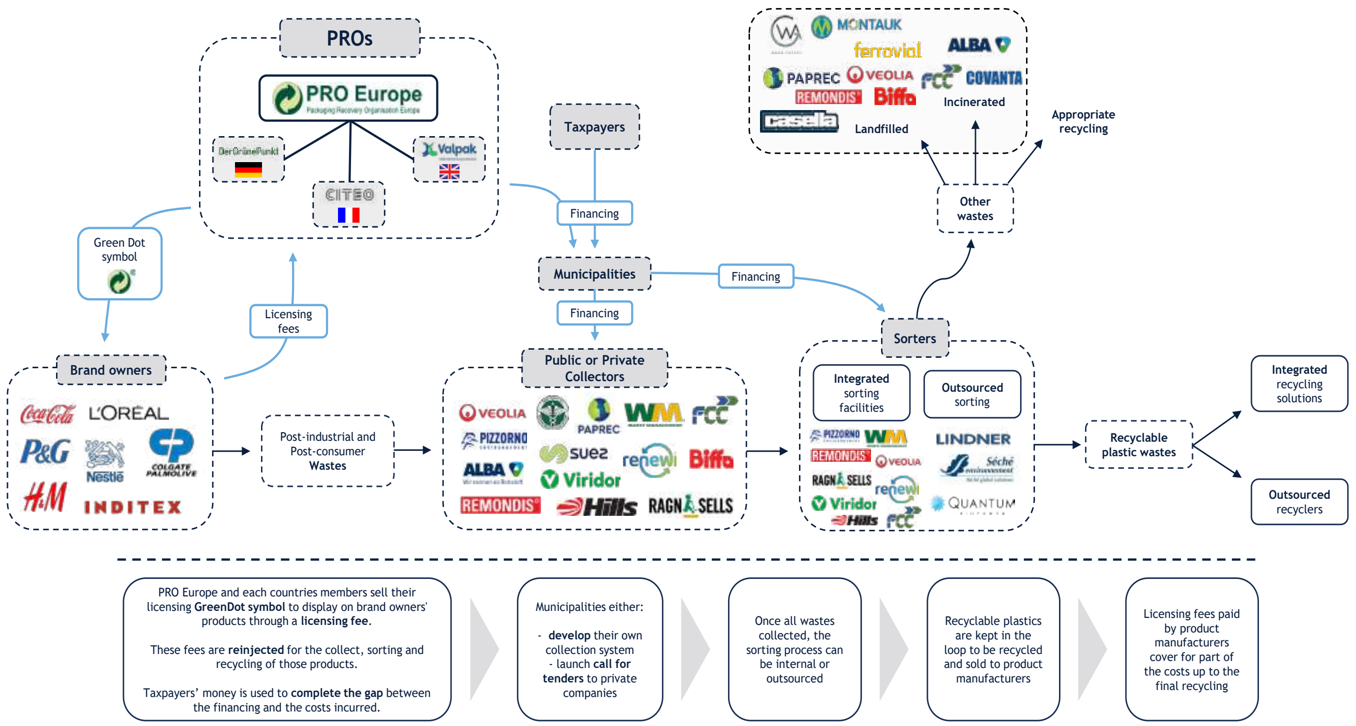
As such, Danone has pledged to achieve 100% recyclable, reusable, or compostable packaging by 2025 igniting a snowball effect on other major players including Coca-Cola, PepsiCo, Nestlé or Dr Pepper. By 2030, Danone also expects to reduce the use of virgin plastic content in its product by a targeted 30%. Led by its sustainability goals, Danone strives to be a leader in promoting a circular economy, emphasizing the importance of responsible production and consumption practices in the broader economy, finally engaging and co-developing in partnerships with stakeholders to improve recycling infrastructure.

French company Citeo resulted from the 2017 merger between Eco-Emballage and Ecofolio. It develops eco-design, collection, sorting and recycling services within the framework of Extended Producer Responsibility (EPR).

Citeo is a non-profit organisation funded by brand owners and packaging producer companies to organise and finance the collection, sorting and recycling of paper and plastic waste in France. Citeo has multiple lines of action which include bringing solutions for eco-designs and reuse of packaging, improving waste collection process, educating French citizens to sort waste properly and acting for the environmental transition alongside French and European institution stakeholders. Citeo's core model works through eco-contributions from producers following a rate calculation method that favours actors contributing to reducing packaging uses and waste as well as the adoption of the Green Dot symbol.

Citeo is a member of the Packaging Recovery Organisation (PRO) Europe alongside dozens of companies implemented in Europeans countries.

