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A Circular European Plastics Economy: A Feasible Concept?

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Affidavit

I, **STEFANIE GRITZMANN**, hereby declare

1. that I am the sole author of the present Master's Theses," A CIRCULAR EUROPEAN PLASTIC ECONOMY: A FEASIBLE CONCEPT?", 80 pages, bound, that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

The European Commission (EC) has defined plastic as one of the priority areas in the transition towards a circular economy due to the increasingly adverse effects of the global plastics economy, such as marine pollution. In response to China's decision to ban the import of certain types of plastic waste, the EC issued a European strategy on plastic, which discusses all life-phases of plastic items. As the strategy puts a particular focus on plastic packaging and waste management, its main aim is the recyclability of all plastic packaging by 2030. As first step towards this goal, the EC proposed to amend the Packaging and Packaging Waste Directive by increasing the legally binding minimum plastic packaging recycling target from the current 22.5% to 55% by 2025.

This thesis examines the feasibility of establishing a Circular European Plastics Economy by 2030. An analysis of all European Union (EU) member states concludes that substantial progress was made in plastic waste management. In fact, for the first time more plastic and plastic packaging waste was recycled than landfilled in the EU in 2016. Nevertheless, problems in regards to data availability and accuracy were encountered. Furthermore, the need for a common legally binding definition of the calculation of recycling rates will be stressed. This work concludes that the majority of member states would struggle to comply with an elevated recycling target. When analysing the national recycling systems of five member states (Austria, Finland, Spain, Germany and the Netherlands), it is found that only Germany and the Netherlands would achieve the suggested targets without major efforts. Contrarily, Austria, Spain and especially Finland, the country with the lowest recycling rates in Europe, would face substantial challenges with higher targets.

Policy proposals frequently disregard the existence of technical, environmental, social and economic barriers on the road towards a circular economy. It is argued that the idea of a closed-loop plastic economy constitutes a rather idealistic concept due to the inherent complexity of the material and the current limited capability of national waste management systems. While waste management plays a vital role in establishing a more sustainable economy, the utter importance of reducing overconsumption, single-use plastic and limiting waste generation is emphasised.

Table of Content

List of Abbreviations

a	anno
ANARPLA	Spanish National Association of Plastic Recyclers
BPA	Bisphenol A
CE	Circular Economy
CO2	Carbon Dioxide
Cr	Chromium
DDE	Dichlorodiphenyldichloroethylene
EC	European Commission
EPR	Extended Producer Responsibility
EU	European Union
EU28	The EU in its current composition of 28 member states
GDP	Gross Domestic Product
Gg	Giga gram
HDPE	High-density polyethylene
Kg	Kilogram
Kt	Kilo tons
LDPE	Low-density polyethylene
PBT	Bioaccumulative toxic pollutants
PCB	Polychlorinated biphenyl
PP	Polypropylene
PS	Polystyrene
PRO	Producer Responsibility Organisation
PET	Polyethylene Terephthalate
POP	Persistent Organic Pollutant
PVC	Polyvinyl Chloride
REACH	Registration, evaluation, authorisation and restriction of chemicals
MFA	Mass Flow Analysis
mm	millimetre
MSW	Municipal Solid Waste
Mt	Million tonnes
NAFTA	North American Free Trade Agreement
NP	Nonylphenol
t	tonne
UK	United Kingdom
WtE	Waste to Energy

A Circular European Plastics Economy: A Feasible Concept?

1. Introduction

Plastic is one of the most versatile materials in the world, offering many practical benefits due to its light weight and resistance to corrosion. Nevertheless, the negative consequences of the prevailing plastics economy on the environment and human and animal health are becoming increasingly apparent. The problem of marine litter, in particular, has caught global attention. The severity of the situation was confirmed, when it was projected that in a business as usual scenario there will be more plastic than fish in the oceans by 2050.

In course of the circular economy package, the European Commission defined plastic as one of its priority areas, putting a particular focus on plastic packaging, its main application. The EU Plastic Strategy is an attempt to establish a circular plastics economy, which takes into account all life-stages of a plastic product. The main aim of the strategy is to achieve the recyclability of all plastic packaging on the European market by 2030. While highlighting the importance of environmentally friendlier waste management in its policy proposals, the European Commission has put its focal point on increased recycling targets for plastic packaging. The purpose of this thesis is to examine the political, legal and technical developments with regards to the European plastics economy. Therefore, the EU Circular Economy Package and the European policy on plastics will be critically analysed. With a focus on plastic packaging, the status quo of current waste management in the European Union is examined. Five country case studies will help to understand the national particularities of plastic recycling systems. To offer predictions on the feasibility of achieving increased recycling rates for plastic packaging recycling, the analysis will focus on the status quo and recent developments in national plastic waste management schemes.

This Master's Thesis will provide an answer to the following question: *To what extent can the European Union become a Circular Plastics Economy by 2030?* To answer the research question, this work was structured the following way: Chapter 2 stresses the severity of the global plastic problem and highlights the utter importance of changing the way plastic is produced, perceived, consumed and disposed on a global level.

Chapter 3 and 4 critically analyse the content of the European Action plan for a Circular Economy concerning plastic and examine the European Strategy for plastics, which was released in January 2018. The main areas of the strategy including all stages of the plastic life cycle will be examined. Furthermore, the ability of biodegradable plastics to substitute conventional plastics will be briefly discussed. Chapter 5 elaborates on the political and legal situation with regard to plastic in the European Union. In Chapter 5.1 the role of the European plastic sector will be elaborated in the global context. Moreover, China's recent decision to ban the import of certain types of plastics and its implications for Europe will be discussed in Chapter 5.2. In Chapter 5.3 the European legal framework on plastics will be examined while discussing the proposed legal changes.

Chapter 6 analyses plastic waste treatment in the EU with a particular focus on plastic packaging. After examining plastic and plastic packaging waste management and its diversity in European member states, recycling rates will be analysed. Diverse statistical sources were used to extract recycling rates to provide an unbiased picture. Chapter 6.2 consists of country case studies on national plastic packaging waste treatment of five European countries, namely Austria, Finland, Spain, Germany and the Netherlands. After considering each country individually, a comparison of key findings was made, while taking into account the challenges of data comparison due to data variability and differing calculation methods and definitions. Chapter 7 looks at the barriers to the implementation of a circular plastic economy, which are frequently overlooked by policy makers. Likewise, Chapter 7.1 discusses the challenges in plastic recycling underlining the fact that an entirely closed-loop recycling system is unfeasible. In Chapter 8, recommendations for transformation of the current plastic economy are given and suggestions for policy proposals are provided. Chapter 9 draws conclusions from this analysis of the Circular European plastic policy while arguing that the majority of member states will struggle to achieve the suggested 55% recycling rate.

2. The Plastic Problem

Although the industrial production of plastic only began in 1907, the material is present in almost all sectors of the economy, such as construction, cosmetics, packaging, transportation, healthcare, electronics and sports (Bourguignon 2017, 2; Ellen

MacArthur Foundation 2016, 24). The invention of plastics brought about many benefits. For instance, the use of polymers in light technology, vehicles and insulation contributes to saving energy. According to Plastics Europe (2018), plastic insulation saves 250 times of the energy, which is necessary for its production. Moreover, lightweight and convenient plastics packaging enhances food safety, while decreasing the amount of food waste (European Commission 2018a).

Nevertheless, the current plastics production, usage and disposal are extremely harmful to the environment. Particularly, the long durability of plastic in the environment, its low price and light weight make the end-of-life stage of plastic problematic (European Commission 2013, 2018a, 5). Therefore, there is an urgent need to alter the way plastic is perceived, designed, used and disposed considering its complete life cycle.

The environmental impacts of our plastic economy become more pressing, as global plastic production has grown twentyfold since the 1960s, amounting to 322 million tonnes in 2015. In the next 20 years production is anticipated to double and increase fourfold by 2050. Only between 2015 and 2016 the total plastic production increased from 322 to 335 million tonnes (European Commission 2018a, 6; Plastics Europe 2018, 16). As the global population is estimated to grow by 790 million people every decade and exceed 9 billion by 2050 (European Commission 2013, 4), an ever increasing demand for plastic and further challenges in waste management can be predicted.

The boom in the plastics demand is largely driven by the growth of the plastic packaging sector, which clearly dominates the plastic industry (European Commission 2013, 4). With a growth margin of 5% annually, the global plastic packaging market is growing substantially. The amount of plastic packaging is estimated to double until 2030 (Ellen MacArthur Foundation 2016, 24). Half of the global plastic materials[1] are produced in Asia, with China being the largest producer (29%), followed by Europe (19%) and NAFTA (18%) (Plastics Europe 2018, 17).

The vast majority of plastic packaging is designed for single-use applications. In fact, around 95% of plastic packaging material value is lost to the economy after a brief first use. If plastic is recycled, it mostly gets reprocessed into low-value applications that

[1] Only including thermoplastics and polyurethanes.

cannot be recycled again afterwards. Global recycling rates for plastic packaging are much lower than those for paper (58%) or for iron and steel (70-90%). Polyethylene Terephthalate (PET) has the highest recycling rate when compared to other plastic types. However, worldwide only half of PET is collected for recycling and merely 7% is recycled “bottle-to-bottle”(Ellen MacArthur Foundation 2016, 17).

As shown in Figure 1 below, globally, only around 14% of plastic packaging is collected for recycling and 14% is incinerated. 72% of plastic packaging “is not recovered”, out of this 40% ends up in landfills, 32% is not collected at all or collected and illegally dumped. In other words, the 32% constitute plastic leakage into the environment. Nevertheless, one needs to be aware that the percentage shares are derived from an accumulation of fragmented data sets with differing definitions and therefore only constitute an estimate (Ellen MacArthur Foundation 2016, 26).

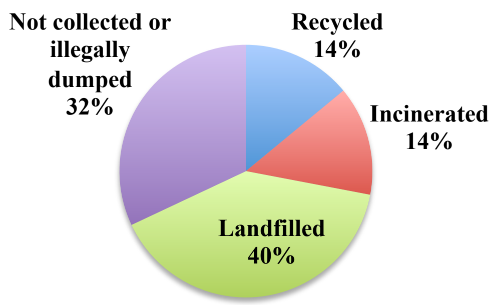

Figure 1: Global Waste Treatment of Plastic Packaging. Data from: Ellen Mac Arthur Foundation, 2016, p. 26

One of the numerous obstacles to higher recycling rates is that incineration plants require large initial investment costs, which can lead to a so-called “lock-in” effect. This effect describes the preference of incineration and therefore constitutes a competition to increased recycling. Besides this, incineration causes pollutants (such as carbon dioxide and nitrogen oxides etc.), which are set free into the atmosphere. Particularly, in developing countries waste incineration is of great concern because of the lack of adequate filter technology to clean the off-gas. While the 14% recycling rate is an already low share, even less is retained in the economy due to losses in sorting and reprocessing (Ellen MacArthur Foundation 2016, 26). Another challenge is that the demand for recycled plastics is small. In fact, in 2012, the volume of trade plastic waste worldwide amounted to approximately 15 million tons, which was less than 5% of the new plastic production (Dahlbo et al. 2018, 53; Velis 2014).

The incomplete and inefficient plastic waste management causes a variety of environmental problems. In fact, the pollution of plastics into the environment is one of the most pressing environmental concerns of today. Worldwide, around 5 to 13 million tonnes of plastic, which represents between 1.5% to 4% of the global plastics production leak into the oceans every year. This amount equals the inside of one rubbish truck being disposed into the ocean per minute. In a business as usual scenario the leakage will amount to the disposal of two truck loadings per minute by 2030 and four per minute by 2050. Plastic packaging constitutes a large part of this leakage due to its small size and low value (European Commission 2018a).

It was estimated that there are more than 150 million tonnes of plastic in the ocean (Ocean Conservancy 2015). Plastics represent up to 80% of global marine litter. Most of this litter (80%) comes from land-based sources, which is mainly the result of poor waste management. More than 50% of the marine plastic waste from land-based sources comes from five countries in Asia. The remaining 20% of global plastics litter arise from marine-based activities, such as shipping and fishing. The marine plastic litter accumulates on the seabed, floats on the surface or is washed up on beaches. Despite many attempts to tackle the problem, marine litter is steadily increasing (Ocean Conservancy 2015; UNEP 2005).

One of the most troubling findings concerning marine pollution is that the ocean will contain 1 tonne of plastic for every 3 tonnes of fish by 2025, and more plastics than fish (by weight) by 2050 (Ellen MacArthur Foundation 2016, 17, 29).

Plastic litter in the ocean poses a threat to wildlife. Larger plastic pieces, as for instance plastic bags, strappings and fishing gear can injure or strangle marine animals. Smaller plastic items, such as lids, cutlery and pens, may be ingested and cause harm to marine life and lead to starvation. There has been a large increase of animals, which suffered from entanglement or the indigestion of plastics (Raynaud, Richens, and Russell 2014, 17).

Especially microplastics, tiny plastic pieces that are less than 5mm in size, are of great concern, posing a threat to the environment and human and animal health. One can distinguish between primary and secondary microplastics. Primary microplastics are released into the environment in their small particle size and secondary microplastics degrade into smaller fractions when leaking into the environment (Bourguignon 2017, 4). Microplastics are used intentionally in the cosmetic industry in products, like shower gels, toothpastes and scrub creams. They frequently end up on agricultural fields, in the food system and in the oceans, as common waste water management systems cannot hold the tiny plastic pieces back (European Commission 2013, 14).

Ingestion of microplastics leads to their storage in cells and tissues of animals and poses a threat to human health when entering the food chain (Browne et al. 2011, 9175). Microplastics have been found in the air, drinking water, food items, as for instance fish, salt and honey (European Commission 2018a, 8). Furthermore, another health concern arises due that the fact that plastic resin pellets in the ocean are used as transport medium by toxic chemicals such as polychlorinated biphenyl (PCB), dichlorodiphenyldichloroethylene (DDE) and nonylphenol (NP) (Mato et al. 2001).

Another important source of microplastics are fibres from washing clothes, which end up in the sewer system. When examining wastewater from household washing machines it was found that a single garment can create more than 1,900 fibres per wash. The exact amount of the contamination of microplastics is unknown. Due to accelerating population growth and the increasing use of synthetic textiles[2], microplastic pollution will increase in the upcoming years. When inhaled by humans, microplastic fibres can be taken up by the lung tissues and cause lung cancer (Browne et al. 2011, 9175). However, further research on microfibers and their environmental and human health effects is needed.

