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Design and implementation of a new certification scheme for recycled polyethylene goods: the case study of PG Plast S.r.l.

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Abstract

The recycling of plastic and the use of recycled plastic as new raw material are now a necessity because the world production of plastic is continuously increasing. Packaging is the main responsible sector for the creation of plastic difficult to recycle due to difficulties in separation and treatment. Moreover, the low economic value of plastics considered non-noble represents another obstacle.

The new European regulation about plastic includes some measures to prevent the use of virgin plastic. The promotion of green purchases in public administrations, the plastic tax, related to the use of virgin plastic, the increasing of the share of recycled plastic waste up to 50% and the expansion of the market of innovative or recycled plastic products, are clear examples of how the European Union and its Member States are trying to reduce the use and production of plastic.

In this context and focusing on the Italian situation, *Polieco*, the national consortium for the recycling of waste of polyethylene goods, promotes the implementation of a new certification scheme for recycled polyethylene goods that certified the content of recycled polyethylene for products. The verified declaration of the recycled content of plastic goods becomes not only an obligation but an opportunity to innovate its processes and products. The purpose of this study is to verify the concrete application of the new certification scheme, called "*rePEv*", to a company that produces polyethylene goods starting from recycled polyethylene collected in Italy, with reference to how this environmental declaration can represent an opportunity for manufacturing companies and how it counters the illicit trafficking of plastic waste.

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Introduction

Plastic has revolutionized the global economy since its application has evolved on an industrial scale. It is a versatile material, and it has enabled a global improvement of goods and services. For this, plastic products have become indispensable in many productive sectors, but this has inevitably led to a massive and uncontrolled production which means more waste and pollution. Despite the good practices of recycling and reuse have been improve in the last few years, the problem of waste and plastic environmental dispersion still actual. It is necessary radically change the way of thinking our society and the way we conceive our economic system.

In this sense, the circular economy represents a strategic and, at the same time, necessary change that companies can undertake to increase the sustainability of the economic system and reduce the environmental impact caused by the mindless production and consumption of sources. The environmental sustainability, the circular economy and the use of recycled materials are essential concepts that are becoming integral part of modern society. These fundamentals should be known and implemented at every level by citizens, companies, and governments.

Businesses are becoming increasingly aware of the possibility of creating a competitive advantage through the adoption of circular and sustainable production. However, the purpose of modern companies is not the only maximization of profits through the reduction of production costs, but it is also the environment protection and the social health and progress.

Nowadays the circular economy is studied in various aspects and there is a focus on the plastics supply chain, cause plastic is one of the most impactful materials from an environmental point of view because it is difficult to dispose due to its resistance to ageing. despite this, it remains indispensable in many applications and for different uses. Recycling and a better use recycled plastic materials are one of the most difficult challenges that global plastic production must face.

To change towards a more circular economic system for plastic, different initiatives were taken to reduce the virgin plastic production and consumption, improve recycling of plastic materials and consequently increase the production of products made of recycled plastic. In particular, the so-called environmental labels, both mandatory and voluntary, have seen a gradual evolution in the last few years and an increasing of their use.

The objective of the thesis work was to demonstrate the effective applicability of a new voluntary certification scheme called "*rePEv*" in a manufacturing company that produce recycled polyethylene (PE) goods, elaborating a traceability procedure to trace the recycled PE through all the production process. The study considered the PG Plast S.r.l. production plant as

base case for further future applications of this traceability system. It is a company which produces reusable bags made of recycled PE and other PE goods for packaging,

The initial theoretical framework is developed based on bibliographic research of international and national reports and European and Italian regulations and laws about plastic recycling, circular economy, and traceability methods. The analysis of the case, on the other hand, is carried out based on information and documentation released by the company. Furthermore, it was applied the current legislation about environmental labels and certification schemes based on international standards.

The thesis is divided into four main chapters. The first chapter describes the circular economy, its principles, its characteristics, and purposes that the new conception pursues to substitute the traditional linear systems focusing on the circular economy of plastic. Furthermore, there is a presentation of the current situation about plastic production and recycling, examining the Italian and European context.

The second chapter is basically divided into two parts. The first part presents the European strategy for plastic describing its main principles and the main regulations adopted to face the problem of plastic packaging waste, both in Europe and Italy. The second one describes the instrument, such as environmental label, plastic tax, adopted to promote a more sustainable and circular system. CAM (*Criteri Ambientali Minimi*) introduced by Legislative Decree 50/2016 have oriented the public administration to green purchasing and to consider the entire life cycle of a product to reduce the environmental impact using sustainable materials, such as recycled plastic but the reasoning could be extended also to the private market. At the end of this chapter there is a short description of the illicit trafficking plastic waste phenomenon focusing on Italian situation, reporting data and example on how it negatively influences the plastic economy. It represents one of the most insidious obstacles towards a circular economy due to its different forms and the inability to understand its exact extent.

The third chapter defines the materials and the methods used for the present study. In particular, the materials used to develop the traceability procedure object of the study was the international standard *ISO 22095* in which there are described the requirements to apply the *chain of custody models* to maintain the traceability of the materials and *ISO 14021* which regulates the voluntary environmental labels of type II. The procedure follows the "*rePEv*" technical disciplinary and adapt its content to a productive contest which establish some criteria and requirements that the company must demonstrate to obtain the "*rePEv*" certification on its recycled products. For this purpose, it was necessary analyse the already existing certification scheme, specifying their strengths and weaknesses, confronting them with the new one.

In the last chapter, there is the presentation of the base case, retracing the steps followed to implement a technical traceability procedure to follows the movements of the recycled PE during the reusable bags production phases. There is also a description and a presentation of the company object of this study and of its production process using recycled PE. Furthermore,

are reported also the advantages and disadvantages of using the "*rePEv*" certification scheme and the operative difficulties encountered during the drafting of the technical procedure to obtain the certification.

Chapter 1

Circular economy of plastic and plastic production

1.1 Circular economy

The circular economy was born as a response to the crisis of the production model and linear consumption, a crisis that is manifesting itself in various aspects and it is destined to intensify (*Martin Geissdoerfer, 2017*).

The reasons to adopt a new and different economic system are the scarcity of natural resources and prices volatility, the growing consumer sensitivity to environmental issues and regulatory changes. There is no doubt that the current exploitation of natural resources is unsustainable and involves problems related to high-cost supply systems, environmental impacts, and limited accessibility to raw materials. The linear economy system, which has characterized the global model of economic development until now, is no more sustainable due to the enormous consumption growth and the global population growth.

Nowadays, the global economy uses more than 100 billion of tons of raw materials (*The Circularity Gap Report, 2022*). Only the 9% (8,6% to be precise) is re-used to avoid the consumption of natural capital. In the past half-century, the world's population has more than doubled, yet the amount of material flowing through the economy has more than tripled, from 27 billion tonnes in 1970 to 84 billion tonnes in 2015.

These two factors are estimated to increase in the next years. For these reasons, the way in which resources are consumed today will affect the ability of nature to support future generation's needs.

In 2021 the mass of human-made things was found to outweigh all living beings and biomass, such as our oceans, trees, animals. Artificial objects have gone from just 3% of the world's biomass in 1900 to on par with it today. The improper use of natural resources to produce more is no more sustainable and it will increase "from 100 to between 170 and 184 billion tonnes by 2050" (*The Circularity Gap Report, 2022*).

The pandemic events of 2020 have highlighted the problems of the linear economy system, accelerating the process towards a circular economy. In fact, Covid-19 showed how the global linear economy is extremely vulnerable and dependent from unexpected events. However, it also showed how fast changes can occur in times of crisis: governments responded fast funding aids for people welfare, jobs, and health.

To guarantee the long-term sustainability of the economic system it is necessary to create a sustainable economy, capable of managing the available natural resources in the best way possible. The principle is to obtain more products with fewer resources, reducing the amount and the number of raw materials used. The problems deriving from the extreme exploitation of natural resources by the production and consumption activities of companies, as well as the consequent generation of high amount of waste, have been fixed with the concept of circular economy. The circular economy is a way of sustainable development that takes into consideration the environmental impact caused by businesses. It is a system that aims to create closed and efficient cycles of material while the value of products is maintained. This is an approach that helps to reduce the flow of raw materials. Closing the circuits and managing waste represent the most important steps to try to reduce the consumption of natural resources and the resulting environmental impact.

A good circular economy model is capable to reintegrate the waste produced through the production cycle and furthermore, it also empowers the use of discarded products and materials. Development is no more considered as increasing of exploitation of raw material, but it is considered as an increasing of efficiency. This approach avoids the increasing demand of natural sources by the companies at the same time allowed them to grow economically. The circular economy thus makes it possible to preserve and regenerate natural capital while minimizing the environmental impact.

Sustainable development through the circular economy gives businesses an important role. The linear economy model doesn't guarantee the sustainability that the modern economies required at all levels.

Figure 1.1.: *scheme of linear economy*

The companies and the other actors involved in the economic system, can contribute to change the global trend towards the creation of systems with a strong regenerative impact for itself and for the environment. The new managerial culture applied to the circular economy is considered pulse for sustainable development and economic growth. The new paradigm is an economy where today's products are the resources of tomorrow (*Martin Geissdoerfer, 2017*), in which the value of materials is maintained as much as possible o recovered, in which there is a minimization of waste and a reduction of the environmental impact.

This global production system promotes a different approach both upstream of the production process when the raw materials enter in the production and downstream when the products exit from the production processes. Although the idea is often considered as the natural evolution of systems of waste management but, in reality, the circular models provide interventions from the more complex management, able to plan the opportunities of waste recovery and reduction from the early stages of the product life cycle. Not just the idea of recycling what is generated by production activities, but rather that of rethinking products and processes in such a way as to maximize recovery capabilities at every stage of the production process.

Circular economy is based on three basic principles (*Ellen MacArthur Foundation, 2015*). The first is to protect environmental capital, and develop it, through the regulated usage of available resources, and the balance of renewable resource flow. This suggests a strong decrease in material use and create the conditions for soil regeneration. The second principle is to optimise resource extraction by circulating products, parts, and materials, which maximises their contribution in the technical cycle. This means that remanufacturing, renovating, and maintenance are well-planned, to make materials part of economic processes long as possible. The third principle is to minimise negative externalities, eliminate toxic substances, by either replacing or reducing them. In the planning phase, waste can be reduced by choosing appropriate materials, which also decreases harmful substance emission. However, resources and energy from fossil fuels can only be replaced by renewable ones.

The model of circular economy is based on closing opened economic flows (*Ellen MacArthur Foundation, 2015*). However, circular economy provides some key principles such as waste is equal to nutrients, variety is an important virtue, energy must be extracted from renewable sources, prices must be consistent with reality, thinking in terms of systems.

***Figure 1.2**: graphical representation of circular economy*

A resume of the most important characteristics of the of circular economy are reported below:

- Less input and natural resource usage, this means minimizing and optimizing the usage of resources, producing more value from less material, decreasing import dependence of natural resources, using in an efficient way natural resources, minimizing energy and water consumption.
- Increasing the share of renewable, recyclable resources and energy, this could be possible by exchanging non-renewable energy resources with renewable ones, and maintaining sustainable supply, increasing the share of recycled and recyclable materials, in exchange of new materials, closing material loops, using materials from sustainable sources.
- Decreasing emission levels, it could be possible by decreasing emission compared to the full cycle of less and sustainable material and increasing less environmental-polluting clean material cycles.

- Reduced losses and waste material, it means construction of waste minimisation, minimisation combustion and waste deposits, minimisation of dissipative losses of valuable resources.
- Protection of the economic value of products, their parts, and materials by increasing life expectancy, increasing re-usage of parts, protecting the value of materials, and implementing high-quality recycling.

To comply with these principles, it is required an eco-design of products and the improvement of the conditions to repair and remanufacture the products. It is also required a better organization of recycling, and to do this it is needed the creation of a new market for secondary material resources. There is a need for economic regulators, tenders, financial tools for domestic establishment, and innovation is indispensable.
Based on the experiences of already realised processes, it seems that the advantages of circular economy really are apparent in the following areas (*Almut R. et al., 2016):*

- reduced material and energy usage,
- reduced unpredictability of material price and supply,
- reduction and diminishing of negative environmental external effects,
- creation of new jobs,
- increase in innovation,
- increase in the economy's international competitiveness,
- conserved advantages for a resistant and sustainable economy.

The main question is if the principles of production processes and their related quality, green workplaces protection (labour safety and labour health), and environmental protection are properly held onto, in the face of increasing economic advantages. In order to create good models, taking the life cycle perspective into consideration is indispensable (*Almut R. et al., 2016)*.

1.1.1 Circular economy of plastic

Plastics offers innovative solutions to human needs and for development of society. Plastic is one of the more versatile, durable, and adaptable material that continue to improve and innovate. Nowadays, this type of material allows to satisfy many functional and aesthetic needs, for example food packaging, technology, health and almost all production sectors.
Plastics are typically composed by polymers combined with chemical additives. A common feature of plastics is that, depending on which chemical additives are used, they can be easily turned into many different shapes during production. Chemical additives may, for instance, improve the flexibility of plastics, reduce their flammability, or increase stiffness. Despite their distinct composition, all plastics are based on carbon. Whereas fossil-based plastics use carbon

derived from oil and natural gas (petrochemicals), bio-based plastics use carbon derived from renewable materials, such as agricultural products, cellulose and even carbon dioxide (CO_2).
Plastic products are too often used as disposable products and they become waste after a single use. The current plastic production and consumption models, based on linear economy, are dangerous from an environmental point of view and an economical one too. This means that there is needed an implementation of a circular economy of plastics, thus enabling longer use, reuse, and recycling.
Adopting a circular approach allows plastic producer companies to obtain important benefits not only on an environmental level, but also under an economic and strategic aspects. One of this advantage could be the identification of areas of improvement for each company that produce or treat plastic. This leads to more efficient production processes, opening to new markets, improving reputation, and adapting by anticipating the growing regulation on various sustainability management and communication ambitions, such as the *EU Directive 2019/904 (5 june 2019)* on single-use plastics.
A more circular plastics economy tries to minimise the need of virgin material and energy in the production of plastics while ensuring that environmental stress linked to resource extraction, production, consumption, and waste is reduced.
By improving design, adopting higher quality plastics, and encouraging and enabling reuse, repair, remanufacturing and recycling, a circular plastics economy aims to retain the value and utility of products within the economy for as long as possible to ensure that plastics never become waste (*Ellen MacArthur Foundation, 2016*). This is as opposed to the current linear system of plastic production and use (dominated by low-value, low-cost and short-life plastics) in which all phases of the value chain consume finite resources and cause environmental impacts (*Lars Fogh Mortensen and Ida Lippert Tange, 2021*).

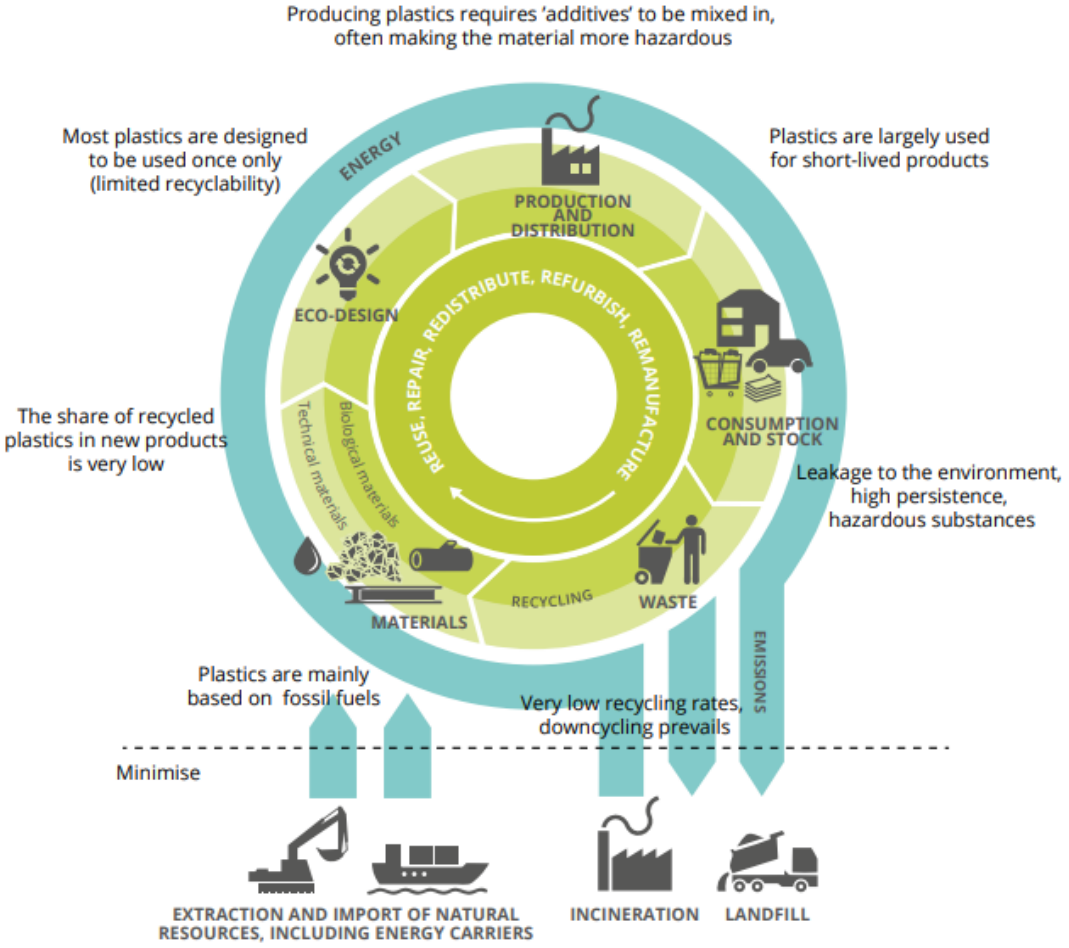

***Figure 1.3**: Circular plastic system*

The main idea behind the concept of circular economy of plastics is to promote recycling and energy recovering, with a better management of the waste deriving from production but also from domestic post-consume. It also reduces the production if by-product and waste that nowadays could be treated in an inappropriate way or discharge in the oceans or in the ground.

Today, the situation is that most plastics are still produced from fossil-based raw materials. Transitioning to a circular, climate neutral economy demands investment and innovation from the plastics value chain to develop new business models for reuse, produce more recycled plastics and new feedstocks that are less dependent on fossil-based oil and gas (*Plastics the Facts, 2022*).

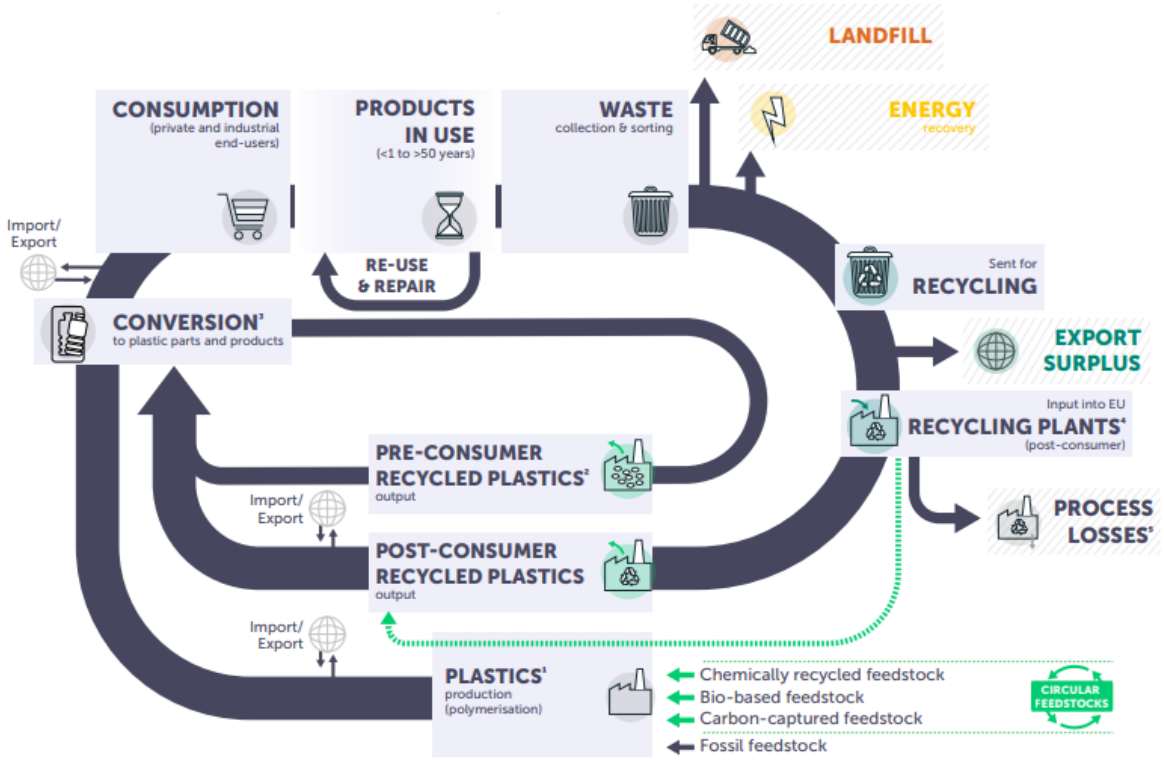

***Figure 1.4**: Circularity of plastic representation*

1.2 Packaging production, consumption, and demand

Plastic represents the present and the future in the actual economic system, however, it has a negative impact on the environment and this one of the most difficult challenges that modern society has to face-off.

The transition towards a circular economy with low carbon emissions where resources and energy are used in the most effective way is the European goal set for the next few years. After a stagnation in 2020 due to the Covid-19 pandemic, the global plastics production increased to 390,7 million tonnes in 2021. Always in 2021, 90,2% of the World plastics production was fossil-based (*Plastics the Facts, 2022)*. Post-consumer recycled plastics and bio-based plastics respectively accounted for 8,3% and 1,5% of the World plastics production.

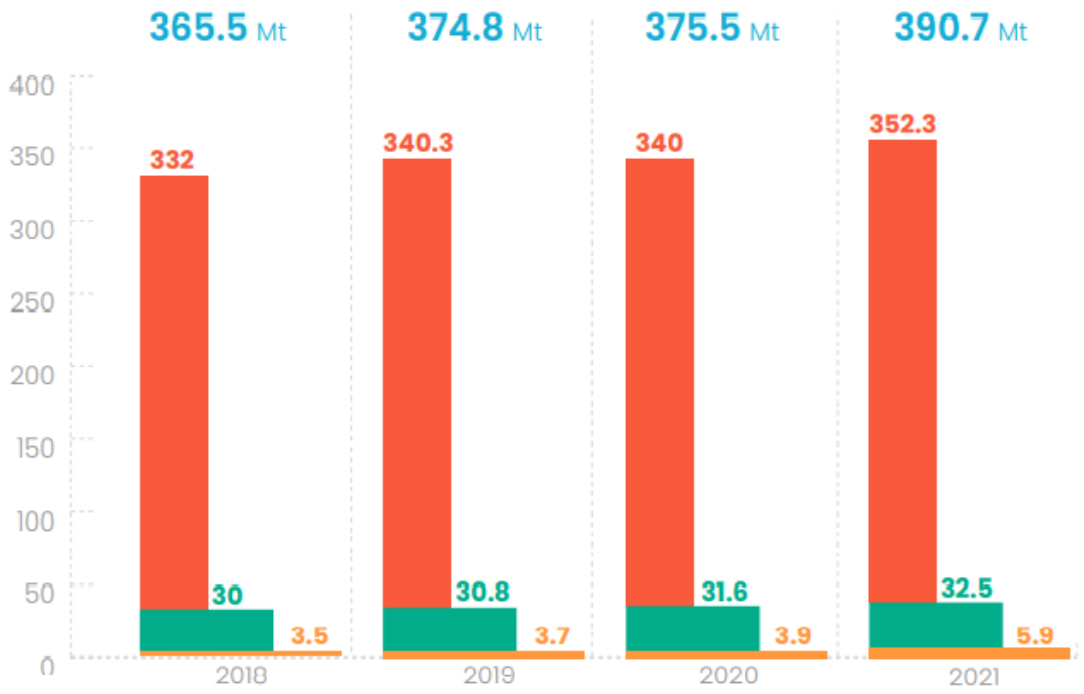

Figure 1.5*: Global plastic production from 2018 to 2021 (in Mt)*

The European production of plastic increased to 57.2 million tonnes in 2021, contributing to almost 15% of global production (*Plastics the Facts, 2022*). Asia represents the most important producer and dominates the market with 55% of global plastic production.