FIG 45: GREENDOT SYMBOL SUPPLY CHAIN



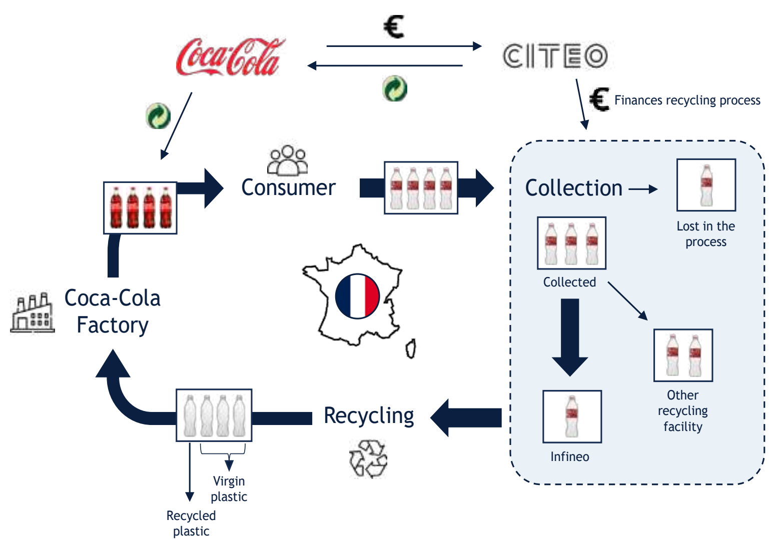
Source: PRO EUROPE, Stifel* IRIS

Case study integrated plastic recycling Coca-Cola

Multinational firm Coca-Cola has developed its own recycling scheme in France through the partnership between Plastipak, CITEO and Coca-Cola Europacific Partners, to build the Infineo factory located in Sainte-Marie-la-Blanche in Côte d'Or. Approximately a third of the collected plastic bottles find their way to this facility. Employing a complete circular process, the plastic is mechanically recycled to create pellets. In 2018, a quarter of the plastic bottles leaving the factory for sale were crafted from recycled plastic, and Coca-Cola's goal is to increase this to 50% by 2030.

However, achieving this objective appears feasible only if we assume that 100% of the plastic bottles are collected after use, which is not the current reality. Thus, attaining Coca-Cola's target would necessitate a more efficient collection process, as the recycling output yield is currently insufficient to guarantee the 50% target.

FIG 46: COCA-COLA CIRCULAR PROCESS IN FRANCE



Source: Stifel* IRIS

Eco-design initiatives

Brand owners are both regulated and offer financial incentives to allocate resources towards research and development efforts focused on eco-design for their products. These efforts can involve reducing the quantity of plastic used or enhancing recyclability.

FIG 47: ECO DESIGN REGULATIONS AND BRAND-OWNERS INITIATIVES

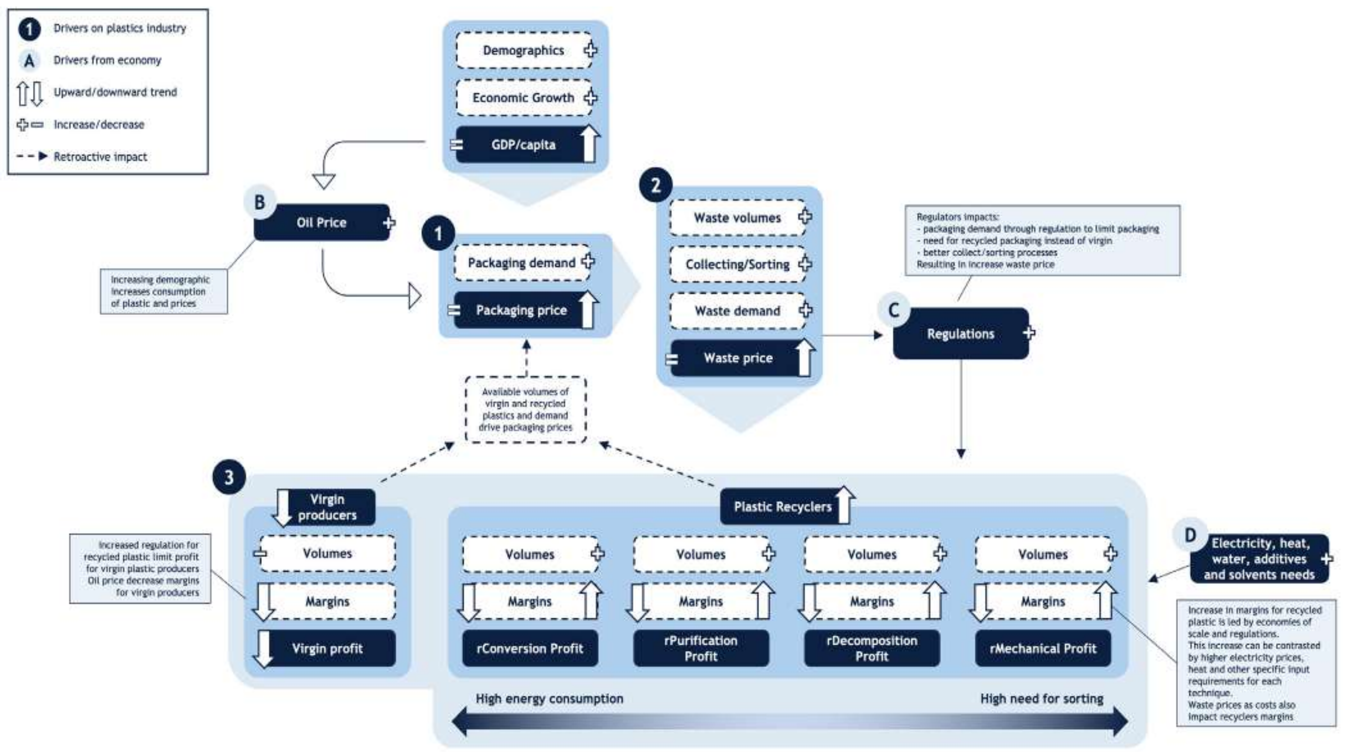
Source: Stifel* IRIS

Breaking into plastic recycling drivers

The entire plastic recycling sector is influenced by a combination of factors, some specific to the industry, while others are interconnected with the business cycle and the broader economy. As is customary, a rise in population and economic expansion ultimately leads to higher GDP per capita and a higher propensity to consume. Coupled with depleting oil reserves and regulatory enforcement around recycled content, this surge in demand for packaging continues to exert pressure on packaging costs, especially in the existing waste-to-value ecosystem (and particularly the energy and fashion sides), progressively closing the bridge to circularity. Going forward, packaging price increases should therefore stem from binding and voluntary recycled content targets, both increasing the waste feedstock thirst, therefore boosting (i) the need for better collection and sorting, as well as (ii) demand for the leanest energy and investment alternatives to (up/re/down) cycle plastic waste, always aiming to extract the most out of each and every available feedstock.