Moreover, plastics are made from polymers combined with different additives, such as stabilisers, plasticisers and pigments. Many of those additives are endocrine disruptors or carcinogenic (European Commission 2013, 5). Besides this, plastics may consist of impurities and contaminants, which arise unintentionally. In particular the long-term effects of certain substances found in plastics are of concern. It is estimated that around 225,000 tonnes of additives are released into the sea every year, although an exact number is heavily disputed. Of the 150 million tonnes of plastics in the ocean, around

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[2] Acrylic, polyethylene, polyamide, and polyester

23 million tonnes are additives. Especially, the use of Bisphenol A (BPA) and some phthalates, which serve as plasticisers in polyvinyl chloride (PVC) have led to concerns about negative health impacts (Ellen MacArthur Foundation 2016, 29–30). A study found that excessive exposure to BPA might lead to endocrine disorders including infertility, tumours, breast and prostate cancer and various metabolic disorders. Food packaging constitutes one of the main sources of exposure to BPA (Konieczna, Rutkowska, and Rachoń 2015).

Another case demonstrating the danger of certain substances is the contamination with persistent bioaccumulative toxic pollutants (PBTs) including polychlorinated biphenols, caused by plastics waste in the Pacific Gyre (Raynaud, Richens, and Russell 2014, 18). These substances are especially harmful when released through unfiltered incineration, which is often practiced in developing countries (Ellen MacArthur Foundation 2016, 29–30).

Another environmental concern is the resource consumption of global plastic production. Plastics are made from organic materials like fossil fuels and cellulose through polymerisation or polycondensation (Bourguignon 2017, 2). In fact, more than 90% of plastics are made out of fossil fuels such as natural gas, oil or coal. Global plastic production accounts for around 6% of the total oil consumption, thereby representing the same share as the global aviation sector. The production process consumes around half of the fossil fuel feedstock and half of the oil is used as material feedstock. It is estimated that by 2050 the plastics sector will be accountable for as much as 20% of the global oil consumption. The increased production of plastics is further straining limited resources on earth (Ellen MacArthur Foundation 2016, 17). Due to decreasing oil reserves and its negative consequences on climate change, a diversification of feed stocks away from fossil fuels to bio-fuels is of utter importance. Nevertheless, the excessive use of bio-fuels would have negative consequences on food prices in developing countries and might lead to adverse effects on the environment. Furthermore, one should not underestimate the power of the global oil and chemical industry, which are in resistance to change.

Moreover, the production of plastics and frequently also the after-use use leads to the release of a vast amount of carbon dioxide (CO_2), in particular the production creates most of the emission. In 2012, around 390 million tonnes of CO_2 were produced by the production of plastics. The release of the carbon stored in plastic products is dependent on the after-use. Incineration of the plastic materials, for instance, leads to direct discharge of the carbon. When landfilled, the carbon can be considered sequestered (Ellen MacArthur Foundation 2016, 29).

This chapter underlined the problems related to the global plastic economy. The rapid growth in plastics consumption and the insufficient global waste management pose major threats to the environment as well as animal and human health. Globally, only 14% of plastic packaging is collected for recycling, 14% is incinerated and 72% is either landfilled, not collected or illegally dumped. Marine litter is mainly caused by plastic leakage into the environment and poses one of the main global environmental challenges. Moreover, microplastics, certain substances and additives used in plastic can have adverse health effects. Therefore, a rapid change in the way plastics are produced, used, treated and disposed is of utter importance.

3. The EU Action Plan for the Circular Economy

During the last decade the international community became increasingly aware of the global environmental challenges and the necessity for an improved waste management. Even though still at its early stages, the concept of Circular Economy (CE) has become increasingly popular due to an evolving understanding about the negative consequences of the current "take, make and dispose" economy. Whereas the European Union opted for a bottom up approach to implement the circular economy, China opted for a top town model (Ghisellini, Cialani, and Ulgiati 2016). Interestingly, with the Circular Economy promotion law in 2007, China was the first country to apply a CE policy (Dodick and Kauffman 2016).

In December 2015, the European Commission (EC) proposed an ambitious EU Action Plan for a Circular Economy, in which the value of products, materials and resources is kept in the economy for as long as possible and waste is minimised (European Commission 2015a, 2). With this Action Plan, the European Union attempts to take the first step in the transition from a linear towards a more circular and resource efficient economy, where plastic was defined as an area of key importance. The advantages of the circular model are enhanced environmental protection, combating climate change, innovation and enhanced security of raw material supply due to the use of waste as a resource (Bourguignon 2016). The package compromises a clear timeline for the proposed measures, which allows for a monitoring process (European Commission 2015b).

The aim of a circular economy is to close the loop at every step of the product life cycle, which should benefit the environment and the economy. This economic transition means going beyond a narrow focus on the end-of-life stage of a product and therefore does not only focus on waste management (European Commission 2015b).

In line with its environmental protection targets, the EC argues that a circular European economy would lead to a reduction of 500 million tonnes of greenhouse emission in the period between 2015 and 2035, resulting from the emission reduction from landfills and increased recycling (European Commission 2016a).

The financial backbones of the Circular Economy Package are the European Structural and Investment Funds, €5.5 billion from structural funds for waste management and €650 million from Horizon 2020. Nevertheless, substantial investments on national level and financial contributions from the private sector will be necessary for the transition to a more circular economy (European Commission 2015b).

Due to the legislative obligation to review the existing waste management targets by the end of 2012, the EC published legislative proposals to amend the Waste Framework Directive, the Landfilling Directive and the Packaging Directive (Bourguignon 2016). The proposed provisions include the following targets (European Commission 2015a, 2015c):

- A common EU target for preparing 65% of municipal waste for reuse and recycling by 2030.
- A common EU recycling target for 75% of packaging waste by 2030, including targets for different recycling materials.
- A binding target to decrease the share of landfilling of municipal waste to a maximum of 10% by 2030 and measures to discourage landfilling.
- A prohibition of landfilling separately collected waste (European Commission 2015a, 2015c)

Currently, the general recycling level in EU households is around 40% with enormous differences among member states having recycling levels between 5% and 80% (Dodick and Kauffman 2016, 8–9; European Commission 2015a). To increase recycling numbers, an amended regulation on waste shipment was adopted in 2014 combating illegal shipments (Dodick and Kauffman 2016, 9). Additionally, the Circular Economy Package highlights the importance of harmonised calculation methods measuring the achievements of the reuse and recycling rates. Furthermore, the EC acknowledged the need for high quality statistics on waste management, which is clearly lacking in many European countries (European Commission 2015a, 2015c, 2016a).

In the light of the transition towards a Circular Economy, the European Action Plan considers all phases of the lifecycle of a product, including the production, consumption, waste management and the creation of a market for secondary raw materials. Particularly the production phase is significant as it determines the effects on the environment, the resource demand and the waste generation at later stages. It is vital to develop an industrial symbiosis where the waste of one sector is used as input raw material for another industry (European Commission 2015a). The "no waste" principle is, however, limited as closing the loop is impossible due to increased resource demand and difficulties in recycling.

Furthermore, smart design choices are necessary to prolong a product's lifetime, facilitating the reuse and recycling of an item. As the lifetime of a product is frequently shortened by planned obsolescence, the EC is working on a program to detect such practices. With the Ecodesign Directive, the EC proposed to introduce new product requirements, which will facilitate the dismantling and recycling of products. Moreover, to achieve more resource efficient production processes and waste minimization, the EC will continue to endorse best practices for industrial installation and waste management by using Best Available Technique Reference Documents (BREFs) (Dodick and Kauffman 2016, 8; European Commission 2015a, 2016b).

When considering the consumption phase, consumers are often confused about labelling and the accuracy of green claims. The EC, therefore, tries to hinder unfair commercial practices and to offer more clarity on the environmental performance of a product by testing the Product Environmental Footprint. Furthermore, the EC encourages member states to apply measures resulting in the inclusion of environmental costs in the price of a product (Dodick and Kauffman 2016, 7; European Commission 2016b), which will be challenging in practice.

Complimentary to increased recycling rates, the EC stresses the importance of strengthening the market for secondary raw materials[3], thereby supporting the demand for recycled plastic. One of the barriers to a growing secondary raw material market is the uncertainty with regard to quality due to the lack of common EU-standards. The advancement of non-toxic material cycles and better identification of substances of concerns are necessary to create an enduring secondary raw materials market. A raw materials information system will support the cross border flow of raw materials (European Commission 2015a, 12). If hazardous substances get recycled into the circular economy they could enter the food stream through packaging. The promotion of a clean circular cycle is crucial for the provision of health safety and the success in the transition towards a circular economy (EU-Umweltbüro 2016, 9).

Although the Circular Economy Package includes valid suggestions and proposes a variety of future actions, the EC fails to suggest the reduction of the amount of generated waste. Clear guidelines on the reduction of consumption and consequently waste are lacking, which would be an essential step in the creation of a more circular economy. Furthermore, the Action Plan puts the focus on the importance of adhering to the waste hierarchy, a concept describing the different waste management options, which are prevention, re-use, recycling, energy recovery and disposal. However, prevention, the most favourable option in the waste hierarchy, is clearly not in the centre of the European policy. The waste hierarchy will be discussed in more detail when examining the EU Waste Framework Directive in Chapter 5.3.1.

The EC identified plastics as one of the five priority areas, next to food waste, critical raw materials, construction and demolition, biomass and bio-based products. Due to the focus of this thesis, merely the role of plastics in the Action Plan will be briefly elaborated. Although the demand for plastics in the EU is growing continuously, only 25% of collected plastics are recycled and around 60% end up in landfills in the EU. The EC stresses the challenge of marine pollution related to the plastics industry and calls for smarter collection and labelling schemes. The EC promised to prepare a strategy regarding plastics, which it delivered in January 2018 (European Commission 2015a, 13–14). The strategy will be discussed in detail in the subsequent chapter.

[3] Secondary raw materials are recycled materials that are injected back into the economy.

Although, the Action Plan represents a significant step to inspire change, it is vital to underline that the described Circular Economy Package represents only a preliminary legislative plan and legislative proposals, which are not enforced and implemented yet. The EU Circular Economy Package contains ambitious goals such as a recycling and reuse target for packaging waste of 75%. Nevertheless, it does not provide concrete recycling targets for the industrial sector. Moreover, concrete targets for reuse are missing. The apparent focus of recycling rather than prevention disagrees with the proposed order of preference suggested by the waste hierarchy. In fact, the package concentrates on recycling rather than reuse. The option of waste prevention / reduction is not stressed enough in the EC's proposal. A mere increase in recycling is insufficient, as a circular economy requires reduced consumption to achieve environmental and resource protection. A significantly reduced consumption of primary material would be necessary to bring about the necessary transition. Increased recycling does not necessarily indicate reduced resource consumption. Therefore, the focus of the Circular Economy Package might be simply put on the wrong end of the product life-cycle to achieve the necessary radical change. Furthermore, the Action Plan contains many theoretical ideas for future measures where it remains to be seen whether they can be put in practice. Although the current European Circular Economy package clearly has its shortcomings, it is definitely a step into the right direction on the road to a more sustainable Europe.

4. A European Strategy for Plastics in a Circular Economy

In 2013, the EC published a Green Paper on a European Strategy on Plastic Waste in the Environment (European Commission 2013). In 2015, when defining plastics as a key priority in the Action Plan, the EC committed itself to "prepare a strategy addressing the challenges posed by plastics throughout the value chain, taking into account their entire life-cycle" (European Commission, 2018a, p. 5). Accordingly, in January 2018, the EU Strategy for Plastics was adopted, which discusses recyclability, biodegradability, the problem of hazardous substances and marine litter. The European Parliament and the Council of the EU still need to agree on the proposed legal changes from them to become legally binding (European Commission 2018a). The main contents of the European Plastics Strategy will be elaborated in the following subchapters.

4.1 Targets of the European Plastic Policy

The EC proposed a set of ambitious measures with the special focus on plastic packaging, which constitutes around two-thirds of plastic waste. The EC aims to increase countries' shares of recycling and has set the extremely ambitious goal for all plastics packaging to be reusable and recyclable in a cost effective manner by 2030. In December 2017, the European Parliament, the EC and the Council preliminary compromised on the following targets: 65% of all packaging (not only plastics) should be recycled by 2025 and 75% by 2030. Concerning plastic packaging the European institutions agreed on a 50% recycling target by 2025 and 55% by 2030. Whereas the specific goals represent a challenge to the majority of member states, it will not suffice to reach the overall goal proposed by the EC. Currently, around 31% of plastic waste goes to landfills and 39% to incineration in the EU (European Commission, 2018a). The waste treatment on plastics packaging in the EU will be elaborated in more detail in Chapter 6. To increase resource efficiency it is vital to stop landfilling of plastic waste. Landfilling represents a loss of resources, which could be recovered by recycling or energy recovery. However, several member state do not have an adequate infrastructure for an extensive resource recovery (European Commission 2013, 8).

4.2 Circular Plastic Design

Like the Circular Economy Package, the European Plastic Strategy applies a life-cycle approach beginning with the plastics design as it influences all later stages of the life cycle. The recyclability of plastics is dependent on the design and the materials used for the production of the plastic item. Currently, plastic packaging producers have almost no incentive to consider the demands of recycling or reuse when designing their products. The challenge is that plastics are made from various polymers, which can make the recycling process more demanding. Certain designs, such as the use of very dark colours, affect recyclability negatively. Challenges in plastic recycling constitute a barrier to the success of the European plastic policy and will be examined closely in Chapter 7.1. In a smart and sustainable plastic economy, plastics need to be designed in a way that extends the lifetime and allows for reuse and a high-quality output when recycled (European Commission, 2018a, p. 9-10). Whereas there are comparatively few polymers, the number of additives in the production can be a barrier to recycling and result in down-cycling instead of product-to-product recycling, so-called "cradle-to-cradle recycling" (European Commission 2013, 13). Down-cycling takes place when the recycled material is of lower quality than the initial material.

Furthermore, information concerning the presence of certain chemicals such as flame-retardants is often missing. In regards to electrical appliances and electronic goods the EC proposed compulsory product design and marketing requirements to facilitate the dismantling and recycling process of electronic displays (European Commission, 2018a, p.11). Design choices that facilitate the recycling process are of high importance when it comes to plastics packaging, which constitutes around 60% of the post-consumer plastic waste. It has been estimated that advances in design would halve the costs for recycling packaging.Ultimately, extensive changes in packaging design will be required to achieve the ambitious goal for fully reusable and recyclable plastic packaging by 2030.

