Chapter 4
The Plastics Ecosystem

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Summary

The plastics industry is an important part of the European and global economy. Beyond the traditional definition of the plastics industry with the three domains of plastics production, plastics conversion, and plastics machinery, there are important other areas belonging to the plastics ecosystem namely recyclers, service providers, science, associations, trade fairs and many others.

All participating institutions work closely together in complex, mostly international networks, often within the framework of customer–supplier relationships that have been built up and proven over decades.

The necessary transformation of today's linear production system is dominated by linear supply chains to a circular economy, with its demanding requirements, deeply intervenes in these structures and workflows. The phasing out of fossil raw materials while waste is becoming an important feedstock resource is not only changing the world in plastics production but also in all other areas of the plastics ecosystem.

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To assess the impact of this change on established processes and companies, it is necessary to understand the structures existing today.

In this chapter, the sectors and sub-sectors are presented in detail. In doing so, the essential characteristics of each sector are dealt with in a structured manner, the important actors are named, and their roles are described. Regional aspects and key figures complete the picture.

4.1 Plastics Industry and the Plastics Ecosystem

For about 20 years, the plastics industry in the narrower sense has been defined as the totality of the three very different sectors of plastics production (part of the chemical industry), plastics machinery manufacturing (part of mechanical engineering), and plastics processing. The plastics industry in Europe has >1.5 million employees, >53,000 companies (mostly SMEs, see Sect. 4.3), and generates a turnover of >400 billion euros (PlasticsEurope 2024).

The plastics ecosystem as defined in this chapter also includes, among others, compounders, distributors (often with their own compounding operations) and additive/auxiliary manufacturers; specialised logistics companies; sorting companies and recyclers (traditionally regarded as part of the waste management industry); trade fair companies, publishers and many other service providers; and finally the relevant scientific community. In addition, there are the associations of the sectors, working and interest groups, think tanks (Agora 2021), market researchers (Conversio 2020) and the like.

4.2 Plastics Production

General

Companies in the plastics manufacturing industry are usually either part of the chemical or petrochemical industry. Today, most of them are globally positioned and supply their customers, being also globally active, with products of the same specification from regional production. Production is location-sensitive and capital-intensive; world-scale units typically have >500 kt annual production (e.g., polyolefins or isocyanates). They are integrated into complex global supply chains and depend on their reliable functioning. Consolidation of this industry is well advanced but ongoing. The range of annual sales in plastics production extends from approx. 1 billion to approx. 25 billion euros. As a rule, these are publicly listed companies.

Regional aspects

The focus of this paragraph is on Europe as a plastics region, even though this is becoming relatively less important due to various developments. Currently, about

14% of the world's production is still produced in existing plants; new plants are only being built to a minor extent (replacement investments). A stagnating plastics market does not indicate particular growth prospects.

The most important oil-producing region is the Middle East, namely Saudi Arabia and the Emirates in the Persian-Arabian Gulf; due to recent political developments, Iraq and Iran currently play only a minor role. For about 20 years, the governments there have been pursuing a policy of reducing dependence on pure oil exports and keeping a larger share of the value added in the country, i.e. producing plastics locally. Currently, the region (incl. Africa) is home to approx. 9% of global production.

China is by far the largest plastics production location and currently accounts for approx. 32% of global production, for which large quantities of raw materials are imported. In addition, enormous quantities of plastics are imported from other regions and countries (USA, Persian-Arabian Gulf) to cover the constantly growing demand of the Chinese plastics processing industry. A further 22% is produced in Japan, India, Malaysia, Singapore, South Korea, Taiwan, and Thailand. Today, Asia and Oceania account for appr. 54% of global production capacity.

Plastics production in North America has experienced a renaissance in recent years due to the massive availability of cheap shale gas, which has been effective like a drug for the plastics industry there. The Americas (including South America) account for around 21% of global production. In addition, shale gas (ethane) is liquefied and exported to Europe, e.g., where it is reduced in gas crackers. The remaining 2% is produced in the CIS and Russia respectively.

All volumes mentioned are from PlasticsEurope (2024).

Companies

The main polyolefin producers can be grouped into two groups.

Plastics/chemical subsidiaries of major oil companies such as ChevronPhilips (CPC), ENI (Versalis), ExxonMobil (EMC), OMV (Borealis), Petrobras (Braskem), Repsol, Saudi Aramco (Sabic) and Total; petrochemical/chemical companies such as Dow, LyondellBasell, and Ineos in North America and Europe; ChemChina, Petrochina, and Sinopec in China; Asahi, Mitsubishi, Mitsui, and Sumitomo in Japan; LG and SK in South Korea, Reliance (India), PTT and SCG (Thailand) and Formosa Plastics (Taiwan).

