Opportunities & Limitations of the EU Single-use Plastic Ban

Supervisor: Mr. van den Bergh

Student: Gabriele Gobbi (17136334)

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The Hague Uuniversity of Applied Science

Faculty of Management & Organisations

European Studies

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Executive Summary

The issue of plastic marine pollution has drastically increased in recent years. The questionable management of single-use plastic items has led to a concerning environmental scenario. The European Union is desperately trying to tackle the issue. In the early months of 2019, the EU approved the single-use plastics ban to mitigate plastic marine pollution. This research aims to understand the feasibility of the Ban and further identify a sustainable alternative to conventional polymers. In the literature review, the journey of EU legislation against plastic pollution and the main legislative action were discussed together with the main scientific aspects of Plastic in the marine environment. Before diving in the discussion part, the EU Single-Use plastic ban was analyzed and the articles were presented and explained.

Furthermore, the EU ban was discussed using academic publications on LCA (Life Cycle Assessment), analysis of the EU plastic lobbies, discussion of the EPR as a new strategy and considerations on illegal waste export. . The results show that despite a margin of improvement, namely 5.5% less in marine plastic pollution, the Single-use plastic ban is vague and provides an incomplete answer to the issue of plastic pollution. To have a concrete example of the implementation scenarios in a Member State, the Italian and German situation on plastic was analysed and discussed. This was done by analysing the law concerning the measures and goals set by the EU Circular Economy Strategy and the 2019 Directive on Plastic. Results show, that despite the proactive attitude of the Italian government, both legislation and infrastructure are not ready yet for the correct transposition of the Directive, while Germany has a better possibility. The final part of the research concerns the identification of one or more sustainable alternatives. This was possible to achieve through the selection of best-performing biopolymers according to scientific research, evaluation of the practical application in the industry, and final comparison. The interview with Professor M.Valente was crucial for this chapter. Results show, that both PHBH (Japan produced biopolymer) and WPC (Wood Polymer Composites) could be sustainable alternatives to oil-based polymers. However, further scientific and economic research is needed. In conclusion, The EU Directive on plastics provides interesting means to fight plastic pollution such as EPR, structural changes in the production of single-use items and more awareness-raising activities. The measurements show that despite the interesting measures, the EU Directive provides for a limited reduction of plastic marine pollution and therefore it represents an unfinished answer to the problem it intends to tackle. It becomes evident that a combination of interventions in several sectors and with the cooperation of EU and non-EU countries is the only possible way to really address the plastic pollution issue.

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Chapter 1

Introduction

In the years, the production of plastic has drastically increased. Given the capacity of its uses, the production of plastic grew more and more until it definitively overtook that of steel in 1979 (F.Stephen,1996). Of the 322 million tons of plastic produced in 2015, it is estimated that between 4.8 and 12.7 million in the same year ended up in the oceans(EU Commission,2015). This share of plastic is expected to increase by 2025 (R.Geyer,2017). The safeguard of the marine environment, therefore, becomes a collective responsibility. Historically speaking, humanity never reached such a high point of ocean pollution (Plastics-The Facts,2018). Several reports published by the European Commission and the EU research institutions show that the problem has been acknowledged (EU Commission,2018). However, an official Directive of this entity was never issued. The European Commission approved the 'single-use plastic' ban during the early months of 2019. Their goal is to considerably reduce the amount of plastic that lands in the marine environment. This research aims at understanding the obstacles that this policy could face in the context of plastic lobbies, illegal waste export and extended producer responsibility. Besides, there is a discussion on the economic, environmental and health impact of plastic in the marine environment. The research was divided into three main chapters. Namely a literature review of the most important scientific publications and historical reconstruction of the European legislative path. Furthermore, it follows an analysis of the 2019 EU Directive and discussion on sustainable alternatives.

What is the European 'single-use plastic' ban and what are the main obstacles for this policy to be effective, is the central research question that builds this paper. Following this central question, the first subquestion to be answered is what kind of environmental, economic and health impact does plastic have as well as a definition of what the plastic soup is. This question aims at understanding the environmental context in which the EU Directive tries to intervene. This first subquestion is a contextual one and finds his answers in the second chapter. The second subquestion investigates the history of European policies on plastic, providing a legislative point of view on the issue of plastic management. It reviews the development and increase of policy and legislative measures against plastic pollution. Following a chronological order, the third subquestion concerns the plastic ban itself and its implementation. This subquestion examines the structure of the Ban and provides an

introduction of the central policy. Moreover, the fourth explores the arguments on how the ban represents a new phase for the European Policy. This question aims to explore the new possibilities and limitations of the Ban, in light of several points of views. Both scientific, economical and political. To contextualize the Directive the Italian and German scenarios were analyzed and confronted. The decision to use Italy and Germany as a case study is given by the fact that Italy is one of the biggest single-use plastic producers and consumers in Europe. Germany, on the other hand, is a leading country when it comes to innovation and recycling. This case study helped to have a more practical example of transposition into national law. The second part of the paper contains the answers to the last two subquestions. The issue of sustainable alternatives and production possibilities is namely the topic that the final two subquestions aim to investigate. Chapter 4 contains examples of biopolymers implementation, and a final comparison to declare the most sustainable alternative. The final chapter presents the main conclusions and answers to the central research question.

Methodology

Desk research has been applied as the method to retrieve useful information and data for the literature review, the discussion chapter and the alternatives chapter. The extensive amount of publications and report on the topic facilitated to produce a complete literature review, both on scientific and legislative aspects. Furthermore, the desk research method was implemented to gather information for the analysis of the Directive and the discussion of sustainable alternatives. The recent outbreak of the Covid pandemic, limited the research to be mainly a desk one. However, an interview with the Biochemistry professor M.Valente enriched the discussion on sustainable alternatives and future plastic production scenarios. The interview was conducted through an email exchange due to the professor's tight schedule. Nevertheless, professor Valente provided extensive answers to the five different questions. Moreover, his 2020 publication ''*Eco-Friendly Approach and Potential Biodegradable Polymer Matrix for WPC Composite Materials in Outdoor Application'' gave additional information for the chapter on alternatives.*

For what the Literature Review concerns the publication ''Biodegradability of biodegradable/degradable plastic materials under aerobic and anaerobic conditions'' by R. Mohee and '' Bio-based and biodegradable plastic-Facts and Figures'' by dutch researcher M.van den Oever, were crucial to comprehend the difference in the terminology and mechanical properties. Furthermore, Michael Niaounakis, in his 2013 publication ''Biopolymers: Reuse, Recycling and Disposal'' explains relevant production processes and recycling features as well as the difference between biodegradable polymers and compostable polymers. Through the use of these publications, it was also possible to

differentiate polymers in three categories. The introduction of the main problem related to the Central research question is the ''Plastic in Marine Environment'' paragraph of the paper. In 2017 the American scholars Roland Geyer, Jenna Jambeck, and Kara Law published an article entitled ''Production, use and fate of all plastics ever made '' in ''Science Advances '' in which they calculated the total of all plastics produced since the 1950s and their final use and destiny. This helped in collecting data and then identify the main problem related to plastic production. To understand the origins of waste the publication ''Dispersion, Accumulation, and the Ultimate Fate of Microplastics in Deep Marine Environments'' by A.Ian Kane, published in 2019, was a fundamental piece of literature when speaking about the plastic issue. The authors suggest that is necessary to pay attention to the accumulation rates in different geographical areas. Besides, the publication ''Marine Anthropogenic Litter'', by Melanie Bergmann explains that debris of terrestrial origin, linked to metropolitan and urban areas, can come from tourist exploitation of the coasts, from industrial discharges, waste abandoned on beaches, unprotected landfills located near the coast, and rivers (M.Bergmann,2015).

To understand the plastic island and the bad waste management issue the publication ''Solid waste management in Asian countries: problems and issues'' by A.Khajuria, was used. The 2018 World Bank report ''What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050'' explains that even in Europe the figures are dramatic. This helped to contextualize the European scenario. In 2013, the oceanographer and boat captain Charles Moore published one of the most relevant and explicative publications regarding the plastic islands all over the world. In his book, C.Moore explains that floating debris drifts as well as the existence of accumulation zones of floating marine debris, the famous oceanic ''gyres'' which are the convergence of plastic in the Pacific and other oceans. The ''Clean Water Act'' published by the US-based EPA, about '' priority pollutants '', was useful to understand the danger of plastic. United Nations and the European Union reports were also included. To analyze the history of EU legislation on plastic, the literature review contains paragraphs about ''The Life Program'', ''Closing the loop - An EU action plan for the Circular Economy'', ''Circular Economy Package'', ''A European Strategy for Plastics in a Circular Economy'', and ''Circular Plastic Alliance''. This helped to reconstruct the path that leads to the 2019 EU Directive.

The third sub-question concerned the 2019 EU Directive on the Ban of Single-use plastic items. Following the structure of the original text, an analysis of the Ban was conducted. It was based on the academic paper ''Sustainability Assessment of a Single-Use Plastics Ban'' by Timo Herberz, Claire Y. Barlow and Matthias Finkbeiner. The reliability and validity of this source are given by the fact that the authors work for the Department of Engineering, University of Cambridge and Sustainable Engineering, Technische Universität Berlin. The use of the paper helped in the identification of the main issues when it comes to the feasibility of the Ban. The structural analysis of the Ban was

considered necessary for the understanding of the opportunities and limitations. Further in the research, an analysis of the Italian and German legislation and infrastructure provided relevant results concerning the transposition of the Directive and its impact on different national scenarios. The focus on Italy and German is due to two main factors. First of all, is because Italy has a leading role in European plastic production, and second because Germany is one of the best-performing countries in terms of recycling. The analysis of the Italian scenario was done by investigating the articles contained in the Italian legislation. This provided enough knowledge to develop a conclusion on the current legislative situation of Italy. To develop considerations on the Italian plastic industry scenario, the focus was set on the statements of the prominent representatives of organizations like PlasticsEurope Italy, Pro-mo, and Flo-Spa. In regards to Germany, the opinions of the government representatives and the experts provided information to build a constructive discussion on their national capacity. The benefits of this analysis are a more broad understanding of the national transposition of the Directive and the analysis of the national differences. The drawback of such an approach is the fact that to have a complete view, more research should be done on other big European countries.

The second part of the research, which mainly concerns the identification of sustainable alternatives and their implementation, was conducted by using both secondary and primary data. Given the limited bio-engineering knowledge, scientific publications of organizations, researchers, and EU institutions on biopolymers were used. On the one hand, to identify suitable biopolymers and on the other, to identify possible examples of application. The market potential of the best performing biopolymers was measured through 3 different existing European examples. This was carried out to prove the potential application of the products. The discovery of these projects was achieved through the reading of EU publications on this matter. Among the scientific reports, the discovery of Professor Valente's research provided a significant contribution to the research. The reliability and validity of his research are given by the fact that he is a bio-engineering Professor of the La Sapienza, University of Rome. Given the complexity of his research and to have a better understanding of the potential, it was considered necessary to interview him.

In conclusion, the opinions of experts and representatives had a crucial role in the development of the final answer the research aims to achieve. It provided sufficient data on which the analysis of the obstacles and opportunities is based. The combined use of secondary and primary data provided an adequate amount of material for all the 3 main chapters. The research and the interview with Professor Valente were conducted respecting the required ethical principles. An informed Consent Form was provided to Mr Valente to assure the confidentiality of the interview and the protection of the data he provided.

CHAPTER 2

LITERATURE REVIEW

From the postwar period to today, plastic has impacted society more than any other material in history and has entered our imagination for that idea of infinite possibilities that were previously unthinkable. Plastic began to substitute everything and create new objects that never appeared in people's lives. Plastic is present everywhere, in electronic devices, clothes, games, machines, food containers, agricultural machines, and even in the home furniture. The production of plastic grew more and more until it definitively overtook that of steel in 1979 (F.Stephen,1996). In 2015, the annual world production of plastic resins reached 322 million tons, with an impressive acceleration if we consider that in 1980 the annual production was just over 50 million tons (R.Geyer,2017). If this trend is not regulated, changed, and reversed, by 2050 the total amount of plastic deposited in landfills and released into the environment could amount to 12 billion tons.

The success of plastics is not difficult to understand. Compared to metal or glass, it requires much less energy to be produced and recycled. It offers a low-cost material, biologically inert, light, resistant, and malleable in multiple forms for the most varied uses(J.Meikle,1995). Furthermore, the raw material from which plastic is obtained comes from only about 4% of all the fossil fuels extracted in the world (A.Anthony,2003). This means that there is a conspicuous capacity to meet the demand for plastic (M.Niaounakis, 2013). In parallel to those decades of production boom, the few and almost absent plans for proper disposal have led to an increase in plastic pollution .

Plastic in the Marine Environment

Of the 322 million tons of plastic produced in 2015, it is estimated that between 4.8 and 12.7 million in the same year ended up in the oceans (EU Commission,2015) leading to today's explosion of a real planetary emergency (EU Commission,2018). Every year an average between 5 and 13 million tons of plastic end up in the sea, as we have seen, estimating the weight of the world fish sector, at this rate in 2050 the quantity of plastic will exceed that of fish (R.Geyer,2017). Charles Moore explains in his publication "Plastic Ocean " that in some marine areas of the globe, called "hot spots", the accumulation of plastic is so evident that it covers 80% of the recorded marine litter (C.Moore,2012). Furthermore, this waste can be carried by currents even to remote distances and in areas such as the Arctic Circle. Up to 95% of the total waste that accumulates on the coasts, the sea surface, and the seabed is plastic (M.Bergmann,2015). Closed seas, such as the Mediterranean, can host some of the highest densities of marine litter on the seabed, reaching more than 100,000 pieces per km2 (A.Kane,2019).

Microplastics and Nano plastics

To date, no plastics are designed to simultaneously satisfy long durability and easy degradation. From an environmental point of view, the main drawback of plastic therefore lies in the lack of biodegradability underwater and in being subject to slow photodegradation (H.Takada,2019). Nevertheless atmospheric agents and microorganisms fragment plastic into persistent small particles, that in the see, becomes what has been described as marine debris (C.Crawford,2017). The definition "nano plastics" applies for pieces ranging from 0.001 to 0.1 micrometers, microplastics from 0.1 to 500 micrometers, mesoplastics from 500 to 5-10 micrometers, and macroplastics from 10 mm to 10-15 cm(A.Lusher,2019). For macroplastics, we mean fragments of plastic material easily visible to the naked eye. Microplastics have been found everywhere: in ice cores, on the seabed, and in coastal sediments around the world. Recently particles of microplastics have been recorded in the Arctic ice (I.Kane,2019). Microplastics can be divided into two broad categories that describe their source and use: primary and secondary (A.Cau,2019). Primary microplastics are defined like this because they are the precursors for the industrial production of consumer polymeric products.This category includes products used in the cosmetics sector, polyethylene particles in hand detergent, and similar products (G.A. Barboza,2018).