4.3 A resilient European market for recycled plastics

The fact that in EU the use of recycled plastics in new products is limited constitutes another barrier to a more circular plastics economy. Yet, recent developments such as the Chinese decision to ban the import of certain plastic waste compel Europe to develop a market for recycled plastics[4]. However, many European companies fear that recycled plastics will not fulfil their quality standards or possible buyers might be afraid that the recycled plastic is contaminated. Therefore, the EC aims to work with the European Committee for Standardisation to introduce quality standards for sorted plastic waste and recycled plastics. Furthermore, the EU together with Horizon 2020 will provide funding for research and development concerning the identification of contaminants of plastic streams and processes to decontaminate plastic waste. High food safety standards shall apply for the use of recycled plastics in food packaging. To inspire change, the EC will initiate a campaign that aims for 10 million tonnes of recycled plastics to be used for new products in the European market (European Commission, 2018a, p. 11-12).

[4] The Chinese decision and its impacts are discussed in more detail in chapter 5.2.

4.4 An improved separate collection & sorting scheme for plastic waste

In order to ensure increased recycling, an adequate infrastructure for separate collection of plastic must be provided. Public awareness and information are essential to ensure high quality separate collection. Clear indication on where to dispose what items are essential to avoid re-separation of already sorted plastics. Furthermore, sorting capacity is vital as it facilitates the reduction of contaminants in the recycling streams (European Commission, 2018a, p.12). Therefore, it is fundamental to encourage research in the waste management sector to develop more efficient separation and sorting mechanisms.

4.5 Innovation & Investment in a New Plastics Economy

It is apparent that reaching the ambitious targets of the European Plastic Strategy requires major investments in infrastructure, research and innovation. It was estimated, that to put the strategy into practice, would require between €8.4 and €16.6 billion. Consequently, the establishment of an investment and innovation framework is absolutely essential for the execution of the strategy. The Plastic Strategy presents itself as a business opportunity for enterprises operating in the European plastic sector. The EC argues that increasing the sorting and recycling capacity in Europe fourfold until 2030 will lead to the creation of 200,000 new jobs (European Commission 2018a), which constitutes a rather idealistic number.

EU funds, such as Structural Funds, the European Fund for Strategic Investment, the Circular Economy Finance Support Platform and Horizon 2020 will support the discussed efforts and guide businesses in their actions to create more recyclable plastics and member states to improve their waste management systems. From 2014 to 2020, more than €5.5 billion are invested for the improvement of waste management systems. This investment is estimated to increase the recycling capacity by 5.8 million tonnes per year. Until now, Horizon 2020 contributed €250 million to finance research and development beneficial for the implementation of the strategy. Until 2020, additional €100 million will be made available for financing the development of processes, which increase the recycling efficiency and facilitate the removal of hazardous substances and contaminants from recycled plastics (Brivio and Petsa 2018; European Commission 2018b).

While the EU can act as a leading example, the private and public must increase its financial contribution to implement the strategy. However, not only businesses need to take action and develop more sustainable business solutions transforming the plastics value chain, but also governments must invest in better separate collection systems. Innovative inventions and solutions in sorting, chemical recycling and advanced polymer design are vital to achieve progress in the recycling industry. New technologies are of key importance because they can facilitate sorting and traceability of material, as for instance, digital watermarking. More research and innovation concerning the prevention of the release of microplastics, the human health effects and alternative feed stocks such as bio-based plastics is required to build a more circular plastics economy (European Commission, 2018a, p. 15-16).

4.6 Limiting plastic waste and littering

Littering and leakage of plastic waste into the environment leads to economic and ecological destruction, negatively impacting the tourism sector, fisheries, the food chain and consequently human health. Therefore, the plastic waste and its leakage must be reduced. With this intention, the EC aims to improve the access to tap water in Europe by revising the Drinking Water Directive. In this way the generation of tonnes of plastic bottles could be reduced substantially (European Commission, 2018a, p. 13).

Moreover, the European Plastic Strategy puts a special focus on single-use plastics, as they constitute a major source of plastic leakage into the environment. Single-use plastics are discarded after a one-time use, are usually not recycled and frequently end up being littered into the environment. As the fast food and take-away culture is on the rise, the use of single-use plastics is increasing and therefore becoming a more pressing environmental issue (European Commission, 2018a, p. 13). Another challenge is that cheap plastics products such as gadgets, toys and fun articles can be purchased at very low prices, which neither reflect their full environmental costs nor the costs of waste management (European Commission 2013, 15).

Single-use plastics constitute approximately half of all marine litter. Therefore, the EC promised a legislative initiative on single-use plastics and over-packaging in order to decrease the amount of plastics ending up in the oceans (European Commission 2018b). Some countries have already taken action concerning the reduction of single-use plastics and encountered legal and political barriers. For instance, France’s ban on disposable plastic plates and cutlery might constitute an infringement to the principle of free movement of goods, which is one of the main pillars of European Union law. A similar case can be observed in Scotland after the government announced to ban plastic straws by the end of 2019 (Dickinson 2018).

In the end of May 2018, the European Commission has indeed proposed new rules to reduce marine litter, which address fishing gear and the 10 single-use plastic products that constitute 70% of the marine litter in Europe. Specific measures for the distinctive plastic items were proposed. If affordable alternatives are available on the market, the product will be banned. The ban should apply for “plastic cotton buds, cutlery, plates, straws, drink stirrers and sticks for balloons” (European Commission 2018c). In case there are no “straight-forward” alternatives to the product, national consumption shall be reduced. For “sanitary towels, wet wipes and balloons” will need to be labelled concerning their disposal, their harmful environmental impacts and their plastics content. Moreover, the producers of “food containers, packets and wrappers, drink containers and cups, cigarette buts, wet wipes, balloons and lightweight plastic bags” will be involved in covering the costs of waste management, clean-up and awareness raising measures. In fact, member states will have to undertake awareness raising campaigns about the adverse effects of single-use plastics, fishing gear and the available waste management options. Furthermore, member states will have the obligation to collect 90% of single-use plastic drink bottles by 2025. The proposed rules also include reduction targets for member states in regards to food containers and drink cups. Additionally, new rules on fishing gear have been proposed as those items account for 27% of all beach litter (European Commission 2018c).

However, the described rules currently only constitute a legal proposal and will need to be adopted by the European Parliament and the Council. These institutions are urged to deliver results before the elections for the European Parliament in May 2019 (European Commission 2018c).

The proposed rules are a historic step in regards to the protection of the environment and particularly in the fight against marine pollution. The EC’s proposal is extremely ambitious and portrays an excellent example of waste prevention measures, which is the most favourable option of the waste hierarchy of the European Union. The new rules will, however, face considerably resistance by single-use plastic producers and legal barriers in regards to European law. Furthermore, the practical implementation of the rules will be rather challenging in practice.

4.7 Microplastics

The Plastics Strategy puts a special focus on microplastics, which are plastic particles smaller than 5 mm. As discussed before, microplastics are either used intentionally added in products such as cosmetics, paints or detergents or created through the breakdown of larger plastic pieces and through the abrasion of products such as textiles. Various countries have already taken action to restrict the use of intentionally used microplastics. Therefore, bans are currently discussed in certain member states. The EC started to restrict the amount of intentionally added microplastics through the Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation (REACH) and requested the European Chemical Agency to review the scientific basis for further action. Furthermore, the EC currently discusses policies concerning unintentionally created microplastics such as labelling, design requirements and promotes financing research and innovation to guarantee the protection of human health (European Commission, 2018a, p. 14-15).

4.8 Biodegradable, compostable & bio-based plastics: Alternatives to conventional plastics?

In response to the plastics problem, alternatives such as biodegradable and compostable plastics have been introduced as possible solutions to over-loaded landfills, littering and resource scarcity. Although biodegradable plastics still occupy a relatively small market share, they are frequently perceived as an answer to the plastics problem (Ren 2003). The challenges and opportunities concerning the use of biodegradable plastic will be discussed in the following section.

First of all, it is vital to note that biodegradable plastics are not suitable for material recycling. The challenge is that if biodegradable plastic waste is mixed with conventional plastics it may degrade the quality of the recycling stream, rendering recycling more difficult. So far waste management systems did not provide an adequate separation infrastructure for biodegradable plastics, as this requires costly technical adaptation. Therefore, biodegradable plastics require clear labelling with information for the consumer in order to guarantee proper sorting. Furthermore, an adequate collection infrastructure is lacking needed to ensure effective separation (European Commission 2013, 17; Ren 2003, 28).

Currently many plastics labelled "biodegradable" degrade only under certain conditions, which are provided in industrial composters. Composting is therefore the most efficient waste treatment in regards to biodegradable plastics. Landfilling is not a suitable option for biodegradable plastic due to its high content of carbon and hydrogen. When disposed in landfills, biodegradable plastics can intensify the contamination of ground and surface water. In line with this problem, the European Landfill Directive points out that member states need to take action to decrease biodegradable waste in landfills (European Commission 2018a, 14; Ren 2003, 28–30).

Furthermore, the term "biodegradable" is misleading as it might lead to the understanding that those plastic items degrade quickly when introduced into the natural environment. In fact, biodegradable plastics can take decades to degrade, particularly in marine environment (European Commission 2018b). The vast part of biodegradable plastics only degrades under certain conditions, namely a constant humidity and constantly high temperatures, which are provided in industrial composting plants and not at home. Therefore, the labels should clearly state whether the products can be only composted industrially or in a natural environment. Correspondingly, further research on the impacts of biodegradable plastics on the environment and on compost toxicity is required (European Commission 2013, 16–17).

A large part of biodegradable plastics is gained from renewable sources. These plastics are called bio-based plastics and are usually made of starch retrieved from rice, sugar can, potatoes or maize. However, biodegradable plastics can also be made from petroleum or a mixture between bio-based sources and petroleum. Moreover, the terms biodegradable and bio-based plastics should not be used as substitutes as some types of bio-based plastics are not biodegradable, such as polyethylene (PE) from bio-ethanol. Furthermore, a global plastic production with merely bio-based plastic would lead to a vast increase in the production of crops, which would negatively impact biodiversity and raw material prices and result in deforestation. The use of agricultural waste or by-products might represent a solution to these problems (European Commission 2013, 17–18). Nevertheless, a detailed discussion of this issue is outside the scope of this thesis.

Under the given circumstances, the use of alternative materials complicates the waste management system and requires an appropriate infrastructure and consumer information (Hopewell, Dvorak, and Kosior 2009a, 2119).

In short, it is currently not feasible to substitute biodegradable plastic for conventional plastic due to insufficient labelling, research and waste management infrastructure. Biodegradable plastics might be a solution to the plastics problem, although only if separate collection and treatment can be guaranteed.

4.9 Extended Producer Responsibility

Extended Producer Responsibility (EPR) is an essential concept in waste management facilitating the recycling process, which is strongly encouraged by the EC. EPR describes a principle where the manufacturer of the product carries the financial and organisational responsibility of the post-consumer stage of a product's life cycle, in regards to waste collection, return and recycling. The concept was introduced in Europe in the early 1990s and has inspired around 400 EPR schemes around the world. EPR serves as an incentive to adapt more sustainable product designs while becoming more resource efficient. Furthermore, the scheme supports efficient collection, treatment and better reuse and recycling. Additionally, the scheme provides a way to include the private sector in funding. In line with the polluter pays principle, the EPR principle contributes towards reducing the negative environmental externalities of a product. The principle follows the logic that producers are most eligible in reducing the negative impacts of their products, achieving a more efficient collection and source separation (Bourguignon 2016, 5).

There are different forms of EPR schemes, including mandatory and voluntary options in Europe. Implementation can vary between take-back requirements and market-based deposit refund systems. Furthermore, individual and collective EPR schemes or fixed fee Producer Responsibility Organisations (PROs) exist. Individual EPRs are usually more efficient as they are a stronger incentive for alternations in design choices (Watkins et al. 2017, 4). The design of a successful EPR scheme is, however, challenging and requires a mature legal and market system (Ren 2003, 37).

In its plastics strategy, the EC calls for a harmonisation of the rules on the use of EPR, trying to maximise its impact. EPR schemes can make financial contributions cutting the amount of plastic litter. Countries with high recycling rates frequently finance the collection and treatment through financial contributions made by producers (European Commission 2018a, 10). Therefore, EPR facilitates the achievements of stringent recycling targets, making the recycling process more efficient and transparent.

4.10 Summary & Conclusions

The EC adopted the European Plastics Strategy in January 2018, serving as a tool enabling the transition towards a circular plastics economy. The EC introduced the ambitious goal of making all plastic packaging reusable or recyclable by 2030. To achieve this target a variety of issues were discussed, such as more circular design options, substitution possibilities for conventional plastics, the importance of EPR schemes as well as the need for improved separate collecting, innovation and investment. Furthermore, it was found that the low demand for recycled plastics constitutes an obstacle to a more sustainable plastic economy. Therefore, various measures will be implemented to strengthen the market for secondary plastic. The EC's proposal to ban/reduce single-use plastic constitutes an extremely positive example of a waste prevention measure, but will, however, face legal and political difficulties concerning its implementation.

The EC does not only desire to change the European approach towards plastics, but also inspires change across the world. Good waste management practices need to be spread across the globe, improving scientific knowledge and increasing environmental consciousness, especially in developing countries. Thereby, public awareness plays a key role in the reduction of waste and littering.

5. The legal and political context concerning plastic in Europe

Although having made significant progress in waste management in recent years, the EU has a long way to go towards a more circular economy. Differences in waste management among member states are enormous: Whereas less than 3% of the municipal waste was landfilled in six member states, over 50%, or even more than 90% was landfilled in certain member states (European Commission 2015c).

To fully comprehend the plastic situation in the EU, Chapter 5 will briefly highlight the importance of the European plastics sector and discuss China's political decision to ban certain plastic imports and its implications for Europe. Furthermore, the current European legal framework on plastics will be analysed, while discussing the proposed amendments to it.

5.1 Plastics sector in the European Union

As the plastics industry faces a substantial challenge due to the European Plastics Strategy, selected facts on the European plastics sector for the EU28 member states will be provided in this subchapter.

The European Plastics industry is composed of plastics producers, converters, recyclers and plastics machinery manufacturing companies. In fact, around 1.5 million people are employed in the plastics industry in the EU, which is comprised of roughly 60,000 companies. In 2016, the European plastics sector had a turnover of almost 350 billion euros. Moreover, plastics raw material producers and plastics converters had a trade balance of around 15 billion euros. In 2016, around 8.4 million tonnes were collected for recycling in the EU (Plastics Europe 2018, 12–13). This number refers to the recycled plastics, which was treated inside or outside the EU, where uncertainty remains over the treatment.