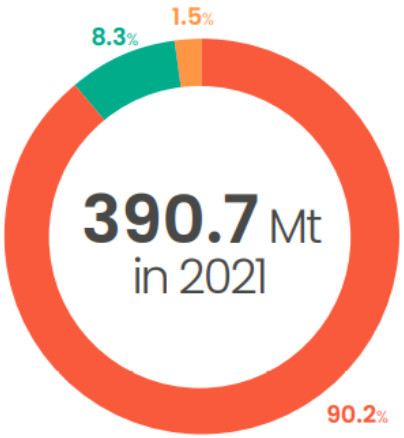

Figure 1.6: *Global distribution of plastic production*

The world manufacturing data describe that for plastic production it is necessary a large amount of transport to supply or buy materials, by planes, boats, trains, and trucks. This consequently increases the CO_2 footprint created using plastics.

As shown in *Figure 1.7*, China is largest producer of plastics of the entire world, with around 31% of the overall production of plastics. China is also the biggest exporter of plastics. The second producer is NAFTA (North America Free Trade Agreement), a free trade zone including USA, Canada and Mexico, accounting about 19% of the global production. Overall, Asia produces half the amount of plastic in the world.

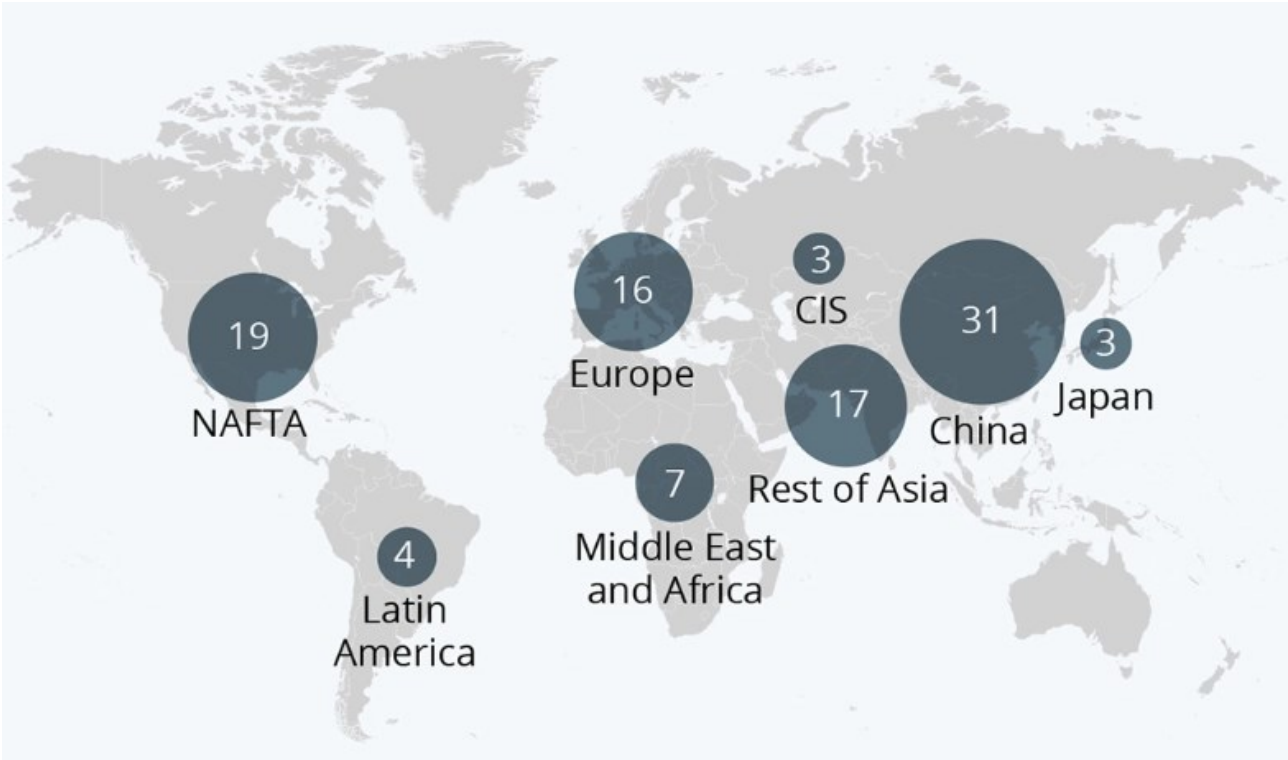

Figure 1.7*: Percentage of Global production of plastic distributed by country*

The causes of a strong import from foreign countries can be justify by a lower cost of the products, often linked to an exploitation of natural and human resources, no longer admissible in the European continent, which uses other countries where it is still possible to make the most of these resources. The usability of polymers for the protection of products from atmospheric agents, from transport, from the preservation of food, to sterilized objects and chemical products, means that plastic is still the best choice from an economic and functional point of view. For this reason, packaging needs special attention, it is necessary to look for alternative materials for packaging that can replace plastic where possible, and it is necessary to experiment with effective methods for optimizing the recycling of used packaging.

The European Union, as one of the main actors involved in the plastics economy. It represents the 4th producers of plastic all around the world, and it is also one of the main global consumers of products made of plastic. For this reason, and for the key role it covers in the global economic scenario, it has the duty to regulate plastic production as well as plastic treatment and recycling.

1.3 Plastic production: European situation

In Europe, plastics converters are the heart of the plastics industry. They manufacture a wide range of plastic products such as building pipes, fruit boxes, car interiors, cutlery, and glasses, and many more. Plastic products can be found in every industry. The European plastics industry makes a significant contribution to the welfare in Europe by enabling innovation, facilitating resource efficiency, and creating jobs. More than 1,6 million people are working in around 50.000 small and medium sized companies of the converting sector, creating a turnover of 260 billion euros annually (*Stefan Gorgels et al., 2022*).

The European demand of plastic is concentrated on country that using more than 3 Mt each. As reported in *Figure 1.8,* Germany holds the largest share with 23% of consumption, followed by Italy with 14%. Following, France, Spain, Poland, and UK represent the European countries with the highest consumption.

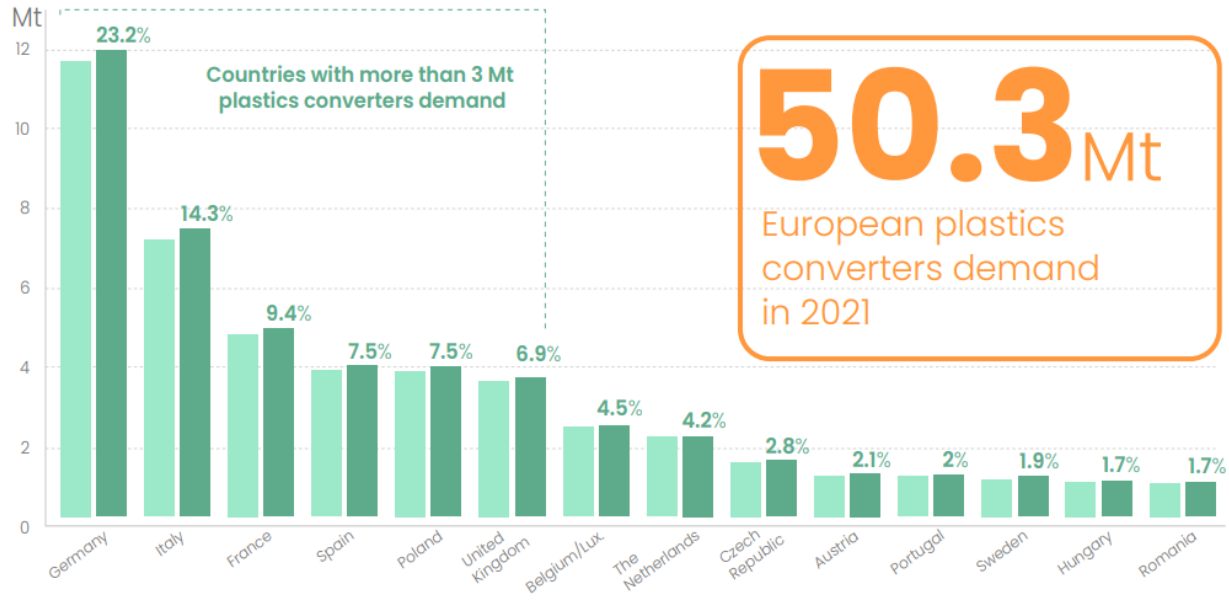

***Figure 1.8**: European plastics converter demands by countries*

Instead, the main sectors of use of plastics are packaging with more than 39%, construction with 21%, automotive sector with about 9%, electrical and electronic with 6%, sports and household sector with 4%, agriculture which has the smallest share with 3% and, in the end, various applications with about 17% (*Figure 1.9*). Analysing sectoral data, it can be seen that the most influential sector is that of packaging due to the fact that all the production companies of all sectors need plastic packaging.

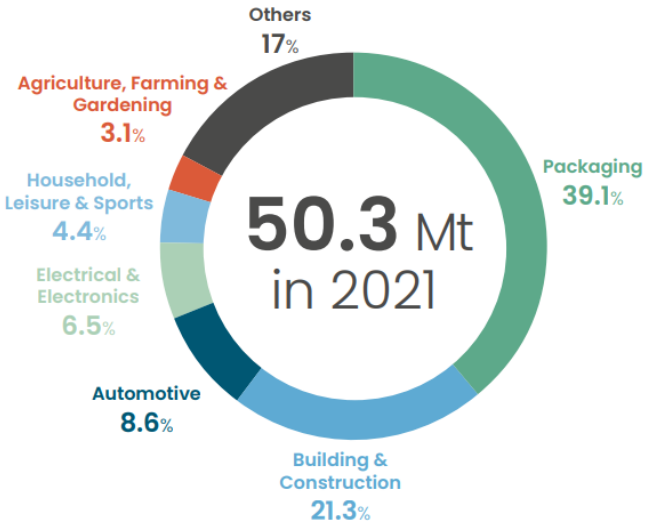

***Figure 1.9**: European plastics converters demand by applications*

In 2021, almost half of the European plastics converters demand was represented by polyolefins (*Plastics the Facts*, 2022). It is clear from data that in Europe there is a high demand for polyethylene (PE). In particular, PE demand represent about 30% of total demand of plastic. Most of this PE it is used in the packaging sector to make mainly films and bags.

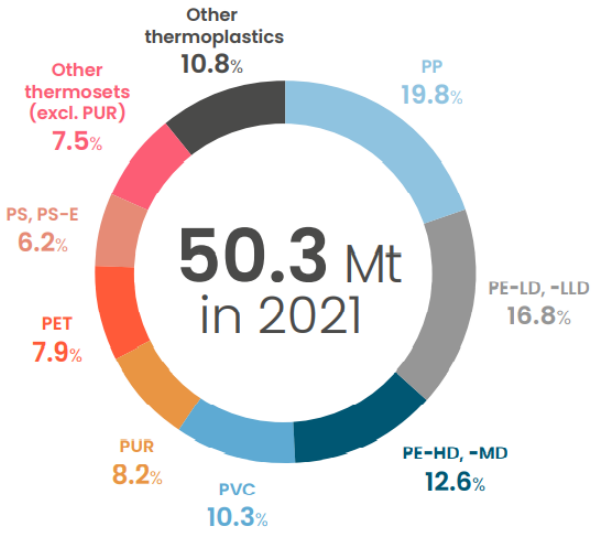

***Figure 1.10:** European plastics converters demand by type of polymer*

According to the reports of the European commission, the realization of the recycling targets for 2030 is based on common strategy for all the Member States (*European Commission, 2020*). This strategy implies the good design of the products in order to extend their life and to allow their reuse and recycling of high quality. This should result could be obtained changing the supply chain, starting from the design of products, and then modifying the production processes. The strategy involves also transport and the managing of the end of life of products allowing

innovation in the recycling sector. The target is focused on a decreasing of exports of plastic waste for which separate collection has not been carried out correctly. The development and use of innovative raw materials for the production of plastics will contribute to a reduction in dependence on fossil fuels and the consequent reduction of CO_2. Furthermore, a drastic reduction of the dispersion of plastic waste in the environment, through effective collection systems and a greater awareness on the part of citizens.

1.4 Plastic production: Italia situation

In Italy, the use of plastic is essential and characterized the economy model of the country. Italy is among the top six European countries for plastic demand, about 14% of total demand and it is second only after Germany with 23% *(Plastic the Facts, 2022)*. The demand for products is only partially satisfied by internal production, while the remainder from non-EU countries. Italy is still far from the results obtained in the most virtuous states such as: Switzerland, Austria and Germany, which managed to reset the percentage allocated to landfills, favouring energy recovery. This solution is desirable whereas landfills are the ecologically worst option, but to them mechanical or chemical recycling would be preferable to further decrease the footprint ecological plastic. The treatment of plastic waste in Italy today also takes place thanks to the export of a large quantity of material to countries responsible for processing them.

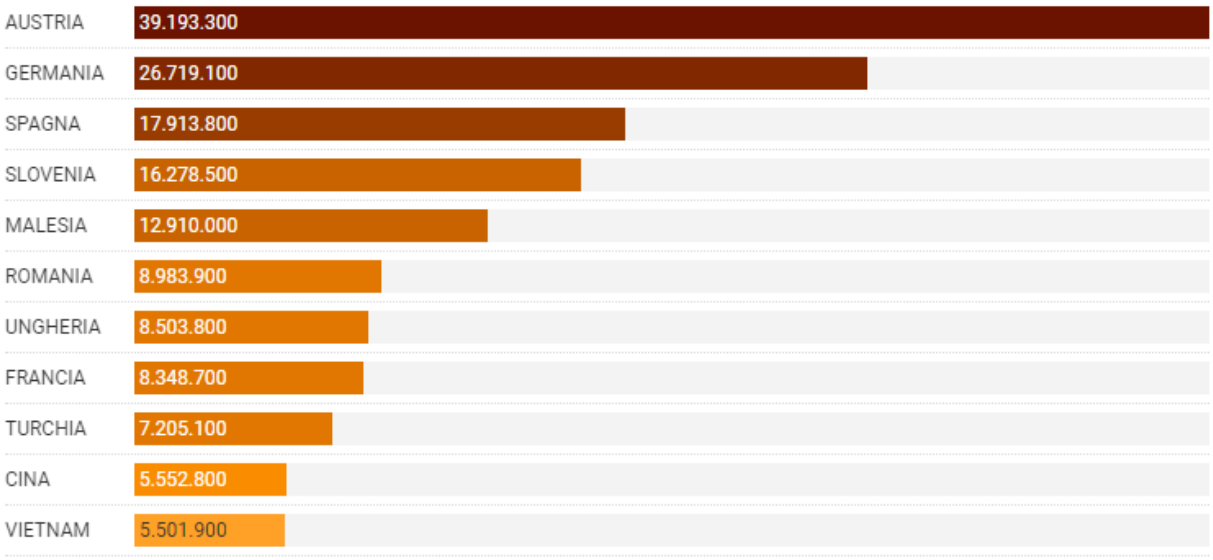

***Figure 1.11**: Ranking of the country towards which Italy exports waste*

The territories to which Italy directed most of the waste in 2018 are: Austria, Germany, and Spain. Italy is in eleventh place among the main exporters of plastic waste in the world: in 2018 alone, there are shipped 197 thousand tons abroad, for a turnover of 58.9 million euros

(*Greenpeace Italy, 2020*). The analysis of these data highlights the inefficiency of the Italian recycling system which is forced to send extra-waste to other places.

In 2018, China introduced the "*China's waste import ban*" also concerned plastic packaging, industrial waste, processed waste, and plastic residue. In 2018, compared to 2016, China reduced the volume of imported Italian waste by 83.5%, effectively accepting only 2.8% of plastic waste. This decision has highlighted the numerous criticalities of the Italian recycling systems of the plastics, and it favoured the illegal trafficking of plastic waste to country as Malaysia. More than 1,300 tons of plastic waste illegally shipped from Italy to Malaysian companies, only in the first period of 2019 (*Greenpeace Italy, 2020*).

1.5 Plastic waste recycling and treatment: European situation

Since 2006, post-consumer plastics packaging recycling waste has more than doubled (*Plastics the Facts, 2022*). This means that the uncontrolled use and consume of plastics is no more sustainable, and it will cause dramatic environmental changes.

In 2020, 29.5 million tons of plastic waste were collected, of which 12.4 million tons were treated through energy recovery, 10.2 million tons through recycling and the remaining 6.9 million tons have been sanded to landfills (*Plastics the Facts, 2022*)

Observing the percentage variations in *Figure 1.9*, it possible to see the European efforts for the optimization of the plastic system in particular the percentage of recycling which increased by 117% in the last twelve years and that of landfill disposal which has instead decreased of 47%.

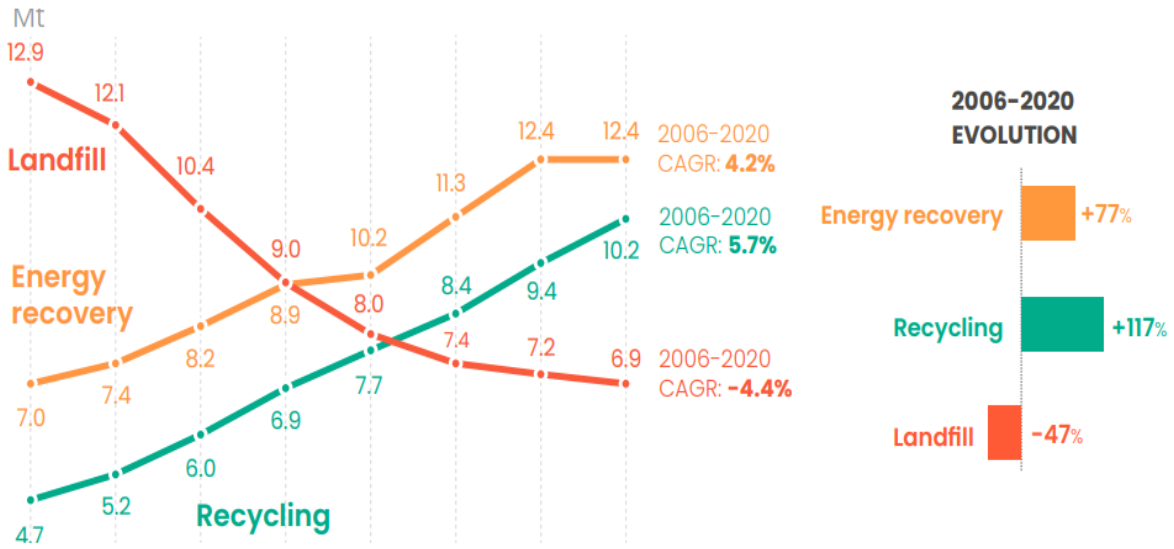

***Figure 1.12**: Evolution of post-consumer plastics waste treatment in Europe*

In 2020, the overall European recycling rate for post-consumer plastics packaging reached 46%, compared to 42% in 2018 that represent an increasing of about 9.5% (*Figure 1.12*)

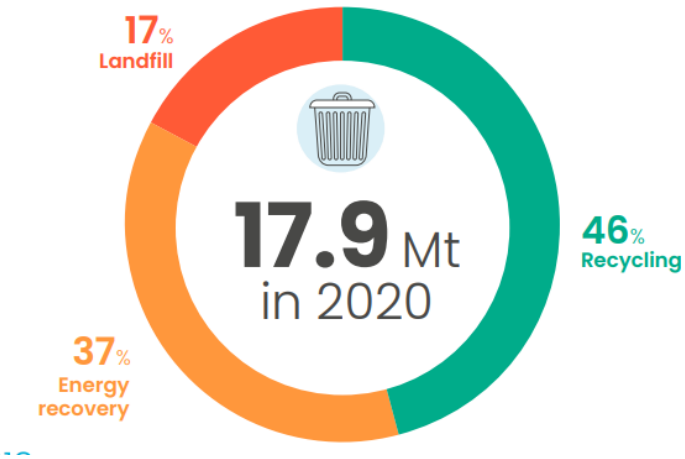

***Figure 1.13**: Recycling rate for post-consumer plastics packaging*

Focusing on the treatment of plastic packaging, *as shown in Figure 1.13* and *Figure 1.14*, the European recycling rates increased by 110% from 2006 to 2020, the share of energy recovery by 76% and landfill rates decreased by 57%. These data highlight the difficulties and the scarce economic interest during the last years for the plastics recovered from the packaging, frequently

less noble than industrial waste and more difficult to treat due to their heterogeneous composition.

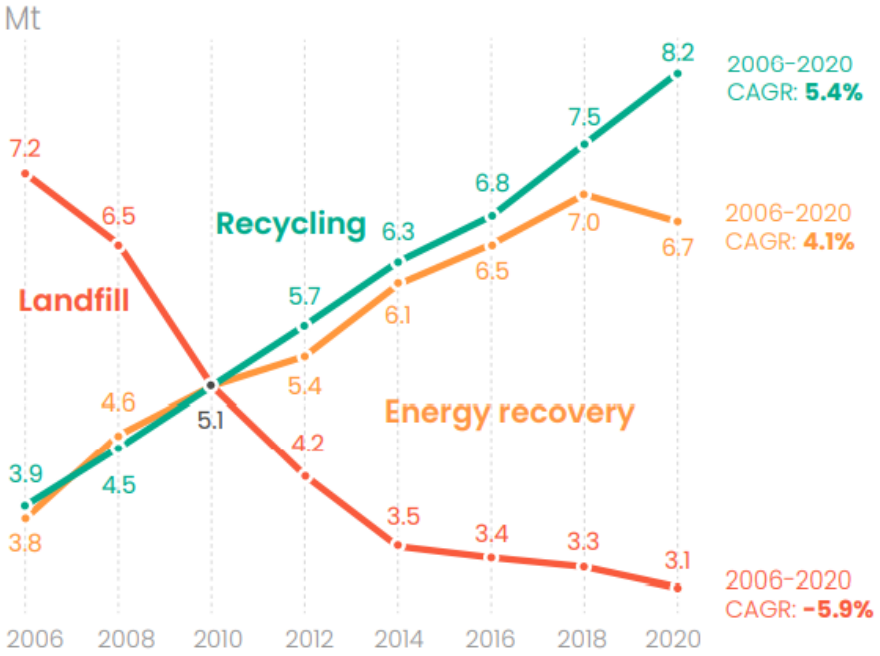

***Figure 1.14**: Evolution of packaging plastics waste treatment in Europe*

Observing the types of treatment of each State, it is interesting to see the effects of restrictions on landfilling. Looking at the data, these limitations produce minimal effects on increasing recycling. The average recycling percentage rates of European countries vary between 20% and 40%. Even the most virtuous countries are unable to improve more recycling rate due to structural limitations. This depends on the characteristics of the material, on the freedom left to the producers, but the critical factor is the linearity of the plastic system which needs a revolution to reach the circularity and consequently an increase in recycling rates. Until 2020, only 6 countries have hatted the target for 2025 of recycling rate set by EU and only Netherlands has already reached the target of recycling rate for 2030.

