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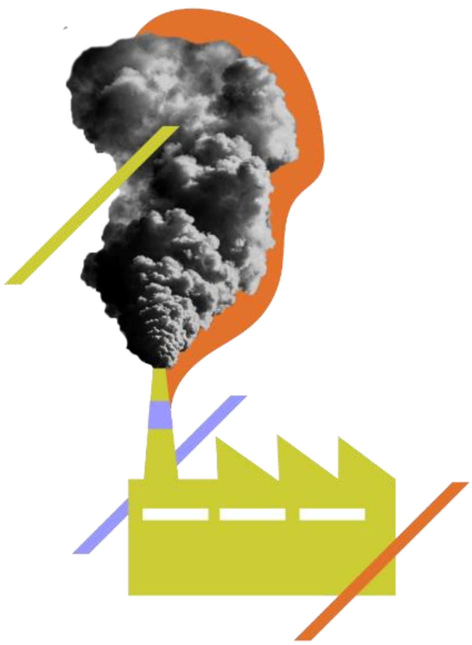
THE ITALIAN CLIMATE CHANGE THINK TANK

PLASTICS IN ITALY
A VICE OR A VIRTUE?

TECHNICAL REPORT

APRIL 2022



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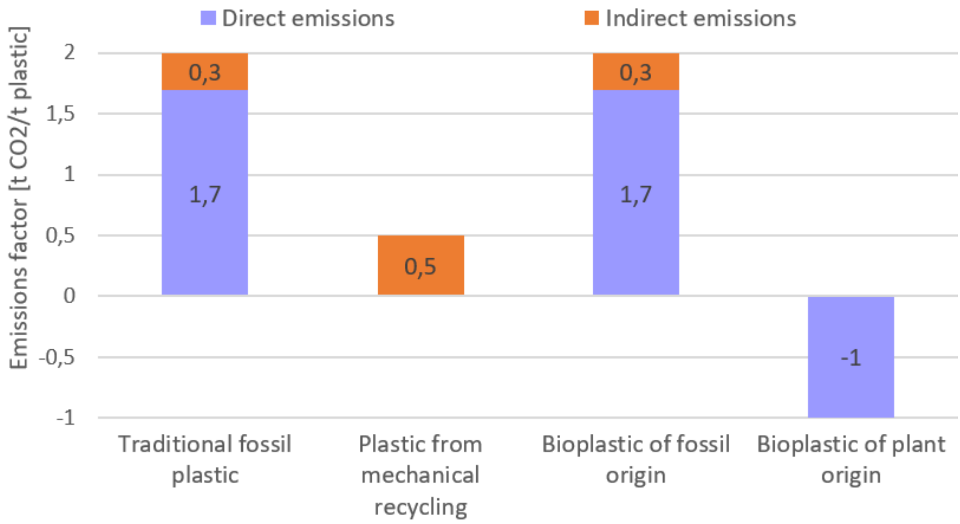
1 EXECUTIVE SUMMARY

Plastics have a wide range of properties, such as low density, low electrical conductivity and the ease with which it can be shaped into an infinite number of different objects, which has made them practically indispensable in large numbers of different applications. **Italy is the second largest consumer of plastics in Europe.** It consumed 5.9 million tons of fossil-based polymers in 2020, almost 100 kg per person[1]. Forty two percent of the plastics consumed in Italy are used in the packaging sector, in which the products have a short lifespan and almost always become waste.

In Europe **99% of virgin plastics are produced from the raw materials oil and natural gas[2] and fossil fuels are also used to generate the heat needed during the production process.** This results in the emission of approximately 1.2 kg of CO_2 into the atmosphere for every kg of plastic[3] produced during the production stage alone. If we also include CO_2 emissions generated by the extraction and refining of the fossil fuels, then **the production of 1 kg of plastic results in total direct emissions of CO_2[4] of 1.7 kg** (Figure 1).

Mechanical recycling of plastics generates no direct emissions, while the indirect emissions are around 0.5 kg of CO_2 per kg of plastic[5]. These indirect emissions can be reduced by using renewable sources for the power generation. The emissions generated by bioplastics depend on the raw materials used in their production. If raw materials of fossil origin are used then the emissions from bioplastics are the same as those for ordinary plastics. If they are of plant origin, then a negative emission factor is estimated of about 1 kg of CO_2 per kg of bioplastics removed from the atmosphere during the growth of the biomass.

***Figure 1** - Emission factors for virgin fossil-based plastics, recycled plastics, fossil origin bioplastics and bio-based plastics. No data on indirect emissions from bio-based plastics was found in the literature.*



[1] "Plastics – the Facts 2020", *Plastics Europe*.
[2] Spekreijse, J; Lammens, T; Parisi, C; Ronzon, T; Vis, M; "Insights into the European market for bio-based chemicals", *JRC*, 2019.
[3] "Breakthrough Strategies for Climate-Neutral Industry in Europe", *Agora Energiewende*, April 2021.
[4] "Breakthrough Strategies for Climate-Neutral Industry in Europe", *Agora Energiewende*, April 2021.
[5] "Industrial Transformation 2050", *Material Economics*, 2019.

As is known, the European Union has set ambitious targets for reducing climate-changing gas emissions with the 2030 Climate and 2050 Climate Neutrality Law[6]. Even if we consider emissions upstream from the plastics manufacturing process with the extraction and refinement of crude oil together with emissions downstream when polymers are processed, the production of plastics cannot be considered compatible with climate targets, due above all to the pace of current production and consumption.

These models of production and consumption have also led to exponential growth in pollution in many marine and terrestrial ecosystems. As decarbonisation has progressed, **the need to implement concrete global measures against pollution from plastics has become increasingly more urgent in recent years.** Eleven million tons of plastic end up in the sea each year and this figure is forecast to double by 2030 and almost triple by 2040[7]. Agreement was reached at the last edition of the United Nations Environment Assembly, held on 2nd March in Nairobi, on a resolution aimed at putting an end to plastic pollution by addressing the entire life cycle of this material from production through to consumption and final disposal. The Nairobi Agreement involves setting up an Intergovernmental Negotiating Committee (INC) to develop a legally binding international instrument on plastic pollution by 2024. Such an ambitious roadmap reflects the understanding reached by the countries that took part in the assembly of the urgent need to make progress on such a critical issue.

The environmental issues involved in the production and consumption of plastics are therefore manifold. Its high level of dispersion and low degradability have prompted the European Union to include plastics among the materials to be prioritised in its Circular Economy Action Plan[8]. In this context, the Circular Economy Plastics Strategy[9], adopted in January 2018, was drawn up. It states that all plastic packaging placed on the European market should be reusable or recyclable "*in a cost-effective way*" by 2030.

The European Union has also introduced a plastic tax of €0.8 per kg[10] on the non-recycled plastic packaging waste produced in each Member State. The cost for Italy should be around €900 million per year and these taxes go into the European budget to then be used to fund recovery plans. **The €900 million contribution that Italy must pay to the European Union will be drawn from the country's national budget, if it is not raised by the national plastic tax.** The Italian plastic tax was introduced in the 2020 Budget Law[11] and should have come into force in the summer of 2020, but was then postponed until January 2021, July 2021, January 2022 and yet again until January 2023. **The Italian plastic tax is levied on the consumption of**

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0080&from=IT
[7] "UNEP head responds to questions on global plastics agreement", *UNEP*, 25th February 2022.
[8] "Closing the loop – An EU action plan for the circular economy" https://eur-lex.europa.eu/legal-content/EN-IT/TXT/?from=IT&uri=CELEX%3A52015DC0614 , European Commission, 2nd December 2015.
[9] "European strategy for plastics in the circular economy" https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0028&from=SK , European Commission, 16th January 2018.
[10] "COUNCIL REGULATION on the calculation of the own resource based on plastic packaging waste that is not recycled, on the methods and procedure for making available that own resource, on the measures to meet cash requirements, and on certain aspects of the own resource based on gross national income" https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CONSIL:ST_13142_2020_INIT&from=IT Council of the European Union, 16th December 2020.
[11] Law No. 160 of 27th December 2019 – State budget forecast for the financial year 2020 and long-term budget for the three-year period 2020-2022.

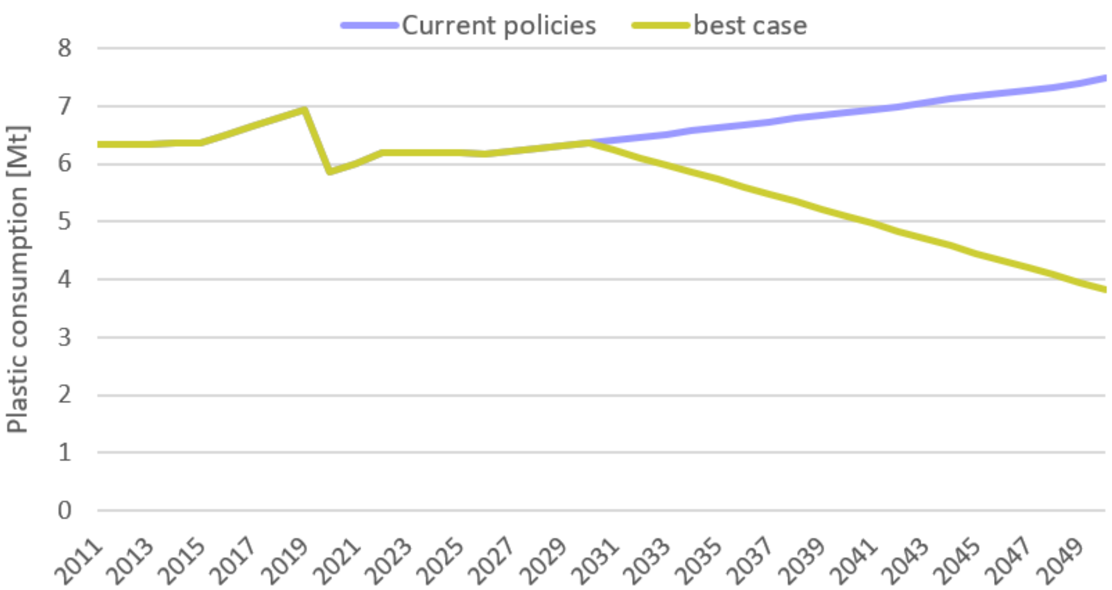
Single-Use Plastic Products (SUPPs) and is €0.45 per kg of plastic material contained in SUPPs. Plastic taxes are levied along the whole value added supply chain of the plastics industry. The delay in introducing a national plastic tax means that the relative cost associated with the plastics industry (the European plastic tax revenue raised) continues to be paid with public funds from the national budget, with no incentive for this industry to transition towards a more circular economy.

The plastic problem therefore has many sides to it and as such there is no one single answer to it, nor is it simple. It requires a complex strategy, able to address the problems of decarbonisation and pollution in a unified manner with the use of synergies. More specifically, the evidence that emerges from this report identifies three "key objectives" around which a policy framework can be built to help meet climate neutrality goals and at the same time address the problem of plastic pollution in terms of the costs and the timeframe of the effects:

1. **A reduction in plastic consumption,** especially in the packaging, construction and automotive sectors, the main consumers of plastics in Italy;
2. **An increase in recycling and reuse rates,** which will reduce emissions and imports of CO_2 intensive materials. Increasing recycling rates also reduces emissions compared with treating plastic waste by incineration;
3. **The use of bioplastics.** Plastics made from plant-based raw materials are one potential solution to environmental problems for those uses where existing alternatives do not resolve them.

Two scenarios for 2050 have been constructed (*current policies* and *best case*) for the consumption of plastics in Italy and the CO_2 equivalent emissions from that consumption. The hypothesis in the 2050 *current policies* scenario is that plastic consumption will increase by 5% every six years, as observed from 2011 to 2017 (Figure 2). On the other hand, in the 2050 *best case* scenario it is assumed that the elimination of overpackaging and a reduction in consumption of single-use plastic packaging together with plastic in other sectors will succeed in reversing the growth trend in consumption to reach 3.8 million tons in 2050.

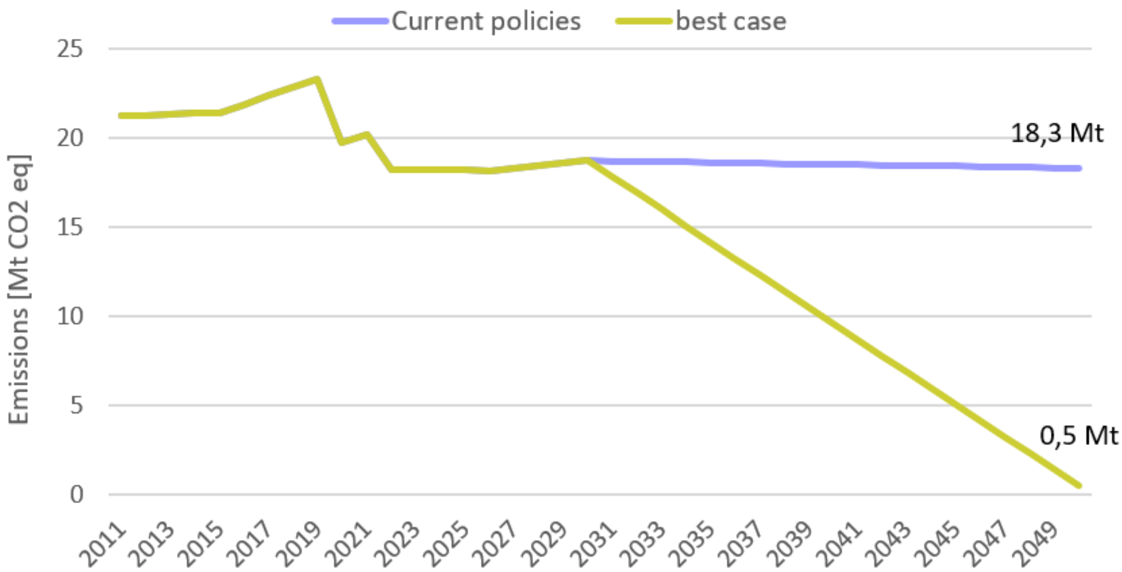
Figure 2 - Trend for plastic consumption in Italy from 2011 to 2050 in the two scenarios.



The emissions associated with this plastic consumption were then calculated. The plastics consumed are considered rather than the plastics produced because Italy is a large consumer of plastic, but a small producer of polymers. The assumptions made in the 2050 *current policies* scenario are that more than half the plastic sold on the Italian market is fossil-based plastic and the remainder is either recycled or bio-based material. With regard to end-of-life, it is hypothesised that 70% of post-consumer plastic waste is recycled, while the remainder is destined for waste-to-energy or industrial composting use. This scenario shows a 9% reduction in emissions compared with 2020 (Figure 3).

The hypothesis for the 2050 *best case* scenario is that no fossil-based plastics are sold on the Italian market, but only those produced from recycled material and bio-based plastics. If European appeals to eliminate landfill disposal and reduce CO_2 emissions from incineration are heeded, it is hypothesised that over 90% of plastic waste will be recycled due to substantial improvements in the collection, sorting and recycling of plastic. In this scenario a 98% reduction in emissions is achieved compared with 2020 (Figure 3).

Figure 3 - Trend for CO_2 equivalent emissions from plastic consumption in Italy in the two scenarios.



The 2050 *best case* scenario is very ambitious. A number of policy instruments need to be deployed to achieve these results. They must above all reverse the growth trend for consumption and at the same time allow recycled and bio-based plastics to occupy larger segments of the market.

The deposit return system, for example, is an effective tool for increasing packaging reuse and recycling rates. In countries where this recycling system is compulsory by law, beverage container collection rates of up to 94% are achieved. A deposit return system would appreciably reduce environmental pollution in Italy and allow it to pursue the ambitious European targets for collection, recycling and the decarbonisation of the sector. The 2021 *Simplifications bis* Decree[12] contains a specific regulation that introduces deposit return systems for plastic beverage containers. While Lithuania, Denmark, Finland, Norway, the Netherlands and Germany have achieved container collection rates of over 90%, Italy is still waiting for the

[12] Decree Law No. 77/2021 – NRRP governance and simplifications

implementing decree to be issued so that the deposit return system can actually come into operation.

The introduction of regulatory instruments to encourage the transition from single-use to reusable products also plays a decisive role in the policies adopted or being adopted in several European countries. These instruments could also be included in the mix of national measures, to make sure that instruments designed to combat single-use plastics do not leave the disposable model intact. If the French legislation were taken as an example, Italy could also introduce a 5% reuse target for all types of packaging sold by 2023 and a 10% target for 2027. This target can then be gradually increased in subsequent years.

Action can be taken upstream in the production chain to improve the quality of recycled plastics and reduce the demand for virgin plastic. This would involve eco-designed products aimed at simplifying the composition of products and also product disassembly into uniform components in terms of the constituent polymer. These strategies can improve the mechanical recycling of many plastic products, thereby raising recycling rates and producing higher quality secondary products.

Action must also be taken on the demand side to maintain the competitiveness of Italian industry, protect employment and ensure that companies move their activities in directions that are compatible with long-term climate neutrality targets. This means creating a market and demand for secondary raw materials and bio-based plastics, for example by introducing special specifications in public tender contracts.

This report has been prepared in collaboration with Cluster Spring, Greenpeace and the Universities of Padua and Palermo.

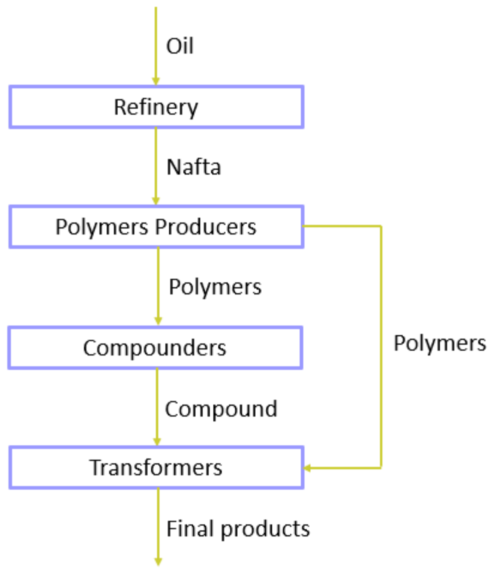
2 THE PLASTICS SUPPLY CHAIN IN ITALY

Francesco Paolo La Mantia, *Lecturer at the University of Palermo, INSTM*

The term plastic refers to a wide range of polymeric materials, consisting of long chains of carbon and hydrogen in which other elements may also be present that result in numerous materials with different properties. A distinguishing feature of plastics is their wide range of properties, such as low density, low electrical and thermal conductivity, the ease with which they can be shaped into an infinite number of different objects and their strength and flexibility which has made them practically indispensable in large numbers of different industries. They are used in countless applications: to manufacture insulation for electrical cables and films for agriculture (polyethylene - PE), mats and dashboards for cars (polypropylene - PP), bottles and food containers (polyethylene terephthalate - PET), textiles and pipes for construction (polyvinyl chloride - PVC), plastic cutlery and plates (polystyrene - PS), packaging and insulation for buildings (expanded polystyrene - EPS), synthetic fibres and textiles (polyamides - PA), mattresses and padding for furniture and cars (polyurethanes - PU).

In Europe **99% of virgin plastics are produced using fossil-based raw materials**[13] such as naphtha, a product of oil distillation (Figure 4). The naphtha undergoes steam cracking, which involves heating the hydrocarbon feedstock to high temperatures. Heat and steam are used to break down the naphtha molecules into simple molecules, called monomers. Next, polymerisation occurs, a chemical reaction in which the monomers join together to form polymers. Additives and dyes are then added to give the polymers the desired properties. What are known as "compounds" are produced in this way, and the companies that do this are called "compounders". The resulting paste is then transformed into granules and powders, which undergo further processing, depending on the type of plastic material and object to be created.

Figure 4 - Schematic diagram of the plastic production process.



[13] Spekreijse, J; Lammens, T; Parisi, C; Ronzon, T; Vis, M; "[Insights into the European market for bio-based chemicals](#)", *JRC*, 2019.