The European plastics production, including EU28, Norway and Switzerland, increased from 58 million tonnes in 2015 to 60 million tonnes (Mt) in 2016. Europe is still a net-exporter when it comes to plastics, having a positive trade balance of approximately 15 billion euros in 2016 (Plastics Europe 2018, 16–18). Even though the EU's plastics production has been constant, its global share has been decreasing due to increasing competition from abroad (Bourguignon 2017, 2). A major part of the global plastic production has shifted to Asia, where more than 40% of the total plastics are produced. This shift towards Asia is driven by lower costs with regard to labour, health, the environment and safety. Furthermore, the local (Asian) demand has increased substantially (Velis 2014, 4). China is the major producer of plastic occupying 27% of the global production, followed by Europe with an 18% share (Plastics Europe 2018, 18). The most important trading partners in regards to European exports are Turkey, China and the United States (US). When it comes to imports, the US, Saudi Arabia and South Korea were Europe's main trading partners in 2015 (Plastics Europe 2018).

The European plastic industry faces many challenges due to increased competition from aboard. Therefore, the European plastic sector needs to adapt strategically if its competitiveness should be maintained in the long run. When taking steps to become more environmentally friendly and increasing the recyclability of the plastic items, the industry could make a vital contribution in the transition towards a more circular plastics economy. Nevertheless, one needs to take into account a fully functioning circular economy is not in the interest of the plastic sector and the oil and chemical industry, as this would lead to a reduction in virgin plastics demand. Also, the influence of industry lobbying in Brussels on law making processes should not be underestimated.

5.2 European Exports of Plastics to China

This subchapter discusses the key role of China in the global plastics economy, its recent ban to import certain types of plastics and its implications for Europe.

In 2012, around 15 million tonnes of plastics were traded around the globe. China imported around 56% of the global waste plastics. Furthermore, around half of the plastic waste collected in the EU is shipped abroad. Europe is highly dependent on China when it comes to plastic waste management as more than 87% of the exported plastic waste went to China, where lower environmental standards apply. From 2006 to 2012, Chinese imports of foreign plastic waste grew from 5.9 Mt to 8.9 Mt amounting to an increase of around 66%. It is often the case that in China, small manufacturers apply uncontrolled low-tech practices involving polluting methods to treat the plastic waste (Velis 2014, 4–5).

European exports of plastic waste increased exponentially during the past decades. Most of the importing countries are located in Asia, which were willing in to pay high prices for plastic imports (European Commission 2013, 8). Only Germany exported around 500,000 tonnes of plastic to China every year (Asendorpf et al. 2018).

Due to the increasing inflow of foreign low quality plastic waste, the Chinese government has been trying to increase the quality of imported waste in recent years. An example of such efforts was the “Green Fence Operation” in 2013, when Chinese customs undertook strict inspections of the import of waste-derived secondary raw materials (Velis 2014, 46).

In the end of 2017, the Chinese government presented its decision to ban the import of certain types of plastic waste, which went into force on January 1st 2018. The ban covers imports of 24 kinds of solid waste, comprising unsorted paper and low-grade PET, which is used in plastic bottles. The reason for the ban was that the imported waste frequently included a high level of contamination and was of poor-quality. Therefore, China introduced a maximum level of contamination of 0.5%. Until now China recycled approximately half of the world's plastic and paper products. So far, plastic waste was pressed into bales and exported to China, where it was manually separated. In 2016, China imported and processed around 8 million tonnes of waste. The manual labour results in a level of precision of separation recycling machines could not achieve. However, the batches frequently contained hazardous materials, as for example medical waste, which presented a danger to workers (Balke 2018; Freytas-Tamura 2018).

China's change in policy shocked plastic exporters and is clearly one of the reasons for the current developments in regards to European plastics policy. However, China's decision will most likely lead to a shift of the waste destination to less developed Asian countries, such as Indonesia, India, Malaysia and Vietnam. This development would constitute a relocation of the problem away from China to other countries with less developed recycling industries and lead to a rising informal recycling sector, thereby, creating increasing environmental and social harm (Balke 2018; Freytas-Tamura 2018).

The European Commission presents the Chinese policy development as an opportunity for the European recycling sector. Nevertheless, many countries such as the United Kingdom (UK) encounter difficulties with China's decision, resulting in accumulating piles of waste with no final destination. As a response to China's decision, the British Prime Minister, Theresa May, announced the goal to eliminate avoidable wastes within 25 years, spreading the idea of plastic-free aisles in supermarkets. The danger of the crisis is that countries might introduce measures such as landfilling, equally harming the environment (Freytas-Tamura 2018).

The best option for the environment would be to recycle the plastic waste in Europe due to the presence of stricter environmental protection laws than in Asia. If waste is exported to developing countries in Asia, frequently uncertainty over its treatment remains. However, it is most likely that the result would be unprofessional landfilling or unfiltered incineration in those countries.

In summary, the EU Plastic Strategy was clearly a response to China’s recent decision to restrict imports of certain types of plastic waste ((European Commission 2018a, 8,16; Velis 2014). Therefore the EU is trying to phase out the export of poorly sorted plastic waste and improve its own recycling infrastructure. Yet, it is most likely that other less developed Asian countries will be willing to serve as the dumpsite of the West, worsening environmental impacts, which represents another alarming form of globalisation.

5.3 European legal framework on plastics

In order to comprehend the plastics situation in Europe and the current policy proposals, it is vital to analyse the existing legal framework on waste management. The following subchapters will briefly elaborate on the most relevant legislations with regard to plastic and plastic waste. Therefore, the Waste Framework Directive, the Landfill Directive, the REACH Regulation and the Packaging and Packaging Waste Directive will be discussed.

5.3.1 Waste Framework Directive (Directive 2008/98/EC)

The Waste Framework Directive provides a common legislative basis for waste treatment in the EU, which entered into force in 2008. The directive contains definitions of waste, recycling and recovery. The most important provisions are the polluter pays principle and the extended producer responsibility as was discussed in more detail in Chapter 4.9.

Furthermore, the Framework Directive contains two binding targets, namely that 50% of household waste need to be prepared for reuse or recycling by 2020 and a 70% target concerning the preparation for re-use, recycling and other recovery of construction and demolition waste (European Commission 2016c). The evolution towards achieving this goal has been uneven among member states. The directive obliges member states to construct waste management plans and waste prevention programs.

Furthermore the Directive highlights the waste hierarchy, which is a preferred order of waste management options as displayed in Figure 2 below (Bourguignon 2016; European Commission 2016c).

Figure 2: The Waste Hierarchy of the European Union. Data: European Commission, 2016, b.

Plastic waste can be treated in various ways. The four **Rs** are the most preferred options, with decreasing desirability, namely **R**educe, **R**euse, **R**ecycle and **R**ecover. In the recycling process the recovered material is used to create a new product, with the aim of extending the product’s lifetime and conserving resources. The reuse and recycling options are forms of material recovery. The difficulty is that it is not economically feasible to recycle all plastic items. Furthermore, most recycled products are recycled into lower grade applications (Hopewell, Dvorak, and Kosior 2009a, 2116–17; Morris 1996; Ren 2003, 29).

Another option of plastic waste treatment is energy recovery, when using the material as a fuel to generate energy. While incineration reduces the volume and therefore the mass to be landfilled substantially, it involves high capital costs and can lead to the emission of hazardous substances, such as dioxins. Although energy recovery constitutes a more environmentally friendly option than landfilling, it requires strict operation and does not decrease the demand for new virgin plastics. Yet, energy recovery might be the preferred option for highly mixed plastics, which are difficult to recycle. The amount of recovered energy varies depending on its application (electricity generation, combined heat and power, etc.). Generally speaking, recycling saves more energy than generated by recovery, taking into account the energy necessary for collection, transport and processing the plastic. Landfilling is a waste management strategy, which should be avoided since it follows a linear rather than cyclic approach. Furthermore, landfilling involves high environmental costs especially in terms of leachate and gas emissions. Nevertheless, increased landfilling is hampered by the fact that suitable landfill sites are becoming more and more limited. Yet, many developing countries still chose landfilling as their waste management strategy, as they serve as a final disposal of waste and are relatively easy to build and operate (Hopewell, Dvorak, and Kosior 2009a, 2116–17; Morris 1996; Ren 2003, 29).

5.3.2 Landfill Directive (Directive 99/31/EC)

Globally speaking, landfilling is the most used option when dealing with waste (Hopewell, Dvorak, and Kosior 2009a, 2117). In the EU, almost half of all plastic waste is landfilled, while the majority is packaging. This practice can be explained by lacking infrastructure for collection and recycling and missing alternatives (European Commission 2013, 10).

The current landfill practice differs considerably among member states. Certain countries have landfill rates below 5% such as Austria, Belgium, Denmark, Germany, the Netherlands and Sweden. The latter countries reported a plastic waste recovery rate (including recycling) between 80 and 100% (European Commission 2013, 10), thereby landfilling only a insignificant portion.

The Landfill Directive aims to prevent or reduce negative impacts on the environment, especially on water, soil and air, and on human health. Therefore, waste needs to be treated before being landfilled (DG Environment 2016). According to the waste hierarchy, landfilling is the least preferable option. Nevertheless, recycling is not appropriate for all plastic waste. Therefore, recovery is a suitable second option in waste management. There are, however, "no technical reasons" to landfill plastic. The reality shows that landfilling fees/taxes are usually very low, which discourages the development of environmentally friendlier options such as recycling. In the EU phasing out of landfilling is already applied to bio waste and a ban has been introduced for used tyres, liquid waste, hospital and clinical waste and explosives (DG Environment 2016; European Commission 2013, 10). However, it needs to be underlined that there exists a contradiction between legal requirements and the current waste management practice in reality (European Commission 2013, 6–7). So far, no EU wide landfill ban for plastics waste has been introduced. Nevertheless, the majority of EU member states has already introduced national measures such as landfill bans or landfill taxes. Ten member states, namely Bulgaria, Cyprus, the Czech Republic, Greece, Spain, Ireland, Italy, Latvia, Malta and Portugal have currently no landfill ban in addition to the bans included in the Landfill Directive. The landfill taxes vary between 3€/t in Lithuania and 100€/t in

Belgium, thereby having highly different impacts on waste management practices (CEWEP 2017).

The EC sees landfill bans an efficient measure to "close the loop". In fact, the Circular Economy Package includes the goal to prohibit landfilling recyclable waste such as plastics, glass, paper, metal and biodegradable waste (Martin 2014). In 2014, the EC adopted a legislative proposal with the objective to phase out landfilling by 2025 for recyclable waste, namely plastics, paper, metals, glass and organic waste by limiting landfilling of those materials to a maximum 25%. Furthermore, the Circular Economy Package includes the proposal for a binding landfill target of maximum 10% for municipal waste by 2030 and a ban of landfilling separately collected waste (DG Environment 2016). Until now, these measures are mere proposals, which are not legally binding. It remains to be seen whether a Europe wide landfill ban will be implemented.

In a policy paper on landfilling, Zero Waste Europe criticises the application of landfill bans to achieve higher recycling rates, while underlining the importance of waste elimination in a circular economy. Accordingly, the danger exists that landfill bans promote waste-to-energy (WtE) incineration creating a "lock-in" effect. This effect describes the preference for incineration to ensure pay-back. In that sense, a landfill ban would not encourage reuse and material recovery (Zero Waste Europe 2017). Furthermore, if not managed properly, incineration releases hazardous substances into the air, such as polychlorinated biphenyls and furans (Hopewell, Dvorak, and Kosior 2009b, 2117).

The policy paper shows that in all seven analysed countries with landfill bans, the introduction of this policy has led to an increased share of waste incineration, which was higher than the growth in recycling. As shown in Figure 3 below, in Denmark waste incineration practices lead to higher amounts of waste generation. In the Netherlands and Germany waste incineration increased almost twice and three times more than recycling. In some cases, like Austria and Norway, the landfill ban led to reduced recycling. Frequently the incineration plants face an overcapacity resulting in less separate collection and lower recycling rates, which goes against the principle of a circular economy (Zero Waste Europe 2017).

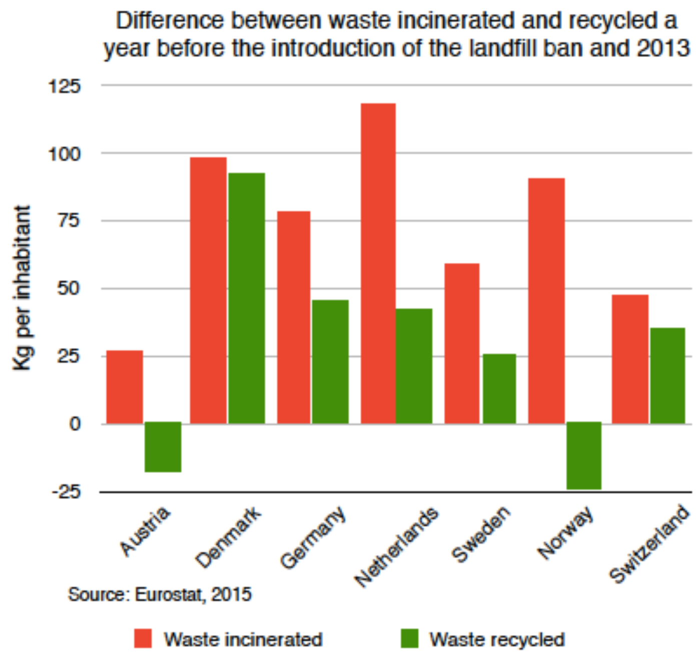

Figure 3: Difference between waste incineration and recycling a year before the introduction of the landfill ban and 2013. Data: Zero Waste Europe, 2017.

In sum, the overall policy aim of the EU is to discourage landfilling. Even though landfilling is the least desirable option in regards to waste management, a landfill ban might not be the ideal option to implement a circular economy as it frequently leads to an increase of waste incineration rather than higher recycling and reuse rates. Once a waste incineration plant with a high capacity is installed, separate collection schemes are likely to be disregarded and waste reduction will not be on the policy agenda, since a certain capacity is needed to reach the plant's economic efficiency.

5.3.3 REACH Regulation (1907/2006/EC)

The regulation on the registration, evaluation, authorisation and restriction of chemicals (REACH) provides a framework on chemicals and their authorisation in the EU, which went into force in 2007. REACH includes the classification of certain substances as hazardous, their prohibition and their substitution with safer ones. In particular cases it authorises the certain applications of certain banned substances. The regulation obliges manufactures and importers introducing substances into the EU to register their chemical substances. REACH also includes provisions with the aim of facilitating the recycling of materials. Even though polymers are not covered by REACH, the regulation is critical for plastics recycling (Bourguignon 2017, 5; Quadrant 2017). As the regulation applies to certain additives used in the plastic production, it influences the recycling process. REACH identifies additives found in plastics that cannot be used in new products and therefore can hinder the recycling of plastics. The regulation helps to reduce harms and contributes to the safety of recycled materials by substituting harmful plastic additives (European Commission 2013, 7). Due to a more extensive focus on substances in European environmental policy making, it is likely that the REACH regulation will become increasingly important, especially in regards to the circular economy concept.