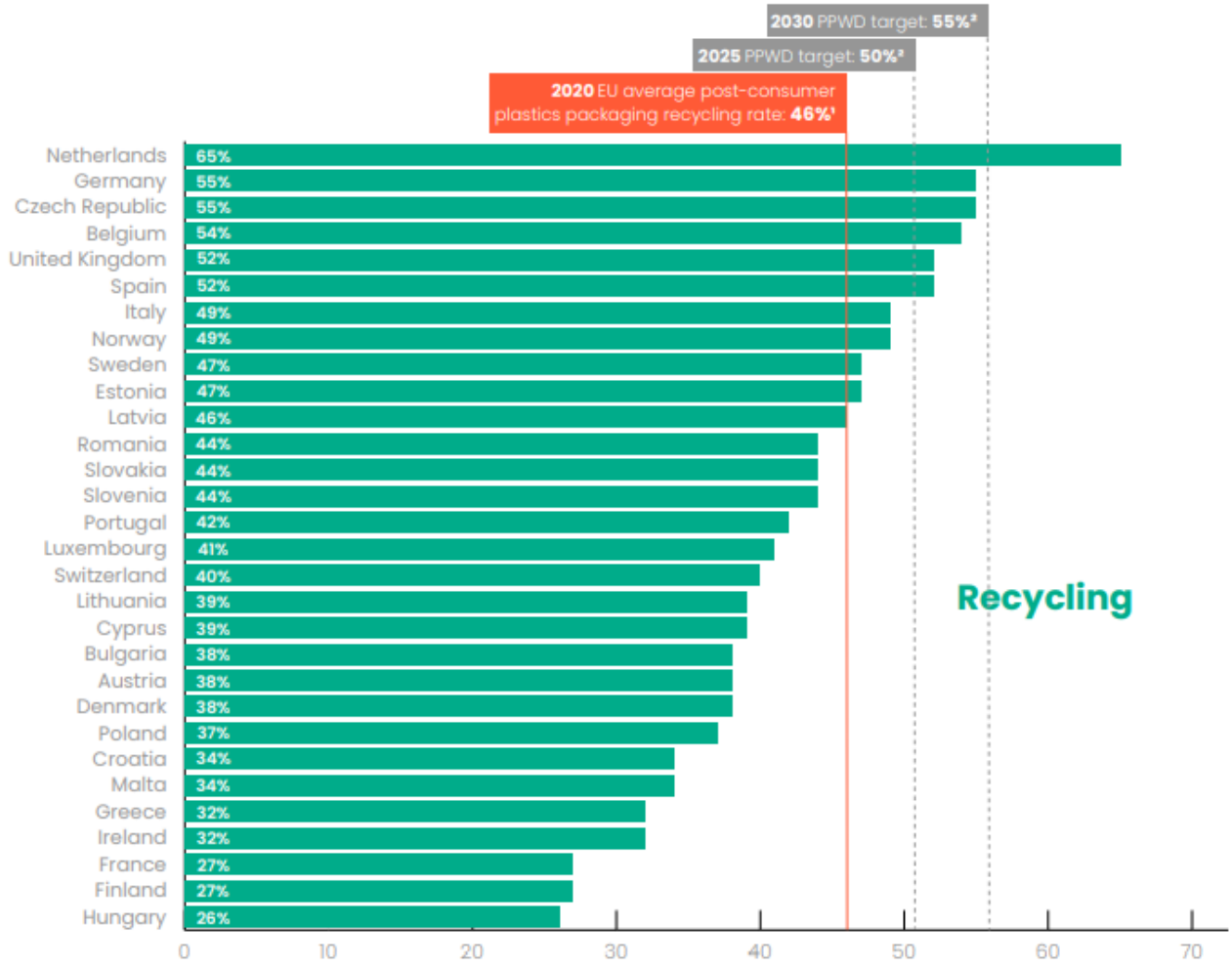

***Figure 1.15**: Post-consumer plastics packaging recycling rate per country in 2020*

The *Figure 1.16* shown a map of the recycling rate for each country. The recycling rate for packaging waste is defined as the share of recycled packaging waste in all generated packaging waste (*Eurostat, 2019*). Packaging waste covers wasted material that was used for the containment, protection, handling, delivery, and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer, excluding production residues.

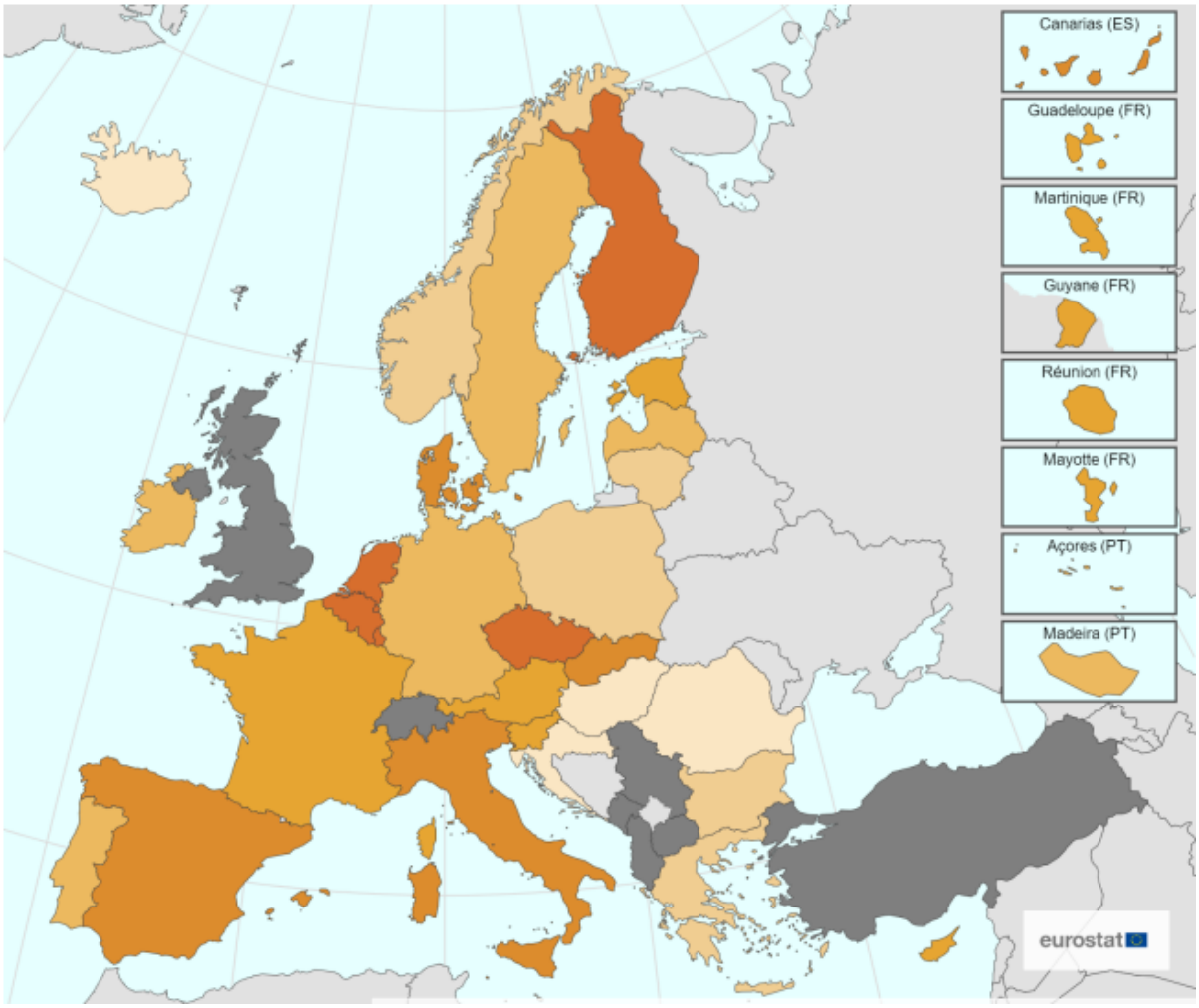

Figure 1.16: *Map of recycling rate in Europe (Eurostat 2019)*

The data from Eurostat shown that the most virtuous countries in Europe, from a recycling point of view are Luxemburg, Estonia, Norway, Iceland, and Ireland meanwhile Italy is aligned with the recycling rates of Germany, Portugal, Spain and Denmark.

1.6 Plastic waste recycling and treatment: Italian situation

In Italy during 2020, 3.545 kt were collected, 34% was sent to recycling, 34% was destined for energy recovery and the remaining 32% was landfilled, as shown in *Figure 1.17*.

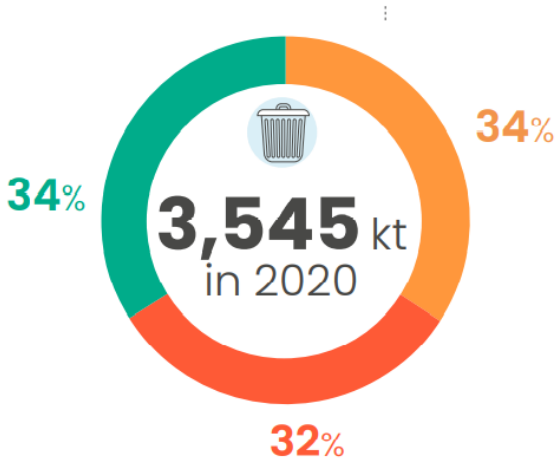

Figure 1.17: *Italian post-consumer plastics waste treatment in 2020 (in kt)*

The quantities sent to recycling increased by 77%, energy recovery increased by 58% and landfill decreased by 52%. The percentage of landfill is lower than recycling and energy recovery, and this confirm a trend started in 2016.

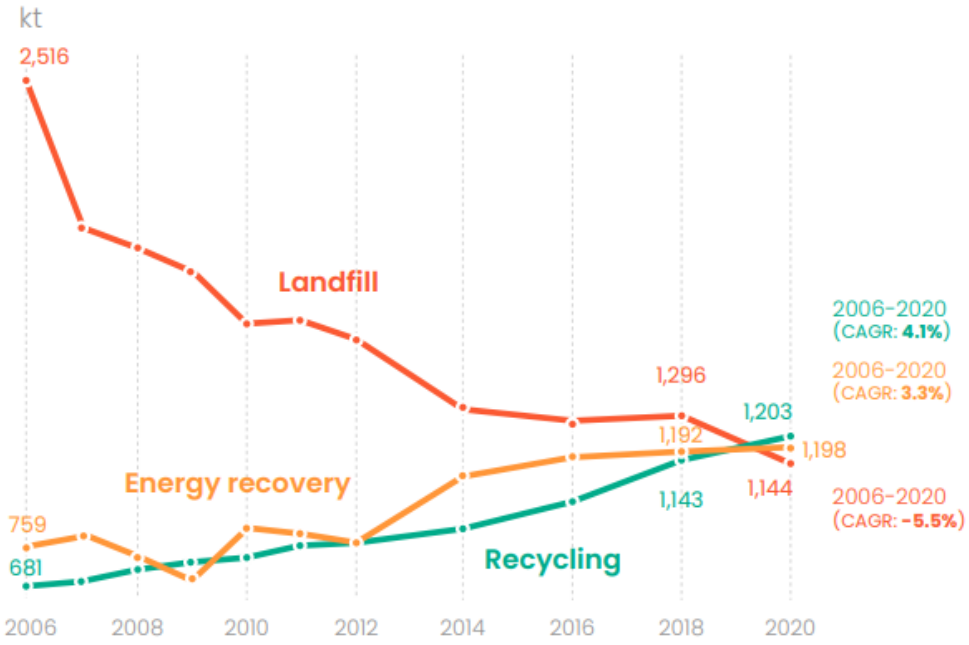

Figure 1.18: *Post-consumer plastics waste treatment evolution 2006-2020 (in kt)*

However, it is still necessary to further increase the recycling rates to reach European targets. Recycling could be better solution from an ecological and economic point of view. The main problem is that in some cases recycling is limited by technological problems or by economic limitations and ideological factors that lead to a preference for energy recovery. The main purpose remains the reduction of landfill disposal, the option which involves the greatest environmental costs and remains the only feasible choice in some situations. It is necessary to specify that the treatment of plastic packaging presents numerous difficulties: the heterogenous products and the difficulty due to collection and selection of waste.

The data of Italy are aligned with the European average, and this allowed to achieve the objectives set by the regulation. Italy is among the few European countries that manage recycling/recovery of all types of plastic packaging. In many other countries, in fact, there is limits itself to managing only the ones that are easier to recycle, such as PET bottles and HDPE bottles. Obviously, Italian choice implies the need to start energy recovery for a part of the collection (for example for the packaging which due to the polymer composition or complexity of realization cannot be recycled), on the other hand, the availability of raw materials has been the driving force behind the development of the downstream supply chain, giving life to recycling companies and transformer companies able to use recycled polymers for get new goods.

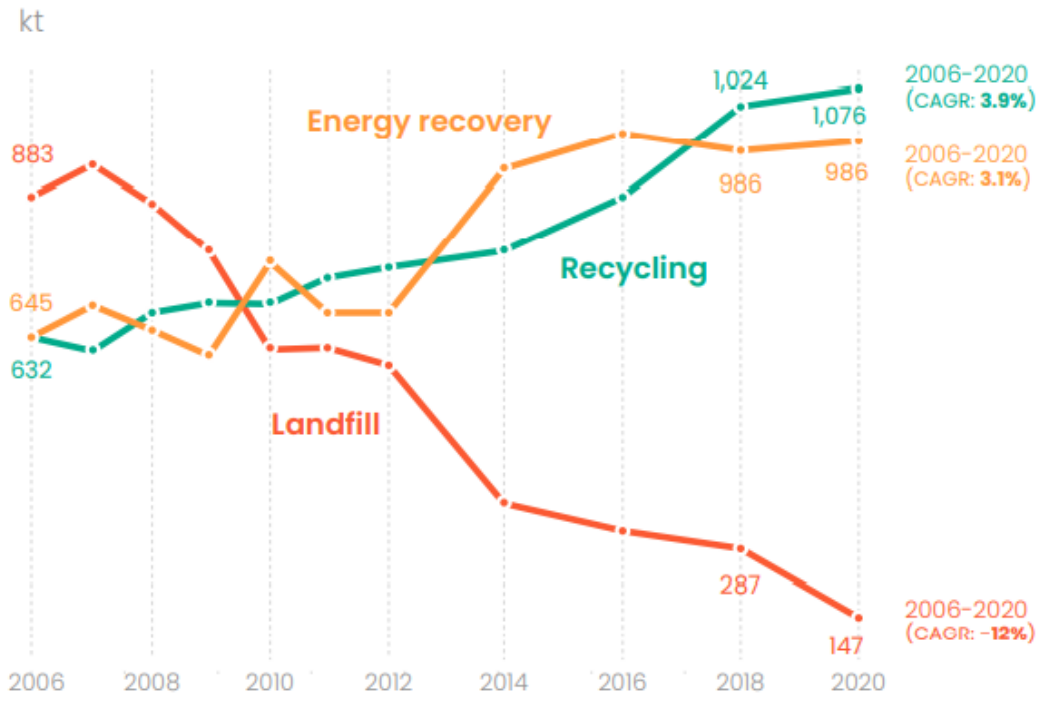

Figure 1.19: *Post-consumer Italian plastics waste treatment evolution 2006-2020 (in kt)*

The recycling of plastic packaging waste also allows to save on virgin raw materials needed to produce new plastic. The process of plastic recycling requires less energy than the production of virgin plastic, thus generating energy savings.

Italy has an economy founded on the little-medium companies. This still valid also in the plastic sector, where the average dimension of the companies that produce or treat is small. The creation of a new market for the secondary raw materials derived from plastic waste, is therefore fundamental to increase the Italian economy and it requires collaboration between companies and government and all the other actors involved in plastic production and treatment.

Chapter 2

Strategies and legislations about plastic: EU and Italy

2.1 European strategy on plastic

Starting from 2015, Europe sets new standards for production and management of plastics. This strategy was thought when plastic was identified as a priority problem. It was clear that the reduction of plastic waste would lead to a reduction in the CO_2 deriving from disposal, to reduce the increasing widespread pollution of the seas and to reduce the dependence from fossil resources for the production. It is evident that the problem to be solved is complex: in 2021, the use of post-consumer recycled plastics by European converters reached 5.5 Mt, representing a 9,9% recycled content. This represents an increase of about 20% compared to 2020. But finding recycled plastic as a raw material remains difficult, due to the prices and market uncertainties.

The European purpose is clear: improving economy and quality of plastic recycling. This means modify the entire process from the inlet to the outlet, improving the way plastic is produced and designed. To do this, it is necessary the strict collaboration between the various players in the chain of value. Plastic producers, designers, brands retailers, and recyclers must support innovative ideas, promote concrete actions and improve separate collection to ensure a quality input to the recyclers thus creating a stable market.
To stimulate producers, the European Commission is looking at new ways to maximize the impact of *Extended Producer Responsibility (EPR)* and to encourage sustainable design. Besides, it stands developing new criteria for *Ecolabels*, such as producing plastic components bigger than normal, so they can be pickable or design items ready for easy unpacking.
The closure of the Chinese market at the beginning of 2018 meant that finding and developing a stable market for recycled plastics has become even more urgent, in Europe approx. half of the plastic collected is taken abroad where uncertainties remain about treatment methods, 85% of this plastic arrived in China before China's ban (*European Commission, 2018*). One of the biggest obstacles for those who should use recycled plastic is the fear that the suppliers are not reliable, both from a quantitative and a quality point of view. The European Commission is working to standardize and develop specifications for sorted and recycled plastic waste.
Europe has proposed various measures to implement the new strategy, resumed as follows:

1. improve product design, through the standardization of rules to allow easy recycling of packaging and traceability of chemical substances in the products, in this way the secondary materials are free from contamination;
2. increase the content of recycled material in new products by encouraging their use through economic incentives corresponding to the percentage of recycled plastic used, launch specific information campaigns by developing quality standards for selected and recycled plastic;
3. increase the efficiency of separate plastic collection by proposing new guidelines and creating an ad hoc collection system for plastic materials.

The reduction of plastic waste, in all its forms, always remains a priority measure, it is therefore important actuate some measures to counter this phenomenon.
The Europe, within its strategy, propose the following statements as countermeasures of environmental impact of plastics:

1. Reduce single use plastics;
2. Tackling marine pollution by adopting waste dumping legislation ports and measures to reduce plastic loss in aquaculture, improve monitoring and marine pollution mapping;
3. Actions on compostable and biodegradable plastics, such as harmonizing the rules and defining clearly with labels what is compostable and what is biodegradable, develop a *Life Cycle Assessment (LCA)* to verify the effective benefits of compostable and biodegradable plastics, block the use of oxo-plastics;
4. Actions to reduce microplastic pollution such as stopping the intentional addition of microplastics in products, look at options to reduce the release intentional, assessments on urban wastewater treatment for the capture of microplastics.

A very important aspect is the European goal to help European country with concrete investments. To do that, it is necessary to promote investments and innovations based on the guidelines for the modulation of EPR, examining the feasibility of private investments and financing the correct ones, looking through LCA alternative sources for plastic production.
During the last years a lot of actions were undertaken to implement the European strategy for plastics but it could be not enough to reach the goals imposed by EU. The transition to a more circular and sustainable model is more difficult than expected due to the complexity of changing from a linear economy model to a eco-friendly one.

2.1.1 Extended Producer Responsibility (EPR)

In this paragraph, it is briefly defining the EPR system and the advantages it can bring to plastic management. *Global Producer Responsibility* (*GPR*) means that producers are responsible for their production process and their product's safety. *Extended Producer Responsibility* is then defined as the additional shift of responsibility for the end-of-life management of products and materials to the producers.
There are two main intentions behind the establishment of these kinds of systems:

- Sharing the physical, organizational and financial responsibility of waste management between producers and government, creating more resourceful and effective schemes increasing the end-of-life collection, waste reuse and recycling;
- Providing incentives for manufacturers to design efficient and eco-friendly products.

These kinds of systems were implemented about 40 years ago, but a significant increase in adoption can be seen in the last decade. Nearly 400 different systems, currently adopted in several countries or states, exist around the globe (*WWF, 2020*). The introduction of EPR has shown a large increasing in collection and recycling rates. In particular, the adoption of this system can reduce the need for virgin feedstocks and decrease costs for secondary raw materials.
The approaches for EPR schemes regarding several aspects such as the materials and products included in the scheme, producers subject to EPR regulation, obligations and regulations companies must comply with, organisation of the EPR scheme, setting of collection, reduction, and recycling targets and establishment of a fee system and for factors as product recyclability, proportion of recycled material in products.
The establishment of systems of the EPR has contributed to the introduction of efficient separate collection schemes for specific waste streams including plastic packaging.

2.1.2 Life Cycle Assessment (LCA) methodology

The European strategy for plastic shown the necessity of using alternative feedstocks including plastic waste, biomass and other bio-based resources, gaseous effluents. These feedstocks should be applied where evidence clearly shows that they are more sustainable than non-renewable resources.

Life Cycle Assessment (LCA) is an analysis tool that allows a holistic view of the potential environmental impacts associated with a product, process, or human activity, from the extraction of raw materials to the management of end of life. The LCA is based on international standards, including:

- UNI EN ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework;
- UNI EN ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines;
- ISO/TS 14072:2014 Environmental management - Life cycle assessment - Requirements and guidelines for organizational life cycle assessment.

The purpose of the Plastics LCA methodology is to provide common and harmonised methodological rules enabling companies and practitioners to conduct as much as possible consistent, reproducible, robust, and verifiable LCA studies of plastic products from different feedstock sources at the EU level (*Nessi S. et al., 2022*). While focusing more specifically on the use of different feedstocks, the method also addresses plastic products with different biodegradability properties, regardless of the feedstock used for production.

Figure 2.1 represents a typical structure of a LCA analysis. During the first phase of the product life cycle analysis, depending on the objective of the study, the following are defined:

- system boundaries (spatial and temporal);
- the functional unit to report the results;
- the categories of environmental impact considered.

The second phase includes all the activities aimed collecting and processing data relating to all inputs and outputs (both in terms of mass and energy) of the production system considered. The inputs and outputs of the production system, identified in the previous phase, are converted into potential environmental impacts by applying the related characterization factors to the inventory data. In this way, a profile of potential environmental impacts is obtained, consisting of the results of the various impact categories considered.