On the other hand, " secondary " microplastics derive from the fragmentation in the environment of larger elements of an innumerable quantity of various waste ranging from packaging products to ropes, sanitary products, bottles, disposable items, and nets (G.A. Barboza,2018). Fibers have been reported in wastewater treatment residues on land and in high quantities around wastewater flowing into the marine environment. Plastic microfibers have been found up to a depth of 5766km in the Kamchatka trench and the abyssal plain with concentrations reaching 2000 microfibres per m2, and even more surprisingly, at the bottom of the Mariana Trench, at 10.903m depth with 1600 microfibres per liter of sediment (R.Lehner,2019).Small fragments affect plankton, which is the main building block of life in the oceans (EFSA Contam, 2016).

Plastic and Human Health: The Real Danger

Plastics enter living organisms by ingestion (R.Lehner,2019). As a result, microplastics are accumulating in the marine food chain, exposing humans to plastic intake. The consumption of fish is the major vector of intake of plastics in human nutrition (M.Kosuth,2018). In October 2018, an Austrian study drew media attention to the issue of plastic ingestion. Eight volunteers from some European countries, Russia and Japan, sent a sample of their stool to the Institute of Gastroenterology of the University of Vienna. According to the research results, 100% of the samples showed the presence of PP and PET. Analyzing fish consumption, it has been estimated that the European population can ingest up to 11.00 fragments of microplastics per year (B.Liebmann,2018). The concerning aspect is the presence of nano plastics (S.M. Mintenig,2019). Unlike microplastics, nano plastics being smaller particles can pass through cell membranes. In June 2019, the University of Newcastle in Australia released an analysis that shocked public opinion. The study found that

an average person could ingest up to about five grams of plastic each week, the equivalent weight of a credit card (Dalberg University of Newcastle,2019).

The effects that these polymer particles can have on human health are still unknown and research has only recently been undergoing dedicated studies. The smallest particles can further penetrate the human body through cellular absorption and then migrate to the lungs or other systems (Dalberg Newcastle University,2019). In general, microplastic particles smaller than 130 microns in diameter potentially translocate into human tissues (E.Srebocan,2019). Nevertheless at present, there is a lack of long-term studies with repeated exposures and tests on multiple plastics, as well as the methodologies for the detection of nano plastics both in the biological and environmental sectors and in organic tissues, the systems used today are still demanding and not very reliable.

Plastic Properties & Disposal

A new branch of chemistry has developed that studies polymers of natural origin and tries to understand how recycling and biodegradation can reduce waste, giving new life and shape to objects otherwise destined for landfills (R.Mohee,2008). But even the much-vaunted bioplastic is certainly not the solution to all evils. The term itself carries different meanings, often with distinctions not clear to the public and linked to definitions deriving from patents. Therefore the consensus of the terminology is not always universal. " Degradable ", " biodegradable ", " bio-based ", " compostable " and " biopolymer " seem to have multiple and overlapping meanings. The publication "Biodegradability of biodegradable/degradable plastic materials under aerobic and anaerobic conditions" by R. Mohee and " Bio-based and biodegradable plastic-Facts and Figures" by dutch researcher M.van den Oever, are crucial to comprehend the difference in the terminology. "Degradable" is a generic term applied to polymers or plastics that disintegrate by various processes, including physical disintegration, chemical degradation, and biodegradation by biological mechanisms (M. van den Oever,2017). "Biodegradable" is an adjective applied to polymers that degrade under the action of microorganisms and natural gases. The outcome of this process varies greatly according to various environmental parameters such as climate, the nature of the soil, temperature, and the presence of oxygen (M.Niaounakis,2013). Normally " biodegradable " means a material that can be microbiologically degraded and whose final products are carbon dioxide and water (R.Mohee, 2008). When the source of the raw material comes from a biological base, plastic is defined as ‘’biobased’’, literally deriving from biomass. These materials can therefore be produced from agricultural waste, they can be obtained from food and vegetable or animal waste (M.van den Oever,2017). Despite this, the terms bio-based and sustainability don't always match.

Michael Niaounakis, in his 2013 publication "Biopolymers: Reuse, Recycling and Disposal" explains that technically, a bio-based polymer is not in itself a sustainable polymer, because to reach this status, its production processes must also be considered. Furthermore, not all bio-based polymers are biodegradable,

and not all biodegradable polymers are bio-based (M.Niaounakis, 2013). The difference between biodegradable polymers and compostable polymers is determined by the rate of biodegradation, disintegration, and toxicity. Therefore a correct way to define biopolymers must refer to the source of the raw materials and the biodegradability of the polymer based (M.Niaounakis, 2013). The authors suggest three different categories.

According to M. van den Oever, the first are biopolymers obtained from renewable bio-based raw materials, therefore compostable and biodegradable. They are produced by biological systems (microorganisms, plants, and animals) or chemically synthesized from a biological base, such as corn, sugar, and starch. These include synthetic polymers from renewable resources such as PLA, biopolymers produced by bacteria such as PHA, and natural biopolymers, such as starch and proteins(M. van den Oever, 2017). These kinds of plastics are widely used in food packaging, shopping bags, fibers, and agricultural applications, all of which share a relatively short functional life (M. van den Oever, 2017). The second type of biopolymers is always obtained from renewable bio-based but non-biodegradable raw materials. These include specific castor oil polyamides, specific bioethanol based polyesters as well as biopolymers such as natural rubber or amber (A. van den Oever,2017). The last type is that of polymers obtained from fossil and biodegradable fuels. Applications range from food packaging films to blends for the production of compostable paper-based packaging products, cutlery, straws, and lids for packaging fruit and vegetables (A. van den Oever, 2017).
Despite scientific limitations, the European Union has carried out a major legislative project in an attempt to limit the impact of plastics. The following paragraph will discuss the evolution of plastic policies, the circular economy project and sustainable development.

EU Legislation Against Plastic Pollution

The Life Program

The main EU program for the environment and climate is called Life. Launched in 1992, it has financed over 4,500 projects, distributing over 5.9 billion euros in grants for the protection of the ecosystem. The action against plastics is the EU's best known and most recent action for environmental protection. This petroleum derivative plays a crucial role in our economy and our daily life, but it is now universally known that how plastic objects are designed, produced, used, and disposed of harms the environment, particularly polluting the seas, which compromises ecosystems. Turning plastic objects into garbage is a waste of profitable raw materials and can consequently damage the economy. To understand the extent of the problem and the attention that the European Union places on the issue, it is necessary to observe the allocation of funds for environmental projects. The Commission has integrated action for the environment and climate into all EU spending programs, in particular in

cohesion policy, regional development, energy, transport, innovation, and agriculture. As part of the cohesion policies for the 2014-2020 period, the EU has earmarked € 63.46 billion for environmental protection and energy efficiency. Italy is the fourth beneficiary with 4.86 billion (added to the 3.59 billion of national co-financing), after Poland (with 8.51 billion), France (4.97), and Romania (4.88). Among the most recent measures taken from the current EU budget, there is also a € 243 million investment package, which is expected to mobilize a total of € 430 million to finance 142 new projects across the continent for the transition to an emission-free future and environmental protection. The projects financed under the Life program are the most diverse. They range from the use of bicycles to reduce emissions, to the funding of research for the creation of more eco-compatible fabrics, up to the fight against criminal organizations that control waste. For the purpose of this research, the focus will be on policies regarding plastic pollution and sustainability. In the subsequent paragraphs, it follows a discussion about the legislative plans that preceded the 2019 EU Directive against single-use plastics. This will provide an adequate political context for understanding the path that has brought the European Union to this point.

''Closing the loop - An EU action plan for the Circular Economy''

The document from which to start to reconstruct the theme of plastic in Europe is "Closing the loop - An EU action plan for the Circular Economy'' of 2 December 2015. With this project, the European Commission has set itself the objective of promoting the transition from the linear to the circular economy (EU Commission,2015). This document describes the European strategy on the circular economy, which has materialized in the four directives on the circular economy and, later, specified in the European strategy for the reduction of plastics.

In the linear economy, the scheme is that of extraction, production, consumption, and disposal. Once consumption is over, the cycle of the product that becomes waste also ends, forcing the economic chain to apply the same production pattern. The circular economy, on the other hand, is a system in which all activities, starting with extraction and production, are organized so that waste becomes a resource for other organizations. The Commission document states that the transition to a circular economy is an indispensable component of the efforts made by the European Union to develop a sustainable economy, release few carbon dioxide emissions, uses resources efficiently, and remain competitive (EU Commission,2015). This transition offers Europe the opportunity to transform the economy and generate new sustainable competitive advantages. The action plan defines 54 measures to "close the loop" of the product life cycle. It goes from production and consumption to waste management and the secondary raw materials market. Also, it identifies five priority sectors to accelerate the transition along their value chain (plastics, food waste, essential raw materials, construction and demolition, biomass, and biological materials)(EU Commission,2015). The document

announces the Commission's willingness to adopt a strategy on plastics in the circular economy to address issues such as recyclability, biodegradability, the presence of hazardous substances in some plastics, and marine litter. There is also a willingness to propose a more ambitious target for the recycling of plastic packaging in the revision of the waste regulations. According to the action plan, the circular economy will boost the Union's competitiveness by shielding businesses from resource scarcity and price volatility and helping to create both new business opportunities and innovative and more efficient modes of production and consumption. In addition to generating jobs for all qualifications, offering opportunities for integration and social cohesion will save energy and help avoid irreversible damage in terms of climate, biodiversity, pollution of air and water (EU Commission,2015).

Circular Economy Package

Together with the Action Plan, on 2 December 2015, the Commission also approved a package of directives on the circular economy with which it envisaged and proposed the amendment of six directives: directives on waste (2008/98 / EC), packaging (1994 / 62 / EC), landfills (1999/31 / Ce), electrical and electronic waste (2012/19 / EU), end-of-life vehicles (2000/53 / EC) and batteries (2006/66 / EC). The European Commission proposal was then submitted to the examination of the European Parliament and the Council of the European Union which, on 30 May 2018, finally adopted the new directives 2018/849 / EU, 2018/850 / EU, 2018/851 / EU 2018/852 / EU, which entered into force on 4 July 2018 and which the Member States will have to implement by 5 July 2020 (EU Commission,2017). The objectives of the new directives include recycling by 2025 for at least 55% of municipal waste by (60% by 2030 and 65% by 2035) and at the same time disposal in landfills is binding up to a maximum of 10% by 2035). 65% of packaging will have to be recycled by 2025 and 70% by 2030. Textile waste and household hazardous waste will have to be collected separately from 2025 and, again from 2025, biodegradable waste will have to be collected separately or recycled at home through composting, there is also a maximum limit of 10% of municipal waste to be disposed of in landfills by 2035 (EU Commission,2017). This directive shows both long term and short to medium term strategies. The goal of the long-term strategy is to involve companies in creating products with new materials, which are entirely reusable and therefore, do not generate waste. The short and medium-term one is to manage the waste produced in a more responsible, through reuse and recycling. In analyzing these directives, it is noted that the new legislative measures aim to improve the environment, with an average annual reduction in emissions of 617 million tons of Co2. They also have a positive impact on employment, with at least 500,000 more jobs. Furthermore, the circular economy could act as a driving force for the euro area economy, favouring, according to estimates by the European Parliament, growth in GDP of up to 7% more by 2035 (EU Parliament,2017).

A European Strategy for Plastics in a Circular Economy

Following up on the Action Plan and the circular economy package of 2 December 2015, on 16 January 2018 the European Commission approved the "European Strategy for Plastics in the Circular Economy''. Starting from the consideration that too often, the way plastic is currently produced, used, and disposed of does not allow to obtain the economic benefits of a more circular approach and harms the environment. The document emphasizes the need to urgently address the environmental problems affecting the production, use, and consumption of plastic. The millions of tons of plastic waste that end up in the oceans every year are one of the most obvious and alarming signs of these problems and a cause of growing concern in public opinion. According to the European Commission To rethink and improve the functioning of such a complex value chain, efforts and greater cooperation are needed from all the main actors involved, from plastics producers to recycling managers, from retailers to consumers (EU Commission,2018). Innovative solutions and a shared vision are also needed to steer investments in the right direction. According to the Commission's publication, the plastics industry is important for the European economy and, by increasing its sustainability, new opportunities for innovation, competitiveness, and employment can be created, in line with the objectives pursued by the new EU industrial policy strategy (EU Commission,2018). The Commission also believes that the European production is in the best position to lead the transition to more sustainable plastics and the Strategy for Plastics in the Circular Economy lays the foundations for a new plastics economy. In this scenario, the design and production of this material and its products fully meet the needs of recycling, and in which their development takes place in the name of sustainability (EU Commission,2018). This will lead to higher added value and greater prosperity in Europe and stimulate innovation. By pursuing these objectives, the strategy also aims to contribute to achieving the Commission's priority objective of achieving an Energy Union with a low-carbon economy and efficiency in the use of resources and energy. This directive precedes that of 2019 on single-use plastics and is part of the path that concretely contributes to the achievement of the sustainable development goals set in the 2030 Agenda in the Paris Agreement.

Circular Plastic Alliance (The EU and The Plastic Lobbies)

The upcoming paragraph will cover an EU promoted project rather than a legislative program. This because the understanding of the relationship between the political and private institutions is essential to address the plastic pollution issue. As part of its commitment to reduce plastic waste, increase the percentage of recycled plastic and promote innovation in the market, the European Commission launched a multilateral platform called the ''Circular Plastics Alliance'' on 11 December 2018. This platform brings together the main actors in the plastics industry, including those from the automotive, packaging, and construction sectors (EU Commission,2018).