5.3.4 Packaging and Packaging Waste Directive (Directive 94/62/EC)

The Packaging and Packaging Waste Directive implemented specific recycling targets for packaging materials, such as glass, paper, metals, wood and plastics. For plastic packaging it sets out a target of 22.5% by weight "counting exclusively material that is recycled back into plastics" (Directive 94/62/EC 1994). The due years to comply with the targets vary among countries, ranging between 2008 and 2015. In fact, most Western European countries had to comply with the 22.5% by 2008. Contrarily most Eastern European member states were granted longer time periods to comply with the goal, as their recycling infrastructure was less developed than in Western European states. Latvia, for instance, was granted the longest time, until the end of 2015 to reach the recycling rates for packaging (Eurostat 2015).

The Circular Economy Package aims to increase the current target on packaging recycling substantially. In 2015, as part of the Action Plan for a Circular Economy, the EC adopted a proposal for an amendment of the current Packaging Waste Directive. As previously discussed, the EC proposed a common EU target of 75% for packaging waste by 2030. Plastic makes up around 19% of the total packaging waste, while the majority of packaging waste is paper and cardboard (41%) (Eurostat 2018a).

The proposal for the amendment of the packaging directive includes the aim to prepare a minimum of 65% of (general) packaging waste for reuse and recycling by the end of 2025. More specifically, the proposal suggests the minimum target of 55% by weight for the preparing for reuse and recycling for plastics packaging by the end of 2025. The specific targets for ferrous metal, aluminium, glass and paper are 75% each (European Commission 2015c, 11). In fact, plastic has the lowest target when compared to the other recyclables. Until 2030, the proposal suggests a minimum target for preparation for reuse and recycling of 75% for all packaging waste. There is no specific target stated for plastics packaging until 2030, unlike for other materials. For 2030 the targets are 85% for ferrous metal, aluminium, and paper respectively and 75% for wood (European Commission, 2015c).

The reason for the missing specific target for plastic for 2030 is explained in the preamble of the proposal stating that the EC might suggest revised targets for 2030 taking into account the member states progress, the evolution of new recycling technology and the demand for recycled plastics (European Commission, 2015c).

Interestingly, the amendment suggests that, if packaging waste is exported, it can only count towards the attainment of the target if it can be proven that the treatment abroad is equivalent to the requirements of the EU legislation (European Commission 2015c, 11). This condition points towards increased environmental protection efforts and tries to combat illegal dumping in less developed countries.

Furthermore, the EC proposes an early warning system to combat implementation difficulties, exerted with the European Environmental Agency. The proposal highlights the importance of statistical data on waste management of member states to review the fulfilment of the targets. To increase the quality of the statistical data, a single entry point for all waste data should be introduced (European Commission 2015c). Without these advances in data collection, statistics and common definitions the proposed targets will remain without real consequences on current waste management practices.

Additionally, the Commission promised to provide detailed rules for calculating whether the preparation for re-use and recycling targets are achieved. It is outlined that the reporting on the recycling targets must be based on the input waste entering the final recycling process. The suggested definition refers to the "weight of packaging that has been recovered or collected by a recognised preparation for reuse operator" and does not require additional sorting and pre-processing. The weight should be counted as the weight of the packaging waste recycled, if "such output waste is sent into a final recycling process". However, according to the proposal member states are also permitted to report the targets based on the output of sorting facilities (European

Commission 2015c, 8–12), which can again cause confusion. Common definitions are therefore essential for the achievement of the targets set out in the legal proposals.

5.3.4 Plastic Bag Directive (Directive 2015/720): Serving as a good example

In 2015, the Packaging Directive was amended in regards to reducing the consumption of lightweight plastic carrier bags with the adoption of the Directive 2015/720. The Plastic Bag Directive puts its focus on waste prevention and is therefore an excellent example for a strict adherence to the priority order of the waste hierarchy.

In 2010, 95.5 billion plastic bags were put on the EU market, which amounts to 1.42 Mt of plastic. The vast majority of those bags were intended for a single use (European Commission 2013, 15). Plastic bags are emblematic of modern consumerism and represent a huge burden to the environment. Due to their light weight, plastic bags are especially prone to littering. In countries where the majority of waste is landfilled, plastic bags are frequently blown away and end up in the ocean (The Ecological Council 2017).

The Plastic Bag Directive has already brought about a significant decrease of the use of plastic bags. The directive obliges member states to charge plastic bags or to take other measures that lead to a reduction by 50% by 2017 and 80% by 2019 when compared to the 2010 levels. Other "equally effective measures" may include pricing, taxes and levies (Directive 2015/720 2015). The directive stresses the importance of environmental awareness and obliges member states to inform their population about the negative environmental impacts of the excessive use of plastic bags. The directive aims to reduce the amount of plastic bags to a maximum of 90 lightweight plastic bags per person per year by the end of 2019 and further decrease the quantity to 40 bags by the end of 2025 (The Ecological Council 2017).

The consumption of plastic bags varies immensely among member states, depending on consumption behaviour, environmental awareness and the effectiveness of introduced policies. One the one hand, due to domestic measures Ireland has managed to reduce the consumption of plastic bags by 95% to 18 bags per person in 2017. One the other hand, in Bulgaria 421 plastic bags were consumed in 2010. Countries have chosen different measures to combat the problem, such as mandatory charges, the ban of non-biodegradable plastics or agreements with the retail sector (DG Environment 2017; Directive 2015/720 2015).

Interestingly, globally speaking 40 countries have introduced plastic bag bans or taxes. For instance, the small East African state Rwanda has introduced a plastic ban in 2008 and is currently considering becoming totally plastic free (Asendorpf et al. 2018).

The Plastic Bag Directive serves as a positive example on how legislative action can decrease the generation of plastic. It seems rather likely that this initiative will be followed by similar legal obligations, such as the single-use plastic policy proposal discussed previously.

6. Plastic & Plastic Packaging Waste Treatment in the EU

This chapter is firstly going to provide an insight into the waste treatment of all plastics and then focuses on plastics packaging in the EU. Consequently, recycling rates of European member states of plastic packaging will be compared using a variety of sources to create a more objective picture. After having gained a general overview of the plastic waste management in the EU, five European countries will be analysed in more detail. Austria, Finland, Spain, Germany and the Netherlands were selected as case studies to comprehend the complexity of national plastic packaging recycling systems. After analysing each country individually, a critical comparison will be made.

6.1 Plastic Waste Treatment in the EU

In 2016, 27.1 Mt of plastic waste were collected for further treatment in the EU28, Norway and Switzerland. According to Plastics Europe (2017), plastic (not only packaging) post-consumer waste was treated in the following way:

- 41.6% Energy recovery
- 31.1% Recycling
- 27.3% Landfill

Around 63% of plastic was recycled inside the EU and the remaining 37% outside the EU. In Europe, it was never the case before 2016 that more plastics were recycled than landfilled. In 2006, the landfill rate for plastics in Europe was still 52%. Therefore, significant progress in diverting plastics away from landfilling has been made. In fact, between 2006 and 2016 plastic recycling grew by almost 80%, whereas energy recovery increased by 61% and landfilling declined by 43%. Furthermore, the total plastic waste collected increased from 24.5 Mt in 2006 to 27.1 Mt in 2016 (Plastics Europe 2011, 10, 2018, 30).

Nevertheless, plastic waste management with regard to landfilling practices varies extremely across Europe. In fact in 2016, eight member states landfilled less than a 10% share of their post-consumer plastic waste, namely Austria, Germany, the Netherlands, Luxemburg, Belgium, Denmark, Sweden and Finland. It is noteworthy that in all of these central and Northern European countries legal restrictions on landfilling exist (Plastics Europe, 2018b, p. 32; Bourguignon, 2017). Therefore, Plastics Europe argues that landfill bans promote higher recycling rates. Nevertheless, as was pointed out before, landfill bans also foster increased incineration, possibly leading to a lock-in effect. Furthermore, the United Kingdom, Ireland, Estonia and Slovenia deposited up to 30% of plastic waste in landfills. Portugal, Spain, France, Italy and certain Eastern member states, namely Lithuania, Poland, the Czech Republic and Slovakia, landfilled up to 50% of their post-consumer plastic waste. The rest of the Eastern European member states, namely Latvia, Hungary, Croatia, Romania, Bulgaria, and Greece landfilled more than 50% of their plastic waste (Plastics Europe 2018).

Reuse and recycling rates for plastic waste are rather low when compared with materials such as paper, metal or glass, which can be explained by the inherent complexity of plastic. In 2015, the recycling rate of glass amounted to 73% in the EU-28, whereas the recycling rate for plastic waste was roughly 31%. The European Commission aims for similar rates for plastic packaging as for other packaging materials in the future (European Commission 2018a, 6–9; FEVE 2015).

6.2 Plastic Packaging Waste in the EU

As shown below in Figure 4, in the EU, Norway and Switzerland the main sectors, which covered the demand of plastics in 2016, were: 39.9% packaging, 19.7% building & construction, 10% automotive, 6.2% electrical and electronic, 4.2% household, leisure & sports, 3.3% agriculture and 16.7% others, such as furniture and medical appliances (Plastics Europe 2018, 22).

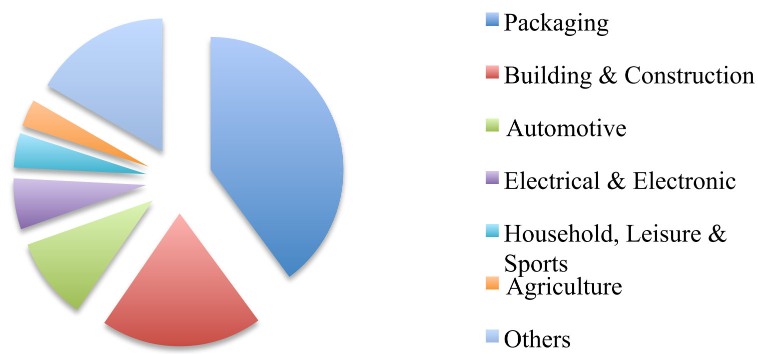

Figure 4: Plastic demand according to market sectors in the EU, Norway and Switzerland. Data: Plastic Europe, 2018b, p.22.

The amount of packaging waste generated in the EU-28 in 2015 amounted to 59% of all plastic waste, as displayed below in Figure 5 (European Commission 2018a; Statista 2018).

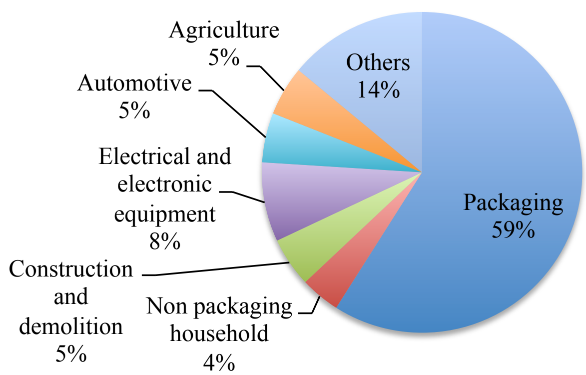

Figure 5: Plastic waste generation according to sector. Data: Statista, 2018.

Thus, as plastic packaging undoubtedly makes up the largest part of the plastic demand and plastic waste in Europe, it will be the focus of a deeper analysis.

In the EU28, 15,888,042 tonnes of plastic packaging waste were produced in 2015. Around 167 kg general packaging waste was generated per capita with huge variations among member states, reaching from 51kg in Croatia to 222kg in Germany. Around 31kg plastic packaging were produced per capita as a EU average in 2015. In 2006, comparably, plastic packaging waste amounted to 29.9kg and has therefore slightly increased during the past decade (Eurostat 2018a).

As shown below in Figure 6, 16.7 Mt of plastic packaging waste was collected for treatment in Europe (EU28, Norway and Switzerland) in 2016. 40.9% were recycled, 38.6% were energy recovered and 20.3% were landfilled. Recycling of plastic packaging increased from 39.5% in 2014 to 40.9% in 2016 (Plastics Europe 2018).

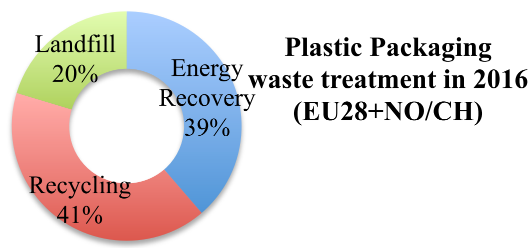

Figure 6: Plastic Packaging waste treatment in the EU, Norway and Switzerland, in 2016. Data: Plastics Europe, 2018, p.34.

Thus, a total recovery rate of around 80% of the total plastic packaging waste could be achieved in 2016. It is remarkable that recycling rates are higher than landfill and energy recovery rates (Packaging Europe 2018). 3.4 million tonnes were landfilled in Europe. Plastic packaging has the highest recycling and recovery rate among other plastic uses in Europe (Plastics Europe 2014, 29). When comparing the waste management of plastic in general with that of plastic packaging one can notice that plastic packaging receives the environmentally friendlier treatment, as illustrated below in Table 1. Plastic Packaging waste treatment shows a higher recycling rate, a lower share of energy recovery and landfilling. This can be explained due to the fact that recycling of plastics packaging is easier than other plastic applications due to less or no additives used.

Table 1: Comparison of general plastic and plastic packaging waste treatment in Europe in 2016. Data: Plastic Europe, 2018.

	Plastic Waste Treatment in Europe	Plastic Packaging Waste Treatment in Europe
Energy Recovery	41.6%	38.6%
Recycling	31.1%	40.9%
Landfill	27.3%	20.3%

With a 40.9% recycling rate for plastic packaging, the EU as whole surpasses the minimum target of 22.5% outlined in the current Packaging and Packaging Waste Directive by far. However, a 55% recycling rate for plastic packaging, as proposed by the European Commission, will be challenging to reach. This will be analysed in more detail in the following chapter.

6.3 Recycling of plastic packaging waste in the EU28 in 2015

To assess the progress in the transition towards a more circular plastics economy, the recycling rates of European member states will be analysed and compared. To provide a more objective picture of European plastic packaging waste treatment, the data provided by two sources, namely Plastics Europe (2018) and Statista (2018), which uses data from Eurostat (2018) will be compared.