The standards also allow a subsequent processing of the results obtained, through the operations of:

- normalization: the values of each category are expressed in relation to a reference value;
- grouping: sorting and classification of impact categories;
- weighting: conversion and aggregation of indicators by applying weighting factors.

The last phase of LCA is the interpretation of the results that allows to derive robust conclusions and recommendations, on which the companies could base a communication strategy or an eco-design process.

The main elements of the interpretation of the results are:

- hot-spot identification, that means the identification of the materials and processes that contribute most to the overall impacts;
- evaluations on the completeness and robustness of the model, such as sensitivity and uncertainty analyses;
- definition of the conclusions of the study.

The Life Cycle Assessment tool therefore allows obtaining a clear, transparent and scientific understanding of the environmental problems related to the products and services supplied to the market in a life cycle perspective so as to allow the planning of actions for improvement (eco-design process)

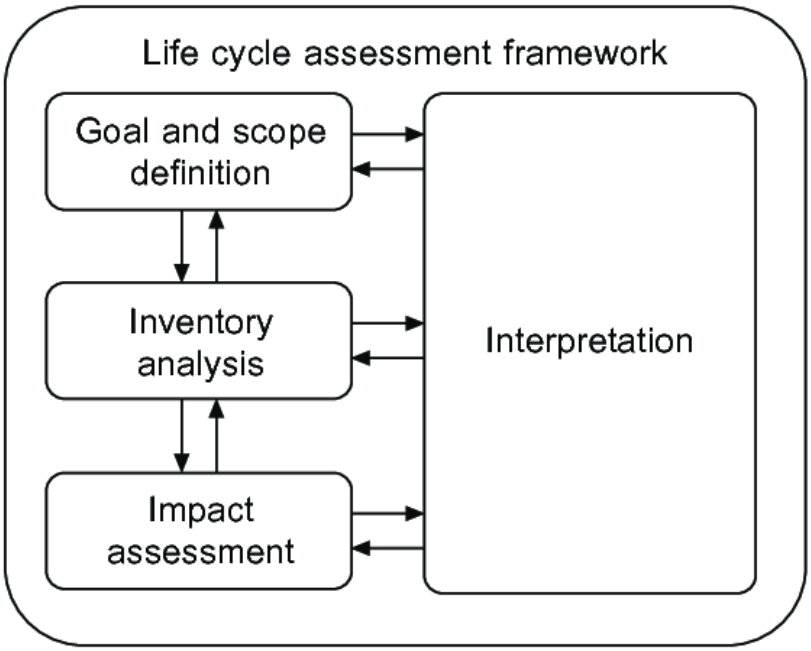

***Figure 2.1**: Life Cycle Assessment: structure of a typical study*

The Life Cycle Assessment represent an important tool that allows to obtain a transparent and scientific understanding of the environmental problems related to the products supplied to the market. A life cycle perspective consents a better planning of actions for improvement of an eco-design process.

2.2 European legislation on plastic packaging waste

The first European Directive that regulates packaging waste is *94/62/EC*. In its first article is reported the purpose of the directive: "harmonising national measures concerning the management of packaging and packaging waste and improving the quality of the environment by preventing and reducing the impact of packaging and packaging waste on the environment". It is clear that it is an outdated directive, but it introduced the concept of waste prevention, in fact, article 1 continues as follows: "*Directive 94/62/EC* contains measures designed to: prevent the production of packaging waste".

This directive is changed over the years and has undergoes different modifications. After *Directive 2004/12/EC* and the *2005/20/EC*, the latest update derives from *Directive 2018/852/EU*, in force since 4 July 2018, which applies to all packaging placed on the European market and to all packaging waste, used or discarded by industries, shops, offices, laboratories, services, households and others type of packaging, whatever the materials that compose them. The latest update comes from the definitive awareness of the European Union on the benefits deriving from the circular economy, the first article is modified thus integrating the following second paragraph: "*Directive 94/62/EC* contains measures designed to promote the reuse, recycling and other forms of recovering of packaging waste, instead of its final disposal, thus contributing to the transition towards a circular economy".

As it is specified in this directive, waste prevention is the most effective way to increase resource efficiency and reduce the impact on the environment, and therefore it is important that the Member States encourage the increase of reusable packaging on the market and the reuse of the same. To do that is necessary the implementation of measures such as the use of deposit-guarantee schemes, setting quantitative targets, considering the accounting for reuse for the purpose of achieving recycling targets and differentiating the financial contributions for reusable packaging under the extended producer responsibility schemes of producer.

EU countries must ensure that packaging placed on the market meets the essential requirements contained the *94/62/EC Directive, Annex II*:

- limit the weight and volume of the packaging to the minimum quantity necessary to guarantee the level of safety, hygiene and acceptability for the packed product and for the consumer;
- minimize the presence of dangerous substances and materials in packaging material or in its components;

- produce reusable or recoverable packaging that includes the design for the recycling of materials or organic substances in addition to the design aimed at energy recovery.

Furthermore, the directive states that Member States should have adequate incentives for the application of the *waste hierarchy*, including economic instruments and other measures. The waste hierarchy is introduced with the *Directive 2008/98/EC*, that establish: "Waste hierarchy: prevention; preparing for reuse; recycling; other recovery (e.g., energy recovery); and disposal".

In a more detailed way, the hierarchy is usually represented in the form of an inverted pyramid with preferred options at the top and disposal as a last resort solution to waste management at the bottom. The options to treat waste are described as follows:

- *Prevention*: measures that reduce the amount of waste, including through the reuse of products or the extension of the life span of products, the negative impacts of the waste generated on the environment and human health or the content of harmful substances in materials and products.
- *Preparation for reuse*: recovery operations aimed at checking, cleaning or repairing, whereby products or components of products that have become waste are prepared so that they can be reused without further preparatory treatment.
- *Recycling*: any recovery operation through which waste materials are reprocessed into products, materials, or substances, whether for their original uses or for other uses. It includes the reprocessing of organic material (for example, composting), but does not include energy recovery and reprocessing into materials for use as fuel or for backfilling operations.
- *Other recovery* (e.g., *energy recovery*): any other operation which the primary result is waste that serves a useful purpose by substituting other materials that would otherwise have been used to fulfil a particular function, or waste prepared to fulfil that function, in a facility or in the economy at large.
- *Disposal*: any operation that is not recovery, even if the operation has as secondary consequence the recovery of substances or energy (e.g., landfill, incineration).

Figure 2.2: *Waste hierarchy pyramid graphical representation*

Measures introduced with *Directive 94/62/EC* should aim at minimizing the environmental impact of packaging from a life-cycle perspective, considering the benefits arising from biomaterials and materials suitable for multiple recycling. It is also specified that measures to raise public awareness of the advantages of packaging made from recycled materials can contribute to the expansion of the recycling sector.

Considering that many Member States have not yet fully developed adequate infrastructure for waste management, it is essential to set clear long-term strategic objectives to avoid recyclable materials being relegated to lower levels of the waste hierarchy. The recycling and recovery targets for packaging of the *European Directive 94/62/EC* have been updated in 2018 to finalize the transition as soon as possible towards the circular economy. These targets are reported below as following:

- By 31 December 2025 at least 65% by weight of all packaging waste will be recycled. The recycling targets for each material are:
  - 50% for plastic
  - 25% for wood
  - 70% for ferrous metals
  - 50% for aluminium
  - 70% for glass
  - 75% for paper and cardboard
- By Tuesday 31 December 2030 at least 70% by weight of all packaging waste will be recycled. The objectives are:
  - 55% for plastic
  - 30% for wood

- 80% for ferrous metals
- 60% for aluminium
- 75% for glass
- 85% for paper and cardboard.

It is also specified that the weight of recycled packaging waste is calculated as the weight of the packaging become waste that, after being subjected to all the necessary control, sorting and other preliminary operations, to eliminate waste materials that are not affected by the next reprocessing phases and to ensure high quality recycling, entered recycling process where waste materials are reprocessed into products, materials, or substances.
Another specification is that the weight of recycled packaging waste is measured at the time of placing the waste in the recycling operation. The weight of the packaging waste recycled could be measured at the output after any sorting operation, providing evidence that output waste is subsequently recycled and that the weight of the materials or substances that are removed with further operations prior to the recycling operation and which are not after recycled is not included in the weight of waste reported as recycled.
It is important to clarify that materials no more waste must be used as fuel to produce energy or are to be incinerated. It means that if the waste is used for operations filling or disposed in landfills cannot be considered for the purposes of achieving the recycling targets.
In addiction the European Commission in May 2018 published new rules to reduce the use of single use plastic. From 3 July 2021, single-use plastic plates, cutlery, straws, balloon sticks and cotton buds cannot be placed on the markets of the EU Member States. In addition, the same measure applies to cups, food and beverage containers made of expanded polystyrene, and all products made of oxo-degradable plastic. Single-use plastic products are made wholly or partly of plastic and are typically intended to be used just once or for a short period of time before they are thrown away. Under the new rules, certain throwaway plastic products for which alternatives exist are banned. Specific measures are also introduced to reduce the use of certain products. The EU is trying to cut off plastic litter because more than 80% of marine litter is plastics. Plastic accumulates in seas, oceans and on beaches in the EU and worldwide. Plastic residues are found in marine species – such as sea turtles, seals, whales, and birds, but also in fish and shellfish, and therefore in the human food chain. While plastics are a convenient, useful, and evaluable material, they need to be better used, re-used, and recycled. When littered, the economic impact of plastics includes not just the lost economic value in the material, but also the costs of cleaning up and losses for tourism, fisheries, and shipping.
It is also important to mention *Directive 2018/851/EU* of 30 May 2018 which amends the *Directive 2008/98/EC* relating to waste. The *Directive 2018/851/EU* reports that "Waste management in the Union should be improved and transformed into sustainable material management, with a view to protecting, preserving and improving the quality of the

environment, protecting human health, ensuring prudent, efficient and rational utilisation of natural resources, promoting the principles of the circular economy, enhancing the use of renewable energy, increasing energy efficiency, reducing the dependence of the Union on imported resources, providing new economic opportunities and contributing to long-term competitiveness. In order to make the economy truly circular, it is necessary to take additional measures on sustainable production and consumption, by focusing on the whole life cycle of products in a way that preserves resources and closes the loop. The more efficient use of resources would also bring substantial net savings for Union businesses, public authorities, and consumers, while reducing total annual greenhouse gas emissions". This directive refers to all type of packaging, but focusing on plastic, it is clear that a good management of plastic waste could represent a concrete opportunity for the companies to reduce import of raw materials, implementing circular system due to the fact that European economy of plastic depends strictly by countries outside the EU, such as China and Saudi Arabia.

2.3 Italian legislation on plastic packaging waste

As regards the Italian situation, the *Legislative Decree of 3 April* is currently in force from 2006, better known as "*Testo Unico Ambientale*" *(T.U.A.),* it divides environmental issues into six parts: General provisions, EIA, SEA and IPPC, water and soil protection, waste and remediation, atmosphere emissions, environmental damage. *Directive 94/62/EC*, with its amendments made by *2008/98/EC*, was implemented in *T.U.A*. In the "*Testo Unico Ambientale*" it is explained that the waste management system in Italy is based on a consortium basis due to the raw materials that compose the packaging. In addition, specific reference is made to principle of responsibility shared by producers and users for correct environmental management of packaging and packaging waste generated by the consumption of its products. The "*Testo Unico Ambientale*" is a reformulation of the legislation on waste that previously belonged to the *Legislative Decree n. 22 of 5 February 1997*, better known as the *Ronchi Decree*. The *Ronchi Decree* was enacted to implement the European directives *91/156/EC* on waste, *91/689/EC* on hazardous waste and *94/62/EC* on packaging and packaging waste. In particular, the chapter concerning the management system of packaging and packaging waste has the aim of preventing and reducing its impact on the environment and ensuring a high level of environmental protection. An important innovation introduced by *Legislative Decree 22/97* is the establishment of the "*Tariff*" instead of the Tax on municipal solid waste (TARSU). In practice it passes from the system based on the taxation of the occupied surfaces, to the payment of a real tariff for the management of urban waste, based on the actual production of waste by the producer.

Italian laws on plastic recycling, as already said, refer to European regulations and evolve in parallel with the recent evolution of European rules. From 2006 to 2020 the so-called "*Environmental Code*" (*Legislative Decree 152/2006*) was in force, which in the part relating to waste management established some fundamental principles. One of them is that the approach to waste must aim at its correct management and recycling, without focusing only on landfill disposal processes. Waste management must be based on a precise hierarchy: in the first place it is necessary to aim at the prevention of waste production, then at the preparation for reuse, then at recycling, at energy recovery and, at the end, disposal. the principles to refer to in waste treatment are those of precaution, prevention, sustainability, and cooperation between all the subjects involved in the waste management chain. These principles are also the basis of the "New Environmental Code" (*Legislative Decree 116/2020*), approved in September 2020, which indicates the recycling objectives that our country aims to achieve within the next few years:

- Recycle 55% of municipal waste by 2025, 60% by 2030 and 65% by 2035;
- Recycle 50% of plastic packaging by 2025 and 55% by 2030;
- Recycle 60% of packaging (of any material) by 2025 and 65% by 2030;

From "*New Environmental Code*", the articles that affect the waste derived from plastic packaging are:

- *Art. 178-bis/178-ter (Extended Producer Responsibility)* that introduced the concept of EPR in Italian legislation and also the concept of waste hierarchy;
- *Art. 217 packaging management (scope and purpose)* that regulates the management of packaging and packaging waste both to prevent and reduce its impact on the environment, by promoting sustained levels of reduction in the use of plastic bags. This article proposes different measures aimed to prevent production of packaging waste, and on the other hand to encourage the reuse of packaging, recycling, and other forms of recovery of packaging waste. This helps the reduction of the final disposal of such waste, and ensure a high level of environmental protection both to ensure the functioning of the market, as well as to avoid discrimination against imported products, prevent the emergence of trade barriers and distortions of competition and ensure the maximum possible return on packaging and packaging waste;
- *Art. 179 (Priority criteria in waste management)* that introduce the following hierarchy for waste management, as already mentioned in *§ 2.2,* deriving from the European strategy for plastic waste:
    a) prevention;
    b) preparation for re-use;
    c) recycling;

d) recovery of other types, for example energy recovery;
e) disposal.

Furthermore, Italian legislation discourages the use of plastics and other non-recyclable materials and in fact provides tax relief for companies that purchase products made with recycled plastic, paper, or aluminium. Likewise, the purchase of biodegradable and compostable packaging is encouraged. Italian companies, as well as private citizens, are also invited to limit the use of disposable products and to adopt separate collection systems. Alongside the national laws there are also the regulations developed by the UNIPLAST technical commission (such as the *UNO 10667-1:2017 standard*), which classify the raw-secondary plastic materials obtained from the recovery and recycling of plastic waste and establish the requirements that these materials must have, the methods for their recycling and possible uses after recycling.

2.3.1 Italian trend on plastic packaging

In Italy, after the 2020 pandemic, the economy showed a good trend in GDP, about +6.5% in 2021. In addition, also an increase of the consumption and an industrial production of +11.8%. The packaging, which is the most important outlet of virgin thermoplastic polymers, recorded an increase. The consumption of full packaging is equal to 2,300 kton (+3.8% if compared to 2020), represented by 44% of packaging flexible and 56% from rigid packaging (*COREPLA*, *Relazione sulla gestione*, *2021*).

It could be shown from *Figure 2.3* that polyethylene represents the 43% of all the polymers used to produce packaging.

	2019	2020	2021
TIPOLOGIA			
IMBALLAGGI FLESSIBILI	43,0%	43,3%	43,4%
IMBALLAGGI RIGIDI	57,0%	56,7%	56,6%
TOTALE	**100,0%**	**100,0%**	**100,0%**
POLIMERO			
PE	43,0%	43,4%	43,3%
PET	23,7%	23,5%	23,6%
PP	19,8%	19,9%	20,0%
PS/EPS	7,3%	6,7%	6,3%
BIOPOLIMERI	3,1%	3,3%	3,5%
ALTRI	3,1%	3,2%	3,3%
TOTALE	**100,0%**	**100,0%**	**100,0%**
FUNZIONE			
IMBALLAGGI PRIMARI	69,1%	69,0%	69,1%
IMBALLAGGI SECONDARI	7,0%	7,0%	6,9%
IMBALLAGGI TERZIARI	23,9%	23,9%	24,0%
TOTALE	**100,0%**	**100,0%**	**100,0%**
CANALE			
DOMESTICO	62,8%	63,9%	63,1%
di cui contenitori per liquidi di origine domestica	*22,3%*	*22,3%*	*22,4%*
COMMERCIO & INDUSTRIA	37,2%	36,1%	36,9%
TOTALE	**100,0%**	**100,0%**	**100,0%**
(*) Fonte Plastic Consult			

***Figure 2.3**: Composition of packaging released for Consumption (%) (COREPLA,2021)*

At the polymer level, the bulk of consumption is covered by polyethylene, addressed predominantly to flexible packaging, where its share is widely above 70%. Considerable quantities of consumption also have to PET and PP, which vice versa are mainly used for rigid packaging.

Among other materials, the consumption volumes of polymers are growing well compostable (especially starch compounds intended for take-away bags goods and ultralight bags), whose share is in the order of 3.5%, in increase compared to the 3.3% recorded in 2020. As regards the function of the packaging, there is a clear prevalence of primary packaging, which covers about 69% of total consumption, while the secondary packaging (mostly shrink film for burden) does not reach 7% of the total.

Finally, observing the distribution of the products released for consumption according to the channels of waste formation, the clear prevalence of the channel can be noted domestic, while the quantities of industry and commerce approach in the complex at 37% of the total, even if including the significant volumes of material (especially containers for liquids), disposed of with solid waste urban.

The percentage of plastic which in Italy is intended for the packaging sector is in line with the data relating to other European countries. The most consumed plastic, as cited previously, is

PE and it is used mainly to produce electric cables, agricultural film, plastic bags and envelopes, containers, piping, inner layer of aseptic containers for food liquids.

2.4 Environmental Declarations or Labels

In the new strategy of Europe for plastic and new European policies, the environmental declarations assume a key role. The environmental labels or declarations are a tool designed to improve environmental communication between producers (*business to business*). On the other hand, it could be used to also improve the communication between distributors and consumers (*business to consumers*).

The environmental declarations deriving from the *ISO 14020* series standards, are based on the use of the LCA (Life Cycle Assessment) methodology (*see § 2.1.2*). Maintaining the attention on products companies could communicate their strategies and commitment to produce respecting the environment and enhancing the products their selves.

There are three different types of voluntary environmental labels, established by the *ISO 14020* series standards:

- *Type I*: voluntary ecological labels based on a multi-criteria system that considers the entire life cycle of the product, subjected to external certification by an independent body, regulated by *ISO 14024*;
- *Type II*: ecological labels reporting environmental self-declarations by producers, importers or distributors of products, without the intervention of an independent certification body (including: “Recyclable”, “Compostable”, etc, regulated by *ISO 14021*;
- *Type III*: ecological labels reporting declarations based on established parameters and containing a quantification of the environmental impacts associated with the product life cycle calculated through an LCA system. They are independently audited and presented in a clear and comparable form. These include, for example, the “Environmental Product Declarations” and they are regulated by *ISO 14025*.

In particular, as previously mentioned, type I labels require certification by an independent body. These types of labels are developed and designed on a scientific basis and require compliance with various specific limits. These limits include energy and material consumption, defined for each type of product taking into account its entire life cycle.

Summarizing the environmental labels, it could be said that:

- They use Life Cycle Assessment (LCA - Life Cycle Assessment) as a methodology for identifying and quantifying environmental impacts. The application of the LCA must be in accordance with the provisions of the *ISO 14040* series standards, in order to guarantee the objectivity of the information contained in the declaration;

- it is applicable to all products or services, regardless of their use or placement in the production chain; furthermore, a classification is made into well-defined groups in order to be able to make comparisons between functionally equivalent products or services;
- it is verified and validated by an independent body which guarantees the credibility and truthfulness of the information contained in the LCA study and in the declaration.

Objectivity, comparability, and credibility are, therefore, the main characteristics on which the statements are based. A more detailed analysis on the environmental labels is made in *Chapter 3*.

2.5 Plastic tax

Another important instrument promoted by EU and implemented by the governments of the Member States is the plastic tax. In the following paragraphs there is a description of the environmental taxation focusing on the plastic tax adopted by EU and Italy.

2.5.1 Environmental taxation

Environmental taxes evolved over the years, from a conceptual point of view. Initially they were configured as purpose taxes, taxes also having non-fiscal purposes, but which did not include the environmental sources as a prerequisite for the tax itself. The most recent are taxes that, on one hand absolve to the function of recovering revenue for the State, and, on the other hand, follow also other objectives identified by the same legislator. These non-fiscal purposes refer to the protection of interests involved in environmental matters.
Subsequently, thanks to the intervention of the European institutions, the concept of environmental tax evolves again. The environmental asset is included within the same tax, which becomes part of its prerequisite. According to European strategy, a tax takes on the quality of an environmental tax if and only if its tax base is made up of a physical quantity or which has a proven and specific negative impact on the environment.
Further classification of environmental taxes could be:

- Taxes levied on production or products that have negative impact on the environment like the “Plastic Tax”;
- Taxes on emissions such as the “Carbon Tax” on CO_2 emissions;
- Taxes on the exploitation or use of environmental resources.

Environmental taxation encourages a shift towards more eco-friendly choices. It could be used together with the other instruments available. The aim of environmental taxation, in principle, is to factor environmental damage, or negative externalities, into prices in order to steer production and consumption choices in an eco-friendlier direction. Environmental taxation concerns all aspects of environmental protection and conservation. The fight against climate

change, pollution, and pressure on the environment, in particular from resource consumption and biodiversity loss, as well as contributory factors, such as gas emissions and the use of potentially harmful substances, can be the subject of tax measures.
These taxes could be seen as general or sectoral measures which are applied in different ways by individual states and their local authorities. In the European Union, environmental policy and tax policy determine the scope for action of Member States and the Union. The existing environmental taxation account for a modest share of national tax revenue. The environmental aims are generally recognized as valid. Although, when environmental taxation measures are implemented a range of factors must be considered, in particular competitiveness and fairness, to ensure that environmental taxation is sufficiently transparent to gain acceptance and so become an effective instrument in the transition that society now so urgently needs (*Cécile Remeur, 2020*).