Chemical companies such as BASF (polyamides and PUR) and Covestro (polycarbonates and PUR), which emerged from the Bayer Group, have become specialists—but they are among the world market leaders with their respective products.

This market is in a constant state of flux, with acquisitions, divestments, and start-ups taking place all the time. Any overview is therefore only just a snapshot.

The defossilisation aimed at the goal of climate neutrality means that many of these companies are revising and modifying their business models. This is leading to restructuring, consolidation, and massive changes in the market. The Abu Dhabi National Oil Company (ADNOC) seemingly is amongst the forerunners in that very process.

4.3 Plastics Conversion

Plastics conversion is at the heart of the plastics industry. Here, the plastic pellets and liquids delivered by plastics manufacturers are formed on plastics converting machines into the shape in which they meet private or commercial consumers in the form of semi-finished or finished parts such as packaging, technical parts, insulating materials and other building products like pipes or fittings, consumer goods, or plastic products for agriculture and fisheries. The plastics converter uses various processing methods such as injection moulding, reaction injection moulding, extrusion, blow moulding, thermoforming, rotational sintering, etc. Larger plastics converters may often be recognized "from the outside" by the silos in which the granulates, usually delivered by tanker truck, are kept for production.

According to the European Plastics Converters Association (2024) the industry, which is made up of predominantly small and medium-sized companies, comprises over 50,000 companies across Europe, makes an annual turnover of around 260 billion euros and employs around 1,470,000 people. 54.1 Mt of plastics were converted in Europe in 2022 (PlasticsEurope 2024), of which 8.7 Mt were plastic recyclates or over 16%. The plastics processing volume in Europe (see Table 5.2) is distributed as follows.

- 39% plastic packaging;
- 23% construction products;
- 8% vehicle construction.

Plastics conversion also takes place in sectors that do not belong to the plastics industry and thus to the plastics ecosystem, such as the beverage industry, the furniture industry, the automotive industry, the toy industry, and many others. For example, PET bottles and their preforms are now mainly produced by mineral water and beverage bottlers themselves and are only supplied to a lesser extent by plastics converters. Most companies in the automotive and electrical industries also have large in-house plastics converting capacities (in-house production).

Small converters focusing on specialties have sales in the single-digit millions, while large packaging manufacturers (films, industrial packaging) generate sales of 1 billion euros and more. Many of the companies, which operate nationally and increasingly on a European scale, are family-run. Some of the large companies are also family-run, while others belong to international groups that are often listed on the stock exchange.

During the Corona pandemic, state economic ministries classified a number of manufacturers of plastic packaging (packaging for disinfectants, pharmaceuticals, foodstuffs, etc.) as systemically relevant.

4.4 Plastics Machinery

Special machines are necessary for processing and shaping the plastics, usually delivered in the form of pellets or liquids. The most important types are extruders for melting and compounding as well as for the extrusion of semi-finished products (films and sheets, hoses, pipes, profiles), thermoforming machines for the production of open hollow bodies (cups, bowls, pots, blisters, etc.), injection moulding machines for the production of moulded parts with diameters from the mm to the m range as well as RIM machines for the production of soft and hard foam parts based on polyurethane. Moulds, presses, calendars, depositing and winding equipment, autoclaves, blow moulding machines for bottles, canisters, drums, intermediate bulk containers (IBC) or fuel tanks are further moulding units. In addition, there are now numerous manufacturers of equipment for 3D printing (additive manufacturing), which is evolving from a special process to a standard process for prototypes, small series, complicated geometries, and remote processing. The list of peripheral devices and the corresponding manufacturers is almost endless. Austria, Germany, Italy, and Switzerland are the technological centres of plastics machinery manufacturing and the largest exporters, but the largest manufacturer globally has been China for years. The industry has a rather medium-sized structure; a few companies (mostly injection moulding machine manufacturers) have annual sales in the order of 1 billion euros. The typical mechanical engineering company is family-owned and operates in Europe or even worldwide.

According to Euromap (2024), the plastics machinery industry comprises about 1,000 companies with a workforce of some 57,000 people creating a turnover of € 14.3 billion. In 2021 machines for the most important processes have the following market shares in Europe (VDMA 2021):

- Injection moulding 27.3%
- Extrusion 49.1%
- Blow molding 7.0%
- EPS Foaming 3.2%
- PET Preforms and Stretch Blow Moulds 5.9%

The development towards a recycling economy brings new requirements and opportunities for plastics machinery and plant engineering in the field of plastics recycling. This initially involves the processing of used, mixed and contaminated waste by washing, separating, and drying to produce clean production waste. After shredding, fine grinding and compacting (agglomeration), the waste is transferred to the classic manufacturing processes (Herbold 2021). Detailed figures are not available yet from the industry.