Figure 7, on the subsequent page, illustrates a data set published by Statista (2018) and Eurostat (2018) and shows that in 2015, all of the European member states achieved the current minimum reuse and recycling target of 22.5% as outlined in the Packaging and Packaging Waste Directive. The majority of member states (24 countries) reported plastic packaging recycling rates higher than 30%. The only countries with lower recycling rates than 30% were Finland (23.7%), France (25.5%), Hungary (27.4%) and Estonia (27.8%). Denmark (30.5%), Poland (31.6%), Luxemburg (32.5%), Malta (32.9%), Austria (33.6%), Ireland (34%), Latvia (35.3%), Greece (36.8%) and the UK (39.4%), all reached recycling rates between 30% and 40% (Eurostat 2018b; Statista 2018). The following countries had recycling rates between 40% and 50%: Italy (41.1%), Belgium (42.6%), Portugal (43%), Spain (44%), Romania (44.5%), Croatia (46.3%), Cyprus (46.3%) and Germany (48.8%). The Netherlands had a plastic packaging recycling rate of 50.7% in 2015 (Eurostat 2018b; Statista 2018).

Surprisingly, according to Statista (2018) and Eurostat (2018), the top plastic packaging waste recycling countries are exclusively member states located in Eastern Europe, namely Slovakia (54.4%), Lithuania (54.8%), Bulgaria (60.8%), Czech Republic (61.7%) and Slovenia (63.4%) (Eurostat 2018b; Statista 2018).

This trend could be related to the fact that many Easter European countries do not have a large capacity in WtE plants and therefore can achieve a larger portion of recycling rates. However, one might question the reliability of data provided.

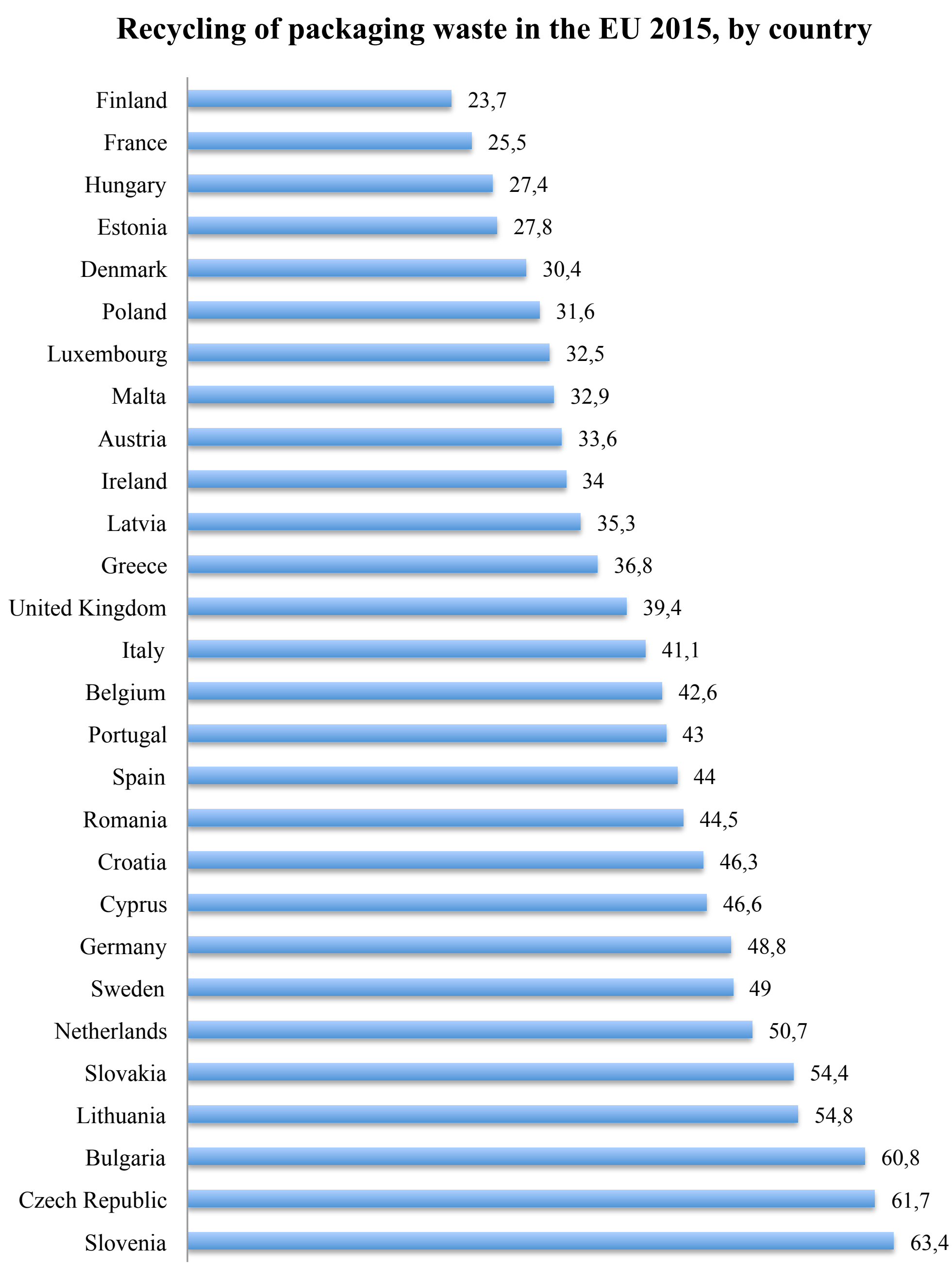

Figure 7: Recycling of Plastic Packaging Waste in the EU 2015, Data: Statista, 2018 & Eurostat, 2018c.

To achieve a more objective picture on the plastic packaging recycling situation in Europe, the discussed data provided by Eurostat and Statista will be compared to the data provided by Plastics Europe, which is displayed on the following page in Figure 8. Although the data set of Statista discusses the year 2015 and the data of Plastic Europe refers to 2016, it still offers a basis for comparison, as 1 year does not allow for substantial change in recycling rates.

Like in the Statista/Eurostat data, all countries have reached the minimum target of 22.5% and the average recycling rate in the EU28+2 was 40.8% according to Plastics Europe. The recycling rate varies between a little over 20% and around 50% among countries. Contrarily, recycling rates provided by Eurostat reach until 63%. Furthermore, instead of Slovenia (as indicated by Eurostat), the Plastics Europe data set represents the Czech Republic as the top recycling country of the EU with a recycling rate of around 56% (Plastics Europe 2018). It is a remarkable trend that an Eastern European country has overtaken top recycling countries such as Germany and the Netherlands.

In general, the two data sets differ substantially from each other. What particularly stands out here is the difference in the top recycling countries. In the data provided by Statista and Eurostat, only Eastern European countries counted to the four top recycling countries, namely Slovenia, Czech Republic, Lithuania and Slovakia (Plastics Europe 2018; Statista 2018). Contrarily, according to Plastics Europe, the countries following the Czech Republic are Germany, the Netherlands, Ireland, Sweden and Spain. Whereas the top recycling countries according to Statista, such as Bulgaria and Romania for instance, were ranked among the countries with lower recycling rates according to Plastics Europe (see Figure 8). This disparity is only one of the saliences**.** Generally, it can be observed that the country ranking is completely mixed in the two sources. For instance, in the case of Romania Statista/Eurostat indicate a rather high recycling rate of 44.5% for 2016, whereas Plastics Europe states a rate of around 30% for the year 2015. An increase of 14.5% in plastic packaging recycling within one year in Romania seems rather unlikely. Moreover, unlike for the Eastern European countries, the data sets do not differ substantially for Western European countries.

Unfortunately, neither of both statistics specifies how the recycling rate is calculated. In other words, it is not indicated whether the input amount or the output amount of the recycling plants are considered in the recycling rate. However, whereas Plastics Europe highlighted that the recycling rates refer to post-consumer plastic packaging waste, this is not specified for the Statista/Eurostat data base.

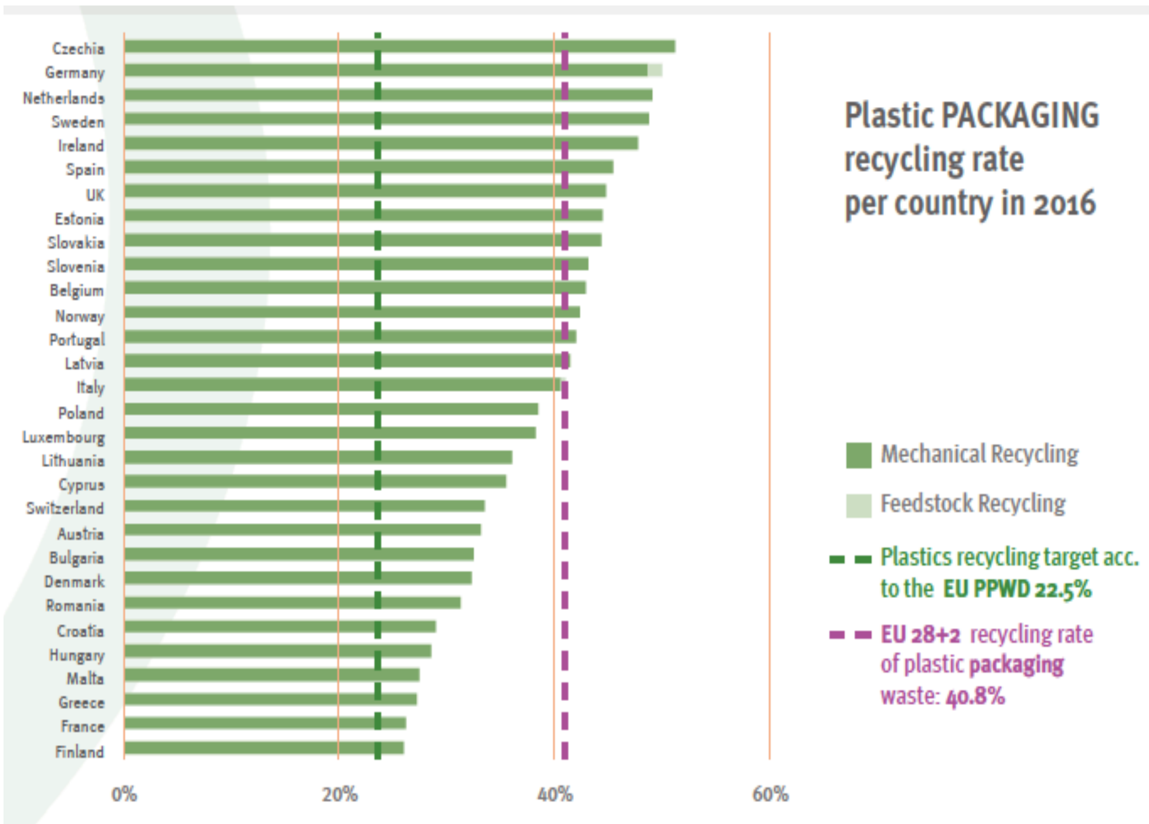

Figure 8: Post-consumer Plastic Packaging recycling rates per country in Europe 2016. Data: Plastics Europe, 2018.

6.4 Case Studies

To improve our understanding of plastic packaging waste treatment in European countries, the data of five European member states, namely, Austria, Finland, Spain, Germany and the Netherlands, will be analysed. An analysis of all 28 member states would be beyond the scope of this thesis. Furthermore the existing lack of data on country specific plastic packaging waste, which is especially apparent in Eastern Europe, would render this endeavour nearly impossible.

The focus of this country analysis lies on the following data, which will be summed up in the form of a table at the end of every case study:

- The amount of plastic packaging waste per capita per year (EU average: 31kg in 2015)
- The amount of plastic packaging, which is separately collected
- Information on the plastic packaging waste composition
- Waste Treatment of plastic packaging divided into following shares:
    - % share of Recycling
    - % share of Energy Recovery
    - % share of Landfilling

The shares will be displayed graphically in pie charts to allow for visual comparison. Different years had to be used for the case studies due to dissimilar data availability. Unfortunately, not all data was found for all case studies. It needs to be underlined that the diverse sources used for the case studies, applied various definitions and calculation methods to calculate the above-mentioned data. Therefore, this chapter only allows for a rough comparison among member states.

6.4.1 Austria

The data for the Austrian case study was retrieved from a detailed study on plastic packaging waste flows in Austria for the year 2013 published by Van Eygen, Fellner and Laner in 2018.

It was found that in Austria 35kg plastic packaging waste was produced per capita in 2013. With this number Austria lies above the EU average of 31 kg. The total amount of plastic packaging waste generated was 300,000 ± 3% tonnes in 2013. The packaging waste was mainly made up of large and small films, small hollow bodies and PET bottles. The plastic waste stream was made up of mainly LDPE (46%), PET, PP, HDPE, LLPE, PS, EPS and PVC. PET had very high collection and recycling rates (Van Eygen, Laner, and Fellner 2018).

The collection rate amounted to 58%, whereas the sorting rate constituted around 34%. The difference between the mentioned rates is due to the fact that not all of the separately collected waste is sent to recycling. In the case of Austria, a part of the sorted plastic goes to industrial incineration and is therefore not recycled (Van Eygen, Laner, and Fellner 2018, 58). The recycling rate, which in the Austrian study indicates the amount of granulate produced in the recycling plants, was calculated to be around 26%. The definition of the recycling rate used in the study for Austria does not comply with the definition suggested by the EC that refers to the input into the recycling part, which would be approximately 34% (defined as the sorting rate in this study). The 34% resembles the data provided by Statista, Eurostat and Plastics Europe. While using a recycling rate of 26%, Figure 9 illustrates that 33% plastic packaging waste was used in the cement industry. The remaining 40% of plastic packaging waste was sent to energy recovery. A marginal share of less than 1% was landfilled. In Austria, it is prohibited to landfill waste that has an organic carbon content higher than 5% ((Van Eygen, Laner, and Fellner 2018).

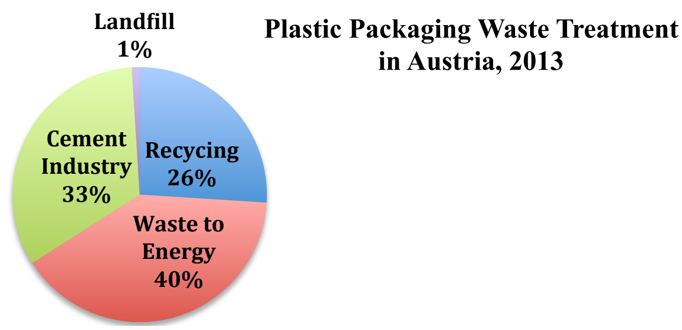

Figure 9: Plastic Packaging Waste Treatment in Austria, 2013. Data: Van Eygen et al., 2018.