In 2020, 1.9 million tons of fossil-based polymers were produced in Italy, mainly polyolefins, such as polyethylene (PE) and polypropylene (PP), but also polystyrene (PS) and polyamides (PA) (Table 1). The production of polyethylene terephthalate (PET) and polyvinyl chloride (PVC) was very modest, close to zero. Pure polymer production is not enough to meet domestic demand, with less than around 50 polymer manufacturers in operation, which employ a total of approximately 7,000 people.

***Table 1** – Key figures for fossil-based polymer production in Italy in 2020. The data reported below relates to fossil-based polymers only and not to manufactured products made of fossil polymers.*

	Polymers from fossil sources
Production [Mt][14]	1.9
Imports [Mt][15]	7.4
Exports [Mt]	3.1
Consumption [Mt]	5.9
Per capita consumption [kg per person]	98.6
Manufacturers	50 approx.
Employees	7,000 approx.
Turnover [€ billion]	8

Italy has many "compounders", companies that buy polymers and additives to then mix them to produce polymer compounds for specific uses. Compounders, do not therefore produce manufactured goods, but "blends", filled or additivated polymers, which are then transformed into manufactured goods by processors.

The plastics processing sector is also well developed in Italy with 5.8 million tons of polymers processed in 2020. Around five thousand companies operated in this sector in 2020, employing 110 thousand people with a turnover of approximately €15 million per year[16].

The data shows that Italy has been a **large importer of polymers** for many years now. Both the compounding and processing industries are heavily dependent on imports.

Another part of the plastics industry that is very important in Italy is the manufacture of processing machines and moulds. Approximately 900 companies operate in this sector, providing employment to 14 thousand employees with a turnover of almost €4 billion in 2020. The Italian industry is a major exporter of machines and moulds and, despite Covid-19 difficulties, recorded a surplus of €2 billion in 2020.

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[14] The item "Production" is for the production of thermoplastic polymers and rubbers and it excludes thermosetting polymers, compounds and plant-based and biodegradable polymers.

[15] *AMAPLAST and Plastic Consult.*

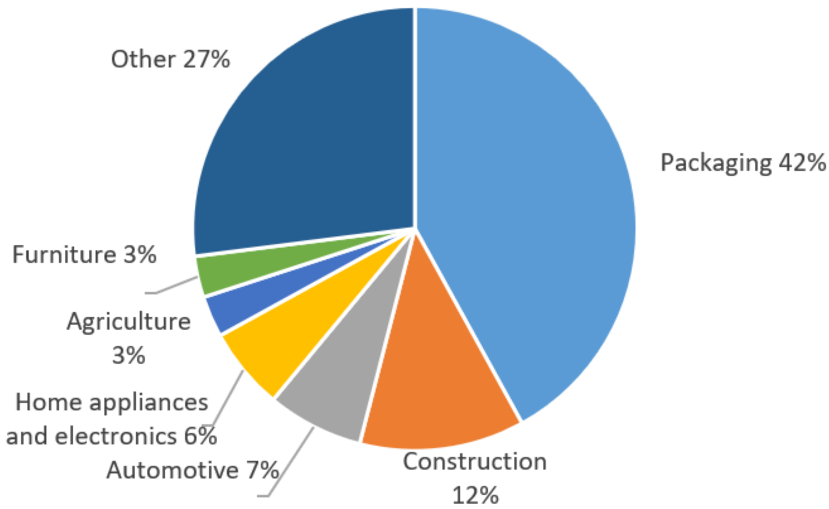
[16] The data reported is for companies that process thermoplastic polymers only. With regard to rubber, 550 thousand tons of rubber were processed in Italy in 2017. Approximately 500 companies operate in this sector which employ 25 thousand people. The data for this sector has not been added to the previous figures, because the latest available data is for 2017 and the data for turnover is not available. However, it can be stated that over 5,500 companies operate in the Italian plastics processing sector, providing direct employment to over 75 thousand people with an estimated turnover of over €20 billion.

2.1 THE SECTORS IN WHICH PLASTICS ARE USED

Francesco Paolo La Mantia, *Lecturer at the University of Palermo, INSTM*

Italy is the second largest consumer of plastics in Europe (EU 28+NO/CH): 5.9 million tons of fossil-based polymers were consumed in 2020, amounting to 98.6 kg per person[17]. The main sectors in which plastics are used are packaging (42% of plastics consumed in 2020), construction and the automotive sector (Figure 5).

Figure 5 - Sectors in which fossil-based plastics were used in Italy in 2020. The data is for 2020, but these percentages have remained fairly constant in recent years (2016 – 2020).



Packaging is a product with a short lifespan that almost always becomes waste and attempts to give it a second life by processing result, more often than not, in poor quality products. The percentage of plastics used for packaging in Italy is similar to that for other European countries (Figure 6).

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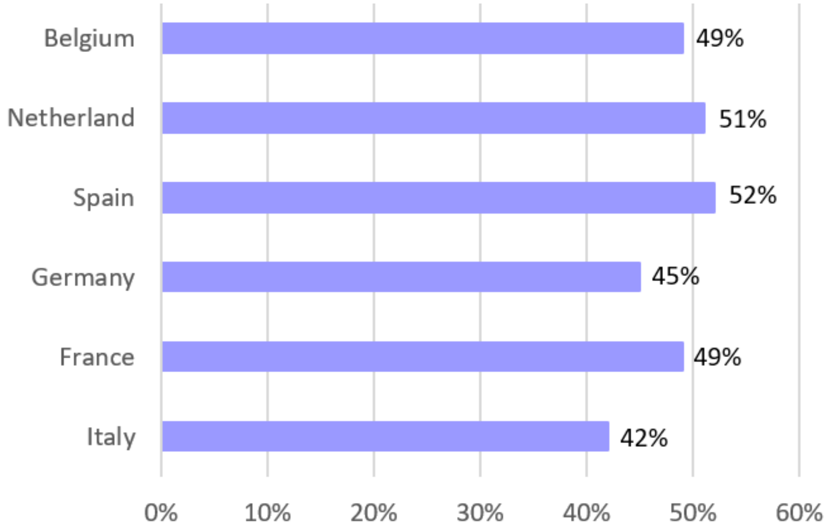
[17] "Plastics – the Facts 2021", *Plastics Europe.*

Figure 6 - Percentage of plastics used in the packaging sector in different European countries[18].



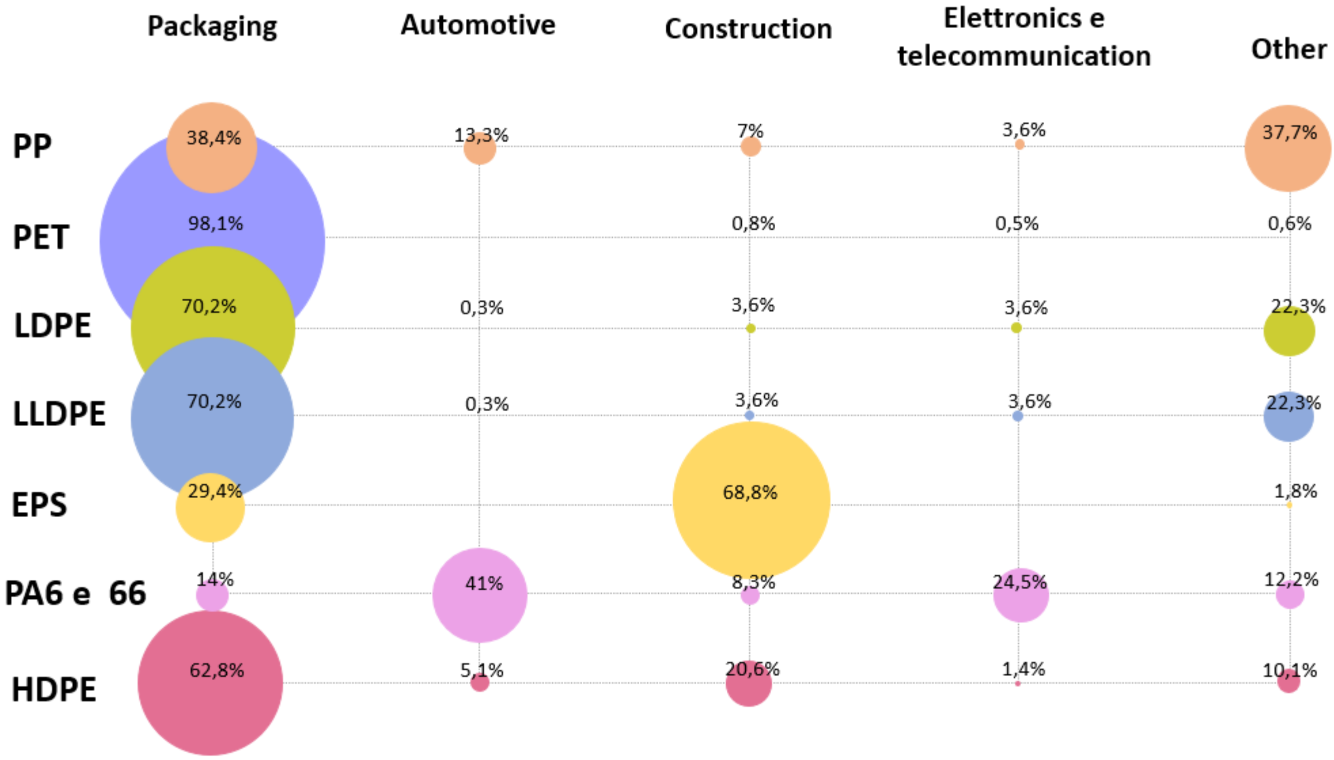
The plastics with the highest consumption in Italy are polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), both ordinary and expanded (EPS), and polyamides (PA, including PA66, or nylon) (Table 2).

***Table 2** – Final consumption of the most widespread polymers in Italy in 2020.*

Type of polymer	Consumption [kt]	Uses
Polyethylene (PE)	1,960	Electrical cables, agricultural film, plastic bags and pouches, containers, piping, inner layer of aseptic containers for liquid foods
Polypropylene (PP)	1,580	Doormats, colanders, car dashboards and bumpers, plastic bottle caps and labels, hail nets, CD cases, coffee capsules, plastic coffee cups, etc.
Polyethylene terephthalate (PET)	680	Bottles, films, tubes, containers, labels, food containers, clothes, sails, ropes
Polyvinyl chloride (PVC)	590	Textile coatings, surfaces, tanks, valves, taps, bathtubs, textile fibres, piping for buildings, electrical cables, profiles for windows, vinyl flooring, packaging films
Polystyrene (PS) and Expanded Polystyrene (EPS)	390	Plastic cutlery and plates, egg cartons, yoghurt pots, CD containers, plate holders, Petri dishes, test tubes and microplates, transparent sheets, packaging, building insulation
Polyamides (PA)	115	Fibres, adhesives, sealants, nylon
Other	554	

[18] *Kunststoffe Cluster*

Figure 7 - Most commonly used plastics by sector.



BOX 1 - THE HISTORY OF THE ITALIAN PLASTICS INDUSTRY

The plastics industry started in 1861, when Alexander Parkers developed the first semi-synthetic plastic, Parkesine. In 1888 the company Montecatini – Società Generale per l'industria Mineraria e Chimica (general mining and chemical industry company) was founded in Florence and over the years, it grew and started operating in various chemical sectors, including synthetic fibres and plastics.

In the early decades of the 20th century, many plastics were developed, such as PVC and cellophane, and studies on the structure and properties of polymers began. In 1914 the Solvay plant at Rosignano Marittimo (Livorno) was opened. Then in the 1930s the modern plastics industry was born, based on the use of oil as a raw material. The Italian company SIR, Società Italiana Resine, was founded in Milan in 1931. It was the first company to start producing moulding powders and polymer-based resins.

After the war, substantial investments were made in the refining sector and by 1950 twenty two refineries were operating in Italy, with a total processing capacity of seven million tons[19]. These years witnessed a real boom in the plastics industry and SIR was considered a major player in the European chemical industry. In 1953, *ENI*, the *Ente Nazionale Idrocarburi* (national hydrocarbons entity), was created. Its operations were not limited to the extraction of hydrocarbons only, but also expanded into the petrochemical sector.

In 1963 Giulio Natta, an Italian engineer and academic, received the Nobel Prize for his discoveries in the field of chemistry and polymer technology. Thanks to an economic boom

[19] Marco D'Aloisi; "Cinquant'anni di raffinazione italiana", *RIENERGIA*, 28th July 2020.

and an increase in consumption in this period, national refining capacity reached over 180 million tons per year, distributed over 38 plants and accounting for 30% of European refining capacity. In 1966 Montecatini merged into Edison and the Montedison Group was born. The *RadiciGroup* started up polymer and synthetic fibre production.

In the 1970s, the first PET bottle was patented by the chemist Nathaniel Wyeth. Oil prices rose after the 1973 energy crisis and some refineries started to close. In this period the *RadiciGroup* started up *Radici Novacips*, a plastics manufacturing plant, and *Radici Chimica*, which produced engineering plastics. Law No. 784[20] of 1980 established a duopoly in the petrochemical industry consisting of the public sector, managed by *ENI*, and the private sector, managed by *Montedison*. *ENI* founded its *EniChem* division and created several subsidiaries, including *EniChem ANIC* (petrochemicals and primary chemicals), *EniChem Elastomers, EniChem Fibre* (engineering fibres and intermediates for plastics) and *EniChem Polymers*. In 1988, *ENI* and *Montedison* joined forces in the *Enimont joint venture*, to create an alliance between public and private sector chemicals.

In the 1990s, 18 refineries remained active in Italy, producing around 100 million tons per year[21]. *Montedison* sold all its chemical operations to *EniChem*, *Solvay* and *Shell*. The latter merged with *Basf* and together they formed *Basell*. In 2012, *ENI*'s elastomer and styrene production operations were merged into *Versalis*. In 2019, refinery production in Italy was 77.6 million tons, 7% of which was naphtha (5.2 Mt)[22].

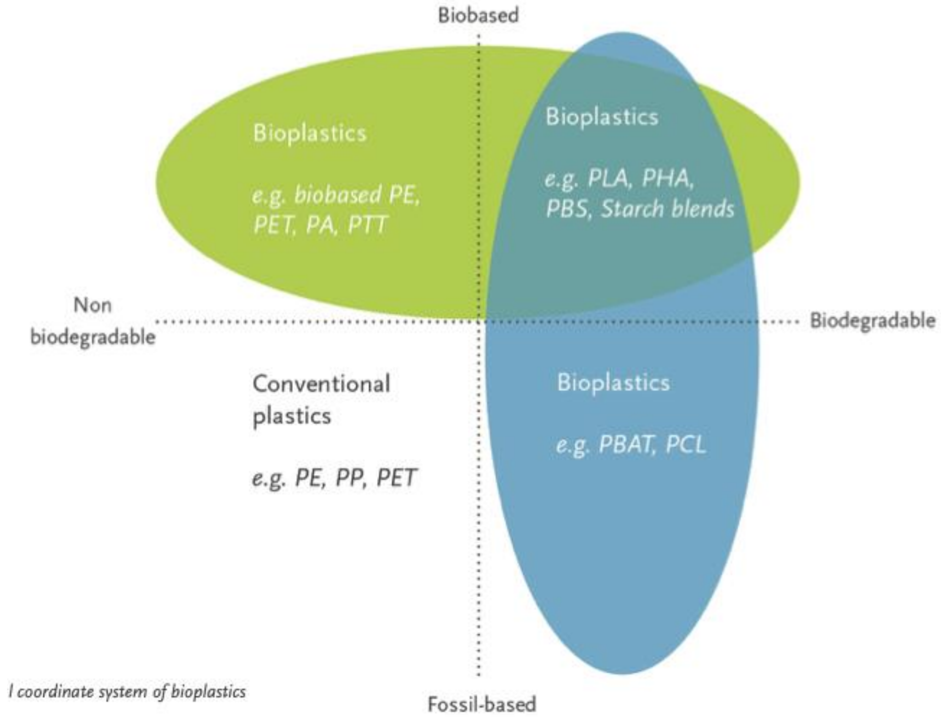
2.2 THE BIOPLASTICS SUPPLY CHAIN IN ITALY

Francesco Paolo La Mantia, *Lecturer at the University of Palermo, INSTM*
Cluster SPRING, *Italian Circular Bioeconomy Cluster*

According to the European definition, a bioplastic is a plastic which is either made from plant-based raw materials (termed "bio-based") or is biodegradable and compostable or alternatively possesses both properties (bio-based and biodegradable and compostable) (Figure 8). On the other hand, the Italian definition used by *Assobioplastiche* considers only biodegradable and compostable plastics as bioplastics, whether they are of a plant or fossil nature. As we will see below, this is because biodegradability does not depend solely on its plant or fossil origin. In other words, fossil-based plastics can be biodegradable and compostable, plant-based plastics can be non-biodegradable or a "blend" of plant and fossil origin can be found in the same product. This report uses the European definition of bioplastics.

[20] Law No. 784 of 28th November 1980.
[21] Marco D'Aloisi; "Cinquant'anni di raffinazione italiana", *RIENERGIA*, 28th July 2020.
[22] "La produzione delle raffinerie", UNEM.

Figure 8 - System of co-ordinates proposed by European Bioplastics to define the different types of plastics. The chart illustrates how the definition of bioplastics encompasses bio-based and biodegradable plastics (quadrant I), bio-based and non-biodegradable plastics (quadrant II) and biodegradable fossil plastics.



Plant-based plastics are made from plant raw materials such as maize, sugar cane and cellulose. Some polymers can be composed of monomers obtained from both biomass (bio-based) and fossil sources. In this case a polymer is said to be partially bio-based and its bio-based percentage is calculated as the ratio of the amount of plant-based monomers to the total weight of the monomers used to polymerise the polymer. From a market analysis viewpoint, no effective distinction exists to distinguish 100% bio-based products from fossil-based bioplastics and from fossil/plant-based blends. However, they are normally distinguished on the basis of their end-of-life destiny (biodegradable and compostable or not).

Biodegradable plastics, on the other hand, are materials that can biodegrade, a process by which microorganisms break down the chemical bonds of the molecules by using specific enzymes which transform these molecules into carbon dioxide (CO_2) and water. The biodegradation processes depend on the surrounding environmental conditions, the biodegradation time and the material.

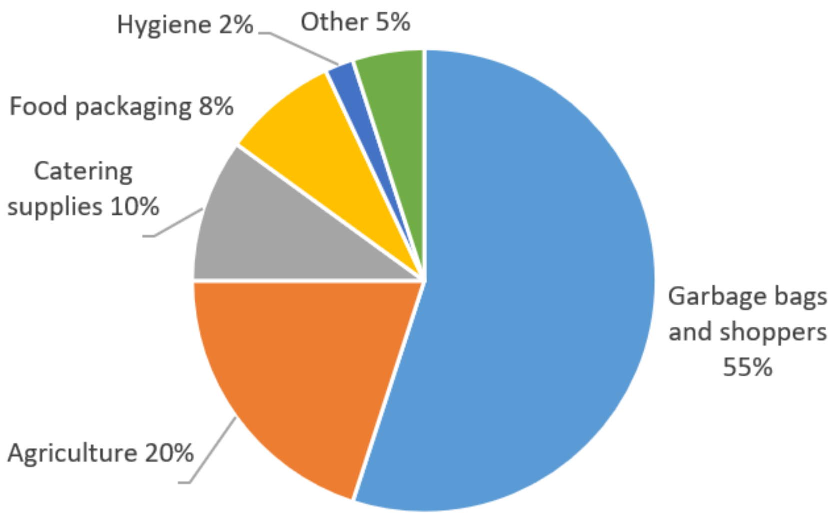
The biodegradability of plastics and their bio-based origin are therefore two very different concepts. It is possible for 100% plant-based materials to be non-biodegradable and for fossil-based materials to be biodegradable. This fact is particularly important for CO_2 emissions because, as we will see later, biodegradable plastics of fossil origin generate emissions of 1.7 kg of CO_2 per kg of plastic. Then a further 3.1 kg of CO_2 per kg of plastic is added if the plastic waste is burnt. **Most of the compostable bioplastics on the market are at least partially plant-based and continuous research and innovation in the sector is progressively increasing the percentage of biomass.** One hundred percent bio-based plastics can significantly reduce greenhouse gas emissions from the plastics supply chain because they are produced without the use of fossil-based raw materials.