2.5.2 Plastic tax in Europe

The idea of a plastic tax was born in Europe. Many Member States including Belgium, France, Ireland, Portugal, and the UK have already adopted legislation to counteract plastic pollution, although different in some respects. A decisive impact has been made by the Directive of the European Parliament and of the European Council of 5 June 2019 **(***Directive (EU) 2019/904*): "the objectives of this directive are to prevent and reduce the impact of certain plastic products on the environment, … , as well as promote the transition to a circular economy with business models, products and materials innovative and sustainable, thus contributing to the proper functioning of the market indoor". This directive becomes important because it contains examples of the products that fall in the application of the future tax.
The first part of this directive analyses the European situation regarding management of plastic products, especially disposable ones, waste management and pollution related to plastic products. In this part, there is a focus on the dangers of plastic waste for the European seas, and the possible corrective measures that the Union can take to resolve the situation. The assets most responsible of pollution are single-use food containers, single-use beverage containers, tobacco product filters, plastic caps, and lids.
Another important aspect highlighted in this *Directive (EU) 2019/904* is that countries are free to take initiatives, such as sensitize the consumer, using economic instruments and relative sanctions. The focus is strongly placed on the fact that a common position must be taken on the side of the Union.
In the second part, however, new restrictions are introduced on certain disposable plastic products (those identified in the first part). For example, according to the new European regulations: plastic plates, cutlery, straws, and cotton buds are to be banned by 2021. Another interesting point is represented by the programmatic budget expected by the Commission for

the period 2021-2027. The Commission has proposed to introduce a tax on non-recycled plastic in each Member of €0.80 per kilogram. This point could represent the Community response for the future, also requested by the European Parliament.
As part of the *Next Generation Eu Mechanism* (better known as the "*Recovery Fund*"), which provides funding to help EU member states affected by the Covid-19 pandemic, increasing the European Union's own resources, the decision of the *EU Council n. 2020/2053/EU*, which entered into force on 1 June 2021, introduced a tax payable by Governments to the EU on non-recycled plastic packaging waste generated in each Member State.
The quantity of non-recycled plastic packaging waste is calculated, according to the methods established in EU *Council regulation n. 2021/770/EU*, as the difference between the packaging waste produced and that recycled each year.
It is clear that the expected effect of the measure is both a push by the Member States to prevent the generation of packaging waste (purpose of the *Packaging Directive 2018/852/EU*) and the revitalization of the plastic recycling, in states that currently suffer due to low prices of raw materials, uncertainties in market outlets and prospects of low profitability.

2.5.3 Plastic tax in Italy

On 24 December 2019, the Italian Parliament voted by majority the *2020 Budget Law* which introduced the tax called Plastic Tax on the consumption of single-use plastic products, so called MACSI. It has the purpose of recovering tax revenue and discouraging the consumption of non-recyclable plastic.
The Italian Plastic Tax is a tax with a fixed value of 0.45 € for each kilo of disposable plastic products sold. The new tax will mainly affect the plastic product manufacturer, any importer of products and, obviously, the buyer.
The tax, provided for by the *2020 Budget Law*, applies to the consumption of products made with plastic material having the function of containment, protection, handling or delivery of goods or food products (also in the form of sheets, films, or strips) that have been designed and placed on the market for a single use. Products, therefore, that are not designed to be reused, or to make multiple transfers during their life cycle (*Alice Coccia, 2022*)
To the Customs and Monopolies Agency is assigned the task of carrying out the tax assessment, verification, and control activities, with the right to access to disposable plastic product in order to acquire elements useful to verify the correct application of the provisions in question. Originally, the minimum amount due at or below which the tax must not be paid has been set at 10 €.
The applicable sanction framework for violations committed in relation to the original Italian Plastic Tax is as follows (*Alice Coccia, 2022*):

- non-payment: from double to ten times the tax evaded, in any case not less than €500;

- late payment: 30% of the tax due, in any case not less than €250;
- late presentation of the declaration necessary for the assessment and payment of the tax and for any other violation of the provisions in question and the relative methods of application: from € 500 to € 5,000.

The 2021 Budget Law, in addition to a first postponement of the Plastic Tax, also provides further changes. The new features introduced are as follows:

- The definition of semi-finished MACSI undergoes a change, since all those products that are obtained from the melding of PET are also included, also called preforms, which are destined to become containers for drinks or bottles, through a particular blowing process;
- to hold up the payment of the tax must also be the clients, or the subjects who intend to sell MACSI to other national subjects;
- the tax exemption threshold deriving from quarterly returns is set at 25 €, instead of 10 € as previously;
- The August Decree introduced, for the year 2021, a measure that favours the recycling processes of polyethylene terephthalate for food packaging. Measure that allows the 50% limit in place so far to be exceeded;
- the penalties are reformulated as follows:
  - late payment: administrative fine corresponding to 25% of the tax due. In any case it is not less than 150 euros;
  - non-payment: the administrative penalty goes from double to five times the tax evaded. In any case, the fine is not less than 250 euros;
  - late presentation of the quarterly return: if previously the sanction envisaged was between 500 and 5,000 euros, with the new provisions it varies from 250 to 2,500 euros.
  - the imposition of tax sanctions for the above taxes takes place according to article *17 of the legislative decree of 18 December 1997, n. 472*.

In addition, the following methods have been introduced to define the scope of application of the provision of the Revenue Agency:

- execution of the liquidation and payment of the tax;
- management of the related accounting;
- registration of interested parties (obligatory);
- indication of the MACSI quantities which include additional goods introduced into the state territory.

The latest updates are that the Italian government delayed the implementation of the plastic tax to 1 January 2022 by the "*Sostegni-bis*" law decree and then to 1 January 2023 by paragraph 12 of *Law n. 234 (Budget Law 2022)*.

2.6 Green Public Procurement (GPP)

The Public Administration is the largest *consumer* of modern societies (*Riccardo Rifici, et al., 2015*). It is therefore immediately the importance of a public policy of "Green Procurement" is evident. With the GPP (Green Public Procurement) system, the Public Administration becomes the leading actor of a sustainable development strategy.
Green Procurement is a system of purchasing environmentally preferable products and services those products and services that have a minor, or reduced, effect on human health and the environment compared to other products and services used for the same purpose.
The GPP became increasingly important for EU. For this reason, in EU were spent more than 14 % of its GDP through public procurement. For other states, purchases made by the Public Administration represent a good percentage of the Gross Domestic Product (GDP). For example, in Italy and Canada, 18% of GDP, and 14% in the USA (*ISPRA,2022*). The GPP practice consists in the possibility of inserting environmental qualification criteria in the demand that the Public Administrations express when purchasing goods and services. On this issue, the Public Administrations can act both as customer and "consumer.
The use of the GPP instrument has been patronize by the European Union, which speaks of it both in the "*Green Book on integrated product policy*" and in the *Sixth Action Program* on the environmental field. However, it is *COM (2001) 274* - "*Community law on public procurement and the possibilities of integrating environmental considerations into procurement*" that represents the main reference guideline of the Commission in the field of GPP. In addition to this, there is the adoption of directive *2004/18/EC* of 31 March 2004, relating to the "*coordination of procedures for the award of public supply, service and works contracts*" which introduces the environmental variable and try to simplify the regulation too much detailed.
Europe's public authorities are major consumers. By using their purchasing power to choose environmentally friendly goods, services and works, they can make an important contribution to sustainable consumption and production. Although GPP is a voluntary instrument that can help stimulate a critical mass of demand for more sustainable goods and services which otherwise would be difficult to get onto the market. GPP is a strong support for eco-innovation. GPP, to be an effective instrument, requires the inclusion of clear and verifiable environmental criteria for products and services in the public procurement process. The European Commission and several European countries have developed guidance in this area, in the form of national GPP criteria. The challenge is to ensure that green purchasing requirements are something

compatible between all Member States. This could help and accelerate the creation of single market for goods and services that is eco-friendly as more as possible.
The GPP could be a valid tool to encourage the growth of a green market, through (*ISPRA, 2022*):

- the inclusion of environmental preferability criteria in the procurement procedures of the Public Administration in the context of the most economically advantageous offer;
- the possibility of considering environmental labelling systems as means of proof for verifying the required environmental requirements;
- the possibility of considering the certifications of the environmental management systems (EMAS - ISO 14001) as means of proof for verifying the technical capabilities of the suppliers for the correct execution of the public contract.

The same strategy as the *Green Deal* is adopted with *Proposal 142 of 2022* which setting the framework for the development of eco-design specifications for products sustainable and implement *Directive 2009/125/EC* has provided for an article on procurement green public bodies (*article 58*). In this article is stated that the provisions relating to procurement public works awarded by contracting authorities may take the form of mandatory technical specifications, selection criteria, award criteria, clauses of performance of the contract or objectives. The provisions for GPP must take into account the following criteria:

- the value and volume of government contracts awarded for the given group of products or for services or works that use the given group of products
- the need to ensure sufficient demand for greener products;
- the economic feasibility, for contracting authorities or contracting entities, to buy more eco-sustainable products without incurring disproportionate costs.

2.6.1 Green Public Procurement: Italy situation

In Italy, a first step towards an environmental and more sustainable economy came with the first sign of the CIPE's (*Comitato Interministeriale per la Programmazione Economica*) approval of resolution *n. 57 of 2 August 2002* "*Environmental action strategy for sustainable development in Italy*", which establishes that "at least 30% of the goods purchased must also meet ecological requirements; 30-40% of the durable goods stock must be reduced energy consumption, taking into account replacement and using the scrapping mechanism".
With the *decree 8 May 2003 n. 203*, moreover, the *Ministry of the Environment and Land Protection* has identified "rules and definitions for the regions to adopt provisions, intended for public bodies and companies with predominantly public capital, also for service management, which guarantee that manufactured goods and goods made with recycled material cover at least 30% of the annual requirement".

Italy, still in the same direction as the Green Deal, approved the document relating to the new "*National Strategy for the Circular Economy*". Here it is stated that the minimum environmental criteria or "*Criteri Ambientali Minimi*" (CAM) and the GPP (*Green public procurement*) constitute one of the main tools for the development of circular supply chains and for improve recycled-materials market.

The document provides the introduction of a supervisory system, to control if CAM are effectively integrated in public tenders. Furthermore, it established an observatory with the task of "monitoring the expenditure made through the CAM and the environmental benefits obtained".

Also, in the scheme for the transposition of *Directive (EU) 2019/904* on reduction of the impact of certain plastic products on the environment, so called *SUP Directive* (*Single Use Products*), Article 4 contains provisions aimed at guaranteeing a quantifiable reduction in the consumption of single-use plastic products listed in part A of the annex of the same directive, by 2026, compared to 2022.

But the real acceleration comes from the *National Recovery and Resilience Plan*. The rules of the PNRR envisage to adopt, as a preparatory element of any financing of public or private entities, the DNSH principle (*Do No Significant Harm*), not causing significant damage to the environment.

In Italy, according to the *Operational Guide that the Ministry of Economy and Finance* has published in October 2022, in revised form, the DNSH requires the mandatory adoption of the CAM. So, the over 200 billion euros attributed by Europe to Italy for the PNRR may not be spent, if not adopting the Environmental Criteria.

The opportunities linked to ecological, energy and social transition are closely linked to compliance with these tender criteria. In other words, there cannot be a contract financed by the PNRR that does not comply with the principle of the DNSH and therefore the CAM.

For this reason, there are needed tools to comply DNSH and CAM. In addition, it is necessary a fast and robust process of collective learning, which considers their constant revision, due to technological changes of products.

At national level, it still evident that there are many improvements to do to adopt a GPP system and respect the stated CAM. For this reason, there are some proposals *(Silvano Falocco, 2022)*:

1. Strengthen the institutional capacity, first of all of the Local Authorities and of the purchasing managers and Contracting Stations to spread the GPP and ensure the adoption of the CAM in the public procurement, both in the purchase of goods and services and in the development of works;
2. Facilitating the Aggregation of Subjects, since it is demonstrated by the present Ratio as the technical capability, function of size, is requirement fundamental in the dissemination of GPP and in the adoption of CAM;

3. Identify the GPP contact person, in all public administrations, to avoid that the cross-sectoral nature of the instrument that complicates its implementation, a contact person helps with GPP implementation and CAM adoption;
4. Extend the scope of GPP by identifying other categories goods for which to approve the CAM;
5. Strengthen the use of CAM in public enterprises, favouring the adoption of specific CAM related to industrial activities, in particular those related to fundamental activities of environmental services (waste disposal, purification, postal services, electricity and water distribution networks, factories for the maintenance of means of transport, etc.);
6. Develop the monitoring activity on the application of the CAMs, to have credible and reliable data on the progress of the GPP in Italy;
7. Link the GPP with the DNSH to facilitate public administrations and private in understanding the close connections between the two systems.

2.7 Illicit plastic waste trafficking

In the previous chapters is evidenced the low efficacy of systems adopted by European countries to manage the waste and produce plastic with a circular system that avoids and prevents the production of waste. For this reason, EU, send its waste to countries that have the ability to treat a large amount of plastic.
Illicit trafficking of waste is one of the worse factors that negatively influenced the transition to a more sustainable circular economy. In particular, the plastic sends to countries that for economic or technological reasons, cannot guarantee the sufficient sustainability of the process adopted to treat the waste, is a great damage for the environment and also for the circularity of the economy.

2.7.1 Plastic packaging waste shipment

First of all, it is necessary to understand where European countries ship their plastic waste and from which countries there is most export.
Plastic waste trade exports to non-OECD countries have dramatically increased in 2022, most likely due to high energy costs shutting down plastic recycling operations in Europe. European Union increased plastic waste exports to non-OECD countries rose to 55.9 million kg/month in October 2022 from 28.1 million kg/month in May 2022 (*European Union Export Data, BAN, 2022*)
In the EU, post-consumer plastic waste is categorized as a non-hazardous waste, and this means that appear as green listed. For this reason, it can be exported to non-OECD countries following the procedure of the *EU Waste Shipment Regulation* and provided the import is not prohibited by the country of destination (intermittently, the European Commission requested an update

from non-OECD countries on waste types they do not want exported to them anymore, waste types they want limited and/or waste types to be continued). Exports for incineration, energy recovery or landfilling are prohibited to non-OECD countries. Each Member State lays down the rules on penalties applicable for infringement of the provisions of the regulation (*Zero Waste Europe, 2019*).

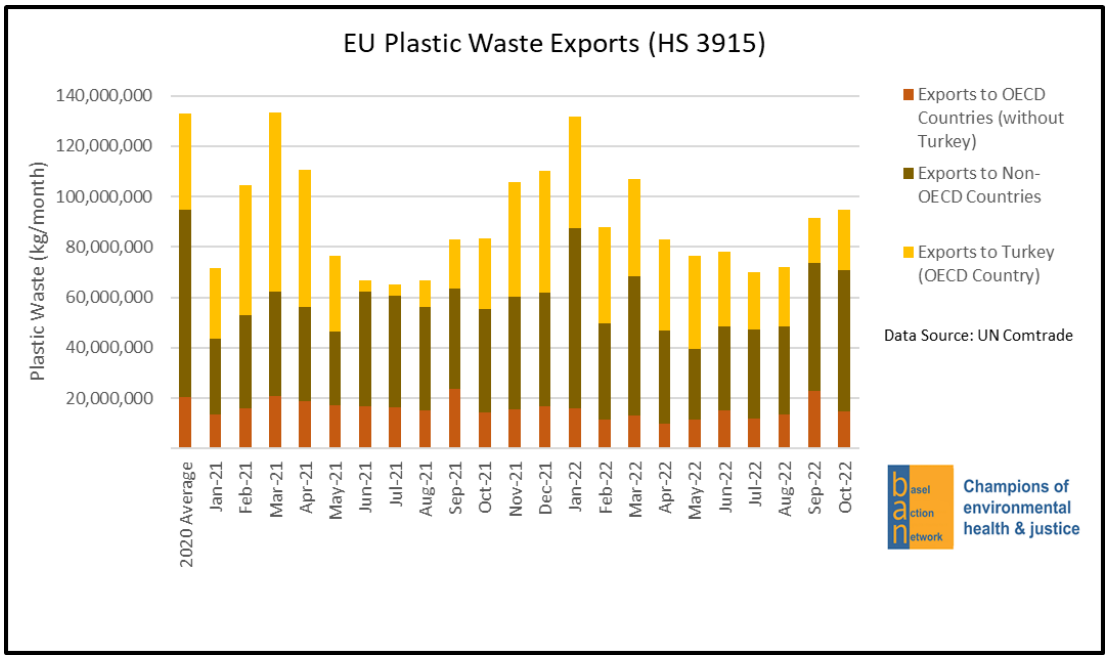

***Figure 2.4**: Amount of plastic exported from EU to OECD Countries, Non-OECD Countries and Turkey between 2021 and 2022*

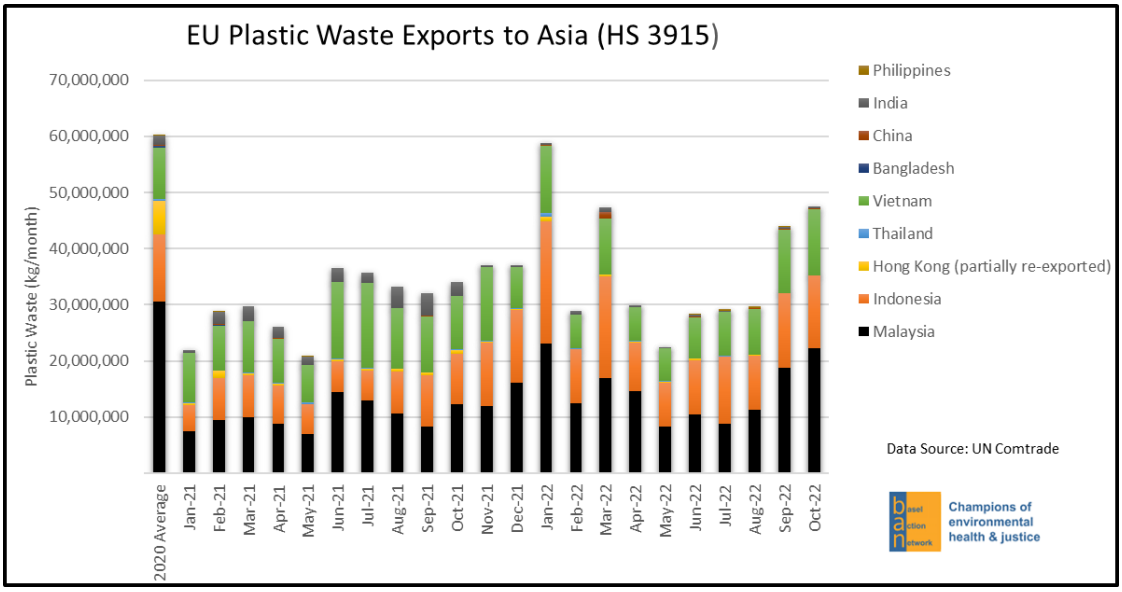

***Figure 2.5**: Amount of plastic exported from EU to Asia between 2021 and 2022*

Furthermore, EU increasing plastic waste exports to Turkey from 4.5 million kg/month in June 2021 to 24 million kg/month in October 2022.
Prior to 2018, China (including Hong Kong) was the main destination for EU plastic waste exports. In July 2017, China announced a ban on the import of plastic waste, effective from the beginning of 2018. As a result of this ban, exports to China have rapidly decreased and the portfolio of destination countries for plastic waste of the EU has diversified. Between 2016 and 2018, other Asian countries saw significant increases in imports of plastic waste from the EU: Thailand saw an eight-fold increase, Turkey seven-fold, Taiwan five-fold and Indonesia three-fold. As a result, other countries have also imposed import restrictions on plastic waste. Data for 2019 shows Turkey and Malaysia as the top Asian destinations for plastic packaging waste exports (*Zero Waste Europe, 2019*).
It is clear that the illegal traffic streams for plastic waste are different and could be different in various aspects, but they follow a scheme.

2.7.2 European countermeasures against illicit trafficking of waste

The European Union has adopted *Directive 2008/99/EC* on the protection of the environment under criminal law, which requires Member States to consider environmental crimes as offenses punishable by law. The main types of environmental crimes include the illegal dumping and shipments of waste.
A European Union Council report ("*Council of the European Union, "Final report of the eighth round of mutual assessments on environmental crime - Information and debate in the Council", 2017*") on environmental crime notes that the current rate of detection of crimes committed in the waste sector, and of prosecutions being initiated against them, is low. The complexity of the shipping chain makes it difficult to prosecute those involved and prove that they were aware of the illegal waste disposal. Waste can change hands several times in many countries before being disposed of illegally, while the first person to initiate the waste stream receives documents proving that the plastic packaging waste has been recycled.
Council of the European Union, "*Final report of the eighth round of mutual assessments on environmental crime - Information and debate in the Council, 2017*", defines this type of crime as a serious threat and one of the main areas targeted by Europol's work, which includes the coordination of Member States' actions.
Also, the environmental labels which certify the plastic recycled content could represent an effective countermeasure to contrast the illicit traffic. In fact, declaring the content of recycled waste inside the products, the companies ensure that the products produced contain recycled waste treated in compliance with the European criteria.

2.7.3 Italian situation about plastic waste trafficking

In 2019, more than 1,300 tons of plastic waste were illegally shipped from Italy to Malaysian companies (*Greenpeace Italy, 2020*). On 65 shipments that took place 43 were destined for plants without permits to import and recycle foreign waste, which will therefore open without any respect for the environment and human health.

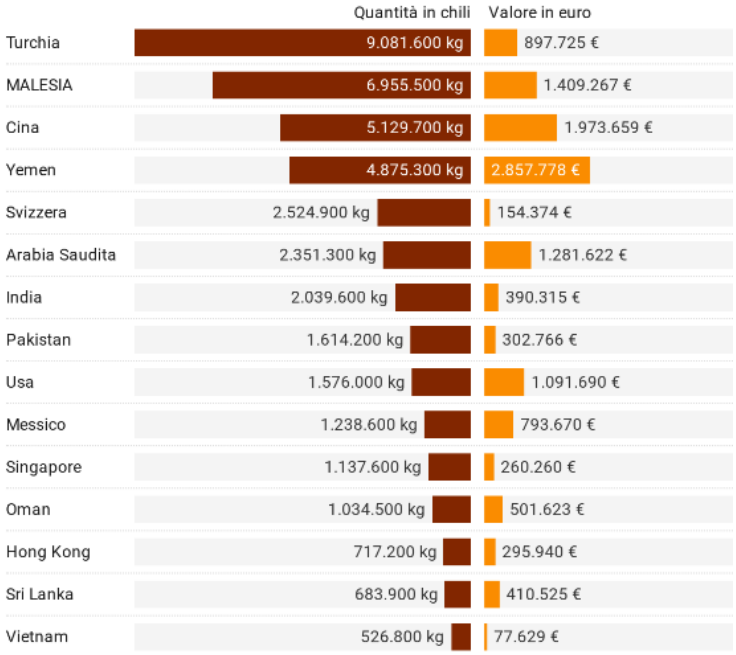

Figure 2.6: *Major extra UE countries to which Italy sends his waste (Greenpeace Italy, 2020)*

Over the past few years for Italy, Malaysia has become a major export destination for low-quality, hard-to-recycle plastic waste, despite lacking an effective treatment and recovery system and stringent environmental regulations, fuelling a global market often illegal, which also affects the export of plastic waste from Italy.

In 2019, this trend is decreased, as shown in *Figure 2.8*, but Italy still one of the main exporters of plastic waste to Malaysia. Nowadays the county which received more plastic waste from Italy is Turkey. This country imports 20% of Italian plastic waste and Italy still sending 36% of its plastic waste to countries extra-EU.