In all, regulations and electricity prices directly affect the equilibrium between profits of producers using virgin plastic, those utilising recycled plastic and recyclers. Whereas virgin producers should increasingly diversify their revenue streams, securing future growth drivers and hedging themselves against decreasing margin pools, recyclers should remain heavily exposed to regulations (methods vs allowed feedstock) and target scalable processes both in terms of logistics and energy requirements.

FIG 48: DRIVERS OF THE RECYCLING INDUSTRY



Source: Stifel IRIS*

RECENT **TRANSACTIONS**

Investment activity in the plastic recycling ecosystem has multiplied globally by four to five times since 2018. From the transaction value perspective, we see that activity skyrocketed in 2021, boosted by both the macro environment and reinforced regulations in European countries, driving mounting interests in circular materials. Given the amount of capital to be deployed in recycling facilities and thereby in collection/sorting, the upward fundraising trend from 2018/2020 should continue to see strong developments, especially considering the number of existing verticals. This would ultimately drive demand for EPC works and a renewed growth cycle for equipment providers.

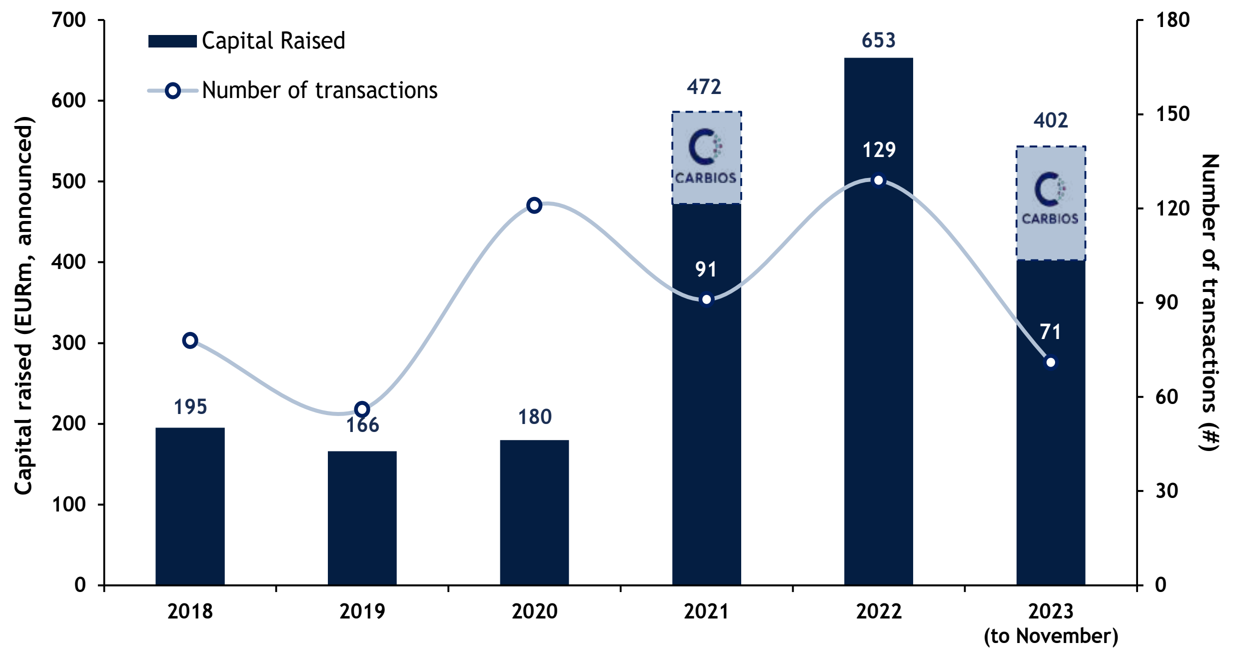
However, a look at the number of transactions also highlights the fact that the ecosystem remains relatively nascent, either with VC-led (and research spin-off) pilot and pre-commercial stage businesses, or family-led (and PE-backed) mature recycling businesses ready for an expansion cycle.

In light of the maturity and realisable size synergies on the mechanical recycling side, which remains quite fragmented with lots of local or regional players, we would expect efficiency moves to kick in between mechanical recycling players, thereby leaving room for consolidation.

Whereas innovative recycling initiatives still stand by the testing and industrialisation of processes, chemical recycling has started to attract significant amounts of money with two highly complementary conceptions of what is expected from recycling players. Regulations should act as a referee, but both would continue to drive expansion in the recycler's ecosystem and mass market adoption of recycled and looped materials.