Bioplastics currently account for less than 1% of the 367 million tons of plastics produced worldwide[23]. Nevertheless, while global production of plastics is decreasing slightly, the market for bioplastics is growing continuously. This trend is caused by growing demand for these materials combined with the emergence of new bioplastic products.

In 2020, 111 thousand tons of biodegradable and compostable polymers (fossil-based and plant-based) were produced in Italy by 280 companies with almost three thousand employees[24]. This is a sector that has grown considerably over the years to reach a turnover of €815 million in 2020. Aside from the absolute numbers, which are certainly still very low, it is underlined that the sector is growing at an extremely fast pace, while no growth has been recorded for fossil-based polymers. The growth rate in Italy for the production of biodegradable and compostable bioplastics was higher than 180% in 2012 and over 9% last year. This market growth has been supported by a number of legislative measures, especially by those requiring the use of compostable bags for organic waste collection.

The most important fields of application for these polymers are the production of waste bags for collecting the organic fraction of waste, plastic shopping bags and use in agriculture (Figure 9).

Figure 9 - Sectors in which biodegradable plastics are used in Italy.



Compostability has advantages, especially when bioplastic products are treated together with organic waste. The use of a compostable bag, for example, is an advantage because both organic waste and the bag containing it can be treated together in the same way when they are both sent to composting plants. Nevertheless, if waste collection and treatment are to be effective, the entire organic waste treatment process must employ a high quality approach, with no large-scale presence of unwanted materials, starting with conventional plastics.

The entire sector must know how to recognise and manage bioplastics. Bioplastic bags risk being separated as waste material and sent to incinerators or landfills because of the way in which the composting and anaerobic digestion plants, which collect the organic fraction of

[23] "Bioplastic market data", European Bioplastics.
[24] Plastic Consult, 2020, *La filiera dei polimeri compostabili*

waste, are designed. Various studies have shown that, because composting plants are industrial plants in which is difficult to control timing and temperature (as required by the 2002 UNI 13432[25] standard), there is a risk that bioplastics do not behave well and fail to reach the required final size. It will then be necessary to launch awareness campaigns so that the general public is able to recognise different types of material and put them in the right collection and recycling systems.

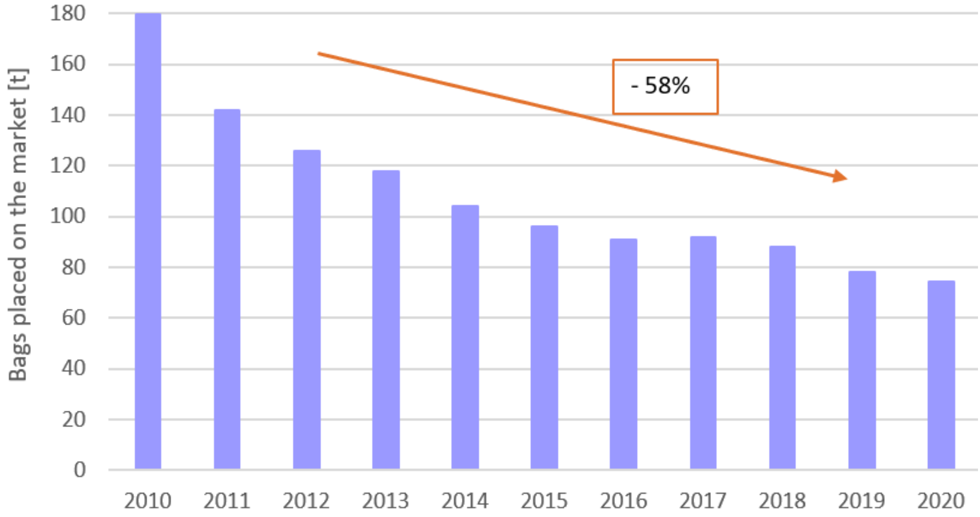
BOX 2 – THE ITALIAN LAW ON PLASTIC SHOPPING BAGS

Francesco Paolo La Mantia, *Lecturer at the University of Palermo, INSTM*

Italy has a special position in Europe for the use of compostable bioplastics. The use of compostable bags, combined with its organic waste treatment sector and a law banning the use of conventional plastic shopping bags[26], is probably one of the factors that have enabled Italy to take a leading position in the recycling of food waste compared with the European average (47% compared with a European average of 16%).

The Italian law on plastic shopping bags came into force on 1st January 2011. It bans the use of conventional plastic shopping bags, which must be replaced by biodegradable bags. This law has not only helped change the polymer that is normally used for the production of these bags (polyethylene PE) to biodegradable polymers but has also led to a decrease in the overall consumption of these bags. No one-to-one replacement of conventional plastic shopping bags with bioplastic bags occurred after law came into force, but on the contrary, as shown in Figure 10, plastic shopping bag consumption fell from almost 180 tons in 2010 to 74.5 tons in 2020. The effect of the law was therefore very positive, because the consumption of plastic shopping bags fell by 60% over 10 years.

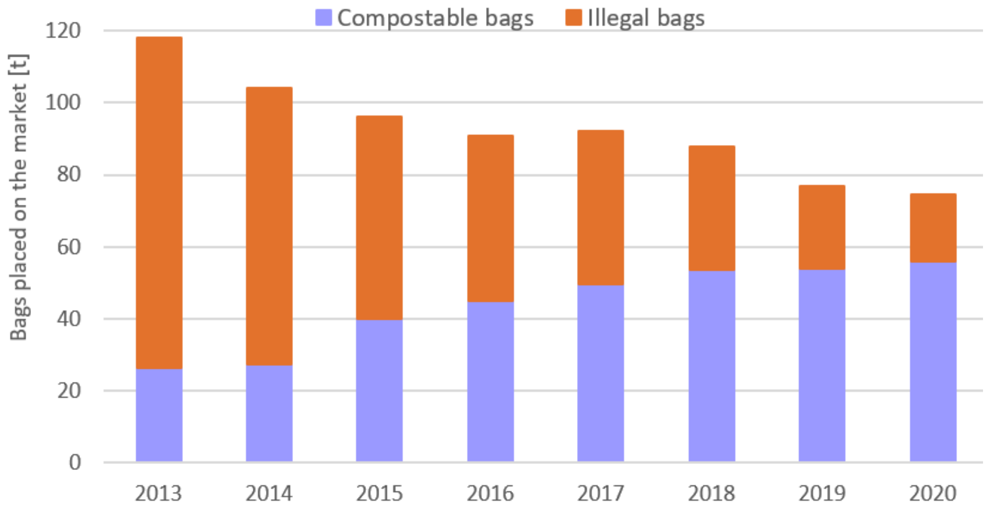
Figure 10 - Market trend for plastic shopping bags in Italy from 2010 to 2020. The consumption of plastic shopping bags fell by 58% in this period.



[25] UNI EN 13432:2002 – Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging
[26] Law No. 296 of 27th December 2006, 2007 Finance Act 2007

However, a black market trade in non-standard polyethylene bags also started up. Figure 11 shows the Italian market for legal (biodegradable and compostable) and illegal plastic shopping bags. Although the trend is positive, given the growth in the market for standard-compliant plastic shopping bags, almost 20% of these bags were still illegal in 2020.

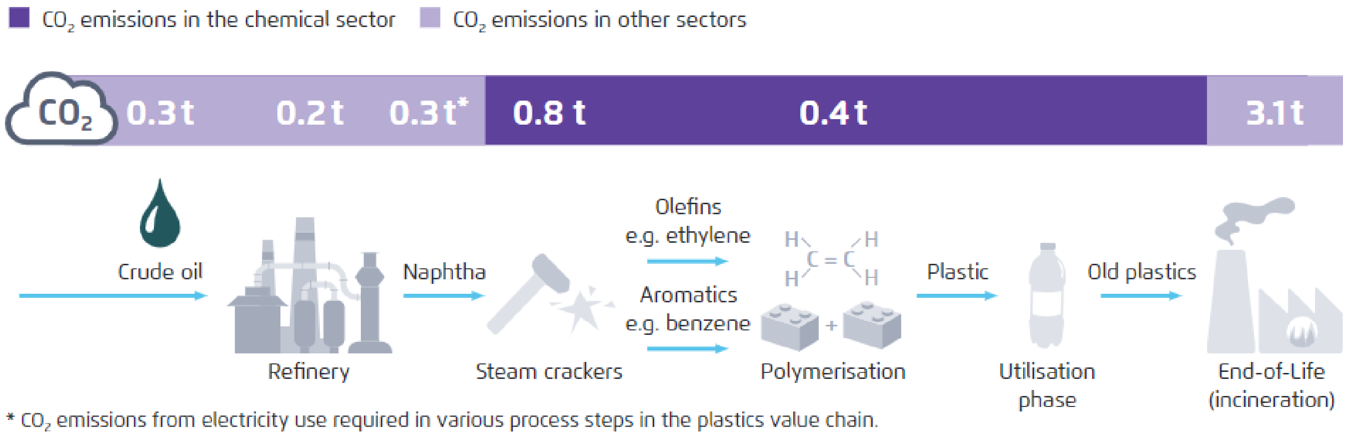
Figure 11 - Market trend in Italy for plastic shopping bags from 2013 to 2020, showing figures for compostable and non-compostable bags.



3 PLASTICS AND CLIMATE CHANGE - THE POSITION IN 2022

In Europe **99% of virgin plastics are produced from the raw materials oil and natural gas**[27] and fossil fuels are also used to generate the heat needed during the production process. This results in the emission of approximately 1.2 tons of CO_2 into the atmosphere for every ton of plastic[28] produced during the production stage alone (Figure 12). If we also include CO_2 emissions generated by the extraction and refining of the fossil fuels, then the production of 1 ton of plastic results in total direct CO_2 emissions of 1.7 tons.

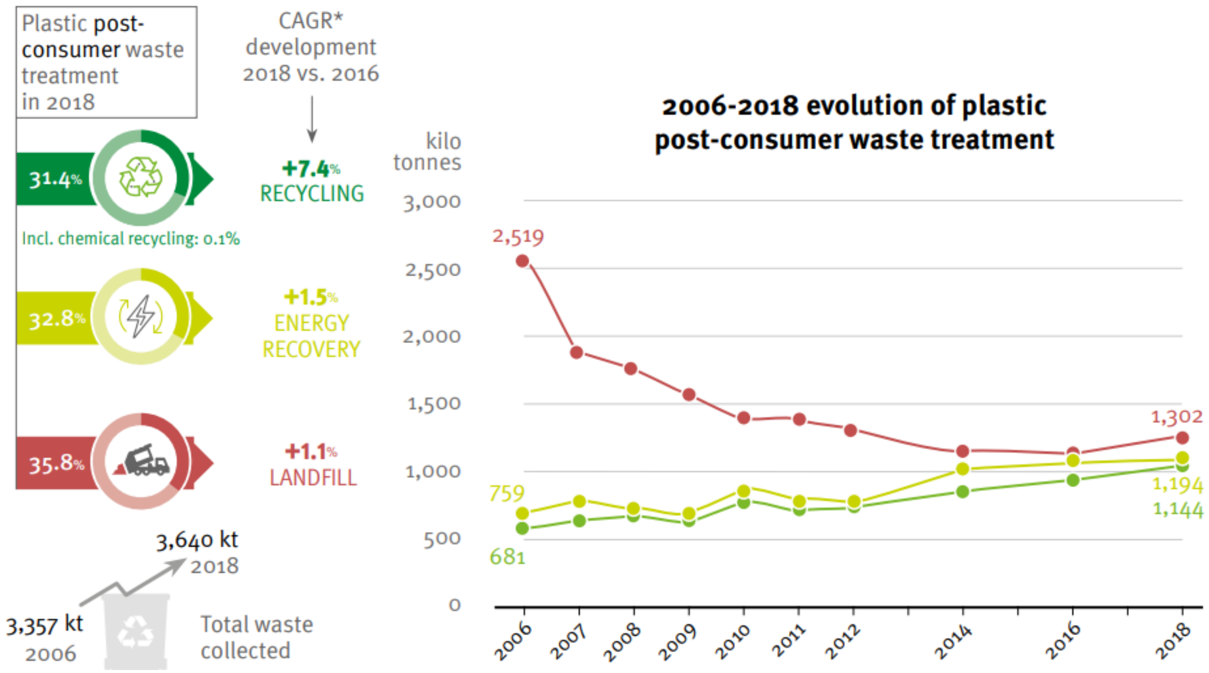
Figure 12 - Stages in the process for the production, use and disposal of plastic with the relative CO_2 emissions[29].



Plastic waste is collected for disposal after its use. In 2018, 3.6 Mt of plastic waste was collected in Italy, of which 31.4 Mt was recycled, 35.8% was sent to landfill, while the remaining 32.8% was used for energy recovery (Figure 13)[30]. In the latter case, approximately 3.1 tons of CO_2 are released into the atmosphere for every ton of plastic waste treated[31]. Although electricity and heat are generated in the process, which at least in part replaces the use of fossil fuels in the energy sector, preference should be given to recycling processes in order to establish a true and genuine circular carbon economy, which closes the carbon cycle.

[27] Spekreijse, J; Lammens, T; Parisi, C; Ronzon, T; Vis, M; "Insights into the European market for bio-based chemicals", *JRC*, 2019.
[28] "Breakthrough Strategies for Climate-Neutral Industry in Europe", *Agora Energiewende*, April 2021.
[29] "Breakthrough Strategies for Climate-Neutral Industry in Europe", *Agora Energiewende*, April 2021.
[30] "Plastics – the Facts 2020", PlasticsEurope.
[31] "Breakthrough Strategies for Climate-Neutral Industry in Europe", *Agora Energiewende*, April 2021.

Figure 13 - Changes in plastic waste disposal processes in Italy from 2006 to 2018[32].



Mechanical recycling of plastics generates no direct emissions, while the indirect emissions are around 0.5 tons of CO_2 per ton of plastic[33]. These indirect emissions can be reduced by using renewable sources for the power generation, instead of fossil hydrocarbons.

The emissions generated by bioplastics depend on the raw materials used in their production. If raw materials of fossil origin are used then the emissions from bioplastics are the same as those for ordinary plastics. If they are of plant origin, then 0.4 tons of direct CO_2 emissions from the polymerisation process are generated per ton of plastic[34]. However, CO_2 is also removed from the atmosphere during the growth of the biomass, which depends on the type of plants used and the bioplastic produced. This is generally assumed to be around 1.4 tons of CO_2 per ton of bioplastic[35]. As a consequence net negative direct emissions of about 1 ton of CO_2 per ton of bioplastic are generated. No data on indirect emissions from bio-based plastics was found in the literature.

Figure 14 compares direct and indirect emission factors for virgin fossil plastics, recycled plastics, fossil-based bioplastics and plant-based bioplastics.

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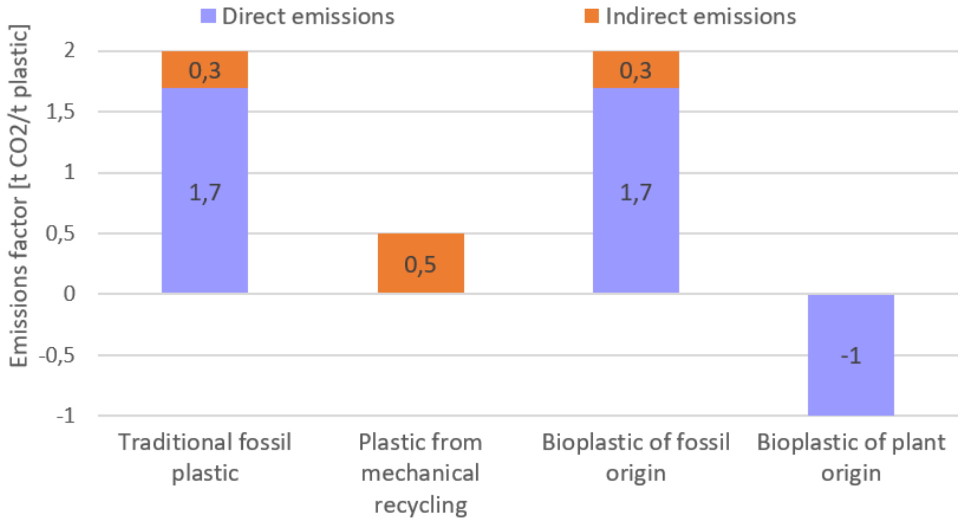
[32] "Plastics – the Facts 2020", *PlasticsEurope*.
[33] "Industrial Transformation 2050", *Material Economics*, 2019.
[34] "Breakthrough Strategies for Climate-Neutral Industry in Europe", *Agora Energiewende*, April 2021.
[35] Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B., 2016. The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, [online] 21(9), pp.1218–1230.

Figure 14 - Emission factors for virgin fossil-based plastics, recycled plastics, fossil origin bioplastics and bio-based plastics. No data on indirect emissions from bio-based plastics was found in the literature.



3.1 THE EUROPEAN FRAMEWORK AND NATIONAL PLANS (PNIEC – NATIONAL INTEGRATED ENERGY AND CLIMATE PLAN, LTS – LONG-TERM STRATEGY, NRRP – NATIONAL RECOVERY AND RESILIENCE PLAN)

An examination of the European regulatory framework shows that the EU has focused on reducing the consumption of virgin plastic. The plastics initiatives carried forward by the European Union are presented below. These are: the circular economy action plans, the European taxonomy of sustainable finance, the European plastic tax and the directive on single-use plastics. An examination of the EU framework clearly shows a focus on prevention and reuse among the key principles of the circular economy, aimed at reducing overall consumption of natural resources.

3.1.1 PLASTICS IN CIRCULAR ECONOMY ACTION PLANS

Giuseppe Ungherese, *Pollution Campaign Manager, Greenpeace Italy*

The use of increasingly greater quantities, the low recycling rate, especially compared with other materials, the high dispersion and persistence in aquatic and terrestrial environments in addition to its increasing contribution to climate change have led the European Union to include plastics among the materials to be prioritised in its **Action Plan for the Circular Economy**[36]. In this context, the **Circular Economy Plastics Strategy**[37], adopted in January 2018, was drawn up. It states that all plastic packaging placed on the European market should be reusable or recyclable "*in a cost-effective way*" by 2030.

[36] "Closing the loop – An EU action plan for the circular economy" https://eur-lex.europa.eu/legal-content/EN-IT/TXT/?from=IT&uri=CELEX%3A52015DC0614 , *European Commission, 2nd December 2015.*

[37] "European strategy for plastics in the circular economy" https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0028&from=SK , *European Commission, 16th January 2018.*

Plastics are also one of the main value chains on which the **new Circular Economy Action Plan**[38], presented in 2020, focuses. The Commission is committed in this respect to taking further measures to address the sustainability issues regarding the production, processing, use, dispersion and end-of-life management of plastics. The renewed focus on the plastics supply chain has arisen because the initiatives implemented so far have not been fully effective in steering this sector towards sustainability and circularity. Therefore, in line with the intentions of EU bodies, action needs to be taken with policies that reduce upstream waste generation and encourage the use of recycled material.

With the **European Parliament Resolution of February 2021 on the new Action Plan for the Circular Economy**[39], the EU Parliament emphasised the key role that unpackaged, loose sales can play in reducing the production of packaging and called on the Commission and Member States to promote these measures. It also called on the Commission to examine the potential of deposit return schemes and extended producer responsibility schemes for reducing plastic consumption[40].