On 20 September 2019, the European Commission announced the accession to the Alliance of over 100 signatories, public and private, who have committed themselves to use 10 million tons of recycled plastic in new products by 2025 (EU Commission,2019). The declaration, signed by small and medium-sized enterprises, large corporations, business associations, standardization bodies, research organizations, and local and national authorities, endorses the 10 million tonnes target and calls for a transition towards total waste elimination of plastic in nature and the stop of landfill use (EU Commission,2019). The declaration establishes concrete actions to achieve the goal, including improving the design of plastic products to make them more recyclable and better integrate recycled plastic; identify both untapped potentials, to increase the collection, sorting, and recycling of plastic waste across the EU. Furthermore, identifying investment gaps and consequently create a research and development program for circular plastics. Last but perhaps most importantly, establish a transparent and reliable monitoring system to keep track of all plastic waste streams in the EU (EU Commission,2018).

However, the European Commission says that the recycling potential of plastic waste is still largely unused in the EU, especially compared to other materials such as paper, glass, or metals. Of the over 27 million tonnes of plastic waste collected each year in Europe, less than a third is sent to recycling plants. As a result, less than 4 million tonnes of recycled plastics were sold in Europe in 2016, accounting for just 8% of the EU plastics market. In this context, the need for a more recycling and producer responsible oriented policy is evident (EU Commission,2018). The 2019 EU Directive on single-use plastic aims exactly at improving the already quite extensive base that the former legislation and projects developed.

Chapter 3

INTRODUCTION OF THE SINGLE USE PLASTIC BAN

With 560 votes in favour, 35 against and 28 abstentions, EU Parliament has approved a new law prohibiting the use of disposable plastic items by 2021. Disposable plastic cutlery (forks, knives, spoons, and chopsticks); plastic dishes; plastic straws; cotton swabs made of plastic; plastic sticks for balloons; oxy degradable plastics, food containers and expanded polystyrene cups (EC,2019).

According to the new directive, as regards to plastic bottles, at least 90% must be recycled by 2029, with an intermediate target of 77% by 2025. The text also introduces the obligation, starting from 2024, to have the cap attached to the bottle to prevent it from dispersing easily. Furthermore, a minimum content of recycled material is introduced (at least 25% by 2025 and 30% by 2030) in the production of plastic bottles to facilitate their separate collection. Objectives that will also be functional to increase the quality of the separate collection and recycling of this material. The directive provides that for fishing gear, Member States must define national collection targets and adopt monitoring plans to verify their achievement.

The extended producer responsibility regime includes manufacturers of cigarettes and fishing gear, which are among the most founded waste on our beaches. The extended liability will cover the costs of collection, waste removal, and awareness-raising, with the possibility of voluntary agreements between producers and national authorities. Besides, the new rules finally establish that the information labeling on the environmental impact of dispersing cigarettes with plastic filters on the street will be mandatory. This should also apply to other products such as plastic cups, wet wipes, and sanitary napkins.

For disposable products for which, however, there are no alternatives, Member States will have to develop national plans, with detailed measures, to significantly reduce their use, to be sent to the Commission within two years of the entry into force of the directive. According to the European Commission, "Over 80% of marine litter is made up of plastic. The products covered by the legislation make up 70% of all marine litter. Due to its slow decomposition, plastic accumulates in the seas, oceans, and on the beaches of the EU and the world. Plastic residues are ingested by marine species (such as sea turtles, seals, whales, and birds, but also by fish and crustaceans) and are therefore present in the human food chain " (EC,2018).

The Belgian rapporteur, Frédérique Ries of the Mouvement Réformateur (Group of the Alliance of Liberals and Democrats for Europe), stressed that "The plenary session of the European Parliament

has adopted the single-use plastics directive almost unanimously. Without a doubt, it is the first step, but Europe has started. This legislation will reduce environmental damage by € 22 billion, the estimated cost of plastic pollution in Europe until 2030. Europe now has a legislative model to defend and promote internationally, given the global nature of the environmental problem marine pollution caused by plastics. This is essential for the planet " (OJEU,2019).

Dutch MEP Bas Eickhout, the EU co-president candidate from the European Green Party, was also satisfied, he stressed that "The EU has finally noticed that we need to radically change our approach to the production and use of plastic in our daily life. The mountains of plastic waste degraded our environment and clogged our seas and this disposable plastic directive could be the first step towards a turnaround. We are tired of hearing empty promises from the industry that claim to face the problem. Instead of reducing plastic production, it has increased dramatically year after year. We will have to act creatively and laboriously to propose new circular models that can help us live sustainably and in harmony with our environment " (OJEU,2019).

Analysis of the Directive

The DIRECTIVE (EU) 2019/904 of 5 June 2019 contains a total of 19 articles. In the upcoming paragraphs follows a presentation of every single article together with an analysis of the implementation steps. This Directive aims to reach its goal through different measures which can be summarized as a market restriction, separate collection, product design, labelling, extended producer responsibility (EPR), and awareness-raising campaigns. The articles express these measures.

Article 1 presents the Directive's Objectives. Reduction and Prevention of the impact of plastic are number one on the priorities list. It follows the second main objective which is a ''transition to a circular economy'' (OJEU,2019). Article 2 contains the scope of the Directive. It addresses the single-use plastic products contained in Annex A as well as ''products made from oxo-degradable plastic and to fishing gear containing plastic'' (OJEU, 2019). Moreover, in the article, the Supremacy principle is applied in regards to previous Directive 94/62/EC or 2008/98/EC. This to assure the legal supremacy of the current Directive on plastic and to avoid non-homogenous implementation of the law. Terminology is indeed key in dealing with a topic like this if we consider the broad spectrum of single-use products and polymers. Therefore, Article 3 contains the main required definitions. It defines terms like oxo-degradable, single-use plastic products, waste fishing gear, and EPR (extended producer responsibility).

Furthermore, Consumption Reduction is the first measure to be introduced. Article 4 and 5 provide a legal basis for market restriction measures implemented by MS as well as containing implementation

steps and deadlines. The first important deadline is set by 2021. According to the directive ''By 3 July 2021, Member States shall prepare a description of the measures which they have adopted pursuant to the first subparagraph, notify the description to the Commission and make it publicly available'' (OJEU,2019). Moreover, there is a description of which measure Member States are allowed to implement. '' The measures may include national consumption reduction targets, measures ensuring that re-usable alternatives to the single-use plastic products are made available at the point of sale, economic instruments ensuring that those single-use plastic products are not provided free of charge at the point of sale'' (OJEU,2019).

According to EU law (Art.34 TFEU) market restriction, and other similar activities shall be prohibited but under specific circumstances, these restrictions can be implemented. Besides that, proportionality and discrimination are also key factors to take into account. The EU Commission underlines this factor writing that '' Where the Member States decide to implement that obligation through marketing restrictions, they should ensure that such restrictions are proportionate and non-discriminatory'' (OJEU,2019). Despite this, there is no further explanation of how these restrictions should be structured and implemented, leaving a crucial part of the implementation process to the single Member States. To assure a long term control the EU requires the Member States to deliver reports and by April 2021 ''the Commission shall adopt an implementing act laying down the methodology for the calculation and verification of the ambitious and sustained reduction in the consumption of the single-use plastic products'' (OJEU,2019).

In addition, the directive addresses the topic of Product requirements. Article 6 is mainly about standard harmonization and how this should be developed in the upcoming years. According to the Directive, the Commission shall delegate the European standardization organizations to develop harmonized standards. The focus of those standards shall be on the need to ensure the necessary strength, reliability, and safety of beverage container closures'' (OJEU,2019). Moreover in the article, there is an implementation timeline that depicts the gradual increase of bio-based materials in the production of single-use products. The main goal is that by 2030 the bottles should contain at least 30% of recycled material (OJEU,2019). Proceeding in the chapter about requirements, Article 7 is of great relevance. The attention is mainly on the correct and functional marking of the packaging. The Member States should make sure that appropriate waste management options and plastic presence are well indicated in the product label (OJEU,2019). This article is not only related to the product and marking requirement but also to the awareness-raising process. The correct marking of the products could potentially lead to an increased awareness of the consumers.

The upcoming paragraph will focus on Article 8. It introduces the concept of Extend Producer Responsibility (EPR) concerning single-use plastic producers. According to the Directive, the

producers have to cover the costs of the awareness-raising measures as well as the waste collection process. Producers have to cover waste collection costs ''including the infrastructure and its operation and the subsequent transport and treatment of that waste; and the costs of cleaning up litter resulting from those products and the subsequent transport and treatment of that litter '' (OJEU,2019). The EU Commission will keep monitoring this process in cooperation with the Member States, by providing guidelines for rules on the cost of litter collection. A subsequent goal of this article is to increase cooperation between producers of the EU countries.

In paragraph 6 it is explained that '' Each Member State shall allow the producers established in another Member State and placing products on its market to appoint a legal or natural person established on its territory as an authorized representative'' (OJEU,2019). This will ensure the fulfilment of the obligations set by the EPR and increase the data sharing between the Member States and private companies. The final paragraphs of this article explain that the same level of EPR applies also for producers of fishing gear. Waste collection and transportation are also on behalf of the producers. Together with EPR, another relevant topic is the one of Separate Collection. As laid in Article 9, Member States have a dominant role in ensuring a standard oriented collection. The EU expects MS to implement deposit-refund schemes and develop collection targets for EPR (OJEU,2019). Moreover, the article contains a brief timeline of the increase of the waste amount collected. By setting these standards and goals the EU provides a clear and structured guideline system that can eventually result in an improved system.

The Awareness Raising process is part of the producer's responsibility towards the consumer, but the Member States '' shall take measures to inform consumers of the a) availability of re-usable alternatives, re-use systems and waste management options for those single-use plastic products and b) the impact of littering and other inappropriate waste disposals of those single-use plastic products and of fishing gear containing plastic on the environment, in particular on the marine environment '' (OJEU,2019). Article 10, therefore, lays down a legal basis for MS to develop a concrete awareness raising system, in which private producers can correctly implement the rules. Article 11 and 12 concern the coordination of measures and specifications and guidelines on single-use plastic products. Both articles allow the EU Commission and the Member States to have a margin of improvement and change in the upcoming years. This is because of different national scenarios and consequent approaches. Additionally, the already existing legislation regarding product requirements makes the transposal of the Directive more complicated than expected. According to Article 11, ''this Directive shall comply with Union food law to ensure that food hygiene and food safety are not compromised. Member States shall encourage the use of sustainable alternatives to single-use plastic where possible for materials intended to come into contact with food '' (OJEU,2019). Therefore by 2020, the EU

Commission together with MS has to publish specific guidelines on what to consider single-use plastic (OJEU,2019).

Plastic products represent a broad and complex topic and the EU is aware that a well-structured reporting system could improve the monitoring operations as well as providing vital information for further adjustments and policies. Article 13 has precisely this function. The reporting process includes reporting on the amount of single-use plastic products in the market, information about adopted measures, monitoring the separate waste collection, and information on fishing gear (OJEU,2019). The first deadline for report submission by MS is set by 2022 while the EU Commission has to deliver a report format by 2021 (OJEU,2019). In case of infringement of the rules established by the Directive, the EU gives MS legal basis for implementing penalties. This is what Article 14 is about. By 2021, the Member States must provide specific rules on penalties '' and shall notify it of any subsequent amendment affecting them'' (OJEU,2019).

Article 15 is strongly related to Article 13. In fact, without a proper information system and reporting, there could not be an in-depth evaluation and review. The EU relies on the reports that will be delivered throughout the upcoming years. Article 14 foresees that ''The Commission shall submit a report on the main findings of the evaluation to the European Parliament, the Council and the European Economic and Social Committee. The report shall be accompanied by a legislative proposal if appropriate '' (OJEU,2019). The report that the Commission has to deliver, shall include several assessments on single-use products, targets for collection, change in materials, and technical progress on biodegradability of plastic (OJEU,2019). In case it is needed the EU institutions will consider producing further legislation to improve the standards. The final Articles concerns Transposition and Entry into force. Their function is to set the timeline of the implementation of the Directive.

Discussion of the EU Directive in light of LCA (Life Cycle Assessment)

The following paragraph concerns the assessment of the European single-use plastic ban. This paragraph of the research builds upon the academic article ''Sustainability Assessment of a Single-Use Plastics Ban'' by Timo Herberz, Claire Y. Barlow and Matthias Finkbeiner. The article was published thanks to the cooperation of the Cambridge Department of Engineering and Technische Unversität Berlin. Through the information provided by the paper, it was possible to further investigate the feasibility of the measures and their impact. The Cambridge and Berlin researches used Life Cycle Assessment (LCA) for both single-use plastic and single-use non-plastic alternatives, mainly focusing on paper, wood, PLA (biopolymer), and PP(biopolymers) (Herberz & Barlow, 2020). Despite the extensive research conducted by Cambridge and the TU of Berlin, there are no considerations on the

role of the PHBH(biopolymer), which seems to be the best performing alternative available right now. In the next section, it follows an assessment of the EU single-use plastic ban in light of the Cambridge report, which will be further discussed by the addition of the PHBH implementation scenario. Moreover, there will be considerations on the role and function of PLA, according to Professor M.Valente's research.

The first aspect to take into consideration is that of scientific evidence. The EU Directive is the result of years of research and reports that aimed at providing essential knowledge. The main EU publications that are building blocks of the 2019 Directive are '' Impact Assessment—Reducing Marine Litter: Action on Single-Use Plastics and Fishing Gear'', '' Life Cycle Inventories of Single-Use Plastic Products and their Alternatives '', ''Towards a Circular Economy—Waste Management in the EU'' and '' Assessment of Measures to Reduce Marine Litter from Single-Use Plastics''. These reports were all published by EU research bodies between 2017 and 2018. This can guarantee a safe degree of reliability and relevance of the information. Despite that, Herberz, Barlow, and Finkbeiner acknowledge that ''the evidence base used for the market restriction is flawed in four ways'' (Herberz&Barlow, 2020). According to Cambridge, the European LCA does not meet ISO conformity standards, does not include the End-of-Life stage in their analysis steps, only considers air pollutants, and the final results are not adequately communicated (Herberz&Barlow, 2020). Furthermore, the mismanaged waste (which can be eventually translated into marine pollution) factor is not part of the EU LCA, which makes the results and the consequent assumptions limited. A similar opinion is represented by J.Schweizer, who expresses his scepticism towards the fact that environmental leakage in waste management is not discussed in EU LCA (J.Schweizer, 2018). The Cambridge & TU Berlin research seeks to improve the LCA by adding plastic marine pollution as an impact category (Herberz&Barlow, 2020). This might represent a turning point for the final overall view on the impact assessment, since no EU assessment was including this category. The main impact categories to use in the evaluation of non-plastic alternatives are global warming potential, acidification potential, eutrophication potential, marine aquatic toxicity, abiotic depletion, and plastic marine pollution (J.Guinée,2001).