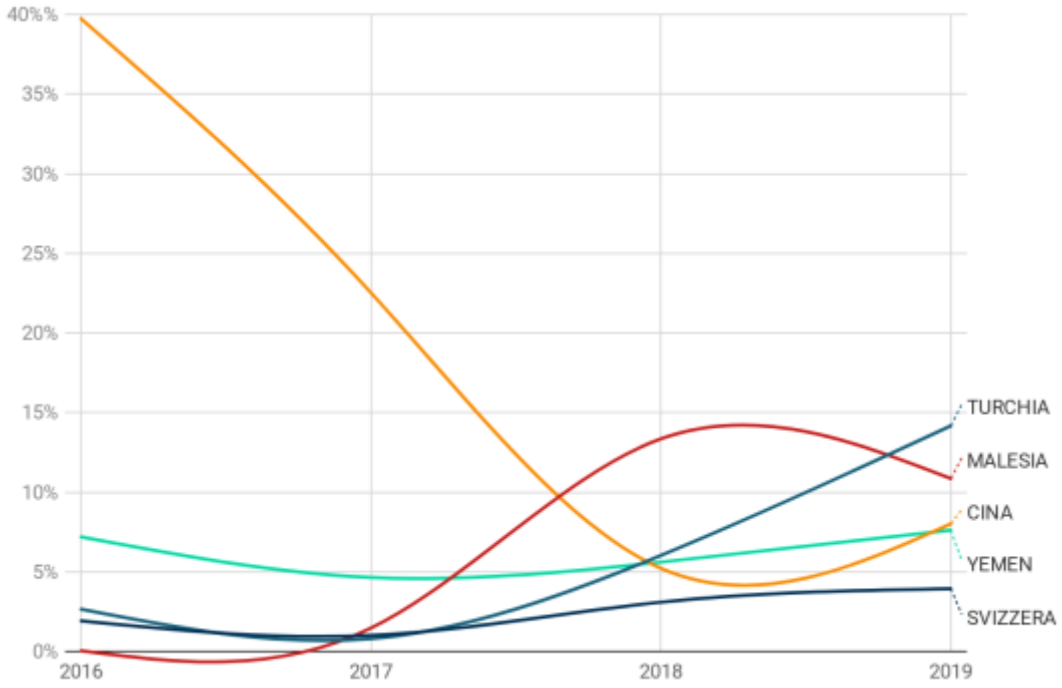

Figure 2.7: *% value respect to total exports between January and September for each year (Eurostat, 2019, elaboration by Greenpeace)*

In 2021, was discovered another traffic of waste between Italy and Tunisia, in which were shipped 120.000 ton of illegal plastic waste (*dangerous waste*). The Tunisian authorities discovered this illegal operation before the waste were receive. International, European, Italian, and Tunisian environmental groups have joined in demanding the immediate return of 282 containers full of mixed municipal waste that were illegally exported from Campania region to the Port of Sousse in Tunisia between May and July 2020 (*Zero Waste Europe, 2021*). This is an example of how the illegal organizations can evade the European and international regulations about recycling and disposal of plastic waste.

Behind the mentioned phenomena, there is the so called "*Ecomafie*". It is a neologism used for the first time by *Legambiente,* to include all the illegal activities of mafia-type criminal organizations that cause damage to the environment. Among the activities of the eco-mafia, illegal trafficking and the illegal disposal of hazardous and non-hazardous waste play a central role. Faced with this situation, the Italian government must undertake some concrete actions and many volunteer associations (e.g., *Legambiente, Greenpeace*) are activated to manage the problem. In 1997, the first *Ecomafie Report* by *Legambiente* was published, which monitors the situation every year since almost 25 years.

On 7 September 2022, the Parliamentary Commission of Inquiry into illegal activities connected to the waste cycle and related environmental crimes "*Ecomafie*" published the final report on the illegal market of plastic shopping bags. In this report, the Commission underlines that the production of disposable plastic bags made of compostable and biodegradable materials is fundamental because since 2018 they must replace plastic bags as required by *Legislative*

Decree 152/2006. Biodegradable shoppers were introduced to counteract the linear economy system and to improve the quality of product recycling and avoid dispersion in the environment. The report shown that 4 out of 10 bags in circulation are not in compliance with the actual rules. This means that not all the operators are aligned with the Italian government laws.

The presence on the market of illegal plastic products is due to the economic advantages deriving from the lower cost of the raw material compared to that of biodegradable, compostable or recycled plastic. Another problem is the amount of money deriving from the sale of plastic waste that arrive in the hands of criminal organizations and they use it to finance their illicit activities. In fact, it must be mentioned that the management of the revenues from the illegal plastic bag market is fully in the hands of organized crime, which uses this market as a source of resources and as a means for greater territorial control over small-sized merchants (*Legambiente, 2021*).

Chapter 3
Materials and Methods

As evidenced in the previous chapters, polyethylene (PE) represents one of the most used plastics for a huge range of application, products, and packaging. In the European Union, PE represents the most produced plastic in 2021, with 14.7% of the total production for the LDPE and 9.3% for the HDPE (polypropylene represent 16.6% of the total).

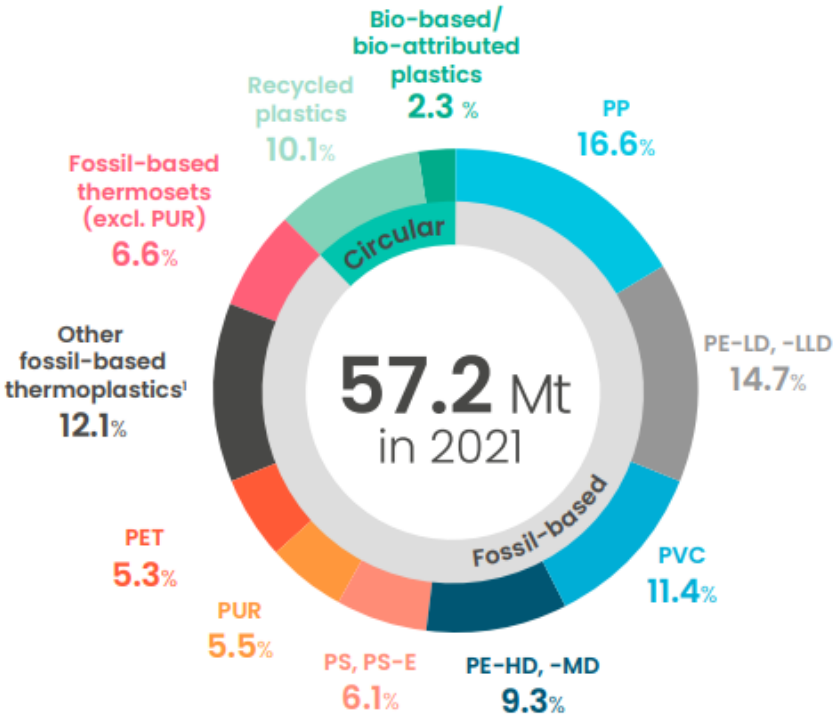

Figure 3.1: European plastics production in 2021 (Plastics the Fact, 2022)

In Italy the productive situation about plastics can be compared with the EU situation. To try to reduce the production of plastic and its consequent use, and to follow the new European regulations, Italy promotes some initiatives involved in a better management of plastic.
The European strategy for plastic evidenced the enormous importance of the Green Public Procurement in optic of a more sustainable circular economy. In this sense, the environmental

certifications become even more an important tool for the market, and, in particular those certifies the content of recycled plastic in plastic goods.
Focusing on PE production, especially for packaging and goods, and to support the plastic strategy proposed by EU, *Polieco*, national consortium for the recycling of polyethylene goods waste, promoted the development of a new certification scheme. This environmental label or declaration is called "*rePEv*" and it applies on producers of polyethylene and recyclers of polyethylene goods. The purpose of this certification is to increase the market entry capabilities of products and at the same time promote a further step towards sustainability and the green economy, guaranteeing the consumer the quality of the product purchased.
The scope of this study is to demonstrate the effectiveness of the application of this scheme, with a focus on producers of PE goods. The purpose was to build a procedure of traceability that allows the producers of polyethylene goods the right method to trace the recycled PE material that enters in the production process.
In the following paragraphs are described both materials and methods used to implement this procedure described in *Chapter 4*.

3.1 Materials

All the content of this thesis, reported in *Chapter 4 (Traceability scheme implementation for recycled PE: PG Plast),* is mainly based on the content of *ISO 22095* "*Chain of custody – General terminology and models*" that defines the requirements for the supply chains to implement the chain of custody methods.

Another standard on which is based the present study is UNI EN ISO 14021 that regulates the procedures for the development of environmental labels of Type II (see *Chapter 2*). The standard includes the description of the certification procedures for assigning the label. A better description of this kind of label is given in § *3.2.1.*

3.1.1 Traceability and chain of custody

The *ISO 9001* ("*Quality management systems - Requirements"*) standard define traceability as the ability to trace the history, application, or location of products. It represents the ability to follow the movement of a product through specified stages of production, processing, and distribution.

In other words, traceability is the capacity to trace all processes, from the procurement of raw materials to production. Knowing the history of the product means knows where, when and from who the products are produced. Due to increasing attention in products quality and products safety, the concept of traceability became important in plastic production, and in many other sectors such as automotive, electronics, food and pharmaceutical, implements systems able to trace their products. The standard that defines the procedures necessary for the traceability of recycled plastic materials is the EN 15343 standard. This document provides the basis of the procedures for calculating the recycled material content of a product.

First of all, it is needed to differentiate and clarify between two concept that could be confused: chain of custody and traceability. As mentioned in the *ISO 22095:2020, Annex A ("Chain of custody – General terminology and models"*), "chain of custody is a chain of responsibility for the custodianship of materials or products as they move through a supply chain". In other words, chain of custody could be thought as a set of activities dedicated to tracking data and information relative to a product. On the other hand, chain of custody protects the identity of a plastic good (but this principle still applicable to many sectors e.g., food and beverage, mechanic, etc.) and its unique characteristics from the production phases to sale to the consumer.

As reported in the standard *ISO 22095:2020 ("Chain of custody – General terminology and models"*) about how to identify the subject involved: "a chain of custody system can use traceability records to identify the supply chain actors that take legal ownership or physical control over a material or product".

While the implementation of some chain of custody models will imply a particular level of the physical presence of specified characteristics, the implementation of other chain of custody models may reduce the need to trace specific materials or products to support the claims being made *(ISO 22095:2020, Annex A ("Chain of custody – General terminology and models")*
In practice, chain of custody is a chronological record to refer to. For the companies is very important to know the origin of input materials, product components and the conditions under which they are manufactured. In fact, the purpose of the manufacturers is to demonstrate compliance with health, safety, environmental and social requirements, and regulations. On the other hand, consumers need to be able to believe to the declarations and labels that the companies subscribe for these products (Ellen MacArthur Foundation, 2020)
Chain of custody systems are, nowadays, indispensable for different applications, such as certification schemes for plastic but they are used also in other sectors: food safety, fishery, agriculture, constructions, etc.
The main promoters of this kind of systems are consumers, which are the most protected thanks to this type of system, and governments, but also the companies understood the importance of implementing chain of custody systems. The reason that the companies involved in a chain of custody (e.g., manufacturers, traders, transport and logistics service providers, retailers) need transparency. A transparent management and communication help to ensure quality and menage the risks. These chain of custody systems allow information associated with the characteristics of a product and their production to be shared among various organizations active in the chain of custody.
The *ISO 22095:2020("Chain of custody – General terminology and models")* represents a reference for the regulation for the chain of custody:

- Specifying a coherent approach to the design, implementation, and management of chains of custody;
- Harmonizing the terminology;
- Establishing general requirements for different chain of custody models;
- Providing a general guidance on the application of the chain of custody models.

To implement a good chain of custody system the companies must identify the different actors involved. In *ISO 22095:2020, Annex A ("Chain of custody – General terminology and models")* is reported: "…it is necessary to distinguish the various actors which play a particular role in the chain of custody or supply chain, for example: manufacturer, trader, distributor, carrier, or retailer". Another important aspect is the identification of the locations and spaces, the identification of inputs and outputs and the recording of associated information in the chain of custody.

Typically, were defined 4 types of chain of custody models. Recently, another type has been added. The five models of chain of custody identified by *ISO 22095:2020, Chapter 4.3("Chain of custody – General terminology and models")* are the following:

1. identity preserved model;
2. segregated model;
3. controlled blending model;
4. mass balance model;
5. book and claim model.

All the five models differ mainly in the requirements that each of them requires. These requirements "allow different claims to be made about materials or products and/or production processes that are delivered using that chain of custody model". *ISO 22095:2020 ("Chain of custody – General terminology and models").* For this, each company can choose the appropriate chain of custody model to adopt basing the selection on the benefits and quality they aim to achieve. The choice of the right model also affects the implementation of administration, logistical and organizational aspects.
The standard *ISO 22095:2020*, *Chapter 4.3 ("Chain of custody – General terminology and models")* also defines two main types of expectation of those using chain of custody protected materials:

1) Item-based: the material or product received bears all the characteristics identified by associated information;
2) Market-based: taken as a whole, the market for the material or product received delivers the characteristics identified by associated information.

The identity preserved and segregated model both satisfy item-based expectations, but the second one also in case the exact origin of the material is not one of the claimed characteristics. The other methods, instead, satisfy the market-based expectations because they ensure that the declared characteristics of a product are satisfy in a proportion specified.

3.1.2 Chain of custody models

As already said in *§ 3.1.1* exist 5 types of chain of custody models, also called traceability models. They are classified in descending order according to the physical presence of specified characteristics in materials or products by *ISO 22095:2020.* The ones that require more physical presence is the identity preserved model, until the book and claim model that doesn't require physical presence. An illustration of this "*hierarchy*" of the chain of custody models is given by *Figure 3.1*.

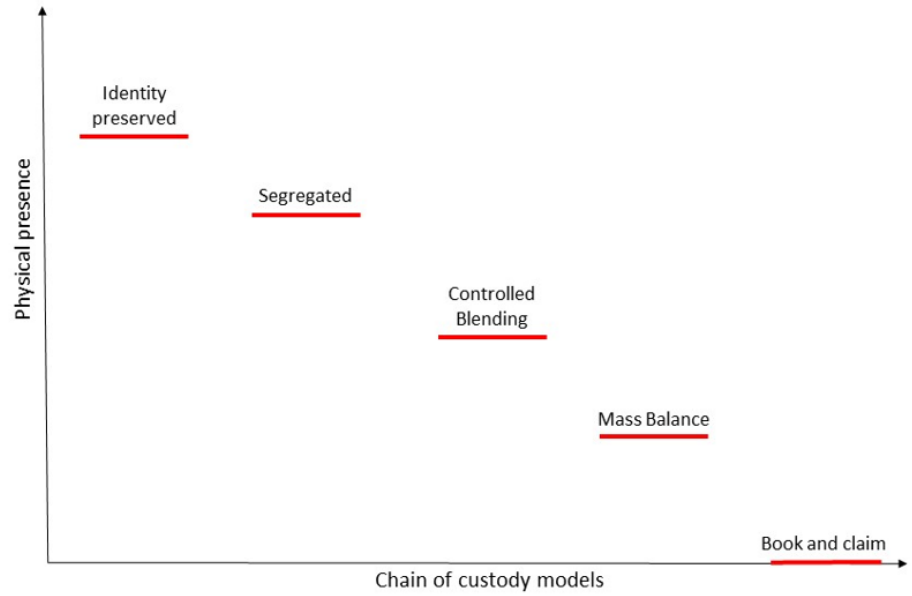

***Figure 3.2**: Ranking of chain of custody models according to the physical presence of specified characteristics*

Chain of custody models have the main purpose to create transparency and trust all along the value chain. They refer to properties of materials and products, such as composition of raw material, production processes, origin of the materials, etc.
It is possible, based on the *ISO 22095:2020* definitions, differentiate between two main group of traceability models:

- Chain of custody models without mixing (identity preserved, segregated)
- Chain of custody models with mixing (controlled blending, mass balance, book and claim)

It means that some models are more able to keep stream of materials segregated than others. It depends on the characteristics of the actors involved and on the type of sector in which they are placed.

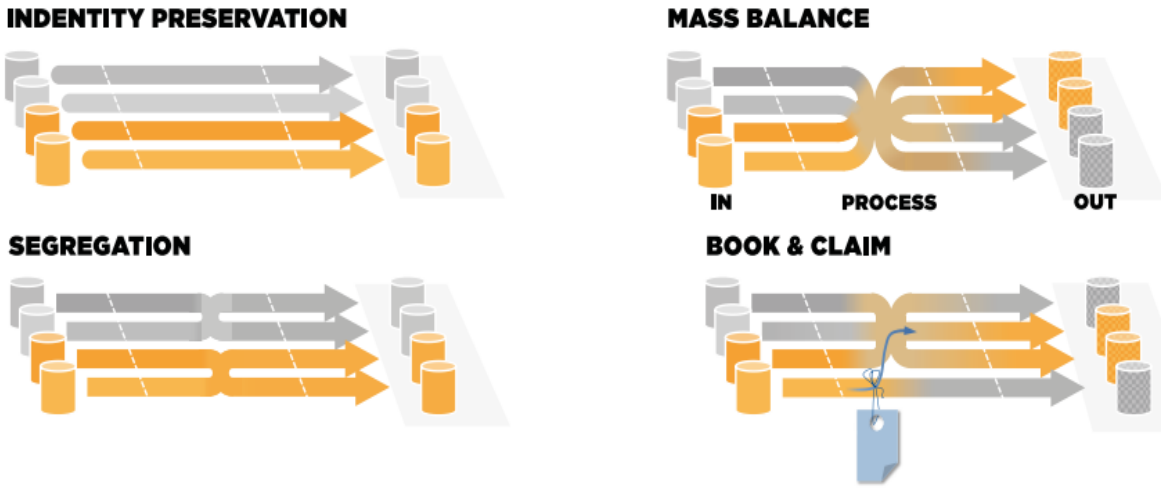

***Figure 3.3**: Graphical representation of 4 chain of custody models*

Analysing each model, the identity preserved model is adopted only if the goods or components can be identified individually. The inputs are generated from a single source (*ISO 22095:2020, Chapter 5.3.1)* and it is possible to maintain a physical traceability of the product from the origin and physical separation of products from other sources all along the supply chain. In fact, the materials or products must be maintained separated during the production and transportation.

The segregated model could apply if the source of origin is not the same, but the goods are themselves equivalent within the defined standard. In the segregation model, materials from different sources could be mixed within a common category, but material categories are kept physically separate. This model basically consists in the aggregation of volumes of products of identical origin or produced according to the same standards in one stock item (*ISEAL Alliance, 2016*). In other words, materials originated from different sources could be mixed but they must have the same characteristics.

In some cases, it could be difficult to process separately the materials due to the low volumes of themselves or because technical processes do not allow to differentiate. For these cases are designed three chain of custody models: controlled blending, mass balance, book and claim.

The controlled blending model maintains segregation of products or materials until the blending or mixing. The mixing occurs according to specific criteria. The result is a well-known proportion of materials with specified characteristics with materials without specified characteristics because "the ratio between inputs is known for all outputs at all times for a contained volume" (*ISO 22095:2020*). This model maintains segregation until the production stage in the supply chain in which the product with specified characteristics can then be mixed without specified characteristics. The proportions of *certified* and *non-certified* product at the overall site level are recorded and reconciled (*ISEAL Alliance, 2016*).

In case of controlled blending model, the calculation of content must be done at different stages of the value chain, as it can change throughout recycling, compounding and converting. Calculation of recycled content is described in the European standard *EN 15343:2007 Plastics Recycling*. Recycled plastics traceability, assessment of conformity and recycled content. Claims based on a controlled blending approach correspond to minimum percentage of recycled plastics, ensuring reliable, understandable, and trustworthy communication towards stakeholders, customers, and consumers.

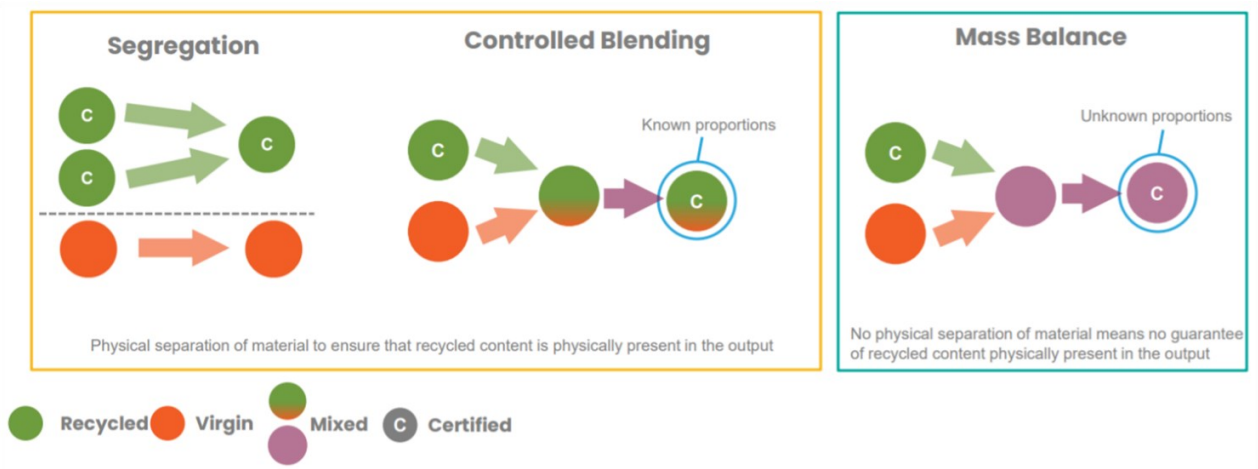

***Figure 3.4**: Segregation, Mass Balance and Controlled Blending chain of custody models*

The mass balance chain of custody model is designed to maintain the traceability of the total amount of the desired material through the production process and during the storage. The key point is that the materials with specified characteristics are mixed during the process with materials that do not have these characteristics. The *ISO 22095:2020* provides two implementation methods for the mass balance:

- Rolling average percentage method, based on a fluctuating proportion of entering materials reaching the specified characteristics;
- Credit method, based on the fact that the recorded amount of two or more inputs when two or more types of input are used in a material or product. The recorded output amount of each type shall be equivalent to the physical input, considering the conversion factor.

This model is based on the fact that outputs do not show any physical or chemical difference. The mass balance ensures that the exact account of volumes of material with certain characteristics and volumes of material without those characteristics is maintained all along the supply chain. It is important to provide that the ratio of sustainable material integrated is reflected in the products.

The mass balance model requires the definition of a reconciliation period, that could be a month, a year, a couple of years, etc. This period is the one in which the company using the mass balance model shall ensure a zero or positive balance.
In the end, book and claim model could be applied when there is no physical connection between the final product and the certified supply. "The book and claim model aim to ensure that for each purchase for which a claim is made, materials or products with the same specified characteristics have been produced" (*ISO 22095:2020*). The book and claim model is most suitable for intangible materials or products and when the entire market is controlled. An example could be renewable electricity where power is traded on a spot market irrespective of where the energy has been produced, and the certified 'green' electricity purchased by the end user is likely to be produced somewhere else (*Ellen MacArthur Foundation, 2020*). This kind of model can be considered as an alternative chain of custody model. In fact, for this model, "the administrative record flow is not connected to the physical flow of materials or products throughout the supply chain".

3.2 Methods

As previously said in *§ 3.1.1, "*the claims regarding specified characteristics may be based on schemes (e.g., certification schemes or programmes for labels), which specified requirements for third party conformity)" (*ISO 22095:2020*)
This study is focused on the environmental label of type II of which it belongs the "*rePEv*" mark, but an overview of the other type of eco-labels, with examples, is given in the *§ 3.2.1.*

3.2.1 Eco-label (or environmental declaration)

As already said previously in *Chapter 2,* eco-labels arise from the need to provide public and private consumers with clear, transparent, and immediate information on the environmental performance of a product.
The goal is to communicate, ever clearer, information to the public, understandable and transparent. It is possible to identify two main types of environmental labels: mandatory and voluntary. Mandatory ones bind the manufacturers, distributors and other subjects involved to comply with the legislative requirements. On the other hand, voluntary ones leave free manufacturers and distributors to decide to join the labelling system once the compliance of the products with the established criteria has been verified from the specific system.
Voluntary labelling can be classified into three categories: type I, type II, and type III.
Type I is an environmental label, which follows the UNI EN ISO standard 14024:2018, as in the case of eco-labels that require certification of an independent body.
An example of environmental label of type I is "*EU Ecolabel"*. It is an EU label promote by the European Union that rewards the best products and services from an environmental point

of view and demonstrates that the environmental impact of product or service is reduced throughout its life cycle. Analysing the impact significant environmental impact throughout the life cycle of a product or service environmental performances are evaluated on a scientific basis, considering the average life of the product and its reusability/recyclability, as well as reducing the recycling of packaging and its contents.