3.1.2 PLASTICS IN THE EUROPEAN TAXONOMY OF SUSTAINABLE FINANCE

Giuseppe Ungherese, *Pollution Campaign Manager, Greenpeace Italy*

In June 2020, the European Parliament adopted the **Regulation on a taxonomy for sustainable finance**[41], a regulation that will help guide investment choices in line with EU environmental policy targets. The Regulation sets six environmental targets and allows an economic activity to qualify as sustainable if it contributes to at least one of these targets. These targets are:

1. climate change mitigation;
2. climate change adaptation;
3. sustainable use and protection of water and marine resources;
4. transition to a circular economy;
5. pollution prevention and reduction;
6. protection and restoration of biodiversity and ecosystems.

The regulation states that plastic production contributes to climate change mitigation if at least one of the following criteria is met:

a) it is produced entirely by mechanical recycling;

38 "A new action plan for the circular economy", *European Commission, 11th March* 2020.
39 European Parliament Resolution of 10th February 2021 on the new action plan for the circular economy.
40 The deposit system is a selective collection scheme in which a person who buys particular plastic packaging, such as a bottle, pays a small extra amount so that he or she has an incentive to return the empty container. Extended producer responsibility, on the other hand, is an environmental policy approach in which a producer's responsibility for a product is extended to include the post-consumer stage, i.e. to its management once it has become waste.
41 Regulation (EU) 2020/852 of the European Parliament and Council of 18th June 2020 on the establishment of a framework to facilitate sustainable investments and amending Regulation (EU) 2019/2088

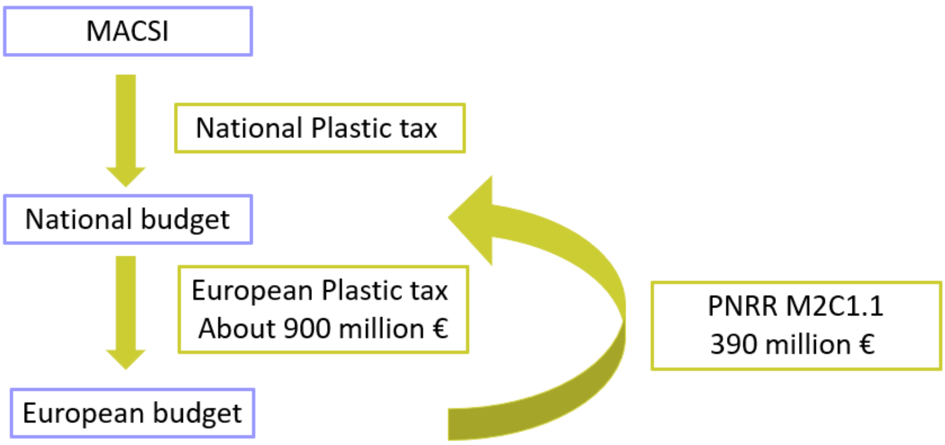
b) it is produced entirely by chemical recycling and if the greenhouse gas emissions of the entire life cycle are lower than they would have been if fossil raw materials had been used;
c) it is produced from renewable raw materials and if the greenhouse gas emissions of the entire life cycle are lower than they would have been if fossil raw materials had been used.

3.1.3 THE EUROPEAN PLASTIC TAX

The European plastic tax is levied at a uniform rate on the non-recycled plastic packaging waste produced in each Member State, effective from 1st January 2021 and amounting to €0.8 per kg[42]. The cost for Italy, net of the flat-rate reduction, should be around €900 million per year. These taxes go into the European budget to then be used to finance the National Recovery and Resilience Plan (NRRP)[43]. The plan, as we will see below, involves a loan of €390 million to expand the plastic collection and recycling network (Mission 2 Component 1.1).

The €900 million contribution that Italy must pay to the European Union will be drawn from the country's national budget, if it is not raised by a national plastic tax (Figure 15).

Figure 15 - Schematic example of national and European plastic taxes.



The Italian plastic tax was introduced in the 2020 Budget Law[44] and should have come into force in the summer of 2020, but was then successively postponed until January 2021, July 2021, January 2022 and yet again until January 2023. **The Italian plastic tax is levied on the consumption of Single-Use Plastic Products (SUPPs)** i.e. articles made with the use, even partial, of fossil-based plastic for containing, protecting, handling and delivering goods. These are therefore products that are not designed to be reused several times during their useful

[42] "COUNCIL REGULATION on the calculation of the own resource based on plastic packaging waste that is not recycled, on the methods and procedure for making available that own resource, on the measures to meet cash requirements, and on certain aspects of the own resource based on gross national income" https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CONSIL:ST_13142_2020_INIT&from=IT *Council of the European Union, 16th December 2020.*
[43] "National Recovery and Resilience Plan".
[44] Law No. 160 of 27th December 2019 – State budget forecast for the financial year 2020 and long-term budget for the three-year period 2020-2022.

life. Examples of SUPPs are plastic bottles and caps, food packaging, Tetrapak containers, detergent bottles, polystyrene and bubble wrap used to protect goods, plastic film used to wrap pallets, etc. Compostable SUPPs and plastic contained in SUPPs produced from recycling processes are exempt from the Italian plastic tax.
Taxpayers for which the Italian plastic tax is compulsory are:

- for SUPPs manufactured in Italy: the manufacturer or its client, i.e. the entity that ordered the manufacture of the SUPPs;
- for SUPPs from other EU countries: the entity that purchased the SUPPs;
- for SUPPs from countries outside the EU: the importer.

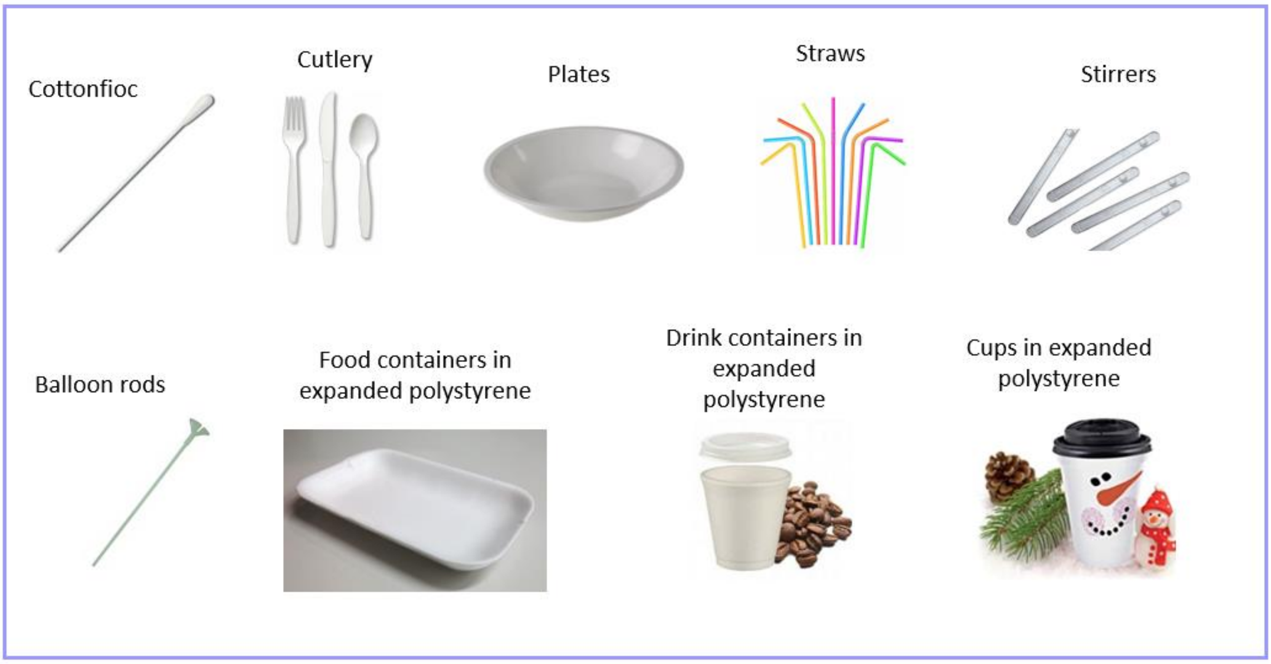
The plastic tax is charged at €0.45 per kg of plastic contained in the SUPPs. The Italian plastic tax should not be confused with the "CONAI" contribution which, as we will see below, is a tax paid by producers and users of packaging to cover the costs of separate collection, recycling and recovery of packaging waste.

3.1.4 THE EUROPEAN DIRECTIVE ON SINGLE-USE PLASTICS

In line with the European circular economy action plans, the need to drastically reduce plastic waste and combat its dispersion in the environment was concretely addressed with the adoption of Directive (EU) 2019/904[45], also known as the Single Use Plastics (SUP) Directive. Based on the paradigm of the circular economy, **the directive aims to reduce the consumption of natural resources by promoting reusable alternatives to single-use and by encouraging recycling and increased use of recycled material in the manufacture of new products.** The European Commission has introduced new rules on the disposable plastic products most commonly found as litter on European beaches and seas (Figure 16), as well as on accidentally lost or abandoned fishing equipment.

45 Directive (EU) 2019/904 of the European Parliament and of the Council of 5th June 2019 on the reduction of the impact of certain plastic products on the environment

Figure 16 - Single-use plastic products banned on the market under the SUP Directive.



These products constitute the largest component of marine pollution and, according to the Commission's own estimates, account for 70% of all waste found on beaches and in the sea[46]. The directive therefore introduces several measures, including the following:

1. **a ban on the sale of numerous disposable plastic products for which environmentally friendly alternatives are already available (cotton buds, cutlery, plates, straws, drink stirrers, balloon sticks, expanded polystyrene food and drink containers, expanded polystyrene drinking cups);**
2. **targets for reducing the consumption of drinking cups and some single-use plastic food containers;**
3. **design requirements for plastic beverage bottles (caps must be attached to containers and PET bottles must consist of at least 30% recycled material by 2030);**
4. **creation of extended producer responsibility schemes for certain types of non-packaging plastic products** (filters for tobacco products, balloons, wet wipes and fishing gear), inclusive of the cost of removing the relevant waste if it is dispersed in the environment;
5. **separate collection targets for plastic beverage bottles with a capacity of up to three litres** (90% by 2029).

According to Commission calculations, the implementation of the Directive will reduce the waste generated by banned single-use plastic articles by more than half, thereby preventing damage to the environment, which would otherwise cost €22 billion by 2030, and generating savings for consumers of around €6.5 billion per year. It is estimated that the Directive will prevent the emission of 3.4 million tons of CO_2 equivalent into the atmosphere by 2030[47].

[46] https://op.europa.eu/en/publication-detail/-/publication/fbc6134e-367f-11ea-ba6e-01aa75ed71a1
[47] https://ec.europa.eu/environment/pdf/waste/single-use_plastics_factsheet.pdf

The EU directive was implemented in Italian law by Legislative Decree No. 196 of 8th November 2021[48]. In recognition of the particular context in Italy for the management and treatment of compostable bioplastics as this relates to the collection of organic waste, the national law introduced exemptions for products made of biodegradable and compostable material with percentages of renewable raw materials equal to or higher than 40% and higher than at least 60% from 1st January 2024, in the following cases:

a) where the use of reusable alternatives to single-use plastic products which come into contact with food is not possible;
b) where use is envisaged within well-defined contexts that deliver waste, with separate collection, to public waste collection services in the normal way, such as canteens and residential and other health and social care facilities;
c) where these alternatives (the reusable alternatives) do not provide adequate guarantees in terms of hygiene and safety;
d) in consideration of the particular types of food or drink involved;
e) in circumstances that involve large numbers of people;
f) if the environmental impact of the reusable product is worse than the single-use biodegradable and compostable alternatives, based on a life cycle analysis by the manufacturer.

It is important to protect companies in the sector and nationally renowned products, while at the same time the problems of climate change and overexploitation of resources that the current model of plastic consumption is helping to fuel must be addressed critically and rationally. Today we have a disproportionately large disposable market that cannot be ignored. In some particular contexts where making reusable products compulsory is more complex, such as for food delivery, the use of bioplastics is nevertheless justifiable. The use of these materials does not necessarily mean that the consumption of single-use items remains constant or increases. This statement is supported by the positive impact of the Italian law requiring the use of bioplastics for the manufacture of plastic shopping bags. This law has not only helped change the polymer that is normally used for the production of these bags, but has also led to a decrease in their overall consumption by almost 60% in 10 years. Although the main objective is to reduce plastic consumption and the exploitation of natural resources, bio-based plastics can provide an option for those uses for which sustainable alternatives cannot be found.

3.1.5 PLASTICS IN NATIONAL PLANS

Despite the huge attention paid at European level to the issue of plastics, neither the National Integrated Energy and Climate Plan (NIPEC[49]), nor the National Long-Term Strategy (LTS[50]) offer scenarios for industrial decarbonisation in which it is possible to understand the policies and measures that the legislator intended to adopt for such an

[48] https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=2021-11-30&atto.codiceRedazionale=21G00210&elenco30giorni=false
[49] "National Integrated Energy and Climate Plan", *Ministry of Economic Development*, December 2019.
[50] "Italian long-term strategy for the reduction of greenhouse emissions", *Ministry of the Environment and Protection of Land and Sea*, January 2021.

important sector of our economy. As a consequence, neither a plan nor guidelines exist for reducing greenhouse gas emissions generated in the plastics supply chain.

The petrochemical sector is only indirectly involved in the **National Recovery and Resilience Plan** (NRRP), where it is found in section M2C1 “Circular Economy and Sustainable Agriculture”, in which €0.6 billion is allocated to Circular Economy Flagship Projects. The objective of this investment is to support improvement in waste collection and the development of recycling plants for various materials, including plastics, by encouraging projects that qualify as “circular districts”. However, the investments do not form part of a clear industrial strategy to decarbonise plastics and, as things stand, the initiative is of a piecemeal nature.

In our view, the lack of a strategy for plastics exposes the sector to risks because, in addition to the known environmental issues, the question needs to be aligned with that of decarbonisation. If the right policies and guidelines were drawn up this would allow companies to direct their investments into activities that are compatible with long-term environmental and climate change objectives in a framework in which the reduction of consumer products forms an important part of decarbonisation. The protection of behaviour that is incompatible with this principle is bad guidance, on a par with the delay in levying a tax (the Italian plastic tax) that causes public money to be used to pay Italy’s European plastic tax to the European Union.

4 STRATEGIES FOR THE DECARBONISATION OF THE PLASTICS SUPPLY CHAIN

The decarbonisation of the plastics supply chain has no single or simple solution and a "composite" approach is needed based on a combination of several strategies. The Waste Framework Directive (2008/98/EC[51]) can be used as a framework to identify policy and regulatory priorities. The directive introduces a waste hierarchy and, in order of priority, identifies prevention (i.e. reduction), preparation for re-use, recycling (or composting), energy recovery and finally landfill as the last treatment method. In our opinion, this hierarchy must also be applied to the decarbonisation of the plastics supply chain, where, however, it will also have to include the replacement of some products with bio-based plastics, which, thanks to their renewable feedstock, reduce greenhouse gas emissions as compared with virgin fossil-based plastics.

The three pillars identified for the decarbonisation of the plastics supply chain are therefore:

1. **a reduction in the consumption of virgin fossil-based polymers.** This action is especially important in Italy as the second largest consumer in Europe;
2. **recycling plastics,** which enables: fossil-based plastic, already present on the market, to be managed at the same time; a reduction in greenhouse gas emissions; and input from new fossil-based plastics, which are almost entirely imported;
3. **replacement with bioplastics.** Plastics made from plant-based raw materials offer a solution for decarbonisation in cases where it is not possible to dispense with the use of plastic and for which no other sustainable alternatives exist. Full substitution of fossil-based plastic with plant-based plastic can already take place immediately for some products and progressively for others.

4.1 STRATEGIES TO REDUCE CONSUMPTION

Giuseppe Ungherese, Pollution Campaign Manager, Greenpeace Italy

The production of plastics has shown continuous increases in growth since it was first introduced on the market and, at least in recent decades, has seen no significant reversals of this trend (Figure 17). In the space of just a few decades worldwide production rose from 15 million tons in 1964[52] to 368 million tons in 2019[53]. According to the most authoritative estimates, if the growth curve were to follow its current trajectory, the volumes produced globally each year would double by 2030-2035 and triple by 2050[1], to reach €1,100 million tons[54].

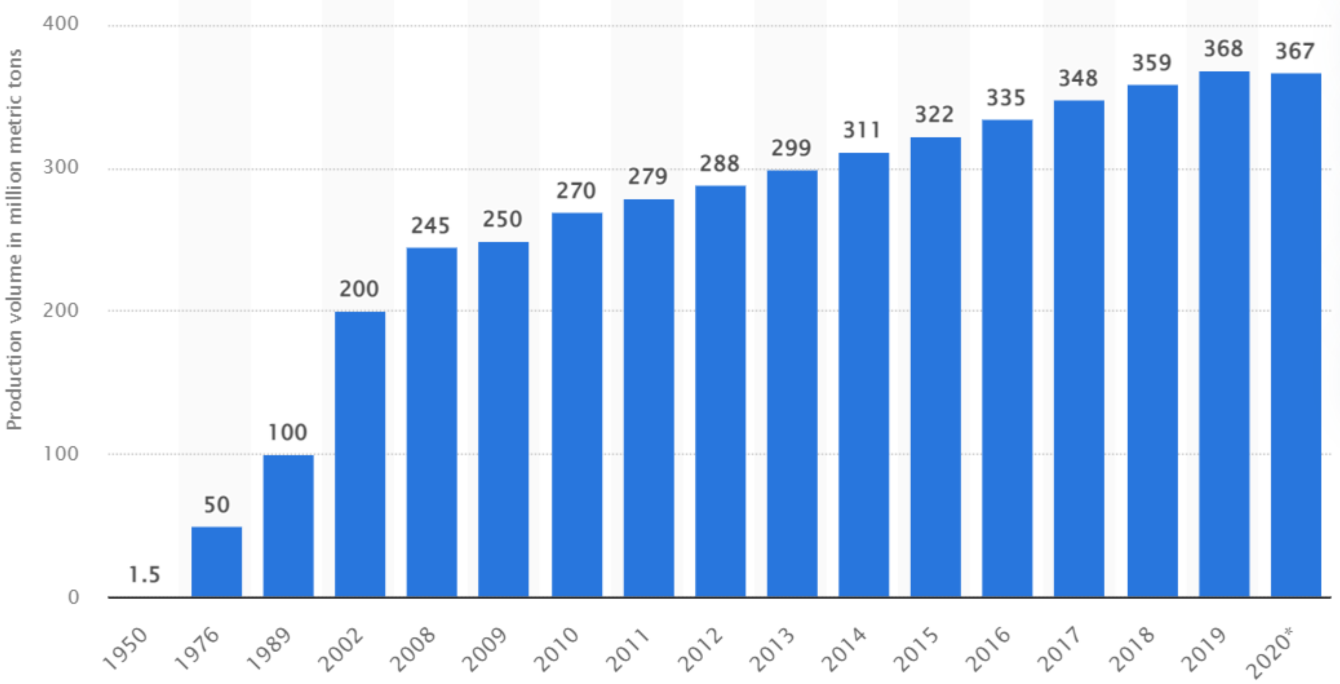
[51] Directive 2008/98/EC of the European Parliament and of the Council of 19th November 2008 on waste and repealing certain directives

[52] *World Economic Forum* (2016), The New Plastic Economy

[53] Ian Tiseo; "Global plastic production 1950-2020", *Statista,* 12th of January 2022.

[54] Geyer R. (2020) Production, use, and fate of synthetic polymers. In: Letcher, T.M. (ed.): Plastic waste and recycling, *Academic Press, Cambridge, MA*, 2019

Figure 17 - Growth in global plastic production from 1950 to 2020. The figure for 2020 is an estimate[55].



The endeavours made to date seem to be insufficient to bring this production down towards real sustainability. The efforts made so far by companies and governments around the world are not ambitious enough to actually solve the problems that result. The different scenarios examined in a study recently published in *Science*[56] indicate that voluntary commitments made by companies and policies pursued by individual countries could reduce the amount of plastic dispersed into the environment by less than 8% each year. This is driving the international and European community to seek the tools for **a rapid paradigm shift in how we use plastics** as they become aware of the huge difficulties involved in managing the end-of-life stage, with actions that do not focus solely on how to treat growing quantities of waste.