After comparing LCIA results with annual consumption figures, Cambridge researchers came to several conclusions. The main focus is on wood-based alternatives which '' often show better results than their plastic counterparts and have the lowest emissions with regards to global warming potential'' (Herberz&Barlow, 2020). Further results of the research show that PLA, paper, and wood do not produce marine plastic pollution (Herberz&Barlow, 2020). This particular result is crucial to the process of identifying a sustainable alternative. Further in this paper PLA potential will be discussed in comparison with PHBH and wood alternatives.

Moreover, in the section ''Sensitivity Analysis 1: End-Of-Life'', there is an analysis of the results in the light of a recycling and composting scenario. Cambridge claims that the addition of this factor leads to quiet positive improvements for all paper products on the impact categories and it reduces the global warming contribution of both PLA and PS products (Herberz&Barlow, 2020). These results suggest that improved collection and waste management might have significant effects on the final impact of non-plastic alternatives. This result implies that the European Directive should focus more on the impact potential of recycling and composting. On the other hand,'' this assumption is the best-case scenario which is unlikely to be achieved in reality. In fact, paper waste from single-use cotton buds, straws and plates is mixed with other materials and therefore often not recyclable'' (Herberz&Barlow, 2020). It seems pretty clear that the interactions between impact categories and the alternative performance can be influenced by numerous factors. Therefore the question on how to assess and measure the impact of the Directive remains tricky.

Cambridge explains that '' considering the relative impacts of the plastics ban, the significant results are the increase in emissions contributing to marine aquatic toxicity and the decrease in plastic marine pollution'' (Herberz&Barlow, 2020). This result leads to a crossroads sort to speak. Because of the complex interaction of the impact categories, it is extremely complex to measure the positive or negative impact. Herberz and Barlow describe it, explaining that is necessary to discuss the compromise between marine aquatic toxicity and plastic marine pollution, to fully analyze the sustainability of the Ban (Herberz&Barlow, 2020).

They conclude by underlining that '' no clear answer can be given as to whether 650 million tonnes of DCB equivalents or 4960 tonnes of marine plastic are worse for the environment '' (Herberz&Barlow, 2020). In terms of percentage, the assessment provides clear results. The ban '' increases emissions contributing to marine aquatic toxicity by approximately 1.4% and reduces emissions contributing to plastic marine pollution by approximately 5.5%'' (Herberz&Barlow, 2020). The results suggest that a non-plastic alternative would have a positive impact on certain impact categories while affecting others negatively. This does not completely coincide with the concept of sustainability because '' When sustainability is understood literally, which means that a sustainable action can be sustained or maintained indefinitely, it becomes apparent that single-use items are intrinsically unsustainable'' (Herberz&Barlow, 2020). Based on this, it is possible to affirm that the main issue is related to the application of material and this put the nature of single-use items into question. This is confirmed also in the Herberz and Barlow assessment in the Conclusion section. According to the authors,'' single-use items cause emissions which are harmful to the environment regardless of their material composition'' (Herberz&Barlow, 2020).

To summarize, the 2019 EU Directive shows both positive and negative aspects. One main limitation is the un-complete LCA and the restricted scientific knowledge which translates into a deficit of information on the aquatic toxicity impact category (Herberz&Barlow,2020). However, the Cambridge Assessment shows that thanks to the European Single-use plastic ban, the European contribution to plastic marine pollution will decrease by 5.5% (Herberz&Barlow,2020). Furthermore, topics such as prevention and waste export should be more addressed by the Directive. According to the '' Plastic waste inputs from land into the ocean'' 2015 study of J.R, Jambeck, the illegal waste export towards third world countries seems to be a considerable issue. Due to different waste treatment standards, EU producers can save a conspicuous amount of money by shipping their plastic waste. The Greenpeace investigation of Italy-Malaysia mismanaged waste treatment is an appropriate example of this (E.Murgese,2020). The consequences of this are a high level of water plastic pollution and practically zero control by EU bodies. Considering the global entity of the problem, the EU should conduct more investigation on the topic and provide a legal base for the implementation of pecuniary fines. The 2019 EU Directive does not contain Articles or consideration on this issue. Of the same opinion, are also Herberz and Barlow who claim that '' the risk that plastic waste eventually leaks into oceans is not mentioned nor mitigated by the single-use plastics directive'' (Herberz&Barlow,2020). In the future, there should be more focus on waste management and prevention as well as considering options '' such as banning or imposing a premium price on single-use items regardless of their material composition, to reduce consumption and thereby pollution''(Herberz&Barlow,2020). In the section ''Plastic Tax'' contained in Chapter 4 of this paper, the idea of a premium price imposition is analyzed and presented. Limitations of the Cambridge assessment are the exclusion of considerations on PHBH (biopolymer) and improvements of PLA through WPC. Both PHBH and PLA scenarios can drastically change the feasibility of the Ban, both from an economic and scientific point of view. These aspects are discussed in Chapter 5 of this paper.

The EU Directive in light of Recycling possibilities & limitations

The recycling and replacement of synthetic polymers with natural ones at the beginning of production, are partially containment measures that will be implemented and combined with the plastic reduction policy, to see a general decline in plastic waste (EU Directive,2019). It is unquestionable that in the complex and articulated matter of recycling, technology plays a crucial and constant role in improving its efficiency with new methods and ideas. One of these new recycling techniques depolymerizes objects with heat and chemicals to break down plastic molecules into the original monomers that can be reused (S.Royer,2018). The market now offers many products recycled from plastic: shoes, clothes, objects of various kinds for multiple uses. But in the light of the observations, a few questions need to be asked.

If the main problem today and in the future will be microplastics and microfibers in a variety of products, does it make sense to produce products from recycled plastic knowing that they will go to the washing machine or other sectors, releasing other fibres into the environment? By proceeding on this path, the risk of returning to the starting point is high. Therefore the primary and most effective action consists in the reduction of plastic at the source, using less material manufacturing the products, avoiding overpackaging, decreasing the weight, facilitating the use of recyclable plastics, and avoiding those not easily recoverable. Another relevant link in the waste supply chain concerns consumers and municipal companies suitable for collection and disposal. This phase, which includes the sorting of used plastics, is an expensive and time-consuming, and organizational process. In the United States, for example, only about 5% of plastic is currently recovered and recycled (EPA,2019). This is because once thrown away by consumers, after their short life cycle, plastic products must be collected and then separated by type of polymer. Sorting systems exist, but they are not yet capable of differentiating and separating when many types of plastics occur within the system (J.R, Jambeck,2015). They usually separate in colour, density, and chemical composition. The danger is that if the types of plastics are not properly separated, the recycled material will never reach the qualities suitable for remodelling. The result will be a low-quality product and lower economic value. To contribute negatively to the recycled product, we must add the possible degradation of the plastic during its primary life cycle and the possible addition of foreign materials to the final plastic during the fragmentation process in the recycling phase. Furthermore, for health reasons, recycled plastics are rarely transformed into food containers, but into items such as bottles of engine oil, other chemicals, and textile fibres (EU Commission,2018).

However, using recycled materials to make new products costs less and requires less energy than using new materials. Furthermore, recycling by reducing the volume of discarded waste decreases the amount of land needed for waste landfills. To date, the forms of recycling are divided into mechanical and chemical, and the first comparative observations between the two suggest that mechanical treatments are not suitable for most plastics due to fragmentation, degradation, and the presence of a large number of additives (R.Geyer,2017). While chemical treatments seem to overcome these drawbacks. In any case, whether mechanical or chemical, the recycling of raw materials allows the production of secondary materials with fewer emissions than waste-to-energy and fewer health hazards, for example, eliminating the combustion of plastics containing chloride. It, therefore, appears evident that the best strategy to reduce plastic in the seas passes from a renewed logic of production, use, and then disposal. It all lies in conceiving plastic differently, and then using it at the end of its life as a raw material for new products and closing the circle. These strategies imply that a reduction in consumer demand will be politically effective in addressing the huge impacts of plastic waste and pollution. A decisive change arises from a convergence of different actions in which, however, the

solution does not weigh only on a single actor in the supply chain. For this, as already mentioned previously, it is necessary to go to the root of the problem.

Thinking of focusing production only on natural materials would mean taking away conspicuous space for the intensive cultivation of this raw material. While today, to limit climate change, the direction must be the opposite. Reduce intensive production to allow spaces to be delivered to nature to restore ecological systems. This issue is not addressed sufficiently in the EU Directive. Another structural problem that the EU Directive does not seem to address is the very nature of single-use products. The real problem of plastic for the environment is the single-use system, which summarizes the maximum waste for an unsustainable resource, very precious, little recycled, and with long-term impacts. A legislative plan is necessary to provide for the production of plastic materials that can remain in the system of the circular economy. In this sense, the directive should develop the appropriate framework to give value to the plastic we throw away, freeing us from the idea that it is a waste product.

The definition provided by the Ellen MacArthur Foundation helps to simplify the contextualization of the circular economy theory. According to the Foundation, what defines a circular economy is the ability to sustain itself (E.MacArthur F.,2017). In this type of economy, material flows are divided into two distinct types. The first is biological materials that can be reintegrated into the biosphere and the second are inorganic materials that will be recycled without entering biological environments(E.MacArthur F.,2017). The circular economy, therefore, intends to plan an economic system where materials are continuously reused in production cycles, minimizing the need for natural resources for all those materials that are unable to return to a sustainable cycle. Only by applying these principles of the circular economy into the recycling system, the European Commission will be able to develop a safeguarding system for the seas. To reach this goal, the EU Commission has to find a balanced and profitable relationship with the European Plastic lobby. The next paragraph will discuss the perception of the EU Directive by the plastic lobbies and the possibilities to develop a sustainable framework.

THE EU DIRECTIVE & THE PLASTIC LOBBIES

Working on reducing plastic is not easy if it does not change the mental criterion to which the word is used. Since the 1950s, the boom in replacing natural materials with artificial ones has become predominant, also thanks to economic propaganda regarding plastics (S.Fenichell,1996). So what political institutions should work on is to rethink the role of plastic and change the production system at its root. However, a cultural and economic revolution of this magnitude is bound to come into conflict with considerable economic interests. This chapter intends to understand and analyze the

point of view of the lobby exponents of the plastics industry. The aim is to have a greater understanding of the perception of the directive and also to understand possible limitations.

The general reaction was critical towards the European Commission. Quite predictable, as always when discussing corporate affairs. PlasticsEurope, the federation of European plastics manufacturers, has argued that a ban on single-use plastics will not solve the marine litter problem (PlasticsEurope,2019). According to the federation, the issue of the impact of plastics on the marine environment is due to poor waste management by the companies in charge(PlasticsEurope,2019). While it is an attempt by PE to offload relatively obvious responsibilities, the problem they raise is legitimate. In the previous chapters, it became clear that the current European recycling system is unable to meet the demand. The consequences, such as the illegal export of waste, is a clear example of a poorly functioning system. Plastics Europe stresses the need for strengthening infrastructure and supranational legislation related to waste itself (PlasticsEurope,2019). Undoubtedly, there is a need to improve the state of the recycling plants to ensure more efficient recycling, but targeting the root of the problem could be more productive. To win the trust of plastic producers, the European Commission should offer an investment program for the conversion of production factories. By doing so, the Commission would favour an infrastructural transition which is the key to solving the problem. In this sense, the European Directive of 2019 encourages producers to make a transition in production, but without providing a clear and sustainable financing plan. The goal should be to reach an economic agreement to start collaborating towards the same goal.

A criticism raised by the EuPc, the agency representing plastics converters, is linked to a criticism already expressed by some academic researchers. The EuPC says the European Commission wants to limit some plastic products without knowing their life cycle (LCA), therefore without evaluating which is the most sustainable solution(EuPC,2019). This is probably the main problem in this European Directive. The fact that it is based on incomplete LCAs offers a limited look at the possibilities of sustainable alternatives. It appears that the European Commission has limited knowledge about the potential of some products already on the market. On top of this, the EU Directive does not include an in-depth analysis of the biopolymers. The absence of complete LCAs on new biopolymers indicates the lack of research that makes this policy only partially complete and efficient. The EuPC also accuses the European Commission of having based the environmental impact assessment on the study of a consultancy company, financed by the EU Commission itself(EuPC,2019). This means that the scientific basis on which this directive was developed is limited. Among the sceptics, there is also the Industrievereinigung Kunststoffverpackungen, an association of German plastic packaging manufacturers. An official document issued by the IK indicates that the Directive does not support a real line for efficient collection and recovery, not involving consumers and not creating awareness on responsible use (IK,2019). This criticism is partially correct because, in the EU Directive, there is

particular attention to the Labeling chapter. The Commission plans to improve consumer behaviour by introducing information labels. It is a measure that has an informative function, which can stimulate attention and increase awareness between the consumers. However, the degree to which this new labelling process can impact plastic production has to be further analyzed.

As we can see, the common position of the representatives of the plastics lobbies is that the problem of marine litter does not lay in single-use products. From their point of view, the accountable institutions are the public administrations that are unable to manage the disposal chain correctly. It is not difficult to understand the reasons for this adverse position. The plastics industry holds on an alliance with the large oil industries, and the two families of corporations converge with economic interests in the field of polymer processing (C.A.Harper,2000). It must always be remembered, that most of the plastics industries are co-owned with large petrochemical industries such as DowDuPont, Exxon Mobil, Shell, Chevron, and Eni. The global plastics market for 2020 is valued at around 654.38 billion dollars, and by 2050 the share of hydrocarbons dedicated to plastics will touch 20% against 6% in 2014 (World Bank,2019). Impressive growth and profit show us why of so much negativity towards the European Directive. It is difficult to understand how the final consumer can be expected to be more aware of the reduced use of plastic if the market does not offer valid alternatives. Furthermore, downloading the management costs for the collection, separation, and subdivision only and exclusively on public administrations is a technique for not taking responsibility for the very high hidden costs of plastic production. Recovery has a very high cost, as well as regenerating, dividing, and recycling endless plastics. In fact, to date, environmental recovery is poured out on third parties, almost always public companies, and all this has a cost that is paid with taxes. All very high costs that no one, especially the producers, wants to take on. This is why Extended Producer Responsibility is the main road to work on.

EPR a revolutionary strategy?