The following charts show past transactions in the plastic recycling ecosystem since the beginning of 2018:

FIG 49: TRANSACTIONS IN PLASTIC RECYCLING YTD 2023 AND OVER THE PAST FIVE YEARS



Source: Stifel IRIS, Pitchbook*

FIG 50: TRANSACTIONS OVER THE PAST 18 MONTHS (1/7)

Date	Target/Investee	Country	Description	Major investors	Deal type
Oct-23	agilyx	NOR	Agilyx is a developer of conversion technologies intended to offer two molecular recycling product for polystyrene and polymethyl methacrylate.	Arctic Securities, Nordea, DNB Asset Management, Delphi	PIPE
Oct-23	Dalmia Polypro	IND	Dalmia Polypro is a plastic recycling company intended for propelling plastic circularity. The company specializes in recycling PET and polyolefin into rPET flakes and polyolefin granules	Circulate Capital	Debt
Oct-23	morssinkhof-group	NLD	Morssinkhof Group is a plastic recycling company producing high-grade recycled raw materials, manufacturing and regrinding granulates	IKEA	Corporate
Oct-23	AMBERCYCLE	USA	Ambercycle provides a chemical recycling technology designed to turn complex end-of-life textiles into new yarns.	H&M, zalando, Drive Catalyst	VC
Sep-23	enval	GBR	Enval developed a recycling technology desinged to create sustainable and economically viable alternative to landfills	greenback	M&A
Aug-23	bpm	GER	Best Plastic Management is a recycling firm inteded to service mainly the plastic industry by specializing in the disposal and recycling of post-industrial plastic waste	Vidia Ventures	Buyout/LBO
Aug-23	CADEL DEINKING	SPA	Cadel Deinking is the designer of a purification recycling technology to remove printed ink from plastic surfaces	European Commission	Corporate
Aug-23	BlueOne	AUT	BlueOne Solutions offers service ranging from sorting, shredding, washing and drying to extrusion	erema group, Lindner	JV
Jul-23	HydroDyn	GER	HydroDyn provides plant technology to clean and purify plastic waste	Undisclosed	Buyout/LBO
Jul-23	CARBIOS	FRA	Carbios specializes in developing enzymatic bioprocesses to address the major challenge of plastic and textile pollution	L'Oréal, Groupe L'Occitane, copernicus, Michelin	Secondary Transactio
Jul-23	Umincorp	NED	Umincorp is a provider of magnetic density separation-based waste management service intended to convert plastic into a source of valuable raw materials	Acquario, INGKA, Invest-NL, delftenterprises	VC
Jul-23	SAMSARA	AUS	Samsara Eco is the designer of an enzymatic recycling technology to treat PET plastic infinitely	lululemon, INP Capital, W23, cefc, DCVC	VC
Jun-23	APK	GER	APK is a provider of Newcycling a patented technology to recycle mixed used plastics into pure granules	lyondellbasell, MIG Capital, Kirkbi	VC
Jun-23	DePoly	CHE	DePoly is the operator of a chemical recycling technique intended to create a circular plastic economy to convert plastics into raw materials without affecting their quality	ACE & Company, European Innovation Council, BASF, Plug and Play	Seed
Jun-23	ROYDON	GBR	Roydon Recycling provides a waste management service intended to serve commercial clients as well as advising on waste management strategies	palatine	PE/Growth

Source: Stifel* IRIS, Pitchbook

FIG 50: TRANSACTIONS OVER THE PAST 18 MONTHS (2/7)

May-23	Plastretur	NOR	Plastretur operates in the plastic packaging sorting and recycling	TOMRA	JV
May-23	Pryme	NOR	Pryme NV is a cleantech company that has developed a technology to convert non-recyclable plastic into chemicals and hydrocarbons.	lyondellbasell, Invest-NL	PIPE
May-23	IBERresinas	ESP	The company engages in transforming plastics into pellets that substitute petrochemicals.	TotalEnergies	M&A
Apr-23	esterform	GBR	The company produces PET bottles and containers, thereby converting plastic flakes derived from plastic bottles into high-purity plastic pellets.	Biffa	Corporate
Apr-23	RITTEC Umwelttechnik	DEU	Developer of PET recycling technology specializing in colored bottles, multi-layer packaging and polyester textiles.	Bingo Systems	M&A
Mar-23	earth wake	FRA	Manufacturer of pyrolysis technology-based machine designed to turn plastic waste into a source of energy.	Banque Populaire Méditerranée, CMA CGM, bpifrance, Créazur France	VC
Mar-23	Interface Polymers	GBR	Manufacturer of polymer additives intended to modify the surface properties of commodity plastics such as polyethylene and polypropylene.	24Haymarket, GC Ventures, porus, Evonik, ingevity	VC
Mar-23	EMC	USA	The company's services use an asphalt modifier that provides a sustainable, high-performance product for making roads with plastic.	Undisclosed	VC
Mar-23	LAVERGNE	CAN	Developer of compounded engineered resins intended to replace virgin plastics. The company's platform uses fully post-consumer recycled (PCR) plastics to create high-value sustainable resins, alloys, and composites.	Venture Partners University of Colorado Boulder	VC
Mar-23	Resynergi	USA	Developer of a biorefining technology intended to convert traditionally non-recyclable plastics into fuel and chemical products.	Undisclosed	VC
Feb-23	PEAK WASTE RECYCLING LTD	GBR	The company operates a fleet of vehicles and provides services such as recycling, waste disposal, plastic recycling, and other related services.	Beauparc, Macquarie	Buyout/LBO
Feb-23	fuenix	NDL	The company focuses on recovering plastics that can't otherwise be reused or recycled using its unique hybrid technology to create pyrolysis oil for making food packaging and medical products.	SULZER	M&A
Feb-23	cycle	USA	The company operates an application which pairs with internet-enabled RVMs (Reverse Vending Machine) to facilitate the proper disposal of recycled materials.	rts	M&A
Feb-23	APK	DEU	The company uses recycled plastics made from used mixed plastics and plastic-metal composites and produces clean and pure re-granulates.	Kirkbi, lyondellbasell	VC