The economic sectors that use plastics on a massive scale are the packaging, construction and automotive sectors. Strategies to reduce virgin plastic consumption specific to these sectors are presented below.

4.1.1 THE SINGLE-USE SECTOR

Giuseppe Ungherese, *Pollution Campaign Manager, Greenpeace Italy*

The food and beverage industry relies extremely heavily on single-use plastics and has developed its business and consumption models around these products. High sales volumes, low unit costs, ease of transport and high frequency of purchase are some of the factors that have led to the growth of single-use plastic products in the food and beverage industry. Nevertheless, these business models have produced a number of environmental externalities,

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[55] Tiseo, Ian; "Global plastic production 1950-2020", *Statista,* 12th January 2022.

[56] Lau W.W.Y., Shiran Y., Bailey R.M. et al. (2020) Evaluating scenarios toward zero plastic pollution. *Science*, 369 (6510) 1455-1461

related mostly to the long-ignored colossal production of scrap and waste. In this context, an urgent need exists to prioritise action on the demand for raw materials for the production of packaging and disposable items, with the adoption of the following measures for:

1. the elimination of useless packaging and a reduction in single-use products;
2. greater use of reusable products;
3. the replacement of plastics with other materials.

ELIMINATION AND REDUCTION OF SINGLE-USE PRODUCTS

Giuseppe Ungherese, *Pollution Campaign Manager, Greenpeace Italy*

Silvia Gross*, Lecturer at the University of Padua*

Dematerialisation of packaging is the elimination of unnecessary and problem packaging through redesign, innovation and the introduction of new sales and distribution models for products. This can start with the direct elimination of superfluous and oversized packaging (overpackaging).

For example, recent research by the German company GVM has shown that oversized and superfluous packaging is a very large contributor to plastic consumption and CO_2 emissions resulting from production of the material, manufacture of the packaging, transport and final disposal[57]. This German company estimated that a reduction in overpackaging had the potential to reduce plastic consumption for packaging by up to 27% in Germany. We believe that a similar result could be achieved in Italy. If we consider that Italy consumed 2.5 million tons of plastic in 2020 for the manufacture of packaging, if overpackaging and superfluous packaging were eliminated this could reduce plastic consumption by 0.7 Mt, which would amount to approximately 1.1 Mt of CO_2 not emitted into the atmosphere[58].

The purchase of loose products, where the consumer refills a container several times, also makes it possible to reduce the use of bottles, flasks and containers considerably, mainly in the detergent, personal hygiene and cosmetics sectors, where the requirements for sterility and contamination are much less stringent than in other sectors (e.g. food and pharmaceuticals). This sales model is also spreading in Italy and, as a result of an incentive promoted by the Ministry for Ecological Transition in the "Loose Products" decree, since 23rd November of last year the model can count on a retroactive contribution of €5,000 to reduce expenses incurred by companies that adopted these sales models in 2020 and 2021[59].

In this context, consumer awareness and knowledge is important to give consumers an objective perception of the environmental benefits and of their shared values. A common and mistaken belief that packaged and canned goods are safer than those that are loose is gradually giving way to greater awareness. The *Negozio Leggero* chain of shops is an example:

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[57] "Potenzial der Abfallvermeidung und des Ressourcenschutzes bei Reduktion von übermäßigen Verpackungen", *GVM Gesellschaft für Verpackungsmarktforschung mbH*, July 2021.
[58] Direct emissions from the extraction and refinement of fossil fuels and industrial processes to produce fossil-based polymers, amounting to around 1.7 kg of CO_2 per kg of plastic.
[59] Incentives for the sale of loose products or products on tap, Ministry of Ecological Transition, Decree of 22nd September 2021.

it opened in 2009 in Turin, the first internationally, and has become a successful example of zero-waste retailing worldwide. Its product range has expanded over the years, and important steps forward have also been taken with the hygiene and sterilisation of the containers, which had initially limited their use to only those areas that were less sensitive to sterilisation requirements and the absence of or a strong reduction in contamination. For example, *Negozio Leggero* has devised a circular system for personal cleansers and some food products by using glass containers that involves the return of the empties and then sterilising and sanitising them for reuse.

Our analysis of legislation in different countries led us to look at France. On 30th January 2020, the French Parliament approved a new law on waste and the circular economy ("*Loi relative à la lutte contre le gaspillage et à l'économie circulaire*"[60]). With this law, **France aims to eliminate all single-use plastic packaging on the domestic market by 2040**. It is an ambitious target to be achieved progressively, partly by setting binding reduction, reuse and recycling targets for plastic packaging sold on the French market. This first set of regulations has been followed by others[61]: **on 1st January 2022, a ban came into force on the sale in supermarkets of fresh fruit and vegetables in plastic packaging if they weigh less than 1.5 kg**. This ban, which at least initially did not apply to all types of products, will be extended over the years to include all fruit and vegetables, leading to a complete ban on these types of packaging by 2026.

REUSE

Giuseppe Ungherese, *Pollution Campaign Manager, Greenpeace Italy*

Reusable containers and dishes are made of materials that can be washed, sanitised and reused, such as glass, ceramics and steel, thereby reducing the consumption of single-use products. The environmental benefits of systems based on reusable packaging have been confirmed by a recent UNEP report[62]. This survey, based on a review of studies using LCA methodology in the scientific literature, compared the environmental benefits of different reusable versus single-use packaging options for a wide variety of products. **The findings of this UNEP study draws the attention of policy makers to the need to shift the focus from the material (plastics) to the model (single-use), and encourages countries to support, promote and provide incentives for action to replace plastic products with reusable alternatives.**

To again take the new French law on waste and the circular economy as an example, this law introduces reuse **targets of 5% by 2023 and 10% by 2027 for all types of packaging sold in France.** In addition to this a series of bans has been introduced on the use and sale of specific types of products, requiring the replacement of single-use products with reusable alternatives. For example, since 1st January 2020 **a ban has been placed on the use of disposable plastic cups, glasses and plates for consumption on the premises in catering establishments and from 1st January 2023 this ban will be extended to all single-use**

[60] LOI no 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire
[61] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000043458675
[62] "Addressing Single-Use Plastic Products Pollution using a Life Cycle Approach", *UNEP,* 2021.

options (not just plastic options), with the obligation to use reusable alternatives. Specific measures are also being introduced for PET bottles for liquid food, even though the SUP Directive only sets design requirements (including a minimum recycled content) and collection targets for the recycling of this type of packaging. The French package of measures for this type of container has the ambitious target of a reduction in sales for consumption of 50% by 2030.

When Germany implemented the SUP Directive into national law, it also introduced further measures in a new packaging law. **From 2023 onwards, restaurants, bistros and cafès will be obliged to also make food and drink available to consumers in reusable containers, for both on-the-premises and take-away consumption.** These establishments will also be obliged to clearly inform consumers that they may purchase the products in reusable containers, whether the sales are made on-site or online.

REPLACEMENT WITH OTHER MATERIALS

Silvia Gross, *Lecturer at the University of Padua*

In those cases where single-use products are employed, alternatives to plastic must be sought and must be based on a number of considerations, which include overall environmental sustainability.

Bio-based materials can be used to create lighter and stronger packaging, or simply packaging with more sustainable materials, by replacing fossil-based raw materials with a natural and biodegradable raw material. One example of this is microfibrillated cellulose (MFC), a material derived from wood that can replace fossil-based plastics in applications such as packaging, barrier films, special papers, coatings and adhesives.

Another area of strong growth is the replacement of plastic packaging with special papers or multi-material and/or multi-layer composites. As food packaging is often involved in this area, effective barrier properties (to oxygen and water vapour) must be guaranteed for compatibility with foods as well as appropriate **oil-repellent and**/or hydrophobic properties in many cases. However, it should be stressed that these types of solutions must be contextualised by considering the entire life cycle of the material.

4.1.2 BUILDING AND CONSTRUCTION

***Giuseppe Ungherese**, Pollution Campaign Manager, Greenpeace Italy*

The building and construction industry in Italy uses around 0.5 million tons of plastics each year, accounting for 7% of the Italian demand for polymers. The most widely used polymers are polyethylene (HDPE, LDPE and LLDPE), expanded polystyrene (EPS) and polypropylene (PP), which are used to manufacture pipes, fixtures and insulation panels, as well as for coatings and dozens of other applications. Their durability and high corrosion resistance, combined with their insulating properties and guaranteed lightness and cost-effectiveness, have enabled these materials to proliferate in the sector.

ELIMINATION AND REDUCTION

The demand for plastic building products is likely to increase in coming years as more incentives for renovation and energy efficiency are introduced. Building certification that is not only energy-related, but also carbon-related could be set as a requirement to limit excessive consumption of virgin plastic in the construction industry. This certification should also consider the greenhouse gas emission impacts of the materials used in the definition of a building class.

In this respect, we mention a recent experience of the Milan Zero Carbon Fund (MZCF) project, as an example of regulatory action that can create a market for low carbon products. This project studied the creation of a demand for low-carbon building materials by drawing up a regulatory mechanism to be implemented by the City of Milan. The MZCF project is based on the following principles:

- ◊ setting a highly detailed "zero carbon" goal for new and extensively renovated buildings;
- ◊ defining an LCA calculation method for estimating the CO_2 emissions generated by the construction of a building for which a building permit is required;
- ◊ putting a price on the CO_2 emitted during the whole life cycle of the materials that will be used to construct the building;
- ◊ establishing a mechanism whereby the property developer pays the City of Milan a fee based on the emissions gap between the project developed and the zero carbon target;
- ◊ allocating the proceeds to actions to offset CO_2 emissions to be taken by the City of Milan.

One of the aims of this project is to broaden the definition of nZEB (nearly Zero Energy Building) to also include the production stages of the materials. If the production processes of the construction materials are not also decarbonised, a price will be indirectly placed on the upstream CO_2 emissions. This extra cost will not be borne by the manufacturing sector, but by the property sector, and it will finance an investment fund for the urban regeneration and decarbonisation of the City of Milan's building stock.

REUSE

Giuseppe Ungherese, *Pollution Campaign Manager, Greenpeace Italy*

According to 2018 Plastics Europe data, 26% of plastic waste from the construction industry in Europe is recycled, 26.5% goes to landfill and the remaining 47.5% goes to energy recovery. This data shows a **need to develop separated material streams in this industry in order to improve the quality of collected waste and allow the establishment of an efficient reuse and recycling chain. The selective demolition of buildings would need to be encouraged to achieve this**, as a necessary condition for the emergence of a true circular economy in the sector. This system carries out an initial on-site separation of the different types of waste into uniform fractions for recycling and reuse. This makes it easier to obtain good quality materials that can be given a second life or, in the best cases, be reused on site.

REPLACEMENT WITH OTHER MATERIALS

In the construction industry, some plastic articles can be replaced with other materials. For example, floor coverings and shade structures made from bioplastics are already on the market. Furthermore, for some applications plastic can be replaced with metals such as steel, copper and aluminium, which can be recycled many times over without running into the degradation problems typical of plastic. As in all the other cases, a serious LCA assessment must be carried out to understand which material is most sustainable for any particular application.

4.1.3 THE AUTOMOTIVE SECTOR

Giuseppe Ungherese*, Pollution Campaign Manager, Greenpeace Italy*

Plastics have been used on a large scale in the automotive sector for decades and are the second most used material after metals. Polypropylene (PP), polyethylene (PE) and polyamides (PA) are widely used in the manufacture of vehicle components, as they can make them lighter, increase their safety and improve interior space management.

REUSE

Giuseppe Ungherese*, Pollution Campaign Manager, Greenpeace Italy*

If we consider that 12% to 15% of each car by weight consists of plastic components, **it is not difficult to imagine that each vehicle may contain over 100 kg of polymers**[63]. This content has also increased in recent decades. For example, the plastic content of the *Volkswagen Golf* increased from 87 kg in the *Golf II* (1983-92) to around 255 kg in the *Golf VII* (2012-19)[17]. Nevertheless, unlike metal components which find a natural outlet in recycling chains, plastics have fairly low rates of recycling and reuse (e.g. as spare parts). **The wide variety of polymers used, their, in some cases, heterogeneous composition and the difficulties in separating them at the end of their life (which adds to costs in the recycling chain) are some of the factors that lead to low recycling rates.**

An assessment of the European Directive 2000/53/EC regarding end-of-life vehicles has also identified several critical issues concerning the recycling and recovery of car components. A revision of the directive itself has therefore commenced[64], in which some aspects related to the "green deal" and the circular economy should be integrated in the directive, with the aim of preventing waste from being produced, providing incentives for the use of recycled materials and at the same time introducing specific eco-design requirements, making end-of-life dismantling, reparability and reuse easier.

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[63] https://ec.europa.eu/environment/pdf/waste/elv/ELVD%20Evaluation-Final%20report%20Aug2020-rev1.pdf
[64] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/1912-Veicoli-fuori-uso-valutazione-delle-norme-dell%E2%80%99UE_en

4.2 PLASTIC RECYCLING

Francesco Paolo La Mantia, *Lecturer at the University of Palermo, INSTM*

Plastic recycling is definitely a very useful tool when it comes to reducing fossil-based plastic production and putting the principles of the circular economy into practice. This is because it reduces the following:

1. carbon emissions from fossil sources into the environment;
2. energy consumption for the production of plastic products;
3. the quality of plastic that goes to landfill.

Plastics can be recycled mechanically or chemically. These two different recycling processes are presented below, with an analysis of their technological maturity, advantages and limitations.

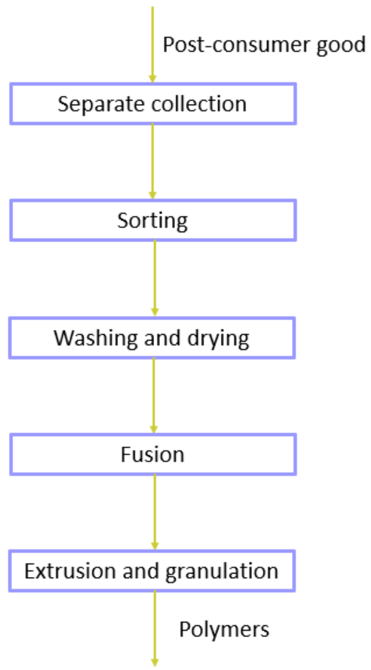
4.2.1 MECHANICAL RECYCLING

Francesco Paolo La Mantia, *Lecturer at the University of Palermo, INSTM*

Mechanical recycling can only be used for thermoplastic polymers and can be divided into primary and secondary recycling. A typical example of primary mechanical recycling is the recovery of material from scrap and defective parts in the same industrial plant. Generally these are granulated and reprocessed in a mixture with virgin material. Even if they are slightly degraded by the processing, the material can be used and processed for the same applications and in the same way as the virgin material.

In secondary mechanical recycling, the input material is post-consumer articles and is reused after a series of operations (separation, washing, processing to a molten state) that result in a second material that can be used for the production of articles that require lower quality performance than those of the original input material (Figure 18).

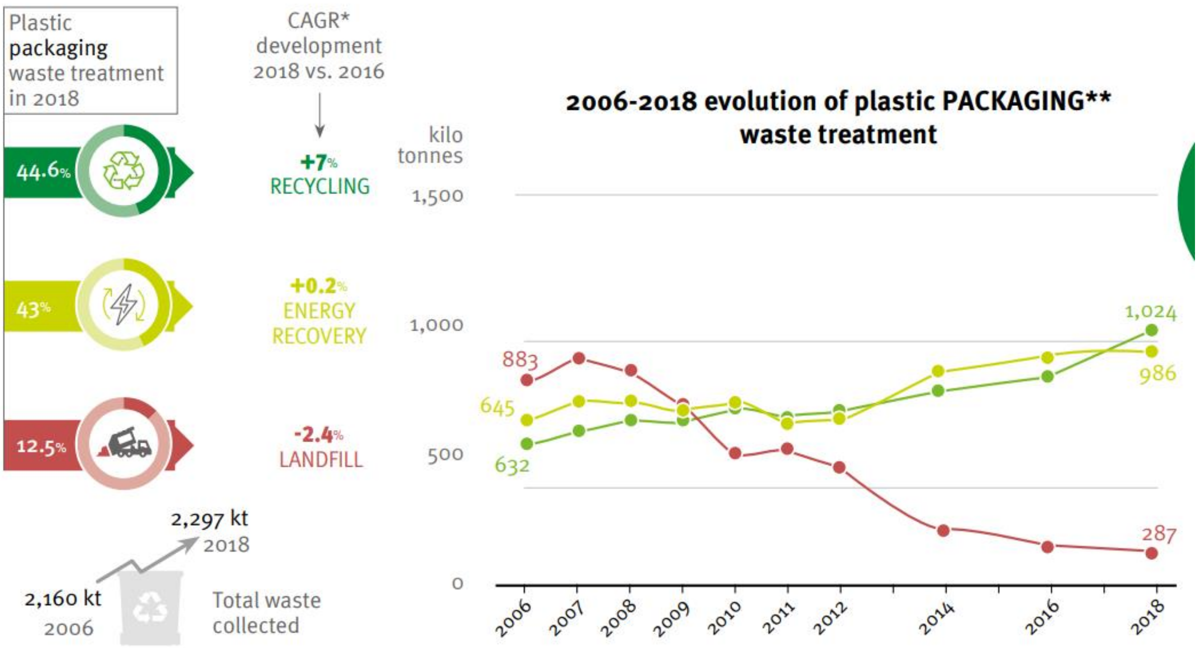
Figure 18 - Schematic of secondary mechanical recycling.



In 2018, 31% of post-consumer plastic waste in Italy was sent for mechanical recycling and amounted to 1.1 million tons[65]. A focus on packaging waste shows that 45% of this (one million tons) (Figure 19) was mechanically recycled in that same year, with HDPE and PET containers accounting for the majority of mechanically recycled products, followed by PE packaging film. The remainder of the waste collected, around 1.3 Mt, went to energy recovery or landfill, because it is composed of articles that are difficult or impossible to recycle using chemical recycling methods (polycoupled products, polymaterial products, etc).

[65] "Plastics – the Facts 2020", PlasticsEurope.

Figure 19 - Changes in plastic packaging disposal processes in Italy from 2006 to 2018[66].



The chart shows a sharp fall in plastic packaging going to landfill from 2007, while recycled plastic and plastic used for energy generation has gradually increased during that period. This occurred as a result of the entry into force in 2006 of Legislative Decree No. 152, the "Environment Code"[67], which introduced a waste hierarchy in the part on waste management. According to this hierarchy, waste management must aim firstly at preventing the production of waste, then at preparing it for reuse, recycling and energy recovery and finally at landfill, but only as a last resort.

This legislative decree introduced the payment of a contribution, known as the "CONAI contribution", by producers and users of packaging to cover the costs of the separate collection, recycling and recovery of packaging waste. These costs are allocated *"in proportion to the total quantity, weight and type of packaging material placed on the domestic market"*. For plastic packaging, the contribution is divided into five classes, depending on how developed the sorting and recycling chain is:

- **Class A1**: packaging with an effective and well-established industrial sorting and recycling chain, mainly from the C&I (Commerce & Industry) circuit, net of flexible polyethylene packaging. In this case the contribution is €104 per ton[68];
- **Class A2**: flexible polyethylene packaging with an effective and well-established industrial sorting and recycling chain, mainly from the C&I circuit. In this case the contribution is €150 per ton;
- **Class B1**: packaging with an effective and well-established industrial sorting and recycling chain, mainly from the domestic circuit. The contribution is €149 per ton;

[66] "Plastics – the Facts 2020", *Plastics Europe*.
[67] Legislative Decree No. 152 of 3rd April 2006, Environmental regulations.
[68] "Environment contribution", CONAI.