Marine litter can be prevented and controlled using legislative measures that limit its abuse, discourage landfills, and encourage recycling, promote biodegradable plastic and reuse. However, EPR stands out because it appears to be a revolutionary strategy. For two main reasons. At the legislative level, there had never been a measure that provided for the commitment of producers in the recovery of waste plastic products. Politically it has a strong meaning. If until now, it was thought that the private sector pressured the public sector with its economic relevance, this decision has shown that is not always the case.

Scientific data indicates that the choice of EPR is in the right direction(M.Niaounakis,2013). More than half of the plastic fraction of marine litter is made up of useless and abandoned packaging. One

measure to tackle this problem upstream is precisely the extended producer responsibility. The organization for safety and co-operation in Europe defines the EPR as the environmental protection strategy in which the responsibility of the entire life cycle is extended to the producer of consumer items, including the post-consumer phase, of the product (OCSE,2019). The producer thus also becomes responsible for take-back, recycling, and final disposal. The European Commission, through the EPR, has among its objectives that of reaching high recovery and recycling rates, to prevent packaging waste to get to final disposal and above all ending up in the sea.

The logic of the EPR on packaging typically requires manufacturers to pay a commission based on the quantity of packaging they place on the market (EC,2019). These fees will cover or contribute to the cost of collecting and treating the discarded packaging. As a possible effect, it could stimulate manufacturers to reduce the amount of packaging they place on the market. The economic value of secondary materials on domestic markets can be relevant and is influenced by both the demand for secondary raw materials and the supply of high-quality materials once a recycling industry is in place. The success of the EPR does also depends on the control that national and supranational institutions will perform on producers. The phenomenon of illegal export of waste has occurred more than once and in various European countries. Failing to prevent this phenomenon would mean that the attempt to reintegrate plastic products into a circular economy would be completely useless. The waste would end up in landfills in Asia, where compliance with standards is almost absent (GreenPeace,2019). This phenomenon demonstrates the need to discuss more thoroughly the prevention policies for the illegal export of plastic waste to Asian countries.

EU Directive and the issue of Illegal waste export

Over the past three decades, China has imported 56% of the world's plastic waste, taking over the disposal on behalf of the rest of the world(GreenPeace,2019). This practice, however, if on the one hand, it contributed to increasing wealth, on the other hand, it had severe effects on internal pollution levels.The problem of the surplus of plastic waste arises with the closure of China's borders in January 2018. The China Ban provided for the stop of imports of Western plastic waste(EC,2019).

The Chinese plants hosted nearly 50% of western non-homogeneous and low-quality plastics. In these plants, sometimes with poor environmental conditions, plastic waste was processed, transformed into other plastic products, and sent back to the Western world. Objects of various kinds have returned to Europe, however not respecting the European conformity criteria in terms of chemical contamination and producing a high-level ecological footprint. Therefore, the closure of the Chinese borders forced the EU waste companies to find alternative roads in other countries ready to receive the plastic. Other Asian countries like Malaysia, Thailand, the Philippines, and Vietnam have allowed imports

(GreenPeace,2019). The governments in these countries lack the strength to enforce proper disposal laws, of which we have little information. Unfortunately, studies like ''Where does your plastic go? Global investigation'' by the Guardian, indicates stories of exploitation of workers and devastating pollution. According to the report's results, 90% of the plastic in the oceans comes from the waters of 10 rivers, 8 of which are in Asia(The Guardian,2019).

In the recent report, 'Criminal trends emerging in the global plastic waste market from January 2018' Interpol analyzes various phenomena. The most evident is precisely the increase in illegal imports of plastic waste not only in the countries of South and Southeast Asia but also in those of the EU, especially in Eastern Europe(Interpol,2018). The waste can be illegally disposed of in these European countries or sent to unauthorized recycling facilities in Asian countries(Interpol,2018). The report shows that Asia is the main importer, the epicentre of global trade, but also illegal trade(Interpol,2018). Europe is the main exporter, but it is also a key player from the point of view of imports. Interpol clearly explains that sending waste to Southeast Asia or other European countries is not enough to compensate for the loss of access to the Chinese market (Interpol,2018). In Europe, the Czech Republic, France, Ireland, Italy, Slovakia, Spain, and Sweden denounced it. On the one hand, illegal landfill disposal and fires, both accidental and intentional, have increased in states that previously exported their waste to China. On the other hand, in importing countries, the rapidly growing supply of waste has fueled unauthorized recycling plants and illegal landfills. Even more so in Eastern countries, where imports of plastic waste have already grown due to a lack of controls. Here it is easier to go to landfills and to pay lower taxes and disposal prices than in other European realities. Crime exploits dependence on landfills to illegally export and dispose of waste, perhaps managing to pass even dangerous ones with false documents(Interpol,2018).

Interpol explains that the EU imposes stricter control regimes on waste destined for recovery exported to non-OCSE countries (including those bordering the EU) compared to exports within European borders. Less restrictive internal controls make it easier to pass dangerous waste for those included in the 'green lists'(Interpol,2018). This type of waste is subject only to general information obligations and not to prior notifications and authorizations. According to Interpol, this explains why illegal shipments within the EU have increased. The Czech Republic and Romania are among the countries where certain phenomena are more frequent. The Interpol report shows that shipments of waste falsely labelled as 'for recovery' end up being disposed of or burned. This error in the disposal system occurs because the destination structure is changed once the shipment enters the country, as there are no further internal controls. The recent report '' Preventing plastic waste in Europe '' published in June 2019 by the European Environment Agency, seems to reach conclusions similar to those of Interpol. According to the EEA, growing global plastics production overwhelms plastics recycling capacities. In Europe, only 30% of plastic waste is collected for recycling while the rest ends

up outside Europe, where environmental standards are not clear and often not as stringent as those in Europe (EEA,2019).

EU countermeasures against Illegal waste export

The president of the European commission Ursula von der Leyen recently launched the European Green Deal, a plan for the environment that aims at climate neutrality by 2050, with the allocation, among other things, of a 100 billion euro fund for a just transition (EC,2020). However, the last legislature also proved sensitive to the issue, with the introduction of the EU 2019 Directive against single-use plastic. Furthermore, measures have been taken to specifically combat the export of plastic waste outside the EU. The enactment of the Waste Shipment Regulation, which prohibits the export of solid plastic waste outside the European borders, except for countries that adhere to the United Nations Basel Convention on Hazardous Waste, or with standards equivalent to those of the EU (EC,2019). Fortunately, from 2019 among the hazardous waste of the agreement, the plastic residues have been included which, therefore will no longer be marketable.

As a consequence of this combination of measures, an increase in landfills within the EU is expected in the short term. The aim, however, is also to send a clear signal to member states to include plastic disposal within a circular economy in the long term. Therefore, it is hoped that practices such as reuse and recycling will be promoted, eliminating the huge CO2 emissions related to the production and intercontinental transport of waste.

On the other hand, the European Court of Audit, a governmental agency responsible for consulting and monitoring, is of a different opinion. In their 2020 report ''EU action to tackle the issue of plastic waste'' the European scenario seems to be more critical than expected (ECA,2020). According to the court's experts, Europe has not only made little progress in recycling plastic but is too dependent on the export of waste to third countries that it cannot recover (or send to landfills). And since the disposal systems of these countries are decidedly more polluting than those in the EU, the result is that European exports produce a huge amount of CO2 emissions and severe plastic pollution (EEA,2020). The data shows crucial information. First, those on production and recycling point that despite the increase in recycled plastics recorded between 2008 and 2017 in Europe, the amount of non-recycled waste has remained stable (EEA,2020). The Court explains that the total amounts to 9.5 million tonnes per year in the last 5 years and the reason is the parallel increase in production. Furthermore, the data on the actual recycling rate of the Member States were not so reliable and this prompted a revision of the calculation system starting from 2020 (EEA,2020). The Court of Auditors after consulting the experts of Plastics Europe reached further interesting conclusions concerning recycling rates. The experts consulted by the Court estimate that the application of the new calculation methods can reduce the reported recycling rates by up to 10 percentage points (Plastics Europe,2020). According to

PlasticsEurope forecasts, the recycling rate for plastic packaging in the EU could decrease from 42% to around 29% (Plastics Europe,2020).

Until 2019, plastic packaging was considered non-hazardous waste internationally. This changed with the Basel Convention, and from 2021 such waste will be part of those classified as dangerous. According to the Court of Auditors, the export of plastic outside Europe for recycling purposes will therefore not be as easy or even impossible. For these reasons, the Court considers that the EU will not meet the targets it has set for the recycling of plastic packaging for 2025 and 2030 (EEA,2020). The initial goal was to achieve 50% recycling of plastic packaging by 2025 and 55% by 2030 (EC,2019). Unless European countries implement concrete measures both to increase the effective capacity for recycling and reuse and reducing illegal export, the initial target will be hard to achieve. To have a better understanding of how these aspects manifest in national scenarios, in the next paragraph it follows a case study on Italy and Germany. Both Member States represent a good share of plastic production and consumption and analyzing their perception of the Directive is useful to understand the possibilities, limitations and improvable sectors of the 2019 EU Directive on Plastic.

Italy & Germany Case Study

The following paragraph is an analysis of the Italian legislation in light of the EU Directive on Single-Use Plastic. To understand the legislative scenario, articles of the national law were analyzed. There is evidence that Italy is working towards the goals set by the European Commission, however, there is a delay in the transposition of the Directive. One of the reasons is that the plastic production industry is not economically ready to execute the shift to other materials. The first paragraph will address the issue from a legislative point of view, while the second one, will focus on practical examples.

The European strategy for plastics in the circular economy was first implemented in Italy with Article 1, paragraph 802, of Law No.145 of 30 December 2018. This Article introduced art. 226-quater in Legislative Act no. 152/2006 ("Single-use plastics"). The new article 226 of the environmental code is concerned with preventing the production of waste from single-use plastic products and that of materials of fossil origin, as well as promoting their separate collection and related recycling. Facilitate and promote the use of environmentally friendly consumer goods in line with the objectives indicated by the EC in the “European strategy for plastics in the circular economy”. Moreover, the article establishes that from 1 January 2019 until 31 December 2023, producers can implement several measures. The first one is the adoption of models of differentiated collection and recycling of plastic cutlery from fossil sources with increasing percentages of a reintroduction of raw materials in the production cycle. The second one consists of the production, implementation, and recycling of cutlery

and plates made with biopolymers (Article 226, Italy). Producers have to focus on the potential of the national supply sources as an alternative to fossil-based plastics.

Furthermore, the second paragraph of Article 226 describes that producers support the collection of the information necessary for the development of eco-compatible raw materials, processes, and products. The collection of data for the construction of certifiable Life Cycle Assessments is also part of it. They should also contribute to the development of quality standards for determining the characteristics of raw materials and additives that can be used in the production phase. A final overview of the performance of the product during several steps is also required (Article 226).

The measures implemented in the Italian law are in line with the European Strategy for plastic in the circular economy and seem to have pretty much the same structure. However, there is no legislative evidence of the correct transposition of the 2019 EU Directive on Single-Use Plastic, in Italian law. Italy remains among the worst EU countries for the transposition and implementation of EU directives relating to the single market. This is stated in the annual report card on the internal market released by the European Commission on 4 July 2019, a document that relegates Italy to the bottom of the European ranking (EU Commission,2019). Despite this, during the early months of 2020, an interesting tax on plastic was approved.

The Plastic Tax

The new tax on the consumption of manufactured goods with single-use, also known as "plastic tax", was introduced with the 2020 Budget Law (Law 190/2019) and entered into force on 1 July 2020. The objective of the plastic tax is to protect the environment by discouraging the use of single-use plastic products by charging 0.45 Euro per kilogram of plastic (Law 190/2019). It applies to food packaging products and products aimed at the protection and delivery of goods, which are made using "plastic materials consisting of organic polymers of synthetic origin" (Law 190/2019). The tax is addressed to the manufacturers of the single-use products made in the national territory, for single-use products importers from other EU countries who can eventually sell again to a final consumer, and for single-use products importers from third countries.

The plastic tax includes both sanctioning and incentive provisions. In the first case, paragraph 650 says that an economical fee should be imposed in case of non-payment of the tax, late payment, and delay in submitting the financial report (Law 190/2019). However, there is not a clear explanation of how the charge should be built in terms of percentages. In regards to incentive options, paragraph 653 provides clear points. To reward ambitious producers, there is an application of a tax credit, equal to 10% of the costs incurred in the period of 1 January - 31 December 2020, for technological adaptation,

aimed at the production of compostable products. The credit can reach amounts up to a maximum amount of € 20,000.00 per single receiver (Law 190/2019).

This part of the Italian law can be related to two other concepts that were discussed in this paper. The first one is the EPR (Extend Producer Responsibility) contained in the 2019 EU Directive and the second is the alternative approach to the Ban, proposed in the paper ''Sustainability Assessment of a Single-Use Plastics Ban'' by T.Heberz. In the first case, the Italian plastic tax is an example of how a reasonable economic measure can promote and increase EPR. However, since it was recently implemented, these assumptions remain purely theoretical. In the upcoming years, it should follow an economical assessment of the plastic tax to establish the effectiveness and potential of it. Only this can declare if the tax can represent a leading example of implementation. Considerations in the light of MERQ's should be also included.

The plastic tax could be also used as an example of the Ban alternatives discussed in Herberz's paper. In a section of his paper, Herberz seeks to provide alternatives to market restrictions, exploring different approaches. According to Herberz '' banning or imposing a premium price on single-use items in general and not only single-use plastic items is a more effective method of reducing consumption and thereby pollution'' (Herberz&Barlow,2020). The Italian scenario seems to fit perfectly with his vision. As mentioned before, being a recently implemented measure limits the possibility of evaluation. In conclusion, it can be affirmed that in both scenarios the Italian plastic tax is a phenomenon to keep under observance in the future. However, a closer look a the economic and structural situation of the plastic industry is crucial for the understanding of the national scenario.

The Italian Plastic Industry

There is the risk that the Italian plastic production industry is not economically ready to execute the shift to other materials. The plastic sector generates one billion Euros a year and employs 3,000 people(Plastics-The Facts,2018). The hope of the producers lives in a paragraph of the latest Budget Law, which provides for less drastic measures than those established by the European Commission. By analysing the statements of the most prominent representatives of the plastic sector, it is possible to understand how the points of view on the EU legislation conflict.