4.5 Recyclers

In the 1980s, the recycling of plastic waste was only weakly developed; it was a niche business for the recycling of production waste and selected separately generated commercial waste. Since then, many recycling companies have been established in Europe and all over the world. It is currently estimated that there are around 2,500 companies and projects active in mechanical recycling worldwide (ICIS 2024), producing 35.5 Mt of recyclate in 2022 (cf. Table 5.1). Plastics recyclers in Europe run around 850 facilities with 12.5 Mt of installed capacity. Some 30.000 employees create over € 10.4 billion in turnover (PRE 2024).

In Europe, many of these companies are medium-sized enterprises, each of which produces 10–50 kt of recyclates, markets them independently and achieves a turnover of < € 20 million.

As indicated in Sect. 4.4 already, recycling begins with classification, screening, sorting, and separation processes followed by homogenization at the heart of which are specialized extruders (cf. Chap. 10.1). The plants are geared to the special characteristics of the input waste material. The plastics recycling industry has been undergoing a (cultural) change from a waste management orientation to an integrated part of the plastics value chain for about ten years. This change is embedded in that of the waste industry towards a secondary raw materials economy and is accelerated by ongoing consolidation. Thus, medium-sized plastics recycling companies are being taken over by various players in the market. Not only large, internationally positioned waste management companies such as Remondis or Veolia are active, but also plastics manufacturers such as Borealis, LyondellBasell, or Total, plastics distributors or compounders respectively such as Mocom, large processors such as Alpla, Berry Global, or Trioworld, dual systems (in Germany) such as DSD or retail chains such as the Schwarz Group (Lidl/Kaufland) with its independent legal entity PreZero being an integrated environmental service provider.

4.6 Value Chains

A typical feature of the plastics industry is its organisation in linear value chains—as is the case in the automotive industry, the packaging manufacturing and filling/packing industry, the E & E industry, the medical technology industry, etc. Such chains are organized from both ends, live from direct, often long-standing contacts and the contractual obligation of almost all of their members to each other, the cooperation with experienced logistics companies (cf. Chap. 9), being sometimes IT companies themselves or integrate them. Such chains are rarely organized on a national or regional basis; in many cases, they are now global organizational structures whose complexity poses major challenges, especially for SMEs.

In addition to the manufacture and supply of plastics by the plastics manufacturing industry, there is close cooperation between the plastics manufacturing and plastics processing industries right from the development stage and during production. Only by bundling and utilizing all competencies along the entire value chain can the challenges posed by competitive products be met. This cooperation is becoming even more important as further and new challenges have arisen and will continue to arise with the circular economy (cf. Sect. 6.1).

Some value-added cycles/networks have been successfully established, e.g. for the PET value chain (PETCore 2024), or are being established, for example in some areas of the construction industry (window frames, flooring, etc.), driven forward by the PVC industry (VinylPlus 2024), but are far from being the rule. (cf. Sect. 7.4).

4.7 Service Providers

Trade fairs are important service providers for the industry. They fulfil important functions as marketplaces and information exchanges, are meeting points and communication centres and, of course, and above all, they show innovation in competition. They enable the exhibitors' customers and their competitors to make direct comparisons, pick up on trends and reinforce them.

The two important leading global trade fairs for the plastics industry are the "K" in Düsseldorf, Germany, and "Chinaplas" in Shanghai and Shenzhen, China. Due to the Corona pandemic, almost all trade fairs planned for 2020 and 2021 were cancelled or postponed. Where trade fairs did take place, it was in experimental virtual formats—visitor presence was impossible. Structures and processes of future so-called hybrid trade fairs will be significantly changed after the pandemic.

The International Plastics Fair "K" takes place every three years in Düsseldorf—most recently in 2022 for the first time after the pandemic. Approx. 3,000 companies (mainly machine builders and raw material manufacturers) exhibited on 175,000 m^2 of hall space and welcomed approx. 180,000 visitors. The "K" is still *the* meeting place for the industry, traditionally based in Germany, the technological centre of the plastics industry. The organiser, Messe Duesseldorf, has a portfolio of a total of 9 plastics trade fairs worldwide, making it probably the world market leader in this sector.

The International Trade Fair "Chinaplas" is held annually, alternating between Shenzhen or Shanghai, with the following figures for Shanghai 2018: exhibition area: 320,000 m^2, exhibitors: >3,400, trade visitors: >150,000. Chinaplas represents the largest and most dynamic market in the plastics industry. Chinaplas's sequence was interrupted by the pandemic, too, and it will after all be important to see how it will come back.

Of regional importance are the NPE in Orlando/FL for North America and Fakuma in Friedrichshafen, Germany, for Europe. Mention should also be made of the JEC in Paris, France, the world's largest trade fair for composite materials, the PlastPol fair in Kielce, Poland, and PLAST in Milano, Italy.