Source: Stifel* IRIS, Pitchbook

FIG 50: TRANSACTIONS OVER THE PAST 18 MONTHS (3/7)

Feb-23	INTERMIX	USA	Developer of multi-block compatibilizer additive technology intended to efficiently recycle plastic waste into resins.	NSF National Science Foundation	Accelerator
Jan-23	earth wake	FRA	Manufacturer of pyrolysis technology-based machine designed to turn plastic waste into a source of energy.	i-Nov	Grant
Jan-23	Capital Paper Recycling Ltd.	CAN	Provider of recycling and shredding services which include plastic recycling, paper shredding, metals recycling and electronic recycling.	E360S	Buyout/LBO
Jan-23	nexus circular	USA	Commercial provider of advanced recycling services that converts landfill-bound plastics into products that are supplied to petrochemical companies to produce virgin-quality plastics.	COX Enterprises	VC
Jan-23	REMAQ	CZE	The company manufactures polypropylene, polyethylene and polystyrene regranulates products.	ORLEN	M&A
Jan-23	LASSO	GBR	Provider of consumer recycling equipment and services intended to ensure captured materials are kept separate with accuracy and then cleaned and processed into a pure, valuable saleable product.	accelerator 100+	Accelerator
Dec-22	NEW HOPE ENERGY	USA	Developer and operator of a pyrolysis plant intended thermally decompose plastics into hydrocarbon products into raw material for resin and petroleum products.	Undisclosed	Seed
Dec-22	OMV	AUT	International, integrated oil and gas company that operates in the exploration & production, refining & marketing, and chemicals & materials segments.	ADNOC	Secondary Transaction
Dec-22	RECIRCLE	CAN	Operator of a waste management company intended to remanufacture plastic waste into consumer products and industrial raw materials.	Spark; VOLTA Energia	Accelerator
Dec-22	PREMIRR PLASTICS	USA	Provider of patented plastic recycling services with a sustainable and eco-friendly method to chemically recycle polyethylene terephthalate.	Undisclosed	Seed
Dec-22	CADEL DEINKING	ESP	Deinking Technology allows ink to be removed from plastic before it is recycled and obtains a product with a quality like that of new plastic.	KEYCYCLE	M&A
Dec-22	LETBEK	DEN	The company offers recycling and upcycling of plastic from industries and oceans, disassembling plastic into fractions and recombining these into new materials.	ZIRQ SOLUTIONS	M&A
Dec-22	KAMILO	USA	Developer of real-time global supply chain tracking platform designed to bring transparency and accountability to the global plastics supply chain and recycled plastics markets.	United States Environmental Protection Agency	Grant
Dec-22	Loop Tas	NDL	Developer of a digital platform designed to improve the waste management structure.	DSIF Dutch Student Investment Fund	VC

Source: Stifel IRIS, Pitchbook*

FIG 50: TRANSACTIONS OVER THE PAST 18 MONTHS (4/7)

Nov-22	Gravity Wave	ESP	The company collects plastic from traditional fishermen and transforms the plastic waste into sustainable products, enabling clients to contribute to the cleaning of the oceans.	an CasalsPablo ferandez Rafael Velazquez; enisa	VC
Nov-22	Biotechnologies GREENTECH	SRB	The company researches, develops and produces high-tech active ingredients from natural sources in the plant, marine and microbial worlds.	Poly Recycling	M&A
Nov-22	LabCycle	GBR	The company offers proprietary sorting systems, plastic segregation, novel decontamination, and plastic waste recycling.	SFC Capital	Seed
Nov-22	PLASCRED	CAN	Provider of green technology services intended to deliver a commercially viable plastic recycling process.	MAG ONE Products Inc.	M&A
Nov-22	KRAS	NDL	The company processes and transit trades waste flows of paper, cardboard, foils and plastics for hundreds of companies throughout Europe.	SCG Chemicals	M&A
Nov-22	Recycle 1	USA	Provider of commercial recycling and product destruction services catering to the state of Arizona and surrounding states.	CarusaHershman Recycling	M&A
Nov-22	EVORALIS	GBR	Developer of plastic recycling technology allowing the discovery and improvement of biocatalysts for the depolymerisation of plastics.	Undisclosed	Grant
Nov-22	LabCycle	GBR	The company offers proprietary sorting systems, plastic segregation, novel decontamination, and plastic waste recycling.	Undisclosed	Grant
Oct-22	PUSA PACK	ESP	Manufacturer of flexible bags catering to food, cosmetics and pharmaceutical industries.	Smurfit Kappa	M&A
Oct-22	ADN Materials Ltd.	IRL	The company recycles contaminated farm film plastic into light-density polyethylene pellets for reuse in the manufacturing of farm film plastic wrapping sheets and exterior plastic furniture.	enva	Buyout/LBO
Oct-22	CIRCULUS	USA	The company manufactures post-consumer recycled resins from recycled plastic.	s2gventures	Debt
Oct-22	ECODECK	GBR	The company offers driveways, plastic sheds, plastic non-slip floor surfaces, path grids and plastic drainage channels made from recycled plastic.	CORAL Products (Mouldings) Ltd	M&A
Oct-22	ITERO	GBR	The company monitors recyclable plastic waste streams by screening incoming feedstock, converts it into hydrocarbons via thermal cracking, recovers the hydrocarbon, and captures excess gas to generate heat for the hydrocarbon conversion process.	Rijksdienst voor Ondernemend Nederland	Grant
Oct-22	MURA	GBR	The company develops a global portfolio of sites using hydrothermal upgrading enabling clients to convert waste plastic into chemicals that can be further used in the petrochemical industry.	Dow; LG Chem; KBR	VC