The European Directive that bans single-use plastic is likely to affect a prolific sector of the Italian industry. According to Pro-mo reports, the group that is part of Unionplast, the companies that manufacture single-use plates, glasses, cutlery, and accessories employ almost 3000 people and produce between 850 million and one billion euros each year(Pro-Mo,2019). Italy is among the biggest consumers and producers of plastic in Europe with an export share that reaches 30% (Plastics-The

Facts,2018). The Italian industry is indeed a solid one, and reshaping the production might be more difficult than expected. According to Mr Omboni, the president of Pro-mo, “Some of our companies have started diversification processes towards other materials, especially bioplastics and in some cases vegetable fibres "(Pro-mo,2019). Despite that, Mr Omboni is aware of the infrastructural limitations and fears the competition with Asian countries like China and Japan, which are leading actors in this sector (Pro-mo,2019). In fact, the Unionplast group is not the only organization that has a sceptical opinion on the Directive. According to PlasticsEurope Italia, which represents Italian producers of plastics, the Directive is a disproportionate measure, which does not solve the serious problem of plastic waste in the sea and can damage the Italian industry (PlasticsEurope Italia, 2019). PlasticsEurope fears that the measures will end up being impractical and risk hindering the correct implementation of the directive, leaving space to open interpretation by national authorities and waste management companies (PlasticsEurope Italia,2019). In the conclusion of their report, they suggest focusing on problematic single-use products, independently from the material (PlasticsEurope,2019). This point of view seems to be shared also by Cambridge and TU Berlin researchers, who discussed possible alternatives to a market restriction (Herberz&Barlow,2020).

However, there are aspects of the Italian legislation that suggest a different interpretation. Art.226 illustrates that plastic producers can voluntarily initiate processes to increase the production of bioplastics and increase the percentage of recycled plastic by 31 December 2023. The understanding of the term 'voluntarily' is of crucial importance. Officially speaking, there are no legal boundaries for Italian producers. The legislation promotes initiatives both in terms of financial adds and legal framework but does not force the producers to implement the measures. Giuseppe Delle Foglie, a lawyer expert in environmental law, claims that Italy is not ready for the transposition of the EU Directive into national law anyway. According to him, the facts clearly show that the infrastructure is not ready yet, and the consequence will be the late transposition of the Directive (G.Foglie,2019). E. Simonazzi is the marketing director of Flo Spa, an Italian plastic producer, and she seems to share the same view. In the video report ''Plastic Emergency'' published by FanPage.it in 2019, she was asked about the Single-use plastic ban. She explains that both the raw materials and the production of biopolymers have high costs. Compared to conventional polymers, the costs of production can be even four times higher (FanPage,2019).

In conclusion, there are several aspects to take into consideration. The first one concerns the Italian legal framework, which shows that despite the introduction of restricting measures, the current law is vague a the 2019 EU Directive has not been transposed yet. The plastic-tax might be useful, but further evaluation is needed. From an economic point of view, the costs for production threaten the financial balance of the companies and this can lead to the refusal of the EU Directive. As indicated several times by experts and representatives, proper waste management and building efficient organic recycling

infrastructures remains the priority in terms of fighting marine pollution. It seems to be clear that Italy is indeed not ready for the correct transposition, both in terms of economical possibilities and structural limitations. Germany, on the other hand, seems to have a more advanced system, despite some structural lacks that are going to be discussed in the next paragraph.

The Germany Scenario

In Germany, one of the countries where waste recycling finds its most efficient expression, there is still a considerable amount of profitable plastic waste that gets lost. Despite all the efforts made over the years to build a participatory circular economy, the recycling system still lacks at some point. Before analyzing the topic in-depth, it is useful to remember that Germany on average manages to recycle 68% of the waste produced in the home (Eurostat, 2017). To make a comparison, we observe that in Britain this percentage stands at 44 points, while in the USA it would not go beyond 26% (EPA,2019). To achieve this, the German government built a widespread sorting network, starting with the first packaging law in the 1990s (Directive-94/62/EC). The ''Green Dot System'' was one of the first most successful awareness-raising campaigns in Europe, counting 23 Member States. It obliged the plastic producers to pay a licence fee on their product and therefore financially contribute to the development of the recycling system (Directive-94/62/EC). The European Commission introduced it with the '' Packaging and Packaging Waste Directive-94/62/EC''.

However, plastic consumption has grown rapidly in recent years and around half of the amount of plastic ever produced comes from the last 15 years (EU Commission,2019). Germany is particularly affected by this increase. According to a study by the Cologne Institute for Economic Research in 2015, the per capita share of plastic packaging waste was 37.4 kg, more than six kg above the EU average (KIDW,2015). Furthermore, according to the Environment State Secretary Jochen Flasbarth from the SPD party, too many valuable raw materials still end up in the waste bin (J.Flasbarth, 2020). To confirm this point, the results of a study by the German Federal Environment Agency (UBA), for which random samples were taken from 14 study areas throughout Germany, shows alarming data (UBA,2019). According to the Federal Environment Ministry, around 320,000 single-use cups are used every hour for hot drinks in Germany (BMU,2019). This means that almost three billion disposable cups come together every year. As a survey by the Society for Packaging Market Research showed, the waste balance of disposable tableware and to-go packaging was more than 346,000 tons in 2017 (GVM,2017). The corona pandemic has exacerbated the problem: According to a report by the European Environment Agency EEA, plastic consumption increased sharply during the corona crisis (EEA,2020). The main reason for this was the increased use of single-use plastic. On the one hand, this was due to the sudden increase in demand for protective equipment such as masks, gloves, robes and disinfectants in bottles. On the other hand, many restaurants in Europe have switched to take-away

and delivery services with single-use plastic containers. Many products that are being sent via the increasing online mail-order business are also packed in plastic, according to the EEA (EEA,2020). The economic damage is also a relevant aspect. Around 700 million euros - this is the amount of money that cities and municipalities in Germany have to spend each year to clean parks and streets of cigarette butts, to-go cups and other single-use plastic products, to empty public rubbish bins and to dispose of waste. The Association of Municipal Enterprises recently determined this in a scientific study (VKU,2020).

To stop this damaging phenomenon, the Federal Council cleared the way in Berlin in November 2020 to implement the EU-plastic ban in Germany. From July 2021, beverage cups and food containers and other listed products will be banned. The goal is to avoid unnecessary plastic waste. At the same time, the Federal Council asked the German Government to create incentives for recycling systems (Bundesrat,2020). Federal Environment Minister Svenja Schulze (SPD) welcomed the decision to implement the EU Directive, claiming that it is an important step out of the consumer society and a serious contribution to clean seas, beaches and parks (S.Schulze,2020). According to the Ministry of the Environment, the Cabinet and the Bundestag must now approve the Federal Council proposal (S.Schulze,2020). With this decision, the Bundestag implemented an agreement at EU level from 2019 into national law.

On the other hand, environmentalists also criticize that Germany just implemented the minimum requirements of the EU. According to Thomas Fischer from Deutsche Umwelthilfe, the program lacks ambition and seems to be vague and therefore ineffective (T.Fischer,2020). In fact, the reaction of the german plastic lobby does not seem to be concerned as the one in Italy. Rüdiger Baunemann sees no direct consequences for the local industry in the one-way plastic ban. The general manager of PlasticsEurope, the association of plastics producers in Germany claims that the products concerned are hardly manufactured in Germany at all and therefore the relevance to the German plastics industry is relatively low (R.Baunemann,2020). Of a similar opinion is Nordostchemie, the employers' association for the chemical industries in the east. According to their interpretation, companies in Central Germany will not be harmed by the new regulation (Nordostchemie,2020). Companies affected by the ban, such as the spirits manufacturer Diageo, have announced that they will change their production. For example, the Trinkhalm-Union from Hamburg, which wants to use PLA for the production of its straws in the future instead of the conventional polypropylene plastic from Asia (Trinkhalm-Union,2020).

What is evident by analyzing and comparing the two national scenarios is that the structural and economic discrepancy could slow down the implementation of the 2019 Eu Directive. There would

also be a problem of effects since the two nations are on two different levels. This would mean the advancement of one nation over another, creating a complex economic and structural gap to be bridged and with possible negative effects. On the one hand, this is the political and economic reality to which many European directives are subject, and it is bound to happen, given the vastness of the European Union. On the other hand, there is a need to calculate the risks of this discrepancy which could result in the Directive's ineffectiveness. This is because, as we have seen in the previous chapters, the problem is of an international and global nature and therefore requires coordinated action by all member states. Checking the interconnectivity between the actions of one member state and those of another is of crucial importance in managing this problem. If this were not the case, the scenarios that would follow would lead the European Union not to solve the problem of plastic pollution. What the European Commission should do is develop a detailed analysis of the individual national scenarios, to better understand the national limitations. By doing so, more precise measures could be developed, which would improve the sectors in difficulty. Ultimately, what emerges from the analysis of the two Member States is that Italy is clearly not ready or able to carry out the transition envisaged by the Directive and risks suffering serious economic, political and environmental consequences.

Germany, despite a system that has room for improvement, has always represented the vanguard in this sector. Looking at its infrastructural capabilities and the opinions of the major exponents of the sector, it is possible to think that the transposition and the effects of the Directive could be positive. Much depends on the sustainable alternatives that are available at the moment. This aspect is marginally covered by the European Directive 2019. As has been understood from the previous chapters, the actions must be coordinated in various sectors, to reach the final goal. Sustainable alternatives remain an uncertain sector both in Italy and in Germany. The next chapter contains an analysis of the most promising sustainable alternatives, to understand the feasibility of the transition in national markets.

Chapter 4
Sustainable Alternatives & Implementation

Food Packaging: PHA as new alternative

The European Directive on Single-Use Plastic contains numerous restrictions regarding food packaging. This because the majority of these items are for single use. The necessity to guarantee certain hygiene and conservation standards lead to conceive packaging items as single-use products. At the same time, they have to guarantee also a certain degree of thermal resistance and reliability. These factors make the development of a bio-based alternative a great challenge.

The 'Europha' project '' is answering this demand by developing 100% natural and biodegradable, polyhydroxyalkanoates-based bioplastic formulations for food packaging applications'' (CORDIS,2017). When analyzing the potential of bio-based polymers is of crucial importance to pay attention to mechanical properties and production costs. These two factors constitute the main issue when comparing biopolymers and petrol polymers. The reason why the European plastic production industry has always preferred oil derived polymers is because of their cost-efficiency rate compared to more expensive and hard to produce biopolymers. Nevertheless, in the Article 'Towards more sustainable food packaging', the coordinator of the Europha project explains that '' Bioplastics like polyhydroxyalkanoates (PHA) are long-term sustainable alternatives because they show equal performance to conventional petrochemical plastics, originate from renewable non-food resources and are 100 % bio-degradable '' (CORDIS,2017). Of a similar opinion is also the Austrian chemistry professor M.Koller. In his academic publication on PHA, he affirms that '' Due to their hydrophobic character and the broad flexibility of their mechanical features, prokaryotic poly(hydroxyalkanoates) (PHA) are considered as promising materials to compete with petro-plastics on the food-packaging market'' (M.Koller, 2014). It seems that from a mechanical point of view, PHA can perform at a high level and guarantee sufficient standards. However, both Koller and Sanchez identify the production costs as the main issue. According to Koller,'' economics of their biosynthesis and purification constitute stumbling blocks on the long way towards broad implementation of PHA for food packaging'' (M.Koller,2014). Europha coordinator Pedro Sanchez explains that PHA has a higher price compared to other bioplastics (CORDIS,2017). According to CORDIS '' EUROPHA overcame this obstacle by taking advantage of the waste generated by the Agri-food industry'' (Cordis,2017). This process aims to create a more circular economy and contributes to facilitating the process of Extended Producer Responsibility. P.Sanchez explains that '' The packaging industry can re-use their surplus

streams as low-value feedstock as starting material in the synthesis of an added-value product, which also saves on treatment cost'' (CORDIS,2017).

In conclusion, PHA seems to be a valid alternative considering his mechanical properties and the opportunity to treat it as 100% biodegradable material. Moreover, it would be a leading product for the development of the Circular Economy because '' PHA production process using mixed microbial cultures makes it possible to use the low-cost feedstock that is currently considered agro-food waste'' (CORDIS,2017). It would also decrease the costs for producers who have to take care of the production chain and waste treatment. Despite the cost-effectiveness and the mechanical properties of PHA, it seems to be limited to implementation in food packaging. Therefore, PHA is a sustainable alternative in the sector of food packaging but it should not be considered as a final alternative to petrochemical polymers.

EPR in the Transport Sector: The Brigit project

The Extend Producer Responsibility is indeed one of the core aspects of the EU Directive. It does represent a crucial change if compared with previous legislation because it reshapes the role of plastic producers. From awareness raising to separate collection and waste treatment, the duties of the plastic producers increased. However, the Directive does not provide a clear and specific alternative to the current plastic products nor transportation methods. Plastic Producers involved in transportation might face severe economic consequences if a sustainable alternative is not available. The upcoming paragraph will investigate a sustainable bio-polymer used in the EU financed project The Brigit. The goal is to understand the implementation feasibility in the Trasport Sector and the possible benefits of it.

The polymers sector is indeed one of the most growing market shares in the last ten years. According to the report 'Bioplastics: Sustainable materials for building a strong and circular European bioeconomy' by 2021 the value of resistant polymers will reach USD 16.67 billion while the biopolymers will reach a growth of 12% (CORDIS, 2017). It is indeed an exponentially growing market, characterized by a multitude of products, but the question of which is the more suitable product remains. The Brigit project aims at finding an answer to this question by providing two polymers to implement mainly in the transport sector. According to the coordinator of the project in Spain Miguel Valera, the goal was to produce two different polymers, namely polyhydroxybutyrate (PHB) and Poly-Butylene-Succinate (PBS) (CORDIS,2017). These polymers seem to have very interesting mechanical properties. PHB presents interesting thermal features that allow it to be one of the most suitable ones. PBS instead '' is used to improve the resilience and processability of PHB. By combining the two, BRIGIT partners can build composites for high-tech fire-resistant applications, mainly for the

transport sector '' (CORDIS,2017). According to The Community Research and Development Information Service of the EU, there is a great margin for a decrease in resource consumption and greenhouse gas emissions as well as a reduction of operational costs (CORDIS,2017).