***Figure 3.5**: "EU Ecolabel" mark*

The trend of *EU Ecolabel* certification shows an interest by companies to certify their products from an environmental point of view, although it is a voluntary certification. It requires the certification by a third party that has the role of generating trust on the market through reliability, competence, and independence.
Figure 3.5 shows the number of EU Ecolabel certifications which does not coincide with the number of products or services with reduced environmental impact because the same company can obtain more licenses for different product groups.

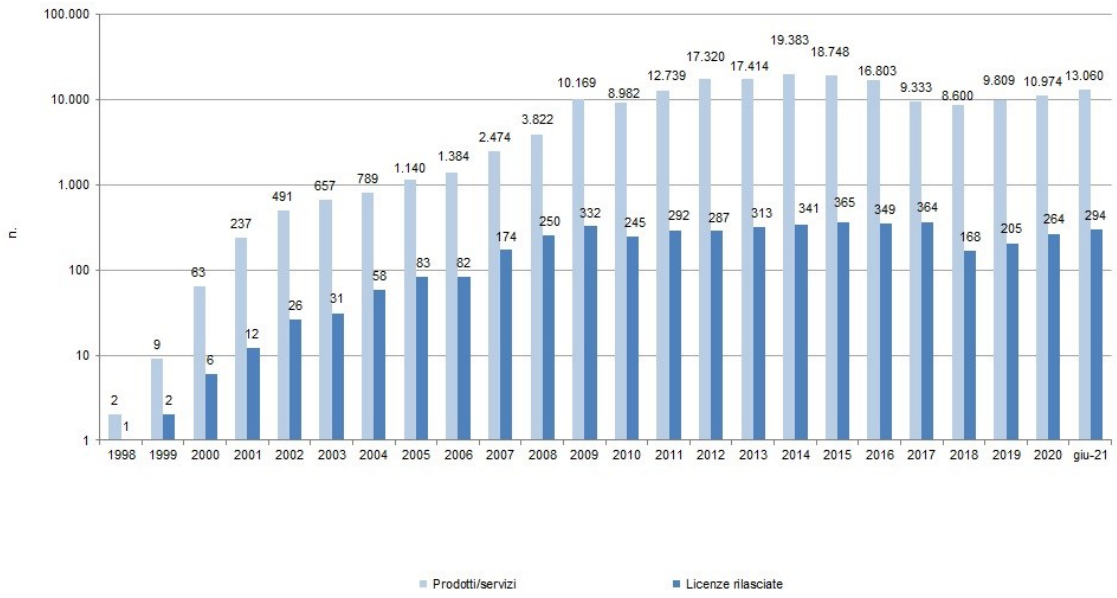

***Figure 3.6**: Ecolabel EU licenses number and products in Italy until June 2021*

Focusing on Italy, in 2022, there were 369 EU Ecolabel licenses currently in force, for a total of 12.068 products/services, distributed in 16 product groups.

Those of type II are called *Self-declared Environmental Assertions*, regulated by UNI EN ISO 14021, which do not need a specific certification. Common "*Reusable and recyclable*", "*compostable*", "*degradable*", etc.

***Figure 3.7**: "Recyclable" mark*

To make the environmental label of this type stronger and more effective, under a reliability point of view, some of them follow certified schemes and procedures. An example is the "*Plastica Seconda Vita*" (*PSV*) mark. It was born considering that the recycled plastic has a lower environmental impact than making new plastic. The economy needs the production and the use of plastics but on the other hand it is better to avoid a large using, preventing an impact on the environment.

"*Plastica Seconda Vita*" mark is an environmental product certification which clearly identifies the products obtained from the plastic waste. It simplifies and make clearer the identification of recycled plastic goods, that fall in green purchasing, for public and private subjects. It applies the concept of traceability of recycled materials and calculates their content according to the indications of the *UNI EN ISO 14021* standard.
This kind of environmental label is dedicated to the materials and products obtained from the valorisation of plastic waste from differentiated collection and industrial waste materials. It is the first Italian and European brand dedicated to recycled plastic, it introduces the concept of quality and traceability in recycled plastics.
The main purpose of "*Plastica Seconda Vita*" mark is to increase the identification of recycled plastic goods that are destined for public administrations, companies, and large-scale retail trade. It represents a great advantage for the consumers, because thanks to PSV certification it easier chooses more ecological products to buy. In fact, it represents a recognizable label (PSV) on any product made of plastic and ensure that part of its composition is made of recycled plastic.

***Figure 3.8**: "Plastica Seconda vita da scarto industriale" mark*

Different types of PSV labels exist depending on the recycled material used and on kind of goods produced, and some of these are reported as follows:

- PSV *from separate collection* for goods made using from 30 to 100% of polymers derived from waste differentiated collection (or other post-consumer circuits);
- PSV *from industrial waste* is for goods made using from 30 to 100% of polymers derived from industrial waste;
- PSV *Food* is for materials and products intended for contact with food;
- PSV *Bag* is for the reusable bags, and it requires more than 35% recycled content bags for the food distribution network and 15% bags for the non-food distribution network;

As mentioned before, the certification of "*Plastica Seconda Vita*" is managed from "*Accredited Certification Bodies"* with respect to *ISO/IEC 17065*.

Another example of eco-label based on UNI EN ISO 14021 is "*Remade in Italy"*. It is an environmental certification of a product under accreditation which allows a company to declare the content of recycled material or by-products, expressed as a percentage, within of a material, semi-finished or finished product, of any type, even made up of different materials, and belonging to any supply chain. To obtain the certification the companies must implement a traceability model for materials and flows within the production process. In addiction they must continuously monitor the suppliers and classify the inlet materials. *Remade in Italy* mark tries to guarantee a careful management of the materials from waste or by-products by the manufacturers.

As already marked, the "*Remade in Italy"* certification is accredited. This means, as for "PSV", that the certification bodies are controlled by an external body, designated by the government, that certifies their competence and impartiality. For these reasons, "*Remade in Italy"* certified products are recognized as suitable green products for public administrations within the GPP framework (see *Chapter 2*). In this sense, the application of the minimum environmental criteria (CAM) is mandatory according to article 34 of the *Procurement Code (Legislative Decree 50/2016)*: "public administrations must include in the tender procedures at least the technical specifications and contractual clauses contained therein".

The *Ministry of Ecological Transition* has implemented in the CAM the provisions of the Procurement Code (in particular those of articles 69 and 82), for which only the certifications with the highest degree of reliability and accredited can perform the function of means of presumption of conformity of the set environmental criteria.

Another example of environmental label of type II is the *EuCertPlast European Certification.* It is a certification scheme different from PSV and Remade in Italy, in fact it refers only to companies operating in the plastics recycling sector, applicable pre- or post-consumer. The main purpose of the *EuCertPlast Certification* is to promote an eco-friendly plastic material recycling process, by defining a standard that allows the integration of different revision schemes into a common one. The certification scheme is based on the European standard EN 15343:2007.

EuCertPlast European Certification is focused on the management systems, the implemented administrative and environmental operational standards. It refers also to the concept pf traceability of plastic materials at each stage along the supply chain, throughout the recycling process. The certification gives indications about the operational and environmental permits required for the country of operation, personnel training, qualifications and organisation, procedures and controls of incoming materials, recycling process, mass balance calculation, production statistics and traceability and disposal of waste from treatment, management of the plant and conditions of the storage areas in compliance with the protection of the environment.

Compliance with the series of standards EN15342, EN 15344, EN 15345, EN 15346, EN 15348 on recycled materials together with the definition of recycled content and traceability provide guarantees with respect to the relevant legal and environmental regulations, contributing to the increase of development policies sustainable.
Type III ecological labels are regulated by UNI EN ISO 14025 into which it falls the EPD (Environmental Product Declaration, or Environmental Declaration of Product). The environmental impacts are calculated for the entire life cycle through an LCA study (*See § 2.1.2*).
An example of this kind of label is the International EPD System and *EPD Italy*, which mark is reported in *Figure 3.7*.

Figure 3.9: "Italian EPD System" mark

3.2.2 "rePEv" mark and certification scheme

In line with the European strategy for plastics, the companies are trying to adopt models of excellence capable of enhancing their environmental sustainability initiatives, using also the already cited environmental labels. In references to the new regulations of EU about plastic, the verified declaration of the recycled content of plastic goods becomes not only an obligation but also an opportunity to innovate processes and products.
The "*rePEv*" mark is an environmental label based on UNI EN ISO 14021. It has the goal to make available to the world of companies that use and process PE goods, a competitive tool for declaring the recycled content of their goods in a verified way and therefore, in addition to facilitating compliance with regulatory requirements, promotes environmental excellence as a competitive variable.
The main purpose of this certification scheme is to define and make available a tool for tracing and certifying the recycled material content of a PE good along its entire chain value. This means tracing the PE good from recycling operations and production processes to the sale of PE semi-finished or finished products. At the same time, the "*rePEv*" scheme aims to enhance PE products containing recycled material obtained from goods resulting from collection and selection operations that took place in Italy. This represent an addition to the others

environmental labels, in which there is not a specification on the geographical provenance of the recycled content of the produced goods.
In particular, the "*rePEv*" is referred to recyclers of PE goods deriving from post-consumer or post-industrial collection operations and producers and manufacturers of PE semi-finished and finished products. The scheme considers as raw material only the recycled waste PE. This means that are excluded from the certification by-products. From *Legislative Decree 152/2006*, the definition of which is no more considered waste is:

- Residues which are transformed into secondary raw materials after reaching the *End of Waste* status, as residues that have lost their waste classification after specific recovery operations.

The same *Legislative Decree 152/2006* highlights what kind of residues are not considered "waste":

- By-products, which are residues originating from a production process whose primary purpose is not their production, used legally without the application of treatments like waste management and without causing damage to the environment and human health.

As by-products are still "products" and not "waste", they cannot formally undergo recovery processes, and this is why they have been excluded from the "*rePEv*" certification.
To access to the mark, the companies must ensure certain minimum criteria. In this way, the companies are allowed to declare in a certified manner the recycled PE content of the goods that they treat or produce. The companies that require the "*rePEv*" certification must implement and maintain a management system capable of ensuring the conformity of the certified products with the criteria established by the "*technical disciplinary*".
In particular, the *technical disciplinary* establish four requirements that the companies must ensure to implement and maintain the mark:

- Define the field of application of "*rePEv*" mark, that means chose the PE goods subjected to the scheme;
- Nominate a person responsible of the procedure and specify the roles and responsibilities of the personnel involved;
- Specify the necessary procedures, both technical and operative;
- Produce, maintain, and make available the necessary documented information, that means implement a traceability system that allows to maintain the traceability of the recycled PE used in the production of semi-finished or finished products.

To access to the "*rePEv*" mark it is required to demonstrate a recycled content of at least 10% for the goods. To implement the traceability system required to obtain the certification the companies have to check and control:

1. Inlet material;
2. Production process;
3. Calculation and declaration of the recycled content of PE goods.

In a more detailed way, the incoming recycled PE goods must be obtained from goods resulting from collection and selection operations that took place in the Italian territory and the companies must control the inlet material to comply with this requirement. These is an incentive for companies to buy from the local market, promoting the development of little-middle industries that operates in plastic sector in all the national territory. The "*rePEv*" certification tries to minimize the environmental impact related to transportation, but it does not refer to a proper extremely short distance; instead, it is referred to the European proximity principle which establishes that "the disposal of urban waste must take place in one of the suitable plants closest to the places of production or collection, in order to reduce the movement of the waste itself" (*art. 182-bis cit*.); that principle is also applicable to special waste and this is why it has been included in "*rePEv*" certification limiting the boundaries to the Italian area.
The *technical disciplinary* of "*rePEv*" distinguishes two types of inlet material control. This division is made on the operations that the companies carry out: recycling of PE or production of semi-finished and finished PE products.
In the case of recyclers, the information required about the inlet raw materials are about the lot dimension that could be measured in mass or volumetric basis, the colour (transparency, single colour, etc.) and the shape of the waste that could be chips, flakes, film, bottles, or sacks. It is necessary to also provide information about the history of the waste, the main polymer of which the waste is made and the other polymers inside the good. In the end, it is required also the packaging of the waste.
The recyclers, when it is possible, must provide from the supplier further information about the waste used as raw material. This information regards the polymer properties, that could be useful when the waste is homogeneous, the impact resistance, the fluency index, the softening temperature of polymers, the additives, contaminants, humectants, volatiles contained in the waste, the ash content, the humidity, the tensile strength at break and tensile strain at yield.
On the other hand, in the case of producers of PE goods, the information required for the inlet material are contained in the technical disciplinary (adapted from the *EN 15347-2 standard*). The raw material is plastic waste (derived from PE goods), that could show up in different ways. To apply the "*rePEv*" certification there are required information about the origin of the materials such as type and form, product type, type of waste (e.g., pre -consumer, post-consumer, demolition waste), identification of the supplier, date, waste history (e.g., evidence of contact with dangerous substances). Other information needed are about logistics, such as type of collection and sorting of the waste, lot size, identification and labelling, pre-treatments as washing and grinding and type of storage (indoor or outdoor). In the end, information about

tests conducted before workings, process parameters, tests conducted after working and details on possible applications are to be checked at the entrance of the raw materials.
In addition, the companies must ensure that the lots of inlet PE goods must be uniquely identified and appropriately stored so that they cannot be confused or mixed with other stored products.
Referring to the production process control, the technical disciplinary establish that during the production process phase the following information must be registered:

1. i: identifier of the i-th lot of incoming PE goods used in the j-th production lot;
2. IR: quantity of PE goods withdrawn from the i-th batch of incoming PE goods used in the j-th production batch;
3. j: identifier of the j-th production lot;
4. Q_j: quantity of output goods in the j-th production lot.

In the end, the declaration and the calculation of the recycled PE content must determine the recycled PE content of the goods referred to the j-th production lot using the following formula, contained in the *technical disciplinary*:

$$RC_j(\%) = \frac{IR_i}{Q_j} \times 100$$

The "*rePEv*" mark is an environmental declaration of Type II, but as previously said in *§ 3.2.1*., it is one of those that follows certified procedure and accredited schemes of certification. This means that a third party is called upon to verify the quality of the processes upstream of the "*rePEv*" labelling. In fact, the companies must contact a third-party body or a suitably *accredited conformity assessment body* to carry out the verification activities of the requirements show up in these chapter. In general terms, the companies must provide documents in which are reported information about the identification of the companies themselves, the identification of the products under certification (description, physical data, performance, quality, etc.), processes (flowcharts of inputs and outputs and machinery used) and traceability system adopted.
The certification body organize the verification of the compliance with requirements providing the following activities:

- Reviewing documentation
- Preparation of a verification and sampling plan;
- Conducting verification activities "*on field"*;
- Verification of compliance with the requirements of these technical specifications;
- Preparation of an opinion on conformity.

The sample size will be determined based on the number of product codes to be certified by adopting a simple sampling approach (√n where n is the number of product codes). Similar products (e.g., same function, same recycled content but different colours) can be grouped into homogeneous families. A family counts as one product code for sampling purposes.

"*rePEv*" certification scheme is not already an accredited scheme. The accreditation process is articulated, and it requires time from the starting demand to the release of certification. During this process the certification bodies demonstrate that companies meet the requirements for assessing the conformity of products. Accreditation is part of a global system including assessment of compliance and market surveillance, born in order to assess and ensure compliance with applicable standards. The value in accreditation lies in the fact that it provides an attestation, endowed with authority, of the technical competence of the bodies to which it belongs ensure compliance with applicable standards. As it helps to increase the competitiveness of economic operators for the quality and safety of products, accreditation is a tool to ensure confidence in the market. It is an effective support tool that brings concrete advantages to the entire socio-economic system such as institutions, business companies and consumers. For companies, the benefits of accreditation are represented by the advantages they acquire when they choose to rely on the conformity assessment services issued by accredited bodies. For all market players, accreditation and accredited services guarantee higher quality and safety of goods. The use of accredited certification makes companies more effective on the market due to the fact they have a formal recognition by an independent entity of processes and procedures in line with international standards. Furthermore, the accreditation gives to companies an international recognition and it allows companies to expand their business more easily on foreign markets. In fact, accredited products must not be submitted without having to subject their products and services to additional checks and controls in the countries of entry. The accreditation certifies that the supplier has fulfilled all the obligations required to place a reliable and quality good or service on the market, according to internationally recognized standards. The consumer can trust products and services certified and tested by accredited bodies, because they meet stringent quality and safety requirements, and reduce the risks associated with consumption.

Chapter 4

Traceability scheme implementation for recycled PE: PG Plast

4.1 Company presentation: PG Plast

PG Plast S.r.l. is an Italian company that produces packaging and flexible plastic products, born in 1973, with fifty years of activity. The company, since its foundation, has always maintained a "family" dimension that has characterized its history. At the same time, it activated a concrete ability to develop and refine studies and research on its products. This results in the materials used and in the adoption of organizational measures and quality standards. PG Plast continuously actively participating in research and development projects focused on the issues of recovery and reuse of plastic waste, pursuing the primary objective of environmental sustainability of their products. The philosophy of the company is to help ensuring a future for the planet with a constant search for increasingly eco-sustainable solutions.

The company produces flexible packaging products in plastic material. In the first period of its activity, PG Plast focused its production on bags for the local commercial circuit. During the years, the company has gradually specialized its production for the industrial sector, supplying plastic packaging for production companies. For this reason, different products were developed. The evolution of the production has also led to an integration of the product packaging with alternative closing systems (zipper and pressure, adhesive tapes) and to an experimentation of the use of alternative materials respect to the traditional polyethylene, with particular attention to bio-compostable or biobased polymers and recycled plastic material.

The company moved its operational headquarters at the end of the 2018, in the new plant sites in Robassomero (TO). The transfer allowed to improve organization of the company production and having warehouse surfaces capable of better support the production needs.

Starting from 2019 the company has decided to extend its range of products with shipping envelopes for couriers and adhesive envelopes for documents. Furthermore, the company has made other investments to produce security envelopes for the transport of valuables and high value goods.

The strategy of PG Plast provides financial investments and furthermore the activation of applied research processes aimed to identify potential accesses to new market segments and to a recovery of margins for the company. The main business objective of the company is increasing its product catalogue with goods for which the use of materials other than plastic polymers is not conceivable now.
The sector of the company could be identified as transformation of plastic products and production batches of small quantities. In this sector operates a lot of small companies that are not able to invest in initiative that guarantee a more sustainable production. PG Plast, differently, is focused on the production and research of solutions with an ever-lower impact on the environmental factors of company products. These could give a competitive advantage in the sector in which the company operates.

4.2 Production process of reusable bags

The company produces flexible packaging using different materials but focusing on polyethylene. Polyethylene is a flexible, economical, durable, and recyclable material, perfect for making multi-purpose packaging and shopping bags. The same type of material can also be used to make light and cheap bags when the packaging must necessarily be unique. PE has an excellent aesthetic performance but, above all, allows the bag to be reused several times and is a cheaper material than the alternatives (paper, textile materials).
The first step of the study was understood and schematized the entire manufacturing process, through all its phases, to implement the traceability model. The study was aimed at understanding the effectiveness application of the "*rePEv*" certification scheme, so the phases of the production process considered were only the ones related to recycled PE.
To do this, the process has been divided into macro-phases which represent the key processing steps from the raw materials to the finished products. The raw materials in this case are PE pellets in sacks (PE could be recycled or virgin depending on type of products). Depending on type of product, it uses both virgin and recycled PE to produce reusable bags.
As in all manufacturing processes, there are phases that do no not transform materials in products. These phases are for example storage, transportation of materials and packaging. On other hand, it is a classic manufacturing process for reusable bags. The main phases in which the raw materials are transformed into final products could be identified as following:

- Extrusion;
- Flexographic printing;
- Thermo-welding;
- Cutting and die cutting.

The *extrusion* phase performed by PG Plast consists in a blown film extrusion that is the most common process to produce endless films. First of all, the plastic material in pellets is melted

in the extruder. The melt streams are brought together in the blow head to form a tube with concentric layers. The tubular element is pulled upwards when it exits from the circular mould. At the same time, it is inflated by injection of compressed air, in order to obtain the desired thickness and width of the film. It is then injected with fresh air which cools it down until it can be folded flat at a desired height and then rolled up to form rolls of PE film.

To personalize the plastic bags PG Plast has two flexographic printing lines, in case in case the customer requests customization. The *flexographic printing* is a direct printing method that uses printing plates, also known as flexographic plates or cliché, to transfer the ink to the support to be printed, typically used in the packaging industries. The raised areas in the printing plate are responsible for the ink transfer, while the recessed areas correspond to non-printed areas. The printing plate is flexible and soft, and it rolls up on a mandrel. The printing is direct: the material to be printed is pressed between a back-pressure cylinder and the mandrel where the printing plate is rolled up: in this way the ink deposited on the raised areas of the printing plate is directly transferred to the support. With this kind of printing technique, it is possible to print on many different supports in terms of thickness and superficial finish.

The *thermo-welding* phase transforms the film reels into finished products of various thicknesses. The result are reusable bags in virgin and recycled polyethylene. The tubular film is inflated and through hot blades, welded on the bottom according to the required length, and welded on the sides to form the final products. This process is also used to add accessories to the bags, such as zips, closures, etc.

The welding phase is immediately followed by the phase of *cutting or die cutting*. The die cutter is simply cutting profile tool capable of reproducing a certain shape starting from PE sheets.

The first part of the work was to schematize the operation through which the raw materials become finished products. To satisfy the requirements of "*rePEv*" certification only the phases in which is involved recycled PE were considered. In *Figure 4.1*, there is the conceptual representation of the of the manufacturing process starting from recycled PE, as raw materials, to reusable PE bags as finished products in which the three macro-phases are: supplying and storage, production and shipment.