Furthermore, it needs to be noted that the recycling rates of the individual product categories varied between 68% and 3%, which confirms the different recyclability of polymers. The plastic packaging going to the cement industry was mainly plastics that were rejected at sorting plants (Van Eygen, Laner, and Fellner 2018).

In Austria, mixed municipal solid waste is treated in a Waste to Energy plant or sorted in a Mechanical Biological Treatment or splitting plant, which is used to separate the materials for recycling (Van Eygen, Laner, and Fellner 2018, 57)

The Austrian study also includes a future scenario, which determined the conditions necessary to achieve the 55% recycling target. It was found that the collection and sorting efficiencies would need to increase considerably. As the sorting rates were stagnating in recent years, real efforts would have to put into the recycling system to achieve higher targets (Van Eygen, Laner, and Fellner 2018, 62). However, a higher impurity content, which was suggested by the EC, would make it easier to reach the suggested target. Table 2 below summarises the findings for the Austrian case study.

Table 2: Plastic Packaging waste data for Austria in 2013. Data: Van Eygen et al. 2018.

Plastic Packaging Waste Data for Austria, 2013	
Amount of Plastic Packaging Waste	300,000 ± 3% tonnes/a
Plastic Packaging Waste per capita per year	35 kg/capita/anno
Plastic Packaging separately collected	170,000 ±2% tonnes
Plastic Packaging waste treatment	
Recycling Rate	26% ± 7%[5] = Amount of granulate produced in comparison to total waste; or output of the recycling plant
Energy Recovery	40% ± 3%
Cement Industry	33% ± 6% cement industry
Landfill	1% (residues from mechanical pre-treatment and WtE ashes)
Total Collection Rate for Plastic Packaging	58%
Sorting Rate = Recycling Rate as defined by the European Commission	34% = refers to the fraction of waste sorted and sent to the recycling plants; roughly the input to the recycling plant minus the amount going to the industrial incinerator
Recycling Rate	26% = refers to the amount of granulate produced in comparison to total waste; or output of the recycling plant

6.4.2 Finland

This chapter analyses the plastic packaging waste management in Finland, serving as an example for a sparsely populated country in Northern Europe. Finland is a particularly interesting case as it is the EU member state with the lowest recycling rates for plastic

[5] Differs to the recycling rate suggested by the European Commission.

packaging according to the data provided by Plastics Europe, Statista and Eurostat. All sources report the recycling rate for plastic packaging to be around 23%, therefore just reaching the current minimum 22.5% required by EU legislation. Finland, thus, faces immense challenges concerning plastic recycling if the plastic packaging recycling rate was increased to 50% or higher.

The data for this case study was mainly derived from a paper published by Dahlbo, Poliakova, Mylläri, Sahimaa and Anderson (2018) on the recycling potential of post-consumer plastic packaging waste in Finland. As in Austria, plastic packaging dominates the plastic flow in Finland. Waste management differs among regions in Finland. There are three waste streams for post-consumer plastic packaging streams in Finland, namely separately collected packaging waste, mixed waste and energy waste, The latter includes plastics, cardboard, paper and wood (Dahlbo et al. 2018, 54). Bring site collection points were introduced in 2016 following a new law on packaging and packaging waste. The decree requires a 90% target for the beverage packaging deposit system and a 22% target for non-deposit plastics in 2020 (Dahlbo et al. 2018)

Therefore, recently, separate collection and sorting and recycling processes for plastic packaging have intensified in Finland. A higher plastic packaging waste recycling rate would also increase the Municipal Solid Waste (MSW) recycling rate (currently at 41% in Finland), which was suggested to be raised to 65% in the Circular Economy Package. The volume of post-consumer packaging in MSW was estimated to be between 73,000 and 104,000 tons in 2014. The sum of plastics in the energy waste amounts to around 5,000 tons annually. Furthermore, it was estimated that out of this plastic energy waste around 1,000 tons were post-consumer plastic packaging waste (Dahlbo et al. 2018).

PET bottles constituted the only separately collected plastic packaging until 2016 in Finland, while using a deposit system. The system is successful since it results in a 93% recycling rate of the yearly sold PET bottles. In 2014, between 86,000 and 117,000 tons of post-consumer plastic waste were created. The majority (84%) of this amount was concentrated in the MSW. Around 18kg of post-consumer plastic packaging per capita per year were produced in Finland in 2014 (Dahlbo et al. 2018). This number is very low compared to the EU average, which is around 31kg, indicating a differing calculation method.

Due to the low recycling levels and the proposed new targets, measures have been undertaken to further develop the recycling of plastics in Finland and are explained in more detail in Dahlbo et al.'s study. The actions are supposed to result in a 40% rate for post-consumer plastic packaging. This rate would, however, be still insufficient, if a minimum 55% rate were implemented. As the majority of plastic packaging waste is found in the MSW waste stream, it is vital for Finland to increase the recycling rate for MSW. Finland's current goal is to achieve a 50% recycling rate for MSW by 2020 (Dahlbo et al. 2018), which would require a 9% increase.

With regard to the waste composition of MSW it was found that the most frequently occurring plastics were PP and LDPE, followed by PET, PS and HDPE. Furthermore, it was observed that the share of monotype plastics in the MSW plastics fraction amounted to 80%, indicating a high recycling potential (Dahlbo et al. 2018, 57).

As the article focuses on the recycling potential of Finland, it was estimated that a 50% recycling rate for post-consumer plastic packaging was needed to achieve a 2% increase for the MSW recycling rate, which is currently 41% (Dahlbo et al. 2018, 59). Due to its focus on future recycling rates the article does not provide details on the current waste treatment of post-consumer plastic packaging waste.

Therefore, data provided by Plastics Europe and Eurostat is used to assess the plastic packaging waste treatment in Finland. According to Plastic Europe, 24% of plastic packaging waste was recycled in Finland in 2014 and around 66% was energy recovered, which is shown in Figure 10 below. The remaining 10% was landfilled. The data provided by Eurostat also reports a recycling rate of 24%. Eurostat, Statista and Plastics Europe report the Finland to be the country with the lowest recycling rates in Europe in the years 2015 and 2016 (Eurostat 2018b; Plastics Europe 2014, 2018; Statista 2018).

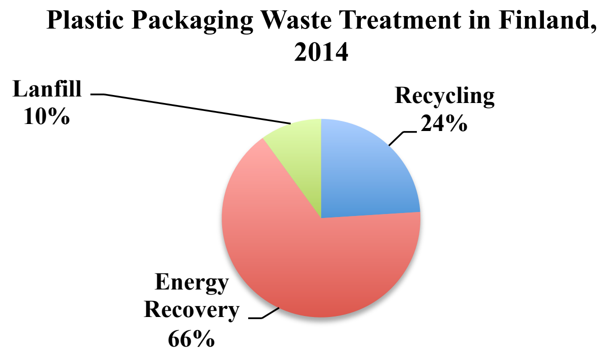

Figure 10: Plastic Packaging waste treatment in Finland, 2014. Data: Plastics Europe, 2015, p. 24.

According to Plastics Europe, the energy recovery rate in Finland for **all** plastics has increased by more than 40%, which helps to explain the large share in energy recovery in Finland. The recycling rate increased by around 25% in the period between 2006 and 2014 (Plastics Europe 2015, 23). If recycling rates for plastic packaging are going to be increased to 55% by 2025, Finland faces a real challenge. Therefore, severe changes to the plastic waste management in Finland are required. Table 3 and 4 summarise the discussed plastic packaging waste data and the waste treatment for Finland.

Table 3: Post-consumer plastic packaging waste data for Finland, 2014. Data: Dahlbo et al., 2018.

Plastic Packaging Waste Data for Finland, 2014	
Amount of Plastic Packaging Waste	86,000-117,000 tonnes/a
Plastic Packaging Waste per capita per year	18 kg/capita/anno
Plastic Packaging separately collected[6]	12,000 tons (2.2 kg/person/anno)

[6] Until 2016 the only PET bottles were collected separately in Finland

Table 4: Plastic packaging waste treatment in Finland 2014, Data: Dahlbo et al., 2018; Eurostat, 2018 & Plastics Europe, 2018

Plastic Packaging waste treatment	
Recycling Rate	24%
Energy Recovery	66%
Landfill	10%
Municipal Waste Recycling Rate	41%
Plastics packaging in Energy Waste	Around 1,000 tons per year

6.4.3 Spain

According to Plastics Europe Spain had the 4th largest plastic plastics demand in Europe, which amounted to nearly 4 million tonnes[7] and 7.7% of Europe's total demand in 2015 (Plastics Europe 2017, 16).

A study by Pozo, Basquero Arbona and Ramos (2012), which discusses the recovery of plastic waste in Spain and provides an overview of the market and applied technologies, is used as the main data source for this chapter. The scholars separately analyse different sectors were plastic is used, including packaging.

In Spain, the plastic consumption amounted to 2,840,000 tonnes in 2010, with the packaging sector representing a 49% share. The consumption led to around 2,206,000 tonnes of plastic waste in 2010, of which 23% was recycled, 17% was sent to energy recovery and 60% was landfilled. Therefore, plastics landfilling was the most frequently used option, implying a foregone use of a vast amount of valuable resources (Pozo et al. 2012)

Industrial and domestic plastic packaging was the most frequent application for plastic. Total plastic packaging waste amounted to around 1,397,689 tonnes of plastic waste in 2010. HDPE and LDPE were the most commonly used polymers in 2010 for plastic packaging, amounting to around 54%. The PET, one of the most important polymers in the packaging sector, occupied a 24% share in the packaging industry. Cicloplast and

[7] This number does not include PET, PA, PP and polyacryl fibres.

the National Association of Plastic Recyclers (ANARPLA) stated that 713,525 tonnes of plastic packaging were recovered in 2010. Figure 11 shows that a 29% share of plastic packaging (407,525 tonnes) was recycled and 22% were energy recovered (306,000 tonnes) (Pozo et al. 2012, 185). It can be observed that the plastic packaging waste treatment was more environmentally friendly than the treatment of all plastics as it included higher recovery rates and less landfilling.

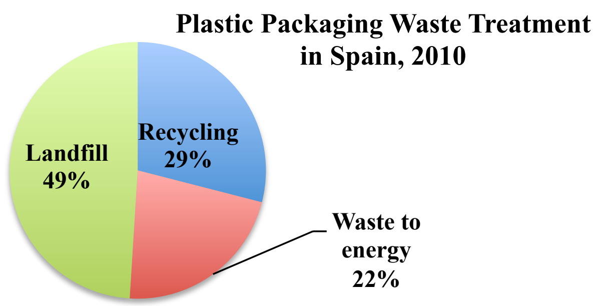

Figure 11: Plastic Packaging waste treatment in Spain, 2010. Data: Pozo et al. 2012, p. 185.

With its 29% recycling share Spain could, therefore, reach the 22.5% recycling target stated in the European Packaging and Packaging Directive in 2010.

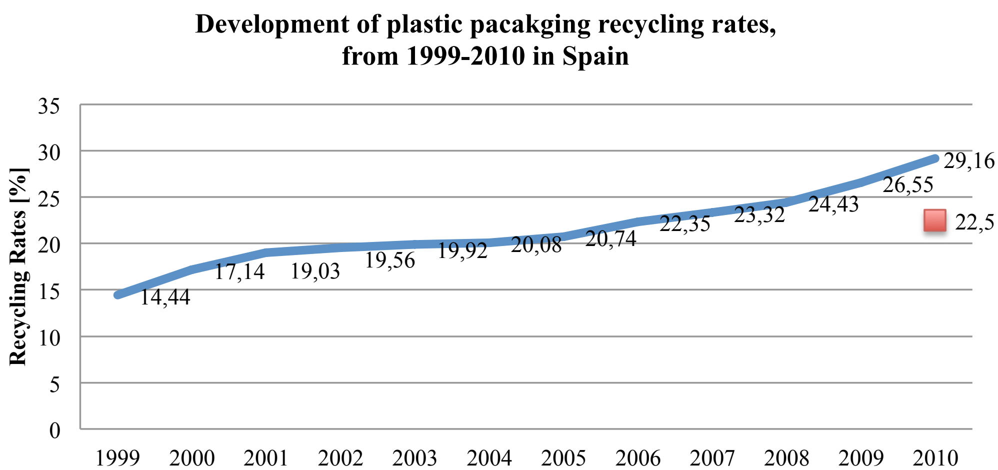

Figure 12: Development of plastic packaging recycling rates in Spain from 1999 to 2010. Data: Pozo et al., 2012, p. 186.

As can be observed in Figure 12 above, Spain has made substantial progress in regards to recycling rates. In 2000, the recycling rate for plastic packaging waste amounted to around 14%, whereas it more than doubled to 29% in 2010. The 29% matches with the data provided by Eurostat for the year 2010. According to Plastics Europe (2013) the recycling rate for post-consumer plastic packaging waste was around 35% in 2012 and the rate of energy recovery was around 23%. Plastics Europe and Statista reported a recycling rate of 44% for the years 2015 and 2016 respectively (Eurostat 2018b; Plastics Europe 2018; Statista 2018). This trend indicates substantial progress in plastic recycling in Spain. However, one might question the reliability of the data as a recycling increase of around 15% within 5 years seems rather unlikely.

Table 5: Plastic packaging waste data for Spain in 2010. Data: Pozo et al., 2012.

Plastic Packaging Waste Data for Spain, 2010	
Amount of Plastic Packaging Waste	1,397,689 tonnes
Plastic Packaging Waste per capita per year	29.7kg/capita/anno (calculated with a population number of 47.02 million in 2010)
Plastic Packaging waste treatment	
Recycling Rate	29%
Energy Recovery	22%
Landfill	49%

6.4.4 Germany

The data used for the German case study was derived from a study for the German Federal Environment Agency (*Umweltbundesamt*) conducted by Kurt Schüler.

The study found that 3,053,000 tonnes of plastic packaging waste arose in Germany in 2015. Taking into account a population of 81.7 million in 2015, this amounts to around 37kg per capita for the same year. As demonstrated in Figure 13 below, out of the 3,053,000 tonnes of plastic packaging waste, 49%, namely 1,490 kilotons (kt) were recycled in total. The study clarifies that this rate is made up of 1,446 kt that were recycled to new plastics and 44 kt of plastic packaging that were used for feedstock recycling in the steel industry. Furthermore, about 50% of plastic packaging was energy recovered, which amounted to 1,546 kt. The remaining 1% was incinerated (11kt) and landfilled (Schüler 2017).