On the other hand, there is a need to consider some mechanical and economic limitations. M.Valera identifies them in weight and cost, explaining that the petrol-based resins are cheaper compared to biopolymers as well as lighter and more functional. Valera underlines that there is a need to develop large scale infrastructure to build a more cost-competitive product (CORDIS,2017). Nevertheless, the research brought them to identifying PHB as a very encouraging alternative. The implementation sectors of it seem to be exactly the ones that the EU Directive aims to address. Despite the margin of improvement, PHB and other similar biopolymers are at the center of the attention of several companies and governmental projects. Extend research on these polymers might lead to game-changing discoveries. The next section is about a similar biopolymer, namely PHBH, which seems to be an improved version of PHB.

Japan & France: The PHBH case

Since 2011, the japan group Kaneka produces bioplastics based on polyhydroxyalkanoates (PHA), in particular, PHBH. The lab/factory is located in the company's headquarters in Takasago. According to their annual report, the capacity production of PHBH will be increased from the current 1,000 tons to 5,000 tons per year. Kaneka is also proceeding with the quality certification for the food use of these bioplastics. In March 2018, it obtained the American registration (FDA) and in May 2019, the PHBH was included in the Japan Hygienic Olefin positive list. It allows its use in kitchen utensils, containers, and packaging distributed on the Japanese market. Furthermore, in August 2019, the extended authorization for food contact was also released for the EU market, allowing the use of a biopolymer in the production of cutlery, straws, straws, cups, as well as in applications such as bags for fruit and vegetables.

According to a BBC report, the biopolymer '' PHBH is certified by TÜV AUSTRIA as: OK biobased, OK biodegradable MARINE, OK biodegradable SOIL, OK compost INDUSTRIAL, OK compost HOME'' (BBC, 2020). EU certification represents a crucial step in the process of tackling the global plastic issue. The first reason is that it shows a mutual commitment both from the private and the public sector. The interaction has always been complicated especially in matters of environmental pollution related to profit. The second reason is that the Kaneka case shows how international cooperation on this matter can effectively work. The french plastic manufacturer Sphere is a supporting example of that. The Ceo of Sphere J.Persenda claims that ''we have developed a compound with PHBH and that is the product,

the compound we are using now to manufacture our bags'' (BBC,2020). It is an encouraging statement, which suggests that the manufacturing of biopolymers in Europe is feasible both from an economic and structural point of view. About the potential of PHBH the Managing Executive Officer of Kaneka, Mr.Yoshiki, says ''using Japanese technology and innovation, we have the potential to address the global plastic issue'' (BBC,2020). Indeed a biased statement, but according to ''Manufacturing and Properties of Binary Blend from Bacterial Polyester Poly(3-hydroxybutyrate-co-3- hydroxyhexanoate) and Poly(caprolactone) with Improved Toughness'', PHBH seems to be the most promising polymer (J.Martinez,2020). Sphere is aware of this potential and in fact, has already implemented PHBH in its production.

Founded in 1976, Sphere has been a leading company in plastic packaging products as well as ''one of the most important global producers of bio-compostable materials'' (Sphere Website,2020). In addition to that, Sphere has invested over 140 million Euro in research and development in the last years (Sphere Website,2020). What makes Sphere also a great leading example is the fact that they always strived for expansion and international cooperation. According to their report ''A French origin and a decidedly European and Asian expansion'' published on their Website in 2020, the company has an infrastructure in several European countries. From the Netherlands, Germany, Italy, Spain, Belgium, and the UK, Sphere provides commercial addresses or factories (Sphere,2020). This network represents a solid starting point in addressing the infrastructural shift most European plastic producers have to undergo because of the EU Directive.

Furthermore, their relation with Asian countries such as Japan, Singapore, and China makes Sphere a ''bridge'' company to the Asian market. The possible results of Sphere's network, are increased data sharing between EU and non-EU countries as well as an international standardization on bioplastic production. In the light of EPR (Extended Producer Responsibility)the Sphere approach seems to be a very suitable one.

Comparison of Biopolymers

The article ''Sustainability Assessment of a Single-Use Plastics Ban'' by Timo Herberz, Claire Y. Barlow and Matthias Finkbeiner provided extensive research and analysis on the topic of non-plastic alternatives as well as improving the Life Cycle Assessment and develop a more in-depth knowledge of the sustainability of the European Single-use plastic ban. According to their results, the wood alternatives seem to be the best performing ones, while PLA performs the worst (Herberz& Barlow, 2020). The main issue lies in the fact that '' The process steps involved in making PLA items lead it to

perform the worst in terms of acidification (almost independent of weight variation), eutrophication (independent of weight variation) and marine aquatic toxicity (almost independent of weight variation)'' (Herberz& Barlow, 2020). Despite that, the assessment by Cambridge covers a restricted number of alternatives excluding some interesting possibilities and mechanical improvements. Recent research leads to the discovery of interesting mechanical implementations that could potentially lead to a general improvement of the biopolymers that Cambridge considers as non-feasible alternatives. That is the case of PLA.

The PLA production and improvement process has been a matter of research for years now. An extensive number of publications have been produced regarding PLA properties and in fact, this biopolymer is already extensively used (K.Hamad,2015). As mentioned in the previous section, finding a balance in the impact categories is everything but an easy task. Not only the production steps but also the mechanical properties of a biopolymer can have a considerable impact on different categories. In the paper ''Eco-Friendly Approach and Potential Biodegradable Polymer Matrix for WPC Composite Materials in Outdoor Application'' by M.Valente, Alessia Quitadamo, and Valerie Massardier, there are interesting suggestions for PLA improvement.

In their research, they acknowledge the limitations of PLA and try to improve them. This limitation consists of the fact that PLA has ''high brittleness and limited toughness'' (M.Valente,2020). Their goal is to improve these mechanical categories by manufacturing compounds with different thermoplastic polymers (M.Valente,2020). The main idea is to produce thermoplastic matrix composites based on natural fillers. The potential of wood derivates was brought to our attention already in the assessment by Cambridge and TU Berlin. According to their Life Cycle Assessment wood was performing better than the other products in almost every impact category (Herberz&Barlow,2020). M.Valente and his colleagues are aware of this potential too, in fact, they focused their research on the implementation of wood fillers. They claim that '' wood flour exhibits interesting properties as waste material used for composite production, obtaining the well-known class of material wood plastic composites (WPC). WPC are (...) characterized by the potential recyclability and possibility to use waste as raw materials, reducing in this way environmental impact'' (M.Valente,2020).

In order to understand the possibilities of the research carried out by Professor Valente, a personal interview was conducted. M.Valente is a Professor at the Department of Chemical and Material Engineering, University of Rome La Sapienza. The goal of the interview was to retrieve qualitative information on several aspects of the topic. The main points concerned PLA and his research, comparison of non-plastic alternatives, and the EU Directive. The interview was divided into 5 main questions.

Part of this research builds upon the results on PLA contained in the paper ''Sustainability Assessment of a Single-Use Plastics Ban'' by Herberz, Barlow, and Finkbeiner. According to its Life Cycle Assessment, PLA has still a large margin of improvement. The research of professor Valente seems to propose a solution. In the first question, Mr.Valente was asked to provide information about the achievable improvements through his project. His answer can be divided into two sections. In the first part, he explains the production process and in the second one, he discusses the results. The main focus is on WPC addition.

Professor Valente explains that ''the WPC uses wood flour and the waste of the wood industry as a wood base. The binder (the matrix that holds the wood flour together) in past applications is either PVC or PP or HDPE in descending order of quality of the WPC. The idea we carried out in the work was mixing a blend of HDPE and PLA with the wood flour trying to obtain better mechanical properties exploiting the characteristics of multiphase mixtures of non-miscible polymers and maybe use a recycled HDPE, which has a considerable degree of availability'' (M.Valente,2020). The results achievable through this process seems to tackle the initial mechanical issues and provide an improved and more sustainable alternative. Mr. Valente presents that they '' developed a completely eco-sustainable WPC product because the wood part is environmentally friendly, the HDPE part is a recovered material and not a new material introduced into the environment and PLA is among the few biodegradable polymers that are industrially available and also stable on the market '' (M.Valente).

This improved product might be an answer to the question of alternatives to conventional polymers on large scale. It shares the view of Cambridge on wood potential and provides a new point of view on the matter. In questioning the feasibility and sustainability of the Single-use plastic ban, this product could lead the way to new possibilities. However, to not limit the research to only one biopolymer, Professor Valente was asked to give an opinion on PHBH as an alternative to PLA. The PHBH, a Japan produced biopolymer, seems to have great mechanical properties too(Kaneka,2020). Mr.Valente on the other hand claims that '' the PHBH is a special PHB produced with a process modification which makes the product a little less expensive. PHAs are materials produced from renewable raw materials that start from the enzymatic processing of sugars or vegetable fats. They are promising materials but not mature both from the point of view of costs and supplies '' (M.Valente,2020). The Sphere case, presented in the previous chapter shows that the application is indeed possible. To what extend the PHBH could replace PLA, requires further research and comparison.

Furthermore, Professor Valente was asked about the PHA. The food packaging case scenario presented in the previous section already provided information about this polymer. It seems to have great mechanical properties, one of the reasons why it is used for the food industry. When asked about PHA alternative implementations, Valente underlines that there is the possibility to use PHA in several

single-use products but the cost and availability still represent an issue. However, he believes that there is still margin for research and improvement (M.Valente,2020). On the one hand, the mechanical properties of PHA seem to be of high level and make it an interesting alternative, but on the other, it presents the same issue other alternatives already showed. The production costs are high and therefore do not stimulate the European producers to implement it. As mentioned in the section ''The Italian Plastic Industry'' Chapter 4 of this paper, most of the plastic companies' representatives claim that the prices of raw materials for the production of biopolymers are too high.
The 10% economic stimulation contained in the Italian Plastic Tax can be considered as an example of financial aid by a Member State. However, the potential of this project has to be measured not only in light of the Italian market but also concerning the other European markets. The reason why is because every Member State has a different scenario concerning plastic production and research.

Professor Valente's research seeks to solve this economic issue. Using wood alternatives, which comes from wood industry waste and are completely sustainable, he addresses a crucial point of this discussion. The cost of raw materials is the main issue according to most prominent actors, and WPC seems to solve this. Further assessment of Valente's research is needed, in order to establish the potential of it. However, it does represent a starting point on which EU institutions and private companies should focus more. His WPC based product can potentially decrease the impact in every category of the LCA and create a new way to conceive biopolymers. In the last question, Professor Valente was asked to give his personal opinion on the potential of the 2019 EU Directive. Generally speaking, he believes that the EU Directive is indeed a starting point but with several limitations. These include the fact that the EU decided to intervene on '' what is easier to convey through the media and at the same time more annoying for people and industries'' (M.Valente,2020). He criticizes the fact that the Ban is scientifically vague and does not provide concrete alternatives (M.Valente,2020).

In conclusion, it can be said that WPC implementation in the production of PLA might represent a concrete improvement in terms of mechanical properties and costs. This discovery tackles the big question mark around the future non-plastic alternatives, providing a new starting point for the research. Financially speaking Valente's results fully incorporate the concept of Sustainability and promotes the circular economy. However, M.Valente is aware that further research is needed in order to establish the future application of this new product. For now, the improved PLA version of M.Valente and the PHBH seems to be the most suitable options that the EU has.

Chapter 5

Conclusion

This study investigated several aspects of the 2019 EU Directive on Single-use Plastic Products. It is possible to affirm that the EU has actively worked on the topic of plastic pollution only in the last 10 years and that the 2019 Directive represents a step forward both in terms of legislation and implementation. Concerning the research question on the Ban and his implementation, it was concluded that the intervention areas indicated in the Directive seem to be appropriate to the goal it wants to achieve.

Not by chance, the Single-use plastic ban decrease European contribution to plastic marine pollution by 5.5% (Herberz&Barlow,2020). Moreover, the implementation of Extend Producer Responsibility in Article 8 represents a crucial step in the administration of the private sector. The implementation of EPR has the potential to change the outcome of waste management in the upcoming years, by developing a network of sustainable and transparent plastic management. By looking at all the other factors, EPR stands out as the real mean to overcome the obstacle of the collection as well as promoting more commitment by the producers. Indeed the plastic producers' attitude till now, represented one of the main obstacles to a clean and sustainable system, mainly because the responsibility of plastic disposal was only on municipal waste institutions. The introduction of EPR is indeed the outstanding achievement of the 2019 EU Directive. The role of plastic lobbies was always a dominant one and the EPR might have the potential to re-establish a balance in responsibility.

However, it was also concluded that scientific knowledge provided by the EU research bodies is lacking. Therefore, the Directive does not indicate well-assessed biopolymers that could eventually substitute the current ones. This partially answers the research question on economic incentives and product alternatives. The Italian scenario is an example of how this lack can be translated into a delay in production shift and therefore a failure to achieve the final goal. The understanding of the relation between scientific progress and the effectiveness of the measures is crucial. By comparing the Italian and German scenarios, it was evident that the national differences in infrastructure, technology and founds might create a non-homogenous implementation of the Directive, which will consequently result in a partially effective result. Europe has a wide range of national realities that have to face different scenarios according to their situation with countless factors to include. The ambition to apply the same EPR or recycling pattern for all Member States can be reached only by developing a similar system in every European Country. Therefore, the cooperation between MS and the EU Commission has to be stronger than ever.

Furthermore, in the process of identifying sustainable biopolymers, different conclusions came up. Three biopolymers can potentially substitute conventional plastic. PHA presents encouraging mechanical properties and several fields of implementation. From food packaging to the transport sector, PH biopolymers could potentially guarantee an improvement. The limit of PHA and PHB is the production cost. The Japanese produced PHBH, which is an improved version of PHB, tries to tackle this economic issue. The French manufacturer Sphere is an example of PHBH market potential and implementation capacity. Moreover, the third selected biopolymer is PLA. The research of Professor M.Valente provides scientific evidence on the potential of it. To summarize, PHBH and WPC can lead the path to a new frontier of research and production. The WPC opens a new chapter in scientific research while the PHBH case can be used as an example for future practical applications.

In conclusion, the European Single-use Plastic Ban presents interesting measures that theoretically speaking, can tackle marine plastic pollution. Practically speaking, the lack of research on sustainable alternatives and the vague nature of the articles, leads to an inevitable delay and partially correct transposition into national laws. The EU Plastic ban presents an incomplete answer to the issue of marine plastic pollution. To reach the goal set by the EU Directive, there is a need for coordinated action in several sectors. Improving recycling capability through EPR, finance sustainable alternatives e limiting illegal waste export.