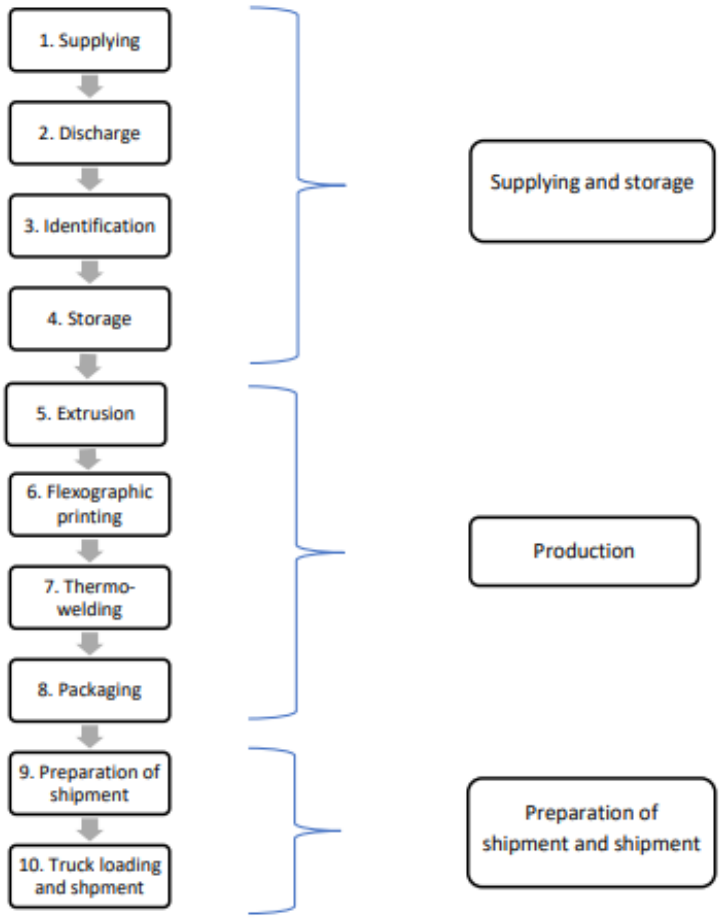

Figure 4.1: Production plant schematization of recycled PE bags production process

In this representation are considered also the phases not strictly connected to production, however, it was necessary to consider these phases because the recycled PE traceability must start at the beginning of the supply chain of the recycled PE.

4.3 Traceability solution to obtain "rePEv" certification

In order to obtain the "*rePEv*" mark, the companies that requires it has to guarantee a traceability system that reaches and respects the requirements established from the "Technical disciplinary". For this reason, it was designed a traceability procedure that allows to follow the entire cycle of production/transformation of recycled PE into PE goods. The procedure is a tool designed on the production process of reusable bags carried out by PG Plast. It makes possible to communicate the methods to maintain the traceability of recycled materials during the

processes, not only production processes, but also procurement, storage, and shipping. Therefore, it is essential to clarify its goal, make the liability system transparent and ensure the availability of the procedure to all interested parties, always in an updated form.
This technical procedure was designed and written basing on the technical disciplinary of the certification scheme "*rePEv*", considering the specific production process carried out by PG Plast to produce reusable bags made of recycled PE.
It is divided into 8 chapters:

1. Scope and application fields
2. Support documentation
3. Company presentation
4. Company's buildings and premises
5. Products identification
6. Production process phases
7. Traceability and product recall
8. How to use "rePEv" mark
9. Non-conformities management

First of all, it was necessary introduce generic parts which allow a better understanding of the context and a better definition of the borders inside which the procedure is applied. The parts in question are: "*Scope and field of application", "Support documentation"*, *"Company presentation"* and *"Company's buildings and premises".*
The *scope* of the procedure, as previously said, is to provide a system for the traceability of recycled PE, in order to obtain the "*rePEv*" mark. The procedure defines all the operation to trace recycled content of a PE good from procurement phase to purchasing. The *"Field of application"* part, on the other hand, specifies where the procedure must be used, defining the activities involved. The proposed solution is based on the identification of materials and operators along all phases of production. In this case, following the process of PG Plast to produce reusable bags made of recycled PE, the activities described are two:

- procurement and storage of incoming recycled PE;
- production of bags and envelope products in recycled PE.

Together with the activities involved are also defined the figures responsible for the execution of this procedure: the company management and all the figures involved in the production of recycled PE products, in particular those involved in warehouse management, quality control and production processes.
In the "*Supporting documents*" section is reported the documents that the procedure refers to. The two main documents used for the implementation of the procedure are the Technical Regulations and the "*rePEv*" Regulation. Other references are supporting documents referred

to therein which are deemed useful for the correct performance of the envisaged activities, in particular, as previously described in *Chapter 3,* the *ISO 22095:2020* and the *ISO 14024:2018.* The "*Company presentation"* part describes the company in which the procedure is applied, the figures responsible for the traceability system, and gives other general information about company, such as number of employees, facility surface, plant address, etc. This section defines also the processes related to recycled PE to which procedure refers. In this case are defined three main processes:

- Procurement and storage;
- Production;
- Preparation and shipping

Furthermore, in this section, there are also defined the figures responsible for the maintenance of traceability within the company. One figure is individuated as responsible for the entire production chain of recycled PE products for the "r*ePEv*" mark (*RSP*). Then, there are intermediate figures responsible for individual phases of the company production process coordinated by the company manager:

- Production manager of recycled PE goods (*RPR*) which is responsible for the phases of identification of incoming materials, storage, use in the production process, registration of uses and finished products;
- Recycled PE internal extrusion manager (*RES*) which is responsible for the phase of extrusion when it is carried out internally.

It is foreseen by the procedure that the production chain manager organizes at least one initial training event when this procedure is implemented for the first time, in order to explain the operations for maintaining traceability to the subjects involved in it. Other training must be organized when the system undergoes significant changes and when there are new hires involved in the operations for maintaining traceability.
In the "*Company buildings and premises"* section the conditions of the buildings of the company to guarantee the correct performance of the activities envisaged in compliance with the safety requirements of the processes themselves are described. It means that if new needs arise, the necessary modifications or expansions are made. These modifications may concern the production plants, buildings, equipment, and management software. Furthermore, it means that the working environment is maintained in conditions such as to guarantee the best performance of the activities and is such as to guarantee the safety of the operators. The hygienic and sanitary conditions must be maintained in all the places used to produce the identified products.

To describe how to maintain traceability of products made of recycled PE (total or partially) inside the PG Plast plant site, there were introduced some specific parts. The parts in question are the following ones:

- Products identification
- Production process phases
- Traceability and product recall
- How to use "*rePEv*" mark

The "*Products identification*" section described the products for which is request the labelling "*rePEv*". For PG Plast, the products are selected on the basis of the recycled PE content, which must not be less than 10% of the total. The selected products are articles for packaging which can be made from recycled PE. Based on the company experience and of checks carried out with its customers, it is believed they can find concrete possibilities of use, also in consideration of the easily identifiable environmental advantages and possible tax advantages recognized by the legislator. All the identified products are made with the use of semi-finished products consisting of reels of film or plastic tubing produced by bubble extrusion of the polymer.
In this section there is also a paragraph that describes the material flows inside the production process. These material flows were evidenced with a graphical representation of the planimetry, using different colours to trace the path of the different semi-finished products (one colour for each material, semi-finished products or products) In this way is possible understanding the movements that materials done during the process, in order to maintain traceability.
The most important part of the procedure is the description of the "*Production process phases"* through which the recycled PE is processed and transformed, maintaining traceability in all phases. The main phases considered to simplify and schematized the process, further divided into sub-parts, are the following:

- Raw materials
- Withdrawal of raw materials
- Production

In the section of raw materials are included and described the following processes:

- Supplying of recycled PE;
- Inlet recording and labelling;
- Unloading and control;
- Raw materials stocking.

In the "*Supplying of recycled PE*" section is described all the information necessary that the inlet recycled PE must be. The raw materials that enter as secondary raw material on PG Plast plant could be of two types:

- Sacks of granules of recycled PE
- Films of extruded PE (mix of recycled and virgin PE)

The first thing to do is to verify if the products are obtained from recycled PE exiting from treatment plants that have obtain the recycled PE from waste produced in Italy. The second one is to check the lots of recycled PE entering in the company plant and used in the production processes.
To be sure the raw materials boughed respect the requirements provided by the technical disciplinary, there are required some information:

- Evidence that the recycled PE product has obtained the "*rePEv*" certification or, alternatively, if leaving a waste recovery plant, the "*EUCertPlast*", "*CSI Recycled*" or equivalent certification;
- In the case of a request for the "*EUCertPlast*", "*CSI Recycled*" or equivalent certification, evidence of the Italian origin of the PE waste used, through a self-declaration by the legal representative listing the waste inputs associated with the single lot and their specific origin*;*
- The mandatory information listed in *Table 4.1,* that is part of the "*rePEv*" technical specification (adapted from the *EN 15343* standard) and dictates the conditions of incoming materials for companies producing PE goods.

Origin	Type/form of material
	Product type
	Type of waste e.g., pre -consumer, post-consumer, demolition waste
	Origin (identification of the supplier)
	Date
	Waste history (e.g., evidence of contact with dangerous substances)
Logistics	Collection (Carrier/type of vehicle)
	Sorting
	Lot size, identification, and labelling
	Pretreatments (e.g., washing, grinding)
	storage (e.g. outdoor)
Tests conducted before workings	EN 15347 Characterization of plastic waste
	or as appropriate for the end use
Process parameters _	Process details as appropriate
Tests conducted after workings	EN 15344
Application (possible) foreseen	Details on possible applications and those to avoid
Other information agreed between seller and buyer	

***Table 4.1**: inlet material requirements established by "rePEv" certification scheme*

As previously seen in *§ 3.1.2,* the inlet information required changing depending on the type of operations the company carries out. In this case, it is referred to production companies of PE goods.

The "*Inlet recording and labelling*" section contains all the information about the labelling and recording of inlet raw materials. Here, there is the description of the alphanumeric code for identification of the single lot. This code guarantees the traceability of lots of recycled PE because is physically reported on the raw material lot. It includes information on the material and on the geometry of lot. The code contains information on supplier (3 characters), data of inlet (6 numbers) and different phase of the process (extrusion, flexographic and thermo-welding) that the lot undergoes.

An example of code thought for PG Plast, based on the production process phases and on already existing identification methods used for batches of materials is reported below:

ZCA-221004 → ZCA-221004/E01 → ZCA-221004/E01-ST → ZCA-221004/E01-ST-S01

Starting from the left, the first code represents the inlet material, the second one is for the extrusion phase, the third one for the flexographic printing phase e the last one for the thermos-welding phase.

In the "*Unloading and integrity check*" section it is described how the lots purchased must be subjected to an external visual inspection and to the measurement of the weight (using pallet truck with weight indicator) in a special area for quantity control and integrity (raw material

acceptance area). All the data and information collected must be registered in the way and in the format better suitable for the company.
The *"Storage of raw materials"* section defines that the recycled PE entering, to obtain the "*rePEv*" certification must be stored in dedicated areas, appropriately marked with the use of horizontal signs or signs, separate from the other storage areas. This section also gives a definition of what is storage defining it as the activity of storing raw materials in the conditions of arrival.
The "*Withdrawal of raw materials*" section is particularly important because it describes all the operations and information necessary to picking and handling the materials stored in the warehouse. For these operations are used forklifts or other mobile systems in a manner that guarantees the general integrity of the materials. Whenever recycled PE material is withdrawn from the designated area of the warehouse, the following information must be recorded on the company management system:

- Lot of material taken;
- Initial lot quantity;
- Quantity of material picked up (kg);
- Withdrawal date;
- Operator.

This information is necessary to maintain the traceability system whenever a part of the material is withdrawn.
The main part of the "*Production process phases*" section is the "*Production*" section in which are described all the operative processes through which the recycled PE passes to become a final product. The phases included in the productive process are (see *§ 4.1.2*):

- Extrusion (if any);
- Flexographic printing and colouring (if any);
- Thermo-welding (Cutting + Welding);
- Die cutting (if any);
- Application of closing (if any);
- Packaging.

During the production the recycled PE granule is processed and transformed with respect to its original appearance. For this reason, a new identifier and a new lot code are created (which contains the lot information of the previous phase), as well as a link, recorded in the production management software, to the lot codes of the previous phase.
For each phase of the production process, timely recordings of the activities carried out on the company management system must be ensured in order to follow the mass flow of the material

so as to trace the recycled PE and arrive at defining the quantity present (in percentage) on the finished product.
In the specific case of PG Plast, the registrations on the management software adopted in the company take place with the use of documents, habitually used in the production cycle, which are renamed for the occasion in order to facilitate the subsequent requirements of traceability of the materials. The used documentation is indicated below:

- *BCF*: Bill of lading from the supplier, which records the recycled PE granules received at the company, with an indication of the quantity stored and the relative production batch;
- CPE: extrusion production load (semi-finished product), which contains an indication of the material used and the semi-finished product produced and reports the update of the production lot;
- *CPS*: internal production load of flexographic printing (if materials undergo flexographic printing), which contains indication of the semi-finished product to be used and the printed semi-finished product and which shows the batch of the semi-finished product to be used and the update of the production batch;
- *CPZ*: load of internal production of the heat sealing, which contains indication of the semi-finished product used and the finished product produced, and which reports the definitive update of the production lot;
- S*CA*: warehouse loading of "*rePEv*" processing waste, which contains the registration of rejected materials and/or semi-finished products, with indication of the relative lots.

The first phase of the transformation process of the recycled PE is the extrusion (see *§ 4.1.2*). This operation only applies if the raw material used is recycled PE pellets. After extrusion, the extruded PE that is not immediately used in the subsequent production phases must be stored in a suitable area and suitably identified by horizontal signs and signs (*semi-finished storage*). In order to maintain traceability after the extrusion operation, the semi-finished products must be stored after being labelled with the speaking identification code. The extrusion phase is recorded in the company management system and reports the following data:

- Amount % of recycled desired in the finished product;
- Identification code of the incoming material;
- Quantity of incoming recycled material (kg);
- Quantity of incoming virgin material (kg);
- Quantity of outgoing material (kg);
- Identification code of the outgoing material.

To avoid the contamination with materials without the specified characteristics, the operator must check that the extruder has completed the previous cycle and is completely emptied of raw materials not intended for products to be marked "*rePEv"*.
The second transformation phase described, "*Printing, cutting, welding, application of closures and die-cutting*", is not a single operation but a set of operations. As already seen in *§ 4.1.2,* the operations of printing, welding, cutting and die cutting are performed in succession to the extrusion phase if the raw material is in the form of recycled PE granules. Due to the low capacity of extrusion process, PG Plast buy part of the raw materials as filmed PE in form of PE film reel, for this reason depending on the type of the raw materials entering the checks performed could be a little bit different.
The flexographic printing phase is to be considered optional, given the possibility of creating so-called anonymous products. The application of the closing components is foreseen only for a type of product.
In the case of using extruded recycled PE (film in reels), it is not necessary to proceed with the quantification of the mass flow, as the recycled PE component inside remains unchanged. However, it is mandatory to monitor the path of this material along the production process through the labelling of the raw material and finished products.
Since these phases are all a mechanical type, they do not imply a change in the chemical composition of the semi-finished product. Therefore, the % of recycled PE is considered unchanged from the input to the printing phase up to the packaging of the finished product.
The mass flow of these processes is monitored step by step, through registrations on the company management system which report:

- Semi-finished lot code;
- Quantity of incoming material (kg);
- Quantity of outgoing material (kg);
- Theoretical difference between input and output (kg);
- Weighted difference between input and output (kg);
- Finished product lot code;
- Production date;
- Operator.

The waste generated by this phase must be weighed using a balance before being thrown away. The weight value of this difference must be recorded and compared with the theoretical weight difference between input and output. These two values must not differ by ±5%.
As the same for the extrusion process, also after these operations the operator must check that the machineries have completed the previous cycle and that no other semi-finished products are used that are not intended be marked "*rePEv*".

During the phase of "*Packaging*" the products must be packed with suitable material and the packaging used must ensure:

- compliance with the provisions of the order;
- maintaining integrity;
- maintenance of external identification.

For recycled PE products, first of all, they are placed in a cardboard box, then placed on a pallet and in the end packaged with PE stretch film.
"*Storage, preparation, and shipment*" is the last phase of the "Production" section. The final products must be stored in an area identified with horizontal signs or signs. Every box must be labelled with an identification label, that report:

- lot code and product name;
- production lot.

To not lose the traceability, the shipping operators must verify the loading product correspondence. For this operation it is necessary to compare the label with production registers.
Another important section of the procedure in which is described the method to maintain traceability during the process, is "*Product traceability and recall*" section. In order to guarantee the traceability of the product of each production, the batches of virgin and recycled PE material used in the production of the products subject to the "*rePEv*" marking are well identified and traced along the entire company supply chain. To do that, PG Plast at least once a year, is carried out a traceability test starting from the finished product.
The way of how to use the "*rePEv*" is well described in "*How to use rePEv mark*" section. To use the "*rePEv*" mark, it is necessary to quantify the percentage of recycled PE contained in each finished product. This percentage can be obtained from the percentage of recycled PE declared by the film supplier in case the extrusion phase is not internal or from the company management system in the case the starting secondary raw material is a recycled PE granule and therefore the extrusion phase is internal.
PG Plast is allowed to use the "*rePEv*" mark on the website, in the description of the company, with reference only to the products included in the valid certificate and in the specific description sheets of the articles produced with recycled material and included in the valid certificate.
To show to the costumers the adhesion to the "*RePEv*", in all the administrative documentation intended for customers such as offers, order confirmations, transport documents, invoices, etc. the branded products are described with extended wording showing: [article code] – [article descriptive name] – ["Prodotto a marchio rePEv"] – [XX% recycled PE]

The declaration corresponding to the "*rePEv*" certification will be reported on the DDT (Document of transportation) and sales documents, specifying the type of detailed declaration for each product code:
eg. "[code] – [article descriptive name] and [XX% recycled PE]".

The mark can be inserted on invoices and delivery notes: in the latter case, if these documents refer to both certified and non-certified products, reference must be made to the declaration shown next to the product, e.g., "[code] – [article descriptive name] and [XX% recycled PE]".
In the end, the "*non-conformities management*" section described how the different non-conformities must be manage from the company. The production flow implemented, and the materials processed in PG Plast can give rise to different types of non-conformities. Non-conformities can be highlighted at the time of acceptance checks (on incoming materials), process checks envisaged by the production flow (on semi-finished or finished products), upon arrival of the goods to the customer (on finished products).
When the non-conformity is detected, responsible in charge of the detection must enter the information relating to the non-conformity in the register of the non-conformities, in which are reported all the detections of non-conformities. Purchased materials deemed unsuitable to be introduced into the processing cycle (where it has not been possible to obtain the necessary traceability evidence) are identified with the wording "*Materiale non conforme*", stored separately and reported to the Administrative Manager who initiates the procedure return to the supplier.
Outgoing semi-finished and finished products deemed non-compliant and for which an effective solution to the non-compliance found has not been found must be deposited in the appropriate waste container (identified and isolated from production) after being entered in the waste register.
The goods delivered and reported as non-compliant, following verification and confirmation by PG Plast, can be disposed of by the customer or returned to PG Plast, which arranges for disposal.

Conclusions

To conclude, starting from the exposition of circular economy, plastic production, and recycling data both in EU and Italy in the first chapter, the second chapter extensively exposed the European strategy about plastic with its principles and gives an overview on the legislation adopted to counteract the use of plastic products and improve recycling solutions. There are also highlighted the main instruments used to change the plastic linear economic model towards a more sustainable and circular economic system, such as plastic tax and environmental labels. It is underlined the importance of the GPP system from which the private market can get inspired and how the illicit trafficking of plastic waste can negatively influence the transition to a circular economic model. In the third chapter is presented the "*rePEv*" certification scheme and the instrument necessary to implement that, such as the chain of custody method and the requirements for voluntary environmental labels of type II. The fourth chapter contains the case study developed to verify the effectiveness of the application of the "*rePEv*" certification scheme through the drafting of a traceability procedure which guarantee to trace the recycled PE through all the operating process of manufacturing of reusable recycled bags.

"*rePEv*" is one of the environmental labels that certified the recycled content of a plastic goods. As mentioned before, this certification scheme is not already accredited although it started the accreditation process. This will reinforce the company's image and its credibility. Thanks to accreditation the companies are more effective on the market because an independent entity certifies processes and procedures. "*rePEv*" refers to PE products, and it is addressed both for producers of PE goods from PE waste and recyclers that treat PE waste.

However, it is first and foremost important to keep in mind the positive and the negative aspects of the application of the "*rePEv*" certification scheme on recycled products, in order to have a clear and well-defined overview. To do this it is necessary to compare the certification scheme under investigation with others schemes of the same type.

In the last years, much has been done to develop a system to give environmental label more credibility and effectiveness. Some results have been achieved by "*Plastica Seconda Vita*", which is one of the first certification that attests the recycled plastic content of plastic goods. Following this trend also "*rePEv*" gives a method to certify the content of recycled content, in this case referring also to PE.

One fundamental concept on which is based the certification scheme object of this study is traceability. The ability to trace materials from the inlet to the outlet through all the production phases it is become very important for the companies and for all the actors involved in the chain

of value of plastic and, in the specific case, of PE. The chain of custody model adopted for the implementation of "*rePEv*" is the controlled blending model, which guarantees the traceability of the materials until they are mixed during a well-identified phase. It could be possible to use a segregated method of chain of custody if the products are made of a single material but in the case of products made of both virgin and recycled PE it is necessary to consider a method that allows mixing.

"*rePEv*" certification scheme gives importance to the aspect of territoriality. In fact, one of the requirements to obtain the mark is to demonstrate that the recycled PE comes from operation of collection and recycling carried out in Italy. This requirement tries to improve the "PSV" certification scheme, specified from where the PE recycled waste used as raw material comes from.

This is a key point, in fact, this specification allowed the consumer to choose products produce on their national territory and with raw materials collected on the national territory. Furthermore, specifying collection on Italian soil, it is a countermeasure to avoid illicit traffic of waste through which country that does not adopt the same polices of EU in term of waste recycling and treatment. In fact, plastic waste is not seen only as a waste to dispose but an opportunity that could be use as raw materials for new qualitative products.

On the other hand, the name "*rePEv*" could be misleading: it is referred to the European proximity principle, but it is not required a proper extremely short distance from the place of waste production to the subsequent place of recycling or manufacturing.

Differently from "Remade in Italy", "*rePEv*" doesn't consider in the certification scheme the by-products (defined in *chapter 3)* content but only the recycled waste content. This could represent a limitation due to the scarcity of recycled raw materials available on the market, considering that the processing residues of plastic materials, consisting of cutting trimmings from the blanking of the finished product or trimming of the semi-finished product, are by-products.

During the collaboration with PG Plast, one of the most difficulties encountered was to find a method to maintain separate the lots of recycled materials of different supplier because, albeit qualitatively similar, they present some different characteristics.

The "*rePEv*" certification goes in the direction to amplify the concept nowadays applied to the public market with the GPP, also to the private market. In fact, using a label in which there is specified the recycled content contained in the products allow the companies to choose eco-friendly and low environmental impact products. This could push the private sector in the direction of purchasing only products with certified content for two reasons. The first one is to ensure high-quality products with low environmental impact. The second one is to use "*rePEv*" certification as leverage to amplify the market of products produced by recycling. The European and Italian data describe a continuous increase in the rates of plastic production, identifying the packaging sector as the most relevant. Over the years, treatment and recycling rates have

similarly increased, but they haven't still achieved the European targets and the quantities of non-recycled packaging are huge. In this sense, European legislation aims at a further increase in interest rates recycling and the Italian regulations comply with these directives. Delegated bodies and consortia to the organization of the collection and recycling system have a fundamental role for the achievement of these rates, translating and concretely implementing the guidelines placed at the upper levels.

Despite the difficulties due to the complexity and variety of plastic sector, the "*rePEv*" implementation could represent a step forward for development of environmental labels capable to trace the content of plastic goods. Furthermore, giving to territoriality a central role, it could be an interesting tool to increase the internal Italian economy about plastic goods made of recycled waste, realising in the sector of PE reusable bags an economy more circular.

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