- **Class B2**: packaging with a sorting and recycling chain at the development stage not yet well-developed from the domestic and C&I circuits. The contribution is €520 per ton;
- **Class C**: packaging with ongoing experimental sorting/recycling activities or which cannot be sorted/recycled using current technology. In this case a contribution of €642 per ton is to be paid.

The collection of post-consumer plastic products is carried out in Italy mainly by national consortia, such as COREPLA (National consortium for the collection, recycling and recovery of plastic packaging) and POLIECO (National consortium for the recycling of polyethylene-based waste). The Biorepack consortium has also recently been set up, which deals with the end-of-life management of biodegradable and compostable plastic packaging (and similar fractions) sent to the separate collection and recycling circuit for the organic fraction of municipal waste (wet waste). Private sector recyclers also exist which collect specific types of articles, such as large retailer, household appliance and electronic equipment packaging.

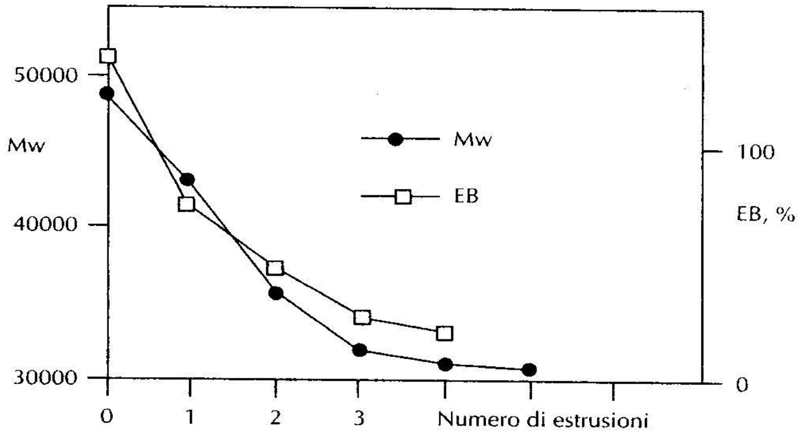
THE LIMITATIONS OF MECHANICAL RECYCLING

Francesco Paolo La Mantia, *Lecturer at the University of Palermo, INSTM*
Silvia Gross, *Lecturer at the University of Padua*

Unlike other materials, such as glass and metals, which retain their properties indefinitely regardless of how many times they are recycled, **polymers undergo degradation processes both during processing and during their use**. Heat, mechanical and electrical stresses and ultraviolet radiation can change the structure, composition and morphology of polymers profoundly, causing the macromolecular chains to break down which decreases the quality of almost all of their properties.

If their chain length shortens, this reduces the molecular weight of the polymer. Since most of the rheological and mechanical properties (and therefore processability and performance) of a polymer depend on its molecular weight, clearly each time a polymer is processed or is used externally, its properties degrade. To give an example, Figure 20 shows the change in the molecular weight and elongation at break as a function of the number of extrusions for a PET sample taken from carbonated drink bottles. The graph shows that reductions in the molecular weight and the elongation at break of PET subjected to a number of extrusions is substantial after the first recycling operation, while the velocity of the reduction of these properties decreases less in subsequent recycling operations.

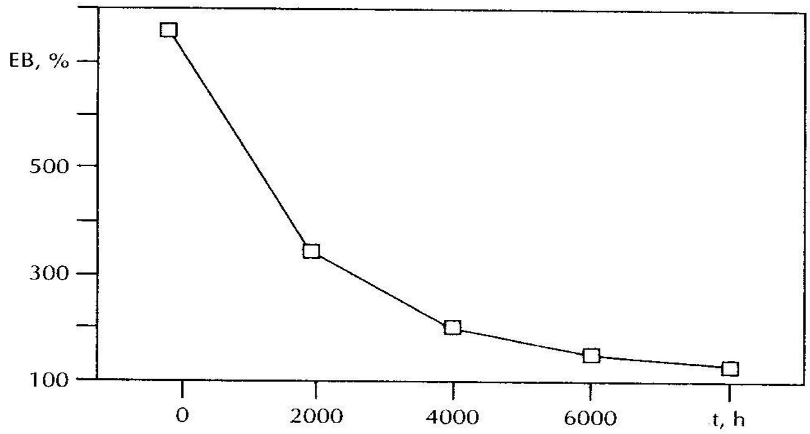
Figure 20 - Changes in molecular weight (Mw) and elongation at break (EB) as a function of the number of extrusions to which a recycled PET sample is subjected.



The molecular weight, and therefore the viscosity, of a recycled material often means that it cannot be used in blow-moulding operations, where high viscosity is required, and there is also a significant reduction in elongation at break. This means that recycled PET cannot be used to produce new bottles again and is used to produce other products such as fibres for the production of textiles (e.g. polar fleece), for which the processing is compatible with the rheological properties of recycled PET.

Degradation by exposure to the sun's ultraviolet rays also dramatically affects the elongation at break, as shown in Figure 21. In this case, the plastic material can no longer be used to produce the same type of film and will instead be used for poorer performing films or for flower pots.

Figure 21 - Elongation at break (EB) as a function of exposure time (in hours) for a recycled PE film.



Recycled polymers can be mixed with the same type of virgin polymers to maintain high performance properties. The percentage of regenerated polymers is generally relatively low and does not exceed 25%-30%. This means that it is in fact possible to reduce the consumption of fossil-based plastics by 25%-30% with a combination of mechanical recycling and the addition of a certain amount of virgin polymers.

All of the above applies when the post-consumer waste collection of plastic products undergoes a further separation process which generates homogeneous polymer fractions, i.e. consisting of the same polymer. We are therefore in the presence of homogeneous recycling.

The presence of different polymeric materials can considerably increase recycling difficulties. It must be considered that each polymer has a chemical nature and molecular structure that is different from the others and that macromolecular chains have different morphologies from one polymer to another. This leads to greater difficulty in mixing and in technical jargon this behaviour is termed incompatibility. Incompatibility between the different phases may result in materials with poor final properties. Clearly, while degradation occurs in all recycling operations, compatibility is only a problem with heterogeneous recycling, i.e. when a mixture of plastics is recycled. The recycling of heterogeneous plastics gives rise to secondary materials with poor mechanical properties, which are used for objects that are either not subject to mechanical stress or are very thick. A typical example is the use of mixtures of plastic waste materials for the production of plant pots, street furniture and garbage bags.

Contamination by elements that cannot be recycled and are difficult to separate from recyclable materials is one of the most complex to solve of the inefficiencies to be eliminated in the field of mechanical recycling. Furthermore, **another critical factor in recycling currently in use is the lack of homogeneity in the initial input materials, which is due not only to the presence of different polymers but also to differences in colour, the average molecular weight and the additives present within the same class of polymers,** which then have consequences on both the look and the mechanical properties of the recycled product. In these circumstances, action can be taken upstream in the cycle to improve the quality of recycled products and therefore reduce the need for virgin plastic, with an eco-design of the product which, on the one hand, aims at simplifying its composition and, on the other hand, makes it easier to disassemble into homogeneous components in terms of the constituent polymers. Finally, more effective sorting systems, typically based on spectroscopic analysis, can be used to improve separation into homogeneous components.

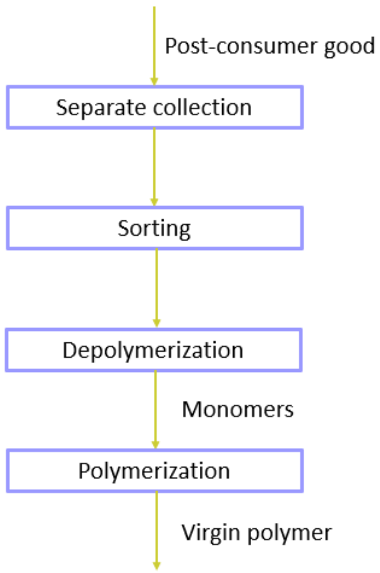
To conclude, mechanical recycling can reduce the extraction of fossil-based raw materials, limit energy consumption and eliminate CO_2 emissions generated from the production of polymers, as compared with the production of new virgin plastics. However, on the down side the processing and use of plastics, the poor efficiency of some waste sorting systems and the addition of dyes and additives limit mechanical recycling to the production of poor quality products.

4.2.2 CHEMICAL RECYCLING

Francesco Paolo La Mantia, *Lecturer at the University of Palermo, INSTM*

Chemical recycling is used to convert post-consumer plastics into smaller molecules (monomers), which can be used both to produce new polymers and for energy generation. Chemical recycling depolymerises macromolecular chains, which means it converts them into either monomers or a mixture of monomers. These are then polymerised to produce the same polymer, according to the process shown in Figure 22. After these operations, a virgin polymer is produced, which is therefore a raw material with properties identical to those of the original polymer. This type of recycling is still at the experimental stage and only 0.1% of plastic waste (3.6 kt per year) is sent for chemical recycling in Italy.

Figure 22 - Schematic of chemical recycling.



Few polymers can be subjected to this type of recycling with high monomer conversions. They include PET, acrylic polymers, polyamides and polyurethanes. Polymers such as polyolefins (polyethylene, polypropylene, polystyrene) have very low degrees of conversion to monomers and, instead, give rise to a mixture of various types of smaller molecules, usually in a gaseous state. This gas cannot be used to produce new polymers, but is generally used to generate energy, with a significant impact in terms of greenhouse gas emissions.

Theoretically, chemical recycling has the potential to contribute to waste disposal and to produce new virgin materials by saving resources (oil), otherwise needed for the production of monomers. The main problem in the use of this recycling process is economic, because large investments are required in the plants and the running costs are high (especially for energy). Costs could be reduced by increasing the capacity of the plants, but this would introduce problems such as the need to collect and deliver a high quality input product to plants in large quantities on a constant basis.

LyondellBasell, one of the world's leading producers of polyolefins, has recently started up the first pilot plant for the chemical recycling of polyolefins, a molecular recycling technology system, at its Ferrara plant, which can reform polyolefins suitable, amongst other things, for food packaging.

4.3 THE ROLE OF BIOPLASTICS IN DECARBONISATION

Cluster SPRING, *National Cluster of the Circular Bioeconomy*

Bioplastics reduce the use of fossil-based raw materials (in the case of bio-based plastics) and/or result in better end-of-life management (in the case of compostable bioplastics). Bioplastics have in fact been developed to improve the end-of-life management of certain types of products, such as packaging for example, which present high risks of pollution and accumulation in terrestrial and marine ecosystems.

Although it is believed that the best way to tackle the problem of greenhouse gas emissions and plastic pollution is through a significant reduction in consumption, especially of disposable products, this strategy cannot be applied immediately to all types of packaging. One example is the packaging used for the sale of certain fresh food products, such as meat or fish. In this case, bioplastics can constitute a virtuous solution, thanks to their particular property of being compostable and to their renewable nature.

Another interesting application to consider is in agriculture for the production of **biodegradable mulching sheets**, which in this case are designed to biodegrade directly in the soil at the end of their life cycle. The use of a biodegradable mulch film in soil reduces impacts in LCA (Life Cycle Assessment) terms from 55% to 80%, compared with traditional sheets[69]. It is estimated that for every hectare mulched with a biodegradable sheet, an average of about 250 kg of CO2 equivalent per hectare can be saved compared with conventional practices[70].

Bioplastics are used more and more often also in the automotive industry, where biological raw materials are used as reinforcement and filler in biocomposites or to create polymers. Biocomposites, which are based on the three-dimensional combination of a polymer resin and a reinforcing fibre, instead of exploiting materials derived from oil, make full or partial use of materials of plant origin, such as linen fibre, hemp, pineapple and banana leaves, sisal, bamboo or jute. Combinations of these natural fibres with polymer matrices are used to produce materials that are increasingly more competitive than synthetic composites. The objective is to combine the lightness of plastics with superior physical and mechanical properties, such as rigidity or impact resistance, for use in structural or semi-structural applications to replace metals. Today, the automotive sector is the second largest market for biocomposites after the construction industry. Most experts forecast continuous growth in the use of WPC (Wood-Plastic Composites) in the automotive industry, due to the high potential of the lightness of these materials and continuous improvements in their properties and the relative technologies.

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[69] Razza e Degli Innocenti, "Bioplastics from renewable resources: the benefits of biodegradability", 2012.
[70] *Cluster SPRING* processing.

Daimler, Ford, General Motors, Mazda, Honda, Stellantis, Volkswagen and *BMW* are among the major automotive groups with an established track record in researching and producing new bio-based components for their cars. Bioplastics are used by car manufacturers for storage compartments, seats and backrests.

4.3.1 NEW BIO-BASED POLYMERS

The main drivers of growth in bioplastics are PLAs, starch-based bioplastics and PHAs. The first is a very versatile material, offering high performance that makes it an excellent replacement for polystyrene (PS), polypropylene (PP) and acrylonitrile-butadiene-styrene (ABS) in more demanding applications. ABS is the plastic used to make the famous Lego bricks, which the Danish toy giant has announced it wants to produce entirely in bioplastic by 2030. PHAs, on the other hand, are an important family of biopolymers that have entered the market on a commercial scale more recently. These polyesters are 100% bio-based, biodegradable and have a very wide range of physical and mechanical properties.

Non-biodegradable solutions in biomass-based plastic also exist, such as polyethylene (PE), polyethylene terephthalate (PET) and polyamides (PA), which currently account for around 56% (€1.2 million tons) of global bioplastics production capacity. Plant-based polypropylene (PP) is also already on the market and has high growth potential due to its application in a wide range of industries such as the automotive, electronics, construction, packaging and consumer goods sectors.

4.3.2 DO PROBLEMS EXIST OVER COMPETITION WITH FOOD CROPS?

Today, bioplastics are mostly produced from agricultural resources and lignocellulosic raw materials. Currently, agricultural raw materials (plants rich in carbohydrates, such as maize or sugar cane) are the most efficient and profitable option. Lignocellulosic raw material can also be obtained from plants that are not suitable for food or feed production.

It is estimated that 0.7 million hectares were employed globally in 2021 for the cultivation of the plant raw materials needed to produce bioplastics[71], amounting to just over 0.01% of the global agricultural land surface area of 5.0 billion hectares. If we consider the expected increase in the production of bioplastics, then competition with the food chain must be avoided and we must limit land use, greenhouse gas emissions from the agricultural sector, deforestation and the destruction of habitats and biodiversity. It is precisely because biomass is valuable that it is important to channel bio-based plastics as far as possible into applications with high added value, that are capable of providing solutions to environmental problems, without applying a logic of one-to-one replacement of conventional bioplastics.

Industry is developing new technologies that use agricultural and food waste and scrap to maximise their use in the production of bioplastics. More specifically, with a view to promoting circularity and waste reduction, several European R&D projects are focusing on the use of alternative raw materials, such as agro-industrial waste, the organic fraction of municipal solid

[71] *European Bioplastics*

waste, wastewater (both urban and industrial), vegetable oils, bio-CO_2 from fermentation, and absorbent hygiene products. An interesting example, in terms of industrial partnerships, is the research project launched by *Novamont* and *Melinda*, linked to the use of apple processing scrap for the extraction of second-generation sugars that may be used for the production of bioplastics.

BOX 3 - THE MAIN PLAYERS IN THE BIOPLASTICS SECTOR

Cluster SPRING*, Italian Circular Bioeconomy Cluster*

A variety of players operate in the bioplastics market. In North America, *NatureWorks* markets the biopolymer *Ingeo*, made entirely from corn starch sugar. Its main applications range from packaging to components for durable goods, non-woven fabric, 3D printing filaments and base material for many chemical compounds.

Germany's *BASF* is also active in the bioplastics market. This chemical giant, which is committed to the research and production of compostable biopolymers with plant-sourced content, has already launched its *ecovio®* bioplastic on the market. The main areas of application for this bioplastic are bags for the collection of the organic waste fraction, shopping bags, paper and cardboard liners, the production of food trays and plastic films used in agriculture for mulching.

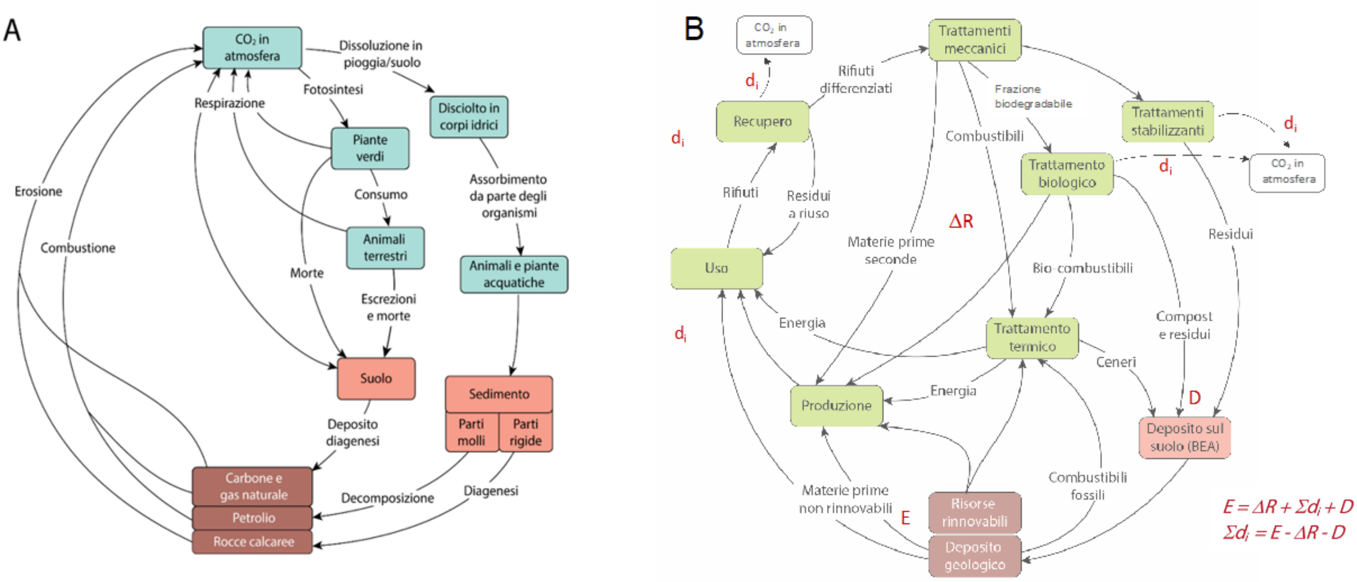
A number of companies exist alongside the chemical giants that operate in the bioplastics, which specialise specifically in bioplastics, such as *Novamont* in Italy and *Biome Bioplastics* in the UK. As already mentioned, *Novamont* is an Italian company and a global leader in the production of bioplastics and biochemical products made from plant-based raw materials. *Mater-Bi,* produced by Novamont, is a family of compostable bioplastics with guaranteed characteristics and properties that are identical to those of conventional plastics. *Mater-Bi* was designed for applications where biodegradability and compostability constitute an added value, such as plastic shopping bags that can be reused for organic waste collection, products for foodservice “contaminated” by left over food or for mulching sheets. Today, *Mater-Bi* has achieved a plant-based raw material content of over 60%, but can already reach higher levels of up to 100% for some applications.
Biome Bioplastics was founded in the UK in 2007. It brought new high-temperature resistant, biodegradable and compostable bioplastic to the market, that uses the lignin contained in waste pulp from paper mills. This new ecological plastic uses a special substance (synthesised in the laboratory) found in the stomachs of termites that is able to decompose lignin in such a way as to obtain eco-sustainable plastic biopolymers.

5 DECARBONISATION SCENARIOS FOR 2050

***Maria Cristina Lavagnolo**, Lecturer at the University of Padua*

Reference is made, in discussions on possible courses of action to take for decarbonisation, to the circular economy of plastics and the interconnections in the cycle and recycling shown in Figure 23 where the circular economy of matter and energy (B) is reproduced on a similar basis to that of the natural carbon cycle (A). In nature, once carbon has been extracted from the soil, it is distributed in the different parts of the environment and interacts with living beings, transforming itself continuously, to then return to the soil, transforming itself back into what it was in the beginning (soil, sediments, organic and inorganic geological deposits). Similarly, the carbon present in plastics can also be reused, recycled and transformed into CO_2 through combustion processes or permanently returned to the soil.