4.8 Science

Across Europe, there is a large and diverse scientific landscape dealing with almost all of the above-mentioned aspects of plastics as a material.

Universities

Polymer sciences with a focus on macromolecular chemistry and plastics engineering are represented at more than 50 universities in AT/CH/DE with about 150 professorships in research and teaching. At many of these universities, there are independent degree programmes in the disciplines mentioned (and beyond), whose graduates find work in the landscape of relevant commercial enterprises, public authorities, and science. The proportion of students from other European and international countries is growing steadily; when they return to their home countries, they become part of a sometimes global network. However, the number of students is currently declining, partly due to the diminished image of plastics as a material because of the unresolved waste problem.

The authors don't have respective figures for all countries in Europe but estimate that the abovementioned numbers stand for almost 40% of European scientific capacities in macromolecular chemistry and plastics engineering.

Non-university Research

Closely linked to the universities are the institutes and working groups of national science foundations, scientific societies, etc. like Christian Doppler Gesellschaft in Austria, Centre National de la Recherche Scientifique (CNRS) in France, Max Planck Society or Fraunhofer Society in Germany, or the Netherlands Organisation for Applied Scientific Research (TNO). Depending on the character of the respective organisation, they are engaged in basic or applied research. In most cases, they are linked to the plastics industry through projects or committee memberships. Of particular importance in the context of this book is the Fraunhofer Cluster of Excellence "Circular Plastics Economy" (FhG 2024), which as a virtual institute (out of 6 real institutes) deals with questions of the plastics circular economy (cf. Back matter). Aspects of the circular economy are now being worked on intensively in almost all plastics technology institutes in Europe.

Of course, no conclusive consideration can be made here. In summary, however, the authors note that the scientific potential available in Central Europe is (still) almost unique worldwide. It contributes significantly to the technological leadership of the plastics industry in Europe.

4.9 European Associations

The plastics industry in Europe is organised by numerous regional and national associations and similar organisations. Within the context of this book, we can only mention on the European level.

PlasticsEurope (2024) is the pan-European association of the plastics manufacturing industry. Centered in Brussels, Belgium, it has national/regional centres in Den Haag, The Netherlands; Frankfurt, Germany; London, U.K.; Madrid, Spain; Paris, France; Vienna, Austria; and Warsaw, Poland.

The European Plastics Converters Association (2024) also centered in Brussels is a European umbrella organization representing 28 national associations from across Europe and 18 sectoral organisations mostly located in Brussels, too.

EUROMAP (2024) is the European umbrella organisation of national machine builders member associations located in Austria, France, Germany, Italy, Luxembourg, Spain, Switzerland, Turkey, and the United Kingdom. Euromap is a resident of the German Plastics Machinery Association in Frankfurt, Germany. EUROMAP collects information about all associations within the plastics and rubber industry. The list with actually 289 items provided on their website should cover most of the plastics industry's associations worldwide.

Plastics Recyclers Europe (2024) also located in Brussels represents plastics recyclers in Europe. The association lists 165 member companies, 10 national member associations, 7 working groups, and 8 task forces.

4.10 Other Parts of the Plastics Ecosystem

(Chemical) trading houses and logistics companies (cf. Chap. 9) play an important role in the distribution and marketing of plastics. The large plastics producers generally concentrate on compounding and packaging a few types of their products, which they have transported to their large customers in the largest possible containers (containers, silo vehicles). They usually sell smaller containers via their distribution partners, who often also act as compounders of smaller types and specialities in terms of volume.

Other ingredients (besides plastic) of the compounds are supplied by specialists who very often exclusively run a plastics-related business: Reinforcing fibers (glass and carbon fibers), fillers ($CaCO_3$, talc, silica gel, carbon black, etc.), pigments, stabilizers, flame retardants, processing aids, and much more.

System houses support the business of PUR raw material producers in formulation, distribution, customer advisory services, etc.

In the circular economy environment, start-ups such as Cirplus (2022) or Plastship (2022), which provide their customers with improved access to recyclates, among other things, or software houses such as Simcon (2022), which offers software and services for parts and tool development and for optimising the production process, are establishing themselves.

The Ellen MacArthur Foundation is a UK charity which aims to speed up the transition to the circular economy. Since it was set up, the charity has emerged as a global thought leader, putting the circular economy on the agenda of decision-makers across business, government, and academia.

The BKV, a company run by the German plastics industry, focuses on the generation of market data, technology assessment, the promotion of the plastics recycling industry, and the treatment of the marine litter problem (BKV 2024).

The Nova Institute for Political and Ecological Innovation is a private enterprise engaged in research (desk-top research) and consultancy in the field of circular raw materials (renewable carbon) (Nova 2022).

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