Source: Stifel IRIS, Pitchbook*

FIG 50: TRANSACTIONS OVER THE PAST 18 MONTHS (5/7)

Sep-22	LASSO	GBR	Provider of consumer recycling equipment and services intended to ensure captured materials are kept separate with accuracy and then cleaned and processed into a pure, valuable saleable product.	Undisclosed	Seed
Sep-22	ioniqa	NDL	The company's platform uses proprietary circular technology and is able to close the loop for plastics and upcycle them	KOCH	PIPE
Sep-22	ERPlastics	NDL	The company specializes in the production of mats, and manhole covers made from recycled plastic.	Braskem	M&A
Sep-22	PRS Plastic Repair System	ESP	The company's services specialize in repairing objects made of polyethylene and polypropylene, such as solid-waste containers, boxes, tanks, and kayaks.	EASO Ventures; iMPACT	VC
Sep-22	polimero srl	ITA	The company offers extraction of low-density polyethylene (LDPE) from post-industrial and commercial films and converting it into packaging applications.	Ara Partners; REPEATS	Buyout/LBO
Sep-22	agilyx	NOR	Agilyx is a developer of conversion technologies intended to offer two molecular recycling product for polystyrene and polymethyl methacrylate.	Undisclosed	PIPE
Sep-22	GreenEarth Recycling	USA	Provider of recycling and waste collection services.	WM Waste Management	M&A
Sep-22	Replace	FRA	Operator of plastic recycling company intended for recycling of complex plastics without recovery solution.	Groupe ILP; Yeast; Key Venture	Seed
Aug-22	Herbold	DEU	The company offers machines for size reduction, fine grinding and pulverizing of clean and contaminated plastic granulates.	coperion	M&A
Aug-22	northwest polymers	USA	The company provides waste plastic disposal solutions that transform plastics into premium-grade resins for use in the production of second-generation plastic products.	atkore International	M&A
Aug-22	vartega	USA	The company's platform uses chemistry-based technology and hardware to divert high-value carbon fiber scrap and waste from landfills and incineration.	Autodesk Foundation; MG Ventures; NCV; SWAN	Buyout/LBO
Aug-22	cpe	GBR	The company utilizes pyrolysis and oil-upgrading technology to convert non-recyclable waste plastic found in landfills or oceans into ultra-clean fuels.	Euston Capital Trust	Seed

Source: Stifel IRIS, Pitchbook*

FIG 50: TRANSACTIONS OVER THE PAST 18 MONTHS (6/7)

Aug-22	SMI Strategic Materials, Inc	USA	The company engages in the supplying of recycled glass and plastic which are processed to turn them into viable products.	Undisclosed	Debt
Jul-22	ITERO	GBR	The company monitors recyclable plastic waste streams by screening incoming feedstock, converts it into hydrocarbons via thermal cracking, recovers the hydrocarbon, and captures excess gas to generate heat for the hydrocarbon conversion process.	Infinity Recycling	VC
Jul-22	impact recycling	GBR	The company's baffled oscillation separation system (BOSS) technology separates the components of post-consumer, mixed plastic waste to recover consistent streams of polyethylene (PE) and polypropylene (PP).	IWCAPITAL Invested Interest	PE/Growth
Jul-22	P	NDL	Peute Papierrecycling specializes in producing raw material from big bags, PET bottles, PP/HDPE/PS mono flows and other production waste.	SCG Packaging	M&A
Jul-22	QUANTAFUEL	DEN	The company converts waste plastic into low-carbon synthetic oil products replacing virgin oil products.	EURAZEO	Buyout/LBO
Jul-22	AURORA Manufacturing	GBR	The company offers shredding, granulation and compounding material trading and produces reprocessed PP and HDPE.	Ravago	Buyout/LBO
Jul-22	Venture Polymers collect | recycle | supply	GBR	Provider of recycling and waste collection services intended for mechanical recycling for buyers, collectors and recyclers of plastics.	Ravago	Buyout/LBO
Jul-22	Royce Corporation	USA	The company offers copper, brass, aluminum, lead, zinc, stainless steel, plastics, minerals and high-temperature alloys.	Undisclosed	Mezzanine
Jun-22	plasticpreneur	AUT	Designer and manufacturer of plastic recycling machines and customized moulds.	erema group	Corporate
Jun-22	oceansix meaningful solutions	DEU	Developer of a technology designed to recycle plastic products.	KB Recycling Industries	M&A
Jun-22	SMILE PLASTICS	GBR	Manufacturer of large-scale decorative flat panels made using recycled plastic from plastic bottles, yogurt pots, plant pots, food packaging, wellington boots and coffee grounds.	Green Angel Syndicate; ACF Investors	Angel
Jun-22	BERGA Recycling	CAN	The company specializes in trading, logistics, consulting and installation services for all fiber and plastics recycled products.	BEWI	M&A
Jun-22	Myplas	USA	Operator of a plastic recycling company aimed at reducing greenhouse gas emissions and curtailing waste.	301 ventures; Closed Loop Partners	VC

Source: Stifel IRIS, Pitchbook*

FIG 50: TRANSACTIONS OVER THE PAST 18 MONTHS (7/7)