Figure 23 - Cycle of matter and energy (A), from production to waste management and return to the soil (B), where: E = extracted carbon, ΔR = carbon put back into circulation through reuse or recycling, D = carbon deposited in the soil, d_i = carbon emissions during the life cycle of the plastic[72].



As is clearly shown in Figure 23 (B), greenhouse gas emissions into the atmosphere are the result of material extracted from non-plant sources (coal, oil and natural gas, indicated by E in the figure), while material transformed into other material (through reuse and recycling, indicated by ΔR) and the material that returns to the ground in a stable form (D) help to reduce emissions. This analysis suggests that the following specific objectives must be pursued to achieve decarbonisation:

- objective E: minimise non-plant, fossil carbon extraction;
- objective R: increase recycling and reuse;
- objective D: maximise return to the ground in a stable form. This objective is often misunderstood and given little consideration in current circular economy policies, as it is considered to be antithetical to reuse and "zero waste", considered cornerstones of the

[72] *Modified from: R. Cossu, V. Grossule, M. C. Lavagnolo "La discarica sostenibile: ruolo nell'economia circolare e proposte normative".*

circular economy as originally conceived, but now partly revised. It should be noted that this objective includes the return of biodegradable plastics to the soil as compost.

The decarbonisation of the plastics supply chain can therefore be pursued through different courses of action to meet the objectives just identified.

Measures to reduce the extraction of non-plant, fossil-based material (E):

- replacement of plastics by alternatives with a smaller carbon footprint through the application of the SUP Directive, for disposable uses, and the replacement of fossil-based plastics in the various industries in which plastics are used, including the more durable uses (construction, automotive, packaging, etc.);
- measures to reduce the use of plastics in the manufacturing sector and in consumption by means of disincentives (e.g. plastic tax, increased costs of plastic packaging, etc.), incentives for collection, awareness campaigns for the general public and educational courses in schools at all levels;
- the use of renewable energy sources in industry for production and recycling.

Measures to increase reuse and recycling rates (ΔR):

- an increase in the recycling rates of plastic waste through the implementation of the Circular Economy Package and a subsequent increase in recycling percentages (through the adoption of new technologies with mechanical and chemical systems);
- reuse of plastic products with their return to consumption, e.g. through incentives for the "return of empties".

Measures to increase CO_2 capture and fixation rates (D):

- measures on the "end-of-life" (EoL) of plastics to increase their carbon sink fraction, such as soil enrichment in agriculture (this possibility can be fully exploited by replacing plastics with bioplastics).

Some courses of intervention can be implemented immediately, because they are already present in the relative legislation (e.g. the Italian plastic tax, the Circular Economy Package and the SUP Directive). Other courses of action are not yet covered by regulations, although it is hoped these will be introduced in the near future.

5.1 DECARBONISATION: REGULATORY MEASURES

One first step towards reducing fossil extraction (E) and increasing recycling rates (ΔR) was the entry into force of the Italian plastic tax. The use of taxation would give greater impetus to the production of recycled plastic packaging and reduce the use of fossil-based plastics. A similar tax levied on plastic packaging with a recycled content of less than 30% is expected to come into force in the United Kingdom from April 2022. It is estimated that the use of recycled plastics in packaging could increase by around 40% in one year, with equivalent carbon emission savings of almost 200 thousand tons in the period 2022 - 2023[73].

[73] "Introduction of Plastic Packaging Tax from April 2022", *GOV.UK*, 20th July 2021.

Legislative Decree No. 116 (the "Waste Decree"), which implements the European Union's **Circular Economy Package**, is helping to increase recycling rates for plastic waste (ΔR). The regulation sets the following targets:

1. a municipal waste recycling target of 55% by 2025, 60% by 2030 and 65% by 2035;
2. for percentage recycling rates for specific packaging depending on the material: for plastics 50% by 2025 and 55% by 2030;
3. a maximum of 10% of waste may be landfilled by 2035 (Legislative Decree No. 121/2020).

The directive will enable a significant proportion of plastic waste to be reduced through recycling by 2030, with a positive impact on EoL and savings on virgin fossil-based material for the production of new plastics.

The **SUP Directive** also encourages a reduction in fossil-based raw material consumption (E) and an increase in reuse and recycling rates for plastics already on the market (ΔR). The SUP target is aimed primarily at reducing the consumption of those plastic products most responsible for marine pollution, by promoting recycling and better packaging design. It is estimated that at European level the implementation of this directive should reduce the waste from single-use plastic articles subject to controls by more than half, thereby preventing the emission of 3.4 million tons of CO_2 into the atmosphere by 2030.

This directive is complemented by a CORIPET (Voluntary consortium for PET recycling) initiative entitled *bottle-to-bottle*, which involves 100% use of rPET, i.e. new PET bottles can be produced from 100% recycled material. The use of rPET for the production of new bottles is permitted by the 2021 budget law, which permanently lifted the 50% limit for the creation of bottles for direct food contact, with the requirement that the recycled material must come from other bottles used to contain food. The aim is to collect and recover 90% of the PET bottles sold on the market by the consortium member producer companies. If we consider bottled water only, Italy consumes 11 billion litres per year, which corresponds to approximately 242 thousand tons of plastic per year. The recovery of 90% of these bottles for the production of new bottles would prevent emissions of around 260 thousand tons of CO_2 per year.

5.2 DECARBONISATION: FURTHER MEASURES

Further measures to reduce greenhouse gas emissions generated by the production and disposal of plastics regard their replacement with materials that have a lower climate impact and the use of post-consumer plastics as a secondary raw material.

5.2.1 REPLACEMENT WITH MATERIALS THAT HAVE LOWER CLIMATE-CHANGING EMISSIONS

Conventional plastics can be replaced with materials that have lower climate-changing emissions in order to reduce fossil fuel extraction (objective E). The choice of plastic replacement material obviously depends on the functions of the product. In fact, not all polymers have a corresponding substitute which will maintain the same performance:

lightness, durability, strength, transparency, impermeability, non-biodegradability, low cost, recyclability, etc.

A great effort is being made with research to develop new low-emission and increasingly better performing materials. At present, bioplastic polymers are those considered most, even if, as already discussed, these have different origins and properties (ranging from the type of polymer to the nature of the source from which it is made). In the automotive, construction and textiles industries for example, in which fossil-based plastics are used in significant quantities, replacement with bioplastics has already begun and is promising. The first prototype of a car with a chassis and body made entirely of bioplastic was built in 2018, so it is possible to imagine, mechanical parts and tyres aside, that there could be a substantial proportion of vehicles made from plant-based plastics by 2050.

Four percent of biopolymer production is currently used in construction. Bioplastics can replace many materials such as insulating foams, facade cladding and partition panels. In addition to the materials themselves, shelves, injection moulds and packaging could also switch to biofilms based on algae or other organic material. This sector is very young and it therefore needs time to test the long-term behaviour of the products used in construction (e.g. climate resistance). Other solutions under consideration in the construction and automotive industries are biocomposites, materials that are totally bio-based and 100% biodegradable or that incorporate biological fibres alongside conventional polymers. These materials are also promising, but are still being researched.

5.2.2 USE OF POST-CONSUMER PLASTICS AS A SECONDARY RAW MATERIAL

A significant reduction in the use of fossil fuels for the production of new plastics can be achieved with the use of post-consumer plastics as a secondary raw material, by re-using and recycling plastics already present on the market. Recycling leads to a real transformation of waste to give a second life to objects or products, which may be the same or a different life. A study conducted on a detailed assessment of the types, life cycles and uses of plastic showed that a combination of reuse and recycling could reduce the global demand for virgin plastics by 60% by 2050.

Measures for the reuse of plastic products in Italy are not yet widely exploited. These measures involve the general public directly and targeted initiatives to publicise them are needed to make them effective.

A number of companies which currently wish to use more recycled plastic are faced with the limited availability of materials of the required quality or the lack of a stable supply. One possible solution would be to provide a comprehensive catalogue of the qualities required for the various products, in order to match the qualities requested with those of the recycled waste. Overlaps do in fact exist between different sectors in which products have the same quality requirements. For example, a regulatory requirement exists for recycling approved for food contact on packaging, for construction (e.g. drinking water pipes) and for electronics (e.g. domestic appliances). Performance standards for recycled materials should be defined in order to promote a plastics recycling market. These rules should also be harmonised at European level to eliminate national differences in requirements and create a common single market.

There is no doubt that if plastics recycling is to be maximised then it must escape from the waste management logic from which it originated. If it is to be high quality then recycling must play an integral part in the design of the main product groups. Design improvements can make it easier to separate different types of plastics, for example, and make it easier to clean post-consumer plastics. At the same time, the production of secondary plastics must move on from today's fragmented, small-scale operations to large-scale operations. Finally, major investments are needed to speed the development of technologies to separate different types of plastics, automate sorting and processing and recycle them. The three sectors most responsible for plastics consumption (packaging, construction and automotive sectors) are examined below and the recycling potential of post-consumer plastics from these sectors is analysed.

The packaging sector is the one which, thanks to regulations, can reduce the consumption of fossil-based plastics fastest. Globally, the sector is responsible for returning only 5% of post-consumer plastics back into production, through the following packaging applications: bubble wrap, transport and shipping films, pallets and containers, packaging tapes, garbage bags, buckets and drums, packaging for cleaning products, beverage bottles (Figure 24). Recycling of PET and PE, including non-fossil based material, is a well-proven process that has further potential to reduce emissions in terms of virgin material refills, the additives used and material losses during processing. It is therefore believed that a very high percentage of fossil-based plastic replacement and close to 100% recycling can be forecast by 2050 in the packaging sector and above all in certain sectors such as rPET, that has a market value that is already reaching levels higher than that of virgin plastics now.

Figure 24 - Overview of the quantity of recycled plastics used in new products in Europe[74].

According to 2019 *Plastics Europe* data, the construction sector puts around 14% of recycled material back into its products, in the form of pipes (pressureless uses mainly for wastewater and rainwater), windows and other construction profiles, flooring, road construction products such as cones, insulation boards and profiles. A recent post-consumer application is the reuse of plastics in concrete. This particular use is expanding but needs to be tested for long-term performance.

The percentage of recycled material used in the automotive sector is 2%. Underhood parts, door handles, bumpers, exterior rearview mirrors, warning lights and safety triangles are commonly recycled. A large proportion of car wreckage, between 15% and 20% by weight, is currently non-recyclable (known as "car fluff"), of which a large proportion is plastic.

Tyres should be discussed separately. They are made of either NR or IR (Natural Rubber or Isoprene Rubber, which are chemically identical as both are composed of either isoprene, although the former is natural and the latter synthetic) or SBR (Styrene-Butadiene Rubber, a random copolymer of styrene and butadiene), or a combination of the two polymers. Tyres also contain a very large number of additives, which include vulcanising agents, accelerators and vulcanisation activators. The presence of so many additives is being researched due to the concentration of toxic substances in the final recycled materials. Finally, tyres contain fairly high percentages of carbon black (which provides mechanical and antioxidant properties) and reinforcing steel wires. Currently, about 70% of the material is recovered/reused, around 20% is recovered for energy and 5% goes to landfill. If we consider that millions of cars circulate on the roads in Italy, which are expected to be replaced by electric cars in coming decades,

[74] From *Plastic Europe*, CPA 2019.

particular attention should be paid to the issue of scrapping vehicles and the end-of-life of tyres.

5.3 POSSIBLE DECARBONISATION SCENARIOS

On the basis of all the considerations discussed above, Table 1 shows the assumptions for two different scenarios for 2050, which differ in terms of plastic consumption and plastic composition (percentage of fossil-based, bio-based and recycled material) and end-of-life (incineration, landfill, industrial composting, recycling). Where data on the situation in Italy was not available, international-scale data was used.

Table 1 - Scenarios for the reduction of direct CO_2 emissions in the plastics supply chain in Italy.

Consumption and end-of-life treatment scenarios				
	2020	***2030***	***2050 current policies***	***2050 best case***
Raw materials (E and ΔR actions)				
Consumption [Mt]	5.9	6.4	7.5	3.8
% virgin fossil-based	88.1%	54.8%	50.4%	0%
% bio-based	1.9%	14.6%	14.6%	30%
% recycled	10%	30.6%	35%	70%
End-of-life (D actions)				
% landfill	33%	10%	0%	0%
% recycled	33%	43.7%	70%	93%
% incineration (with energy recovery)	33%	42.6%	26%	0%
% industrial composting	0%	3.7%	3.7%	7.5%

The hypotheses on which the 2050 scenarios were based are described below. The situation in Italy in 2020 was taken as the baseline.

A projected growth trend of 5% every six years in Italy was used to forecast plastic consumption, as observed in the period 2011-2017. However, a drop in consumption to 5.9 Mt was recorded in 2020 due to the Covid-19 pandemic. A fast recovery is therefore expected in the years immediately following it and a growth trend of 5% every six years is again hypothesised from 2026 onwards.

In **2030**, it is assumed that 54.8% of the plastics placed on the market will be of fossil origin, 30.6% will come from recycled material (i.e. 70% of recycled plastics will be put back into consumption[75]) and the remaining 14.6% will be bio-based, in accordance with projections reported in the literature[76]. The hypotheses for end-of-life are that the percentage sent to landfill will be the same as that required by the legislation (Legislative Decree No. 116/2020) [77] for municipal solid waste (a conservative hypothesis for plastics), that 43.7% of post-consumer plastic waste will be recycled and that a quarter of bio-based plastics (3.7%) will be sent for

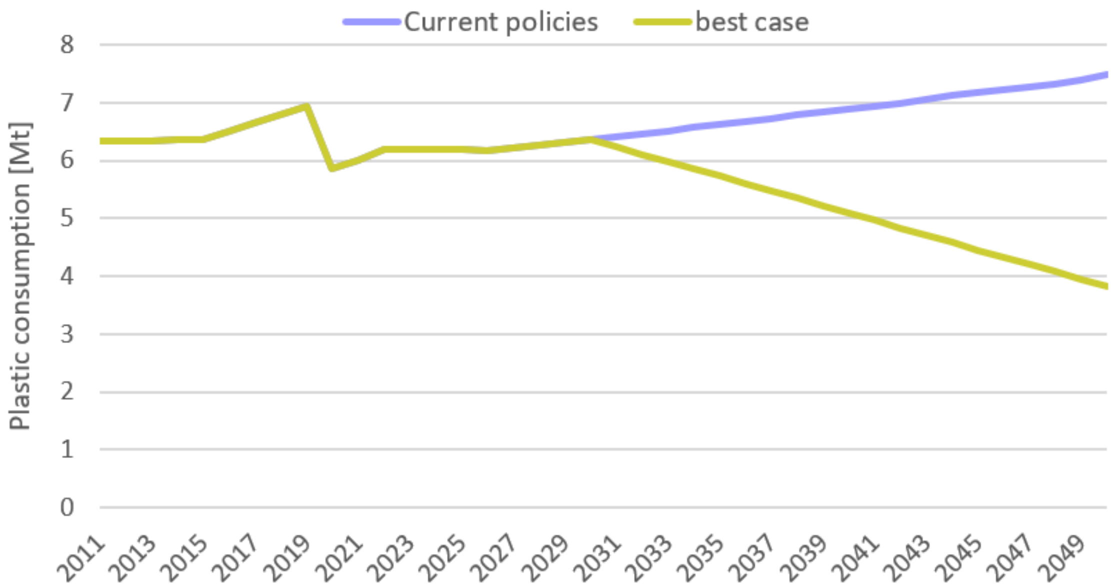
[75] Meyes et al, 2021. Achieving net-zero greenhouse gas emission plastics by a circular carbon economy. *Science*. Vol 374, Issue 6563.
[76] "Statistiche e fatti sull'Italia", *Statista*.
[77] Legislative Decree No. 116 of 3rd September 2020

industrial composting. The remaining 42.6% of plastic waste will be sent for energy recovery incineration.

The 2050 current policies scenario hypothesises a growth trend of 5% for consumption over the six-year period that ends in 2050, to therefore reach 7.5 Mt (Figure 25). It is hypothesised that 50.4% of the plastics placed on the Italian market is still fossil-based, 35% is produced using secondary raw materials and the remaining 14.6 % is bio-based[78]. The hypotheses for end-of-life are that 70% of post-consumer plastic waste will be recycled and that a quarter of the bio-based plastic (3.7%) will be sent for industrial composting[79]. The remaining 26% of plastic waste will be sent for energy recovery incineration.

The 2050 best case scenario hypothesises that the elimination of overpackaging will reduce consumption of plastic packaging by 30%. It also assumes that in 2050 single-use packaging will account for 50% of the plastic packaging placed on the market and on the basis of the downward trend in consumption of plastic shopping bags in recent years we consider that the reduction in demand for single-use plastic packaging will settle at around 50% by 2050. A 50% reduction in demand for plastics in other sectors is also forecast[80]. This therefore results in plastics consumption of 3.8 Mt in 2050, about half that of the 2050 current policies scenario (Figure 25). The hypothesis for the 2050 best case scenario is that no fossil-based plastics are placed on the Italian market, but only those produced from recycled material (70% of consumption) and bio-based plastics (30% of consumption). Hypotheses for end-of-life, which act on European calls for the elimination of landfill and the reduction of CO_2 emissions from incineration, are that a quarter of bio-based plastics (7.5%) is sent for composting and 92.5% of post-consumer plastic waste is sent for recycling.

Figure 25 - Trend for plastic consumption in Italy from 2011 to 2050 in the two scenarios.



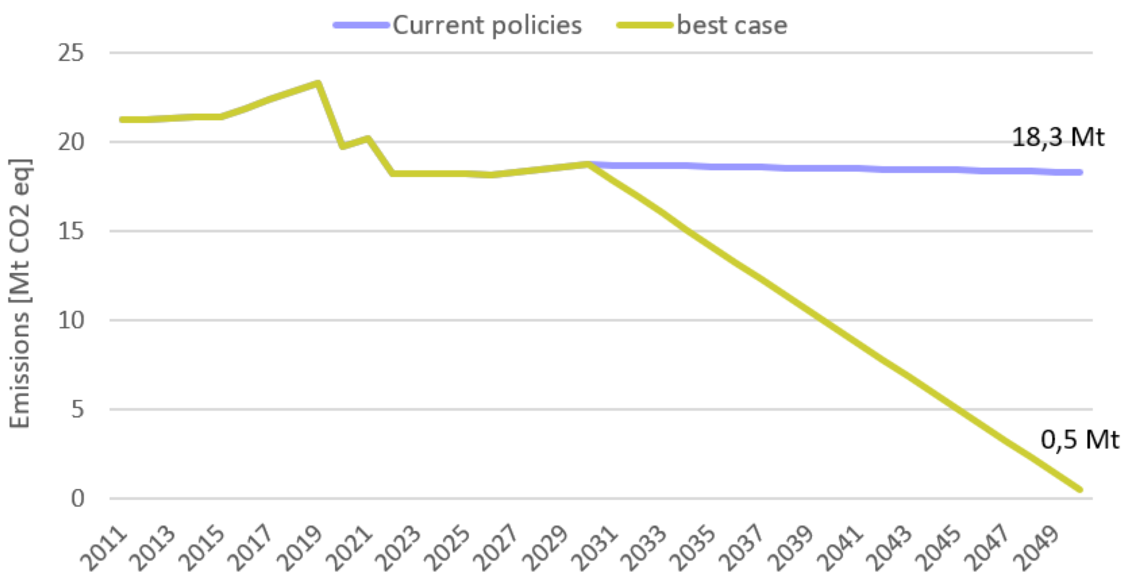
[78] "Statistiche e fatti sull'Italia", *Statista*.
[79] "Statistiche e fatti sull'Italia", *Statista*.
[80] Geyer et al. (2017); "Phasing out Plastic"

We report the following on how the data was processed:

1. reference was made to Wernet et al., 2016 for the calculation of the unit emission values[81];
2. a mix of different plastics was considered for virgin plastic consumption. The quantity of emissions was therefore calculated as a weighted average of the emissions of seven types of fossil-based plastics;
3. a mix of bio-based plastics consisting of 50% PLA and 50% Mater Bi was hypothesised;
4. in order to simplify for bio-based plastics that are sent for composting, we hypothesised that the quantity of biogenic CO_2 not emitted was the same as that emitted at end-of-life.