The following recommendations are addressed to policymakers and private producers. As indicated by almost every source used in the paper, the European Union should improve legislation on waste management and tackle the illegal waste stream towards Asian countries. These two factors are one of the main reasons for marine plastic pollution. The investigation of Greenpeace on Italy-Malaysia mismanaged waste treatment should be taken as an example. Furthermore, is recommended to include LCA of PHBH and WPC in scientific research on this matter. The assumptions behind the Ban might change drastically if PHBH and WPC are included in their assessment. Given their potential, further investments and research on both biopolymers are strongly recommended. Concerning Italy, the Plastic Tax should be carefully assessed and eventually used as an example of functional charges. Moreover, there is the need to rethink the nature of single-use items since it does not match with the concept of Sustainability and investigate the production of plastic items at their core. The 2019 EU Directive on single-use plastic items has the potential to tackle plastic marine pollution only if in a combination of international initiatives, that cover several sectors and try to solve this issue from plastic production to illegal waste export. In this case, more than ever, unity and cooperation is strength.

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Appendix

Informed Consent Form

1) Opportunities & Limitations of the EU Single-Use Plastic Ban. Interview with Professor Marco Valente.

2) The written interview with Professor Marco Valente focusses on the PLA and contains questions on other biopolymers and their application. Professor Valente is asked to explain his research in comparison to the results of other academic papers. His final comment on the EU Directive is also required. The information provided by M.Valente is contained in the interview script and in the chapter "Comparison of Biopolymers". He can withdraw from the study by asking the removal of the chapter containing his contribution. The information provided by M.Valente was not shared or published elsewhere then this paper. The personal email exchange with Professor Valente should ensure confidentiality. There is no audio & video recording since the interview was conducted by e-mail.

If you agree to take part in this study, please read the following statement and sign this form.

I am 16 years of age or older.

I can confirm that I have read and understood the description and aims of this research. The researcher has answered all the questions that I had to my satisfaction.

I agree to the audio recording of my interview with the researcher.

I understand that the researcher offers me the following guarantees:

All information will be treated in the strictest confidence. My name will not be used in the study unless I give permission for it.

Recordings will be accessible only by the researcher and relevant university assessors. Unless otherwise agreed, anonymity will be ensured at all times. Pseudonyms will be used in the transcriptions.

I can ask for the recording to be stopped at any time and anything to be deleted from it.

I consent to take part in the research on the basis of the guarantees outlined above.

Signed: _____ ____ **Date:** 13 / 09 / 2020

European Studies Student Ethics Form

Your name: Gabriele Gobbi
Supervisor: Bergh, A.J. van den

Instructions/checklist
Before completing this form you should read the APA Ethics Code (http://www.apa.org/ethics/code/index.aspx). If you are planning research with human subjects you should also look at the sample consent form available in the Final Project and Dissertation Guide.
a. [x] Read section 2 that your Supervisor will have to sign. Make sure that you cover all these issues in section 1.
b. [x] Complete sections 1 and, if you are using human subjects, section 2, of this form, and sign it.
c. [ ] Ask your project Supervisor to read these sections (and the draft consent form if you have one) and sign the form.
d. [ ] Always append this signed form as an appendix to your dissertation. This is a knock-out criterion; if not included the Final Project/Dissertation is awarded an NVD.

Section 1. Project Outline (to be completed by student)

(i) Title of Project: Opportunities & Limitations of the EU Single-use Plastic Ban

(ii) Aims of project: This research aims to understand the feasibility of the Ban and further identify a sustainable alternative to conventional polymers

(iii) Will you involve other people in your project – e.g. via formal or informal interviews, group discussions, questionnaires, internet surveys etc. (Note: if you are using data that has already been collected by another researcher – e.g. recordings or transcripts of conversations given to you by your Supervisor, you should answer 'NO' to this question.)
YES I will involve other people.

If no: you should now sign the statement below and return the form to your Supervisor. You have completed this form.
This project is not designed to include research with human subjects. I understand that I do not have ethical clearance to interview people (formally or informally) about the topic of my research, to carry out internet research (e.g. on chat rooms or discussion boards) or in any other way to use people as subjects in my research.

Student's signature _____- date _____
If yes: you should complete the rest of this form.

Section 2 Complete this section only if you answered YES to question (iii) above.

(i) What will the participants have to do? (v. brief outline of procedure):
The written interview with Professor Marco Valente focusses on the PLA and contains questions on other biopolymers and their application. Professor Valente is asked to explain his research in comparison to the results of other academic papers

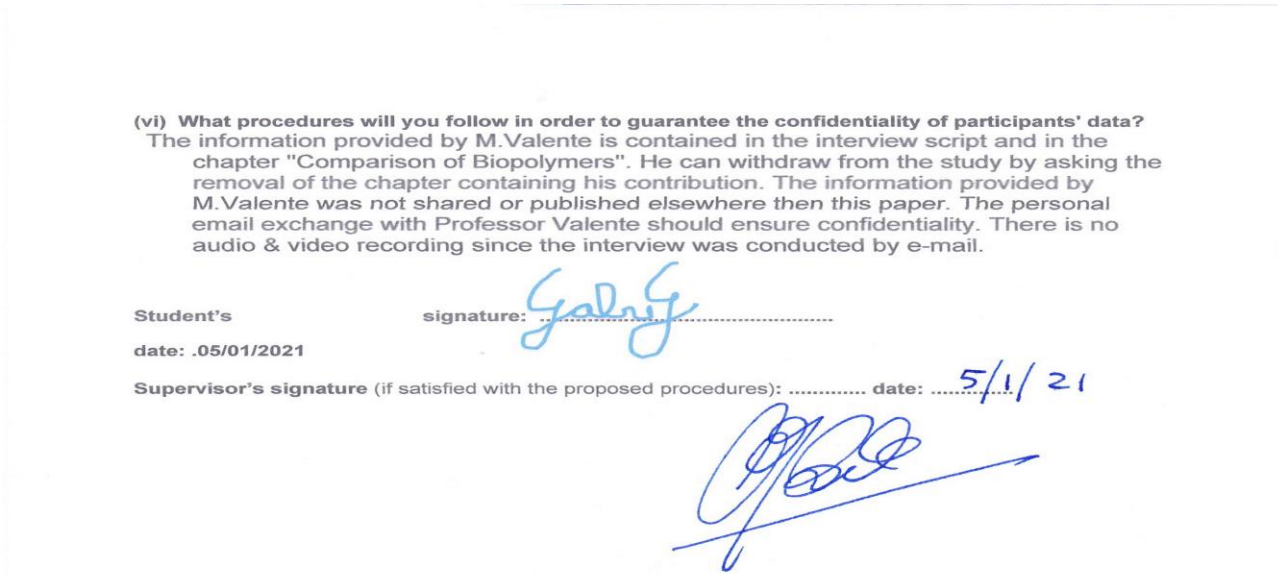
(ii) What sort of people will the participants be and how will they be recruited?
The interviewed person is a University Professor. Contacted through official channels.

(iii) What sort stimuli or materials will your participants be exposed to, tick the appropriate boxes and then state what they are in the space below?

Questionnaires[x]; Pictures[ ]; Sounds [ ]; Words[ ]; Other[ ].

5 different questions written down on a Word Document. Available in the Appendix.

(iv) Consent: Informed consent must be obtained for all participants before they take part in your project. By means of an informed consent form you should state what participants will be doing, drawing attention to anything they could conceivably object to subsequently. You should also state how they can withdraw from the study at any time and the measures you are taking to ensure the confidentiality of data. A standard informed consent form is available in the Dissertation Manual.



(vi) **What procedures will you follow in order to guarantee the confidentiality of participants' data?**
The information provided by M.Valente is contained in the interview script and in the chapter "Comparison of Biopolymers". He can withdraw from the study by asking the removal of the chapter containing his contribution. The information provided by M.Valente was not shared or published elsewhere then this paper. The personal email exchange with Professor Valente should ensure confidentiality. There is no audio & video recording since the interview was conducted by e-mail.

Student's signature: .....

date: .05/01/2021

Supervisor's signature (if satisfied with the proposed procedures): ..... **date:** 5/1/21

Original Script of the Interview (translated from Italian)
SCRIPT PER INTERVISTA

AL PROF. M.VALENTE
Studente: Gabriele Gobbi

Tema: Comparazione Bio-Polimeri.

1. ‘’ Where wood was compared to PP, PS and PLA (cutlery, stirrers), wood shows lower GHG emissions which are independent of the weight variation in three out of five cases. PLA always performs worst in terms of GHG emissions. This can be explained partly by the deployed landfill scenario from Papong et al. [37] described as the “potential methane generation” from PLA. The process steps involved in making PLA items (see Figure 1) lead it to perform the worst in terms of acidification (almost independent of weight variation), eutrophication (independent of weight variation) and marine aquatic toxicity (almost independent of weight variation)’’ (Cambridge, 2020)

‘’ PLA was excluded from the analysis since it falls under the plastics ban and is still a niche material in comparison to PP and PS cutlery ‘’ (Cambridge, 2020)

Question 1: According to a publication from the Cambridge Engineering Department, PLA appears to have lower performance than other polymers. Could the addition of " wood flour " (as proposed in the research by Prof. Valente) represent an improvement in terms of methane emissions? Can the addition of " wood flour " improve factors such as acidification, eutrophication, and marine aquatic toxicity, making PLA a long-term solution?

Answer by Prof. M.Valente:

I try to explain the scientific philosophy of my work that you mention a little better, but before that, I have to address the current problem of polymers very briefly.

• The real fault of polymers is that they are economically efficient and practically indestructible. All those characteristics that have made them successful, affirm, and replace other classes of materials, are now their most fearful enemy. The point is that being indestructible by the environment independently (without our further action which obviously has a cost and must be profitable otherwise it does not happen, and this has little to do with the laws of nature but concerns to economic laws) they are always produced in greater quantities and above all, they accumulate on planet earth. From the 1940s to the 1980s and 1990s, neither their source of supply nor the fact that they accumulated in a way that would have become intolerable, was thought of. These two problems impacted the planet because

a) the source from which almost all of the starting materials for the production of polymers are produced is oil

b) not being degraded by nature after 40/50 years of accumulation underground, in the seas, in wild and inhospitable places...We find them knocking on the front door. This problem has led, first the researchers, then the politicians, and finally, the industries (both producers and users) in the last 20/25 years to question what to do, where to start, what solutions to hypothesize, what temporal strategy to propose

• Considering (to simplify enormously but with the hope of being clear) that the problems to be faced and to be solved have two different philosophies, substitutive materials that would address the two problems have been studied. All together for the public opinion, they are called BioPolymers or eco-sustainable polymers but in reality, there are very different families of polymeric materials or materials that simulate classic polymers (deriving from oil). Starting from renewable raw materials such as ethanol or other fermentation products of organic vegetable material (but which solve only one question ... they derive from renewable raw material but are not biodegradable), or even deriving from petroleum (from a non-renewable source) are however biodegradable or have in their macromolecule some "functional groups" that can be attacked by fungi or bacteria and therefore "digestible" by the environment in non-biblical times, say 6 months 4-5 years depending on the thickness of the environment in which they are found temperatures and microclimate (keep in mind that the classic and indestructible polymers we are talking about have degradation times ranging from 500 to 1000 years).

• Last very general information .... although today plastics and polymers have several hundreds of thousands of different species with immoderate specific characteristics that cover practically all possible applications except those at high temperatures (where high means above 150/200 degrees centigrade above these temperatures, plastic materials give way to metals and then to ceramics) in reality, plastic materials of global reach and which in terms of quantities alone occupy about 70% of use and therefore of diffusion are practically 5 and very few others ... PE, PP, PET, PVC, PS, All of these deriving from petroleum and practically unassailable.

Prof. M.Valente on his research and goals:

I try to explain the scientific philosophy of my work. My work is based on the possibility of creating an effective and sustainable material at a low cost. The work focuses on the production of WPC (Wood Polymer Composites); these WPCs are a family of materials that already exist and have been studied for more than 10 years to replace all applications of wood planking and timber as such (even timber is a species to be safeguarded and a replacement for) the WPC uses wood flour and the waste of all carpentry work as a wood base. The binder (i.e. the matrix that holds the wood flour together) in past and extensively studied applications is either PVC or PP or HDPE in descending order of quality of the WPC. The idea we carried out in the work was if we mix a mixture of HDPE and PLA with the wood flour trying to obtain better mechanical properties (exploiting the characteristics of multiphase mixtures of non-miscible polymers) and maybe use a recycled HDPE (that we say that it is now with certain repeatability) we have completely made the WPC product eco-sustainable because the wood part is obviously environmentally friendly, the HDPE part is a recovered material and not a new material introduced into the environment and PLA is among the few biodegradable polymers and industrially available and stable on the market.

I hope that everything is more clear now.

Question 2: Could PP biopolymer replace PLA, and if so why?

Answer by Professor. M. Valente:
As you have understood by reading before, PP (PolyPropylene) is not a BioPolymer at all, it is a Polyolefin a very popular classic polymer.

Question 3: Could the PHBH biopolymer produced in Japan and used by Sphere (a French plastic manufacturing company) potentially replace PLA?

Answer by Professor M.Valente:
Here the matter becomes a little more complicated ... .. the PHBH is a particular subspecies of a wider family which are the PHA which stands for PolyhydroxyAlcanoates of which the most promising and which has the best chance of significant uses is the PHB PoliIdrossi Butyrate ...Now the PHBH is a special PHB produced with a process modification which makes the product a little less expensive. PHAs are materials produced from renewable raw materials that start from the enzymatic processing of sugars or vegetable fats. They are promising materials but absolutely not mature both from the point of view of costs and from the point of view of supplies

Question 4: PHA biopolymer is mainly used in food packaging, can it be implemented for the production of other single-use products?

Answer by Professor M.Valente: In principle, yes, but we are not there with the prices or with the requested availability.
Food packaging is one of those sectors where the most stringent laws and the ability to download costs allow you to do some industrial experimentation.

Question 5: Your personal opinion on the potential of the European Directive on single-use plastics. In your opinion, are the proposed measures (especially those on Product requirements) concrete or too vague?

Answer by Professor M.Valente:
Here a world opens up… .. the point is that you have to start from something. Did we start from what better than other sectors and choices will bring scientifically sustainable solutions? NO, we started from what is easier to convey through the media and at the same time more annoying for people and industries…. So that it is more visible….

I'll give you an example, if you want to go on strike and you want to complain about something wrong with whom you have to make the highway toll booths strike or those who drive public transport? Obviously the seconds.