Jun-22	SK geo centric, suez, loop Industries	FRA	Construction of the first Infinite Loop™ 100% recycled and infinitely recyclable plastic production plant in Europe.	SK geo centric, suez, loop Industries	JV
Jun-22	Kelco Recycling, Inc.	USA	Operator of a full-service recycling company intended for commercial as well as residential clients.	NEWGATE Capital Partners	Secondary Transaction
May-22	AION	NOR	The company offers flexible and traceable end-to-end services in the field of circularity on plastics with a documented sustainability effect for its customers.	AKER BIOMARINE, OCEAN 14 Capital	VC
May-22	SHERMAN	USA	The company offers a wide range of services including plastic grinding, plastic blending, plastic pelletizing and laboratory testing services as well as supplies regrind, reprocessed pellets and virgin materials.	SPARTECH	Buyout/LBO
May-22	Plastic Recycling	USA	The company's services specialize in processing capabilities for plastics including sorting, toll grinding, washing, and pelletizing for recyclable material.	aliaxis, WM Waste Management	JV
May-22	Cedar Poly	USA	The company's services specialize in processing capabilities for plastics including sorting, toll grinding, washing, and pelletizing for recyclable material.	UFP INDUSTRIES	M&A
May-22	General Industries	FRA	The company offers post-consumer plastics, post-industrial plastics, reclaimed plastics and virgin plastics.	TERTIUM	PE/Growth
May-22	NORTHSTAR RECYCLING	USA	Operator of a national recycling company intended to serve food, consumer packaged goods and other industrial clients.	BARINGS	Debt
May-22	CIRCLE BACK	DEU	Circleback provides technology and services to power packaging take-back systems for producers.	NCA Next Commerce Accelerator	Accelerator
May-22	Cool Clean Technologies	USA	Developer of carbon dioxide-based technologies intended for cleaning, extraction, and cooling applications.	National Science Foundation	Secondary Transaction
May-22	magnomer	USA	Manufacturer of novel magnetic inks intended to enhance plastic package recycling.	WALNUT VENTURES	VC
May-22	WeaponX	USA	The company develops a plastic recycling agent, enabling the companies to combine, grind, and reform different plastics without the need to separate the used plastic products.	start engine	Equity Crowdfunding
Apr-22	WPU Waste Plastic Upcycling	DNK	WPU Waste Plastic Upcycling AS is engaged in the upcycling of plastics. It converts plastic waste to oil that turns into new products. Its technology is based on pyrolysis	Undisclosed	IPO
Apr-22	avantium	NDL	Avantium NV along with its subsidiaries is engaged in developing and commercializing next-generation bio-based plastics and chemicals based on its technological capabilities in advanced catalysis research and development.	Undisclosed	Secondary Transaction

Source: Stifel IRIS, Pitchbook*

CONCLUSION

SECTION 3

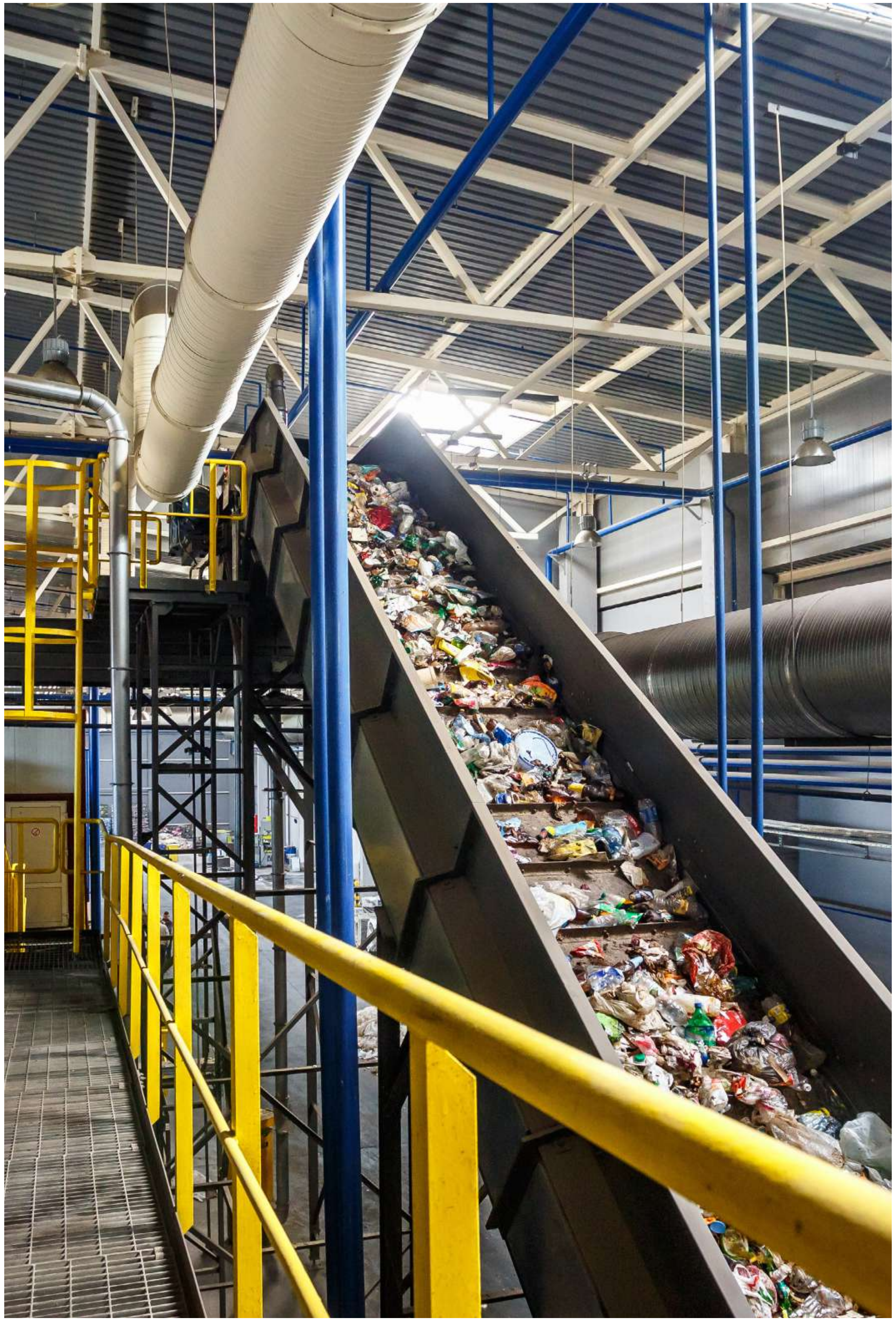
Over the years, the petrochemicals industry has created numerous plastic polymers with plenty of benefits for modern society. Nonetheless, plastics have gradually become a victim of their own success, with this "miracle" material being taken for granted and improper disposal of used plastics therefore leading to environmental pollution, waste build-up and valuable resource wastage. For decades, efforts to collect and recycle plastic waste have been economically challenging. However from now on, broad coalitions of players across the plastics value chain, from plastic manufacturers to brand owners and waste processors, boosted by growing regulatory pressure and the prominence of the problem, are taking actions to address this transgenerational issue.