The results of the processing in Figure 26 show the total emissions for the plastics consumed in the different scenarios. The plastics consumed are considered rather than the plastic produced because Italy is a large consumer of plastic, but a small producer of polymers. We believe this reasoning is valid because it is important to consider the environmental and climate impacts of these high-consumption goods, even if they are produced in other parts of the world.

Figure 26 - Trend for CO_2 emissions in the two scenarios.



The **2050 current policies scenario** shows a 9% reduction in emissions compared with 2020, because although the quantity of plastics consumed is higher, less fossil-based plastic is put on the market (50.4% in 2050 compared with 88.1% in 2020) and there is a consequent increase in bio-based and recycled plastics. Post-consumer plastics going to incineration also reduces (26% in 2050 compared with 33% in 2020) and more plastics are sent for recycling and industrial composting.

[81] Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B., 2016. The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, [online] 21(9), pp.1218–1230.

The **2050 Best Case Scenario** achieves a 98% reduction in emissions compared with 2020, primarily as a result of a substantial reduction in the amount of plastic consumed (-35% compared with 2020). Furthermore, in this scenario virgin fossil-based plastics are no longer placed on the Italian market, as they are fully replaced by recycled and bio-based plastics. An end-of-life analysis shows that this plastic is no longer burnt in incinerators but is either totally recycled or sent to composting plants.

The 2050 best case scenario is very ambitious. A number of policy instruments need to be deployed to achieve these results. They must above all reverse the growth trend for the consumption materials and at the same time allow recycled and bio-based plastics to occupy larger segments of the market. Various policies that might help achieve these results are proposed below.

6 POLICIES AND MEASURES FOR THE DECARBONISATION OF THE PLASTICS SUPPLY CHAIN

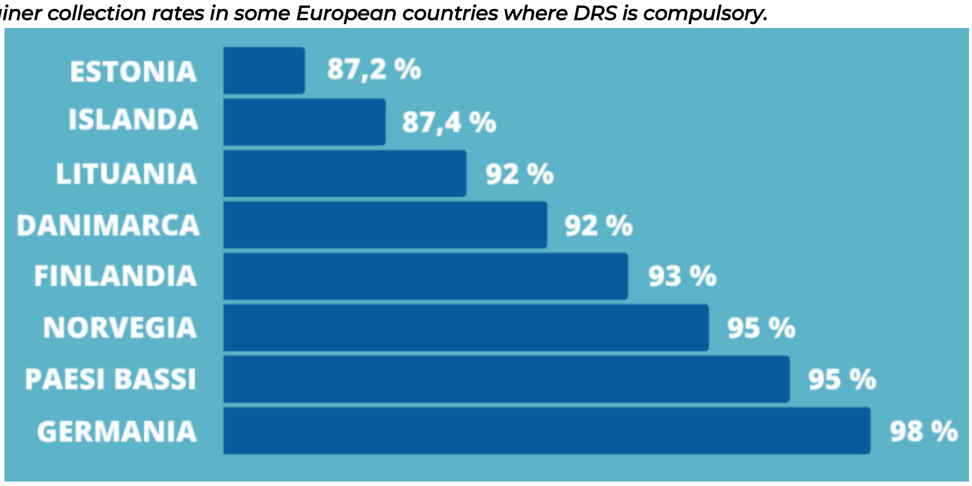
Investments and policies must prioritise climate-friendly economic activities if long-term climate goals are to be achieved. Recommendations are made on the basis of the analysis conducted in this report for national policies aimed at decarbonising the plastics supply chain, reducing waste and the consumption of natural resources.

6.1 INTRODUCTION OF DEPOSIT RETURN SCHEMES

***Silvia Gross**, Lecturer at the University of Padua*

One of the most effective tools for reducing packaging waste, especially in the food industry, are Deposit Return Systems (DRS). Deposit return systems maximise the separate collection of packaging by providing an incentive for consumer involvement by requiring payment of a deposit which is added to the sales price of the product (usually between 10 and 25 euro cents in Europe) and returned in full when the consumer returns the empty packaging. An analysis of DRS systems in 46 countries around the world where they have been adopted shows that collection rates of up to 94% of beverage containers can be achieved in countries where DRS for recycling is compulsory by law. Ten countries in Europe charge a deposit on both single-use (DRS for recycling) and reusable (DRS for reuse) packaging and achieve collection and recycling rates that in some cases exceed 90%, as shown in Figure 27.

Figure 27 - Container collection rates in some European countries where DRS is compulsory.



Thirteen more countries are preparing to introduce DRS in the next four years, including Italy. A deposit return system on beverage packaging would appreciably reduce environmental pollution in Italy and allow it to pursue the ambitious European targets set for collection, recycling and the decarbonisation of the sector. The "Simplifications *bis*" Decree approved on 28th July 2021[82] contains a specific regulation that introduces deposit return systems for beverage containers made from plastic, glass and metal. It has a very clear objective to *"increase the percentage of reusable packaging placed on the market in order to help*

[82] Decree Law No. 77/2021 – Governance of NRRP and simplifications

transition towards a circular economy" and it stipulates that "*traders, either individually or collectively, must adopt deposit return systems and systems for the reuse of packaging*".

However, quite substantial operational and logistics problems are faced for the actual implementation of DRS schemes, which require substantial changes to current waste management systems and logistics for the collection of empty packaging and its treatment. A number of important points exist, not explicitly mentioned in the amendment to the Simplifications *bis* Decree, which include the creation of an IT system, the involvement of major retailers and relations with municipalities. If it is to function well a DRS scheme requires an IT system to read the barcode on each container and allow the deposit to be downloaded. The creation of a deposit return system in Germany had a cost of €2 billion, of which €1 billion was for the IT system.

The issues regarding the involvement of major retailers are more delicate. Most DRS schemes in Europe are of the "return-to-retail" type, which means that the collection of empties takes place at the major retailers. However, when a consumer returns a bottle to a major retailer, the question of who owns the empty bottle then arises. These types of technical, logistical and management problems require prior agreements between the parties involved (manufacturer, major retailers, local authorities). According to some waste management experts interviewed by *Materia Rinnovabile*, the regulations needed for the introduction a DRS scheme should be coordinated and aligned with the laws already in force to regulate the extended producer responsibility (EPR) regime that already exists for packaging and was recently amended by Legislative Decree No. 216 of 2020. In terms of financial responsibility, by 2024 packaging manufacturers will be obliged to cover the costs of the separate collection of the waste resulting from packaging placed on the market in full (or by way of derogation at least 80%) and also the costs of its subsequent transport, including the treatment required to achieve the ambitious recycling targets set by the EU, the costs incurred to achieve any further targets (e.g. reduction targets, reuse, recycled content) set at national level and the publicity, data collection and communication costs.

6.2 PROMOTE THE ADOPTION OF REUSABLE PRODUCTS

The introduction of regulatory instruments (e.g. obligations and prohibitions) to encourage the transition from single-use to reusable products plays a decisive role in the policies adopted or being adopted in several European countries. These instruments should, with due caution and sufficient time for their entry into force, also be included in the mix of national measures, to make sure that instruments designed to combat single-use plastics do not leave the disposable production and consumption model intact, as this would be unsustainable, regardless of the material employed. Furthermore, on the subject of single-use articles subject to consumption reduction obligations, the SUP Directive itself clearly states that Member States may introduce market restrictions to ensure that these are replaced by reusable alternatives. If the French legislation were again taken as an example, Italy could also introduce a 5% reuse target for all types of packaging sold by 2023 and a 10% target for 2027. This target can be gradually increased in subsequent years.

6.3 COMMAND AND CONTROL TOOLS TO COMBAT SINGLE-USE

With its new law on waste and the circular economy[83], France aims to eliminate all single-use plastic packaging on the domestic market by 2040. A similar command and control measure could also be introduced in Italy by setting binding targets for the progressive reduction of single-use packaging. In this respect, two simple measures have been identified that could be adopted in Italy in the short term:

1. a ban on the sale of fresh fruit and vegetables in plastic packaging. This ban may initially be introduced for certain less perishable products only and then be progressively extended to include all fruit and vegetables, leading to a total ban on this type of packaging by 2026;
2. a ban on catering establishments providing single-use dishes of any material for consumption on the premises, with a requirement to use reusable alternatives.

6.4 IMPROVEMENTS TO WASTE PLASTIC COLLECTION AND RECYCLING PLANTS

As a consequence of the ban on importing waste by foreign countries and the progressive reduction of waste going to landfill promoted by the European plan for the circular economy[84], the facilities that collect and manage waste are struggling to keep up with the current rates of consumption of plastic, and of single use plastics in particular. Recycling plants are having to dispose of greater quantities of plastic waste than in previous years and investment in new plants for the separate collection and recycling of plastic waste is therefore needed.

In order to support plastic recycling, the National Recovery and Resilience Plan (NRRP[85]) has allocated an investment of €0.6 billion for circular economy "flagship" projects (section M2C1 "Circular Economy and Sustainable Agriculture"). The objective of this investment is to improve the collection and the development of recycling plants for various materials, including plastics, by encouraging projects that qualify as "circular districts". While this investment is a positive sign, it nevertheless seems rather small because the funds have been allocated not just to plastics, but also to the recycling of other materials such as paper and cardboard, WEEE (Waste Electrical and Electronic Equipment) and textile waste.

6.4.1 STANDARDISATION OF POLYMERS

Action can be taken upstream in the production chain to improve the quality of recycled plastics and therefore reduce the demand for virgin plastic. On the one hand, this would involve eco-designed products aimed at simplifying the composition of products by placing limits on the use of additives and dyes and, on the other, it would require simplification so that products could be disassembled into uniform components in terms of the constituent polymer. These strategies can improve the mechanical recycling of many plastic products, thereby raising recycling rates and producing higher quality secondary products.

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[83] LOI no 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire
[84] "A new action plan for the circular economy", *European commission*, 11th March 2020.
[85] "National Recovery and Resilience Plan", Italia domani.

For example, *Adidas* has designed its *Ultraboost DNA Loop* shoes using one single material, thermoplastic polyurethane, and without using glues. These shoes can be easily recycled and they are designed to be returned to the company when the customer decides to discard them. Consumers can send their shoes back to *Adidas* which cleans them and grinds them into polyurethane pellets, which are then melted down to create new components to manufacture new shoes.

Public procurement can play a major role in fostering demand for certain types of standardised products. Requirements could be specified in public procurement contracts for specific types of polymers and compounds to be used in certain articles, in order to support a market for these products.

6.5 CREATION OF A MARKET FOR LOW-CARBON PRODUCTS

The creation of a market for secondary raw materials and bioplastics would promote the use of these products as a replacement for virgin fossil plastics. The public sector can play a major role here by setting strict sustainability criteria for public procurement contracts (green public procurement). Special requirements regarding the carbon footprint of products used in the public sector can help create secure markets for low-carbon products and, as a consequence, also reduce the risks for companies investing in climate-friendly solutions. For example, minimum percentages of recycled or bio-based material content for determined classes of products or applications (e.g. in cars or buildings) could be included in specifications for public procurement contracts.

Public procurement standards can also stimulate the private sector market to adopt similar sustainability criteria. However, if these measures are to be effective, then sufficient data on LCA (life cycle assessment) assessments of products and an effective labelling system to certify low-carbon products according to appropriate sustainability standards must be available.

6.6 PROMOTION OF RESEARCH IN THE BIO-BASED PLASTICS SECTOR

Bioplastics generally cost more than conventional plastics because their final price also includes the R&D costs companies incur to create these new materials. If the government were to subsidise some of these costs, the price of bioplastics could fall, thereby encouraging greater use of them, especially in those applications where they constitute a sustainable alternative to conventional plastics.

The "Catalogue of Environmentally Damaging Subsidies"[86] reports that in 2020, funds for the research, development and demonstration of fossil hydrocarbons (oil, natural gas and coal) totalled €81.2 million. This funding could be terminated and part of the funds allocated to research and innovation in bio-based plastics. If the government were to do this, it could help

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[86] "Catalogue of environmentally damaging and environmentally friendly subsidies 2019-2020", *Ministry of ecological transition*.

reduce the risk associated with investing in new solutions that are compatible with long-term climate objectives.

6.7 EDUCATION AND AWARENESS OF THE GENERAL PUBLIC AND LAWMAKERS

Silvia Gross*, Lecturer at the University of Padua*

An important measure that would have an "empowering" impact which would boost and amplify regulatory action taken to decarbonise the plastics supply chain also regards consumer awareness and strong shared values. In this regard it is important to design and conduct sound and consistent educational programmes targeted at public opinion and institutions which promote discussion based on scientific concepts around plastics issues and how it can be produced from plant sources and recycled, because the education of a generation of people who are informed and aware can have a much greater impact than rules and directives to govern consumer behaviour.

On the institutional side, it would be best to adopt an inter-ministerial approach to communicate and address plastic-related issues, for example by setting up an inter-ministerial body that could bring together politicians, institutions and key stakeholders in this area.

7 CONCLUSIONS

With its great variety of properties, plastic is one of the most widespread materials in society. Italy in particular is the second largest consumer of plastic in Europe, an unenviable record if we consider that almost all plastic is now produced from fossil-based raw materials such as oil and natural gas. This results in the emission of 1.7 tons of CO_2 per ton of plastic into the atmosphere, plus 3.1 tons of CO_2 if the plastic waste is incinerated.

The current pace of plastic production and consumption has also caused grave problems of pollution in numerous marine and terrestrial ecosystems and the over exploitation of natural resources. The environmental issues involved in the production and consumption of plastics are therefore manifold and a complex strategy is needed to address them. More specifically, on the basis of the findings that have emerged from this analysis, three "key objectives" can be identified around which a policy framework can be built to help meet climate neutrality goals and, at the same time, address the problem of plastic pollution:

1. **A reduction in plastic consumption**, especially in the packaging, construction and automotive sectors, the main consumers of plastics in Italy;
2. **An increase in recycling rates,** which will reduce emissions and imports of CO_2 intensive materials.
3. **The use of bioplastics.** Plastics made from plant-based raw materials are one potential solution to environmental problems for those uses where existing alternatives do not resolve them.

To achieve these goals, policies are needed to control production and consumption, together with polymer standards to promote recyclability. However, action must also be taken on the demand side to maintain the competitiveness of Italian industry, protect employment and ensure that companies move their activities in directions that are compatible with long-term climate neutrality targets. This means creating a market and demand for secondary raw materials and bio-based plastics, for example by introducing special specifications in public tender contracts.

GLOSSARY

Biodegradation
Biodegradation is a process by which microorganisms break down the chemical bonds of the molecules by using specific enzymes which transform these molecules into carbon dioxide (CO_2) and water. Biodegradable polymers are polymers that are able to undergo biodegradation processes by these microorganisms. Biodegradable polymers can be synthesised from monomers originating from both fossil-based and plant-based raw materials.

Composting
Composting is a bio-oxidation and humidification process which a mixture of organic matter undergoes, carried out by macro- and micro-organisms under specific conditions. In the organic cycle, composting, or biostabilisation, is a human-controlled, aerobic biological process that leads to the production of a mixture of humidified substances (compost) from biodegradable residues through the action of bacteria and fungi. The compost can be used as a soil improver for agronomic or nursery gardening purposes[87].

Standard EN 13432 is a harmonised standard of the European Committee for Standardisation which governs properties that a material must possess in order to be defined as biodegradable or compostable. According to the standard, for a material to be defined as compostable, it must possess the following properties:

- decompose by at least 90% in 6 months in a carbon dioxide-rich environment;
- when in contact with organic materials for a period of 3 months, at least 90% of the mass of the material must consist of fragments smaller than 2 mm;
- the material must not have any negative effects on the composting process;
- a low concentration of heavy metal additives in the material;
- pH values within the established limits;
- saline content within the established limits;
- concentration of volatile solids within the established limits;
- concentration of nitrogen, phosphorus, magnesium and potassium within the established limits.

Compounder
Compounders are companies that buy polymers and additives to then mix them to produce polymer compounds for specific uses. Compounders, do not therefore produce manufactured goods, but “blends”, or polymers that are filled or contain additives, which are then transformed into manufactured goods by processors.

Rubber
Rubber is also a polymer, because it consists of long carbon and hydrogen chains. However, as natural rubber preceded synthetic polymers historically, it continues to be considered as a separate industry from polymers.

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[87] A soil improver is any substance capable of modifying and improving the chemical, physical, biological and mechanical properties and characteristics of a soil. Soil improvers are products used primarily to increase and maintain the organic fertility of soils. Their nutrient content is relatively low.

Naphtha
A mixture of light petroleum fractions used as solvents or as a basic chemical raw material.

Plastic
The term plastic refers to a wide range of polymeric materials, i.e. materials consisting of long chains of carbon and hydrogen in which other elements may also be present that result in numerous materials with different properties. A distinguishing feature of plastics is their wide range of properties, such as low density, low electrical and thermal conductivity, the ease with which they can be shaped into an infinite number of different objects and their strength and flexibility which has made them practically indispensable in large numbers of different industries.

Bio-based polymers
Bio-based polymers, which are plant-based polymers, are polymers synthesised from biomass monomers and therefore not from fossil sources.

Thermosetting polymers
Thermosetting polymers are made up of long, cross-linked macromolecular chains that form a network, even a three-dimensional network, through chemical bonds that make the polymer insoluble and infusible. These polymers are therefore difficult to recycle.

Thermoplastic polymers
Thermoplastic polymers are fusible and soluble products and, as a result, are easily processed and suitable for normal processing technologies (such as extrusion, blow moulding, injection moulding, etc.). They soften when heated and harden again when cooled, so they are easily processed under heat and can be recycled as manufactured goods. Polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyamides, etc. belong to the family of thermoplastic polymers.

Chemical recycling
Chemical recycling is used to convert post-consumer plastics into smaller molecules (monomers), which can be used both to produce new polymers and for energy generation. Chemical recycling depolymerises macromolecular chains, which means it converts them into either monomers or a mixture of monomers. These are then polymerised to produce the same polymer.

Mechanical recycling
Mechanical recycling can only be used for thermoplastic polymers and can be divided into primary and secondary recycling. A typical example of primary mechanical recycling is the recovery of material from scrap and defective parts in the same industrial plant. Generally these are granulated and reprocessed in a mixture with virgin material.

In secondary mechanical recycling, the input material is post-consumer articles and is reused after a series of operations (separation, washing, processing to a molten state) that result in a second material that can be used for the production of articles that require lower quality performance than those of the original input material.

Steam cracking

Steam cracking is a hydrocarbon pyrolysis process (in the form of natural gas or naphtha) carried out using water vapour. Steam is not involved as a reagent in the main pyrolysis reaction. Its functions are:

- as a diluent;
- as a thermal vector;
- to react with the coke (unwanted by-product), preventing it from accumulating on the reactor walls.

Processors

The term "plastics processing industry" is used to refer to the industry that processes polymers or compounds to produce any kind of manufactured goods.

THE ITALIAN CLIMATE CHANGE THINK TANK

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This report was edited by:
Giulia Novati, Industry Programme Researcher, ECCO giulia.novati@eccoclimate.org

Manager and reviewer:
Matteo Leonardi, Co-founder and Executive Director Domestic Affairs, ECCO

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The views expressed in this report are exclusively those of ECCO think tank, the author of the report.

For interviews or more information on the use and distribution of the content in this briefing, please contact:

Andrea Ghianda, Head of Communication, ECCO

andrea.ghianda@eccoclimate.org

+39 3396466985

www.eccoclimate.org

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