From technologies to process and design, many innovations are required to shift from a linear to a circular, waste-to-value, plastic economy. In the materials' world, this is one small step for man but one giant leap for mankind. The challenge requires a multifaceted approach, including product design for recycling, advancements in waste sorting technologies, and improvements in recycling processes.

Starting with designing products for easier recycling through material reduction and simplification is crucial, therefore anticipating emerging technologies in identification/sorting, and facilitating recycling processes. As such, with bottlenecks stemming from access to feedstock, waste sorting should also benefit from machine vision and AI, while cleaning and conditioning technologies should not be overlooked.

Process-wise, when mechanical recycling has so far been limited to downcycling rather small factions of plastic production, the industry should leverage better structured collection and sorting infrastructures and continue to play a key part in the transition, progressively addressing more demanding applications. Nevertheless, chemical recycling techniques should ultimately excel where mechanical recycling is challenged, either dealing with mixed/contaminated waste streams or maintaining high-grade product quality. However, clear binding frameworks around plastic waste traceability and sourcing will be required to avoid too much reliability on naphtha/fuel conversion, incineration, and landfilling.

Now close to answering part of its material cycle, real growth for sustainable plastics is just about to start and should merely accentuate over the coming years, with viral greenfield initiatives by 2030 and consolidation not far off either. This flourishing ecosystem is set to contribute to a smooth roll-out of recycling infrastructure while realising up and downstream synergies.



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WHITE PAPER **AUTHORS**

PAUL DE FROMENT
Managing Director
Paris
paul.defroment@stifel.com

MAHAUT ARNAUD
Analyst
Paris
mahaut.arnaud@stifel.com

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STIFEL | IRIS

INTELLIGENCE • RESEARCH • INSIGHTS • SERVICE

LONDON, UNITED KINGDOM

Stifel Nicolaus Europe Limited
150 Cheapside
London, EC2V 6ET

T: +44 20 7710 7600

FRANKFURT, GERMANY

Stifel Europe AG
Kennedyallee 76
60596 Frankfurt am Main

T: +49 69 788080

LONDON, UNITED KINGDOM

Bryan Garnier & Co Limited
Michelin House 81 Fulham Road
London, SW3 6RD
Tel: +44 20 7332 2500

T: +49 89 2422 62 11

PARIS, FRANCE

Bryan Garnier Securities SAS
26 avenue des Champs-Elysées
75008 Paris

T: +33 1 56 68 75 00

PARIS, FRANCE

Stifel Europe AG – Paris Branch
80 Avenue de la Grande Armée
75017 Paris

T: +33 1 7098 3940

FRANKFURT, GERMANY

Stifel Europe Advisory GmbH
Bockenheimer Landstrasse 24
60323 Frankfurt am Main

T: +49 69 247 4140

MUNICH, GERMANY

Stifel Europe AG – Munich Branch
Maffeistrasse 4
80333 Munich

T: +49 89 9992 9820
T: +49 89 2154 6000

MUNICH, GERMANY

Bryan Garnier & Co GmbH
Königinstraße 9
80539 Munich

T: +49 89 242 262 11

MILAN, ITALY

Stifel Europe AG – Milan Branch
Via Privata Maria Teresa, 8
20123 Milan

T: +39 02 85465761

OSLO, NORWAY

Bryan Garnier & Co AS
Haakon VIIs Gate 1, 2nd Floor
0161 Oslo
Postbox: 0117 Oslo

T: +47 908 45 025

ZURICH, SWITZERLAND

Stifel Schweiz AG
Tessinerplatz 7
8002 Zurich

T: +41 43 888 6100

GENEVA, SWITZERLAND

Stifel Schweiz AG – Geneva Office
Place de la Fusterie 12
1204 Geneva

T: +41 22 994 0610