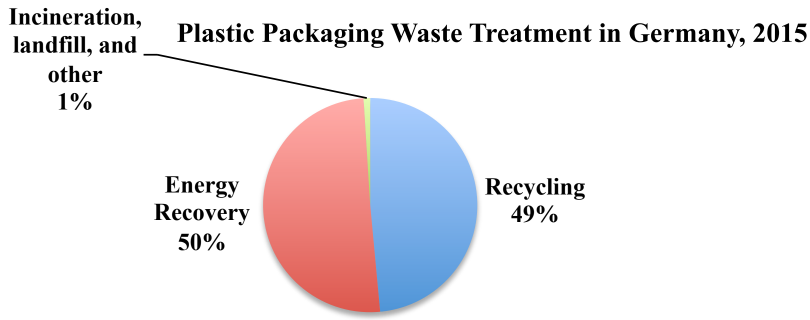

Figure 13: Plastic Packaging waste treatment in Germany in 2015. Data: Umweltbundesamt, 2017.

According to Eurostat, the recycling rates for plastic packaging have remained rather steady for the last years. Since 2009 the rate has been between 48% and 49%. In 2005, however, the recycling rate was still at 39% (Eurostat 2018b). This development implies that a lot of progress in recycling as was made in the early 2000s and after 2005 the rates stagnated.

Table 6: Plastic packaging waste data for Germany, 2015. Data: Schüler, 2017.

Plastic Packaging Waste Data for Germany, 2015	
Amount of Plastic Packaging Waste	3,053,000 tonnes
Plastic Packaging Waste per capita per year	37kg/capita/anno (calculated with a population of 81,707,789 in 2015)
Plastic Packaging separately collected	Not indicated
Plastic Packaging waste treatment	
Recycling Rate	49% (1490 kt)
Energy Recovery	50% (1546 kt)
Incineration + Landfill	1% (11 kt + 6 kt)

In an article on plastic published in the German newspaper *Die Zeit*, Germany's plastic consumption is highly criticised. In fact, Germany has the highest per capita rates (total) packaging in Europe, amounting to 220kg in 2015. Total plastic waste more than doubled in the period from 1994 to 2015. The article underlines that in Germany a highly developed recycling system is used to justify overconsumption with a clear conscience. While calling the German recycling system a sham (*Mogelpackgung*), Germany has become a victim of the recycling lie. When discussing China's import ban, it is highlighted that German plastic waste exports increased by 50% in 2017, indicating a high dependence on Asian countries. Furthermore, the negative impacts of heavily practiced energy recovery are discussed. The operation of 100 waste incineration plants in Germany reject filter cakes, consisting of dioxins, lead and furans. The toxic waste of all incineration plants is buried in a village close to Thüringen, 600 m in depth in a former mine, which is almost full. Incineration gives rise of around 350,000 tonnes of ashes and dust per year (Asendorpf et al. 2018), which need to be landfilled. Although the recycling system is known for its efficiency, around 1,400 tonnes of German plastic still leak into the ocean.

To sum up, a highly developed waste management system like in Germany cannot completely remove the negative consequences of overconsumption, which highlights the importance of implementing waste reduction measures.

6.4.5 The Netherlands

According to Plastics Europe, the Netherlands has increased its recycling rate for all plastics substantially by around 15% in the period between 2007 and 2014 (Plastics Europe 2015).

The data for the Dutch case study was mainly retrieved from an article on the Dutch post-consumer packaging recycling system published in 2018 by Brouwer, Van Velzen, Augustinus, Soethoudt, De Meester and Ragaert. The study used a Mass Flow Analysis (MFA) to undertake a detailed study examining 35 different plastic packaging types and their end-of-life fates (Brouwer et al., 2018).

There are three consumer plastic packaging waste systems in the Netherlands: a separate collection from households, mechanical recovery from mixed MSW and also a deposit-refund system for large PET bottles (Brouwer et al. 2018, 62). The latter system was excluded from the Dutch study. 75% of plastic packaging ended up in the MSW being subjected to mechanical recovery[8] (255,000t) and 25% were collected separately (Brouwer et al., 2018).

Around 474,000t of plastic packaging are placed on the market annually including post-consumer and industrial packaging, which equals around 133,000t. The potential of post-consumer plastic packaging in 2014 resulted in 341,000t, which amounts to 20.2kg per capita, lying well below the EU average. 129,100t of gross packaging were separately collected. This number consists of 86,000t net plastic packaging, 10,200 t non-packaging plastics, 9,000t residual waste, 23,900t moisture and dirt (Brouwer et al., 2018). Compared to the other cases, the distinction between net and gross weight was only indicated in the Dutch case study. Usually the gross weight is used for calculations to achieve a higher recycling rate even though not only consisting of recycling material as explained above.

Moreover, it was calculated that the net collection response was around 25%. The remaining packaging waste fraction is discarded in the MSW, which undergoes mechanical biological treatment (Brouwer et al., 2018, p. 66).

It was found that the net combined recovery and sorting rate was 36%. This rather low percentage (for Dutch standards) can be explained by the fact that plastic bags were included in the definition of plastic packaging. The number would be higher if plastic bags were excluded. In 2014, the Dutch recycling system yielded 75.2 giga gram (Gg) net plastic milled goods. Therefore the recycling chain yield was around 22%. Unlike the recycling rate definition of the EU, the 22% is calculated by using the output of the recycling process. Due to high PVC concentration the side products of the recycling products are mostly incinerated. PE and PET bottles were recycled to a larger extent than PP flexible packages (Brouwer et al. 2018, 66).

According to Eurostat, the reported recycling rate was 50.6% for the Netherlands in 2014. This enormous difference can be explained by the use of different calculation methods. Furthermore, unlike the Dutch study, the official method does not include plastic bags as packaging type (Brouwer et al. 2018, 68; Eurostat 2018b). These highly

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[8] Mechanical recovery is also referred to as central sorting of recyclable from MSW, technical sorting and mechanical biological treatment.

different recycling rates show that recycling rates need to be analysed with caution, highlighting the need for a common definition.

The recycling outputs are most frequently used in non-packaging items and non-food packaging. Indeed, plastic recycled in a conventional recycling process from post-consumer plastic packaging will result in blends (Brouwer et al. 2018, 70). Therefore, the Dutch system is far from being a closed loop recycling system, as it is the ideal concept of a circular economy. The presence of foreign polymers would have to be decreased in order to create a higher quality of recyclates.

According to Plastics Europe, the post-consumer plastic packaging waste recycling rate for 2014 was around 45%, 53% was energy recovered and around 2% were landfilled, as illustrated below in Figure 14 (Plastics Europe 2015, 24). Although the Dutch study and Plastics Europe both report the post-consumer plastic packaging recycling rate, the results differ substantially.

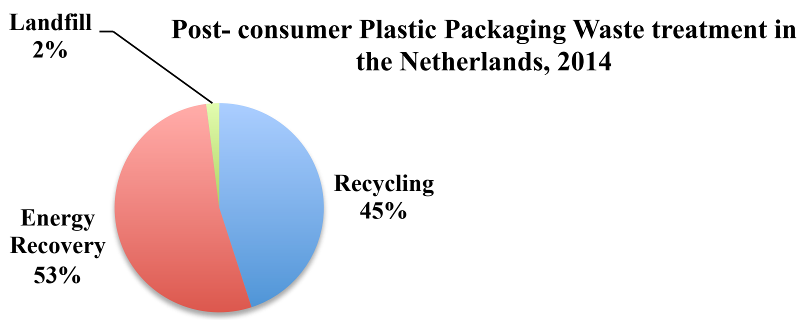

Figure 14: Post-consumer plastic packaging waste treatment in the Netherlands in 2014. Data: Plastics Europe, 2015, p. 24.

Interestingly, the recycling rate for the same year (2014) provided by Eurostat is 50.6% and therefore differs by 5.5% to the Plastics Europe rate. As the Eurostat numbers refer to the *domestic* plastic packaging waste flow, industrial plastic packaging cannot be used to explain the difference. Unfortunately neither Eurostat nor Plastics Europe defines at which stage of the recycling process the recycling rates were calculated.

Table 7: Plastic packaging waste data for the Netherlands, 2014. Data: Brouwer et al., 2018.

Post-consumer Plastic Packaging Waste Data for the Netherlands, 2014	
Amount of Post-consumer Plastic Packaging Waste	341,000 tonnes (Industrial plastic packaging waste: 133,000 t; total plastic packaging: 474 Gg)
Post-consumer Plastic Packaging Waste per capita per year	20.2 kg/capita/anno
Plastic Packaging separately collected	129,1000 tonnes (gross) (= 86,000 plastic packaging (net) +10,200t non-packaging plastics+ 9,000t residual waste + 23,900t moisture + dirt)
Plastic Packaging waste treatment	
Recycling Rate	22% (refers to post-consumer packaging from households, calculated with the net plastic milled/ output of the recycling process)

Table 8: Plastic packaging waste treatment for the Netherlands provided by Plastics Europe, Data: Plastics Europe, 2015.

Post-consumer Plastic Packaging waste treatment	
Recycling Rate	45%
Energy Recovery	53%
Incineration + Landfill	2%

6.3 Comparison of the national plastic packaging waste treatment

This chapter compares the findings of the country case studies for Austria, Finland, the Netherlands, Germany and Spain. First of all, it needs to be pointed out that one has to be careful when making comparisons, as different years were used for analysing the countries depending on data availability. Nevertheless, it was impossible to find equal data with a common definition on how recycling rates were calculated. Also definitions on plastic packaging and even post-consumer plastic packaging differed nationally. Furthermore, frequently the data was not clearly defined.

Nevertheless, a rough comparison among those Western European states can still be made and is graphically shown on the subsequent page in Table 9. Due to the described challenges, an additional table with Eurostat recycling rates for 2006, 2010 and 2015 is provided to understand the progress in the selected countries based on one source.

Among all analysed countries, Germany had the highest recycling rate with 49%, followed by the Netherlands with 45%. It was observed that in countries with rather high recycling rates, the majority of the recyclates were blends and were used for lower quality applications. Therefore, even countries with a highly advanced recycling scheme are far from achieving closed loop system. The idealistic concept of a circular economy is currently unfeasible in practice, when it comes to plastic. All analysed countries had a low landfill rate, except for Spain, where the landfilling rate in 2010 still amounted to 49%. This trend has, however, changed due to significant progress in recycling rates in Spain, as will be demonstrated in the section below. It was observed that in all discussed countries except for Spain, certain landfill restrictions exist which rationalizes why the landfilling rates of the remaining countries are low. Furthermore, what is apparent is that high recycling rates usually go hand in hand with rather high waste energy recovery rates. As landfilling needs to be avoided, energy recovery is the only feasible alternative to recycling.

Plastic packaging waste per capita was highest in Germany amounting to 37kg in 2015, followed by Austria with 35kg and Spain with 30kg. Comparatively, the packaging waste in Finland and the Netherlands amounted to 18kg and 20kg respectively, well below the EU average of 31 kg. The immense disparity in per capita waste among countries would indicate that the Dutch and Fins consume considerably less plastic packaging than the Austrians and Germans. Nevertheless, the difference might simply point towards the use of distinctive calculation methods and statistical disparity, as the discussed Western European countries do not have widely differing consumer behaviour patterns.

Energy recovery was highest in Finland, occupying a 66% share of post-consumer plastic packaging waste treatment. On the other hand, Finland has the lowest recycling rates in the EU, barely reaching the legally binding 22.5% for plastic packaging waste. Therefore, the Northern European country would struggle considerably with the implementation of a minimum 55% recycling rate by 2025. Furthermore, only Austria indicated the use of plastic packaging waste in the cement industry.

Table 9: Comparison of plastic packaging waste data for Austria, Finland, Spain, Germany and the Netherlands.

	Austria 2013 *(Van Eygen et al., 2018)*	**Finland 2014** *(Plastics Europe, 2018)*	**Spain 2010** *(Pozo et al., 2012)*	**Germany 2015** *(Schüler, 2017)*	**The Netherlands 2014** *(Plastics Europe, 2015)*
Recycling	26% (Eurostat: 34%)	24%	29%	49%	45%
Energy Recovery/ Incineration	40%	66%	22%	50%	53%
Cement Industry	33%				
Landfill	1%	10%	49%	1%	2%
Plastic packaging waste per capita per year	35kg	18kg	30kg	37kg	20kg

There is a current research trend focusing on plastic waste management and increased recycling, which is inspired by the circular economy concept and the proposal to raise the recycling targets. In fact, the national studies for Austria, Finland and the Netherlands were all published in 2018. All of these studies share a focus on plastic packaging, analyse the waste flow in detail and try to improve the national plastic waste management. Furthermore, the studies are an attempt to make predictions on how to reach higher plastic recycling targets. Nevertheless, it has also been observed by the analysed studies that on a national level that a closed-loop circular plastic economy is merely an idealistic concept.

More research on national waste management systems is needed to understand the waste flows and the recycling potential, especially in Eastern European member states.

Nevertheless, recycling should not merely be focused on the quantity, but also on the quality of the material. Additionally the creation of a more sustainable economy should not be left to waste management alone. Prevention of waste and a reduced consumption are key tools to environmental protection.

Table 10: Development of plastic packaging recycling rates for Austria, Finland, Spain, Germany and the Netherlands for the years 2006, 2010 and 2015. Data: Eurostat, 2018.

Countries	Plastic Packaging Recycling Rates for 2006	Plastic Packaging Recycling Rates for 2010	Plastic Packaging Recycling Rates for 2015
Austria	35.8%	33.4%	33.6%
Finland	15.9%	26.2%	23.3%
Spain	22.4%	29.2%	44%
Germany	41.3%	49.4%	48.8%
The Netherlands	32.5%	47.6%	50.7%

Table 10 shows the development of the recycling rates for plastic packaging waste in Austria, Finland, Spain, Germany and the Netherlands for the years 2006, 2010 and 2015. The data was derived from one source only, namely Eurostat, and thereby allows for direct comparison. In the case of Austria, one can observe that the recycling rate has remained rather steady between 2006 and 2015. In Finland the highest recycling rates since 2006 were measured in 2010, amounting to 26.2%. Within four years (2006-2010) the Northern country managed to increase its recycling by more than 10%. In the time between 2010 and 2015, the rate in Finland dropped again by approximately 3% amounting to 23.3% in 2015. For Spain immense progress can be observed as the recycling rate doubled from 2006 to 2015, amounting to 44%. Nevertheless, the 15% increase between 2010 and 2015 in Spain, leads to doubts about the accuracy of the provided data. German recycling rates were already high in 2006, crossing the 40% mark. Currently around half of plastic packaging is recycled and the other half is incinerated in Germany. For the indicated time period, positive development can be observed for the Netherlands. Especially the development between 32.5% in 2006 and 47.5% in 2010 in the Netherlands is noteworthy. Comparably to Germany, the

Netherlands recycles around 50% of its plastic packaging. As stated above, the four countries with higher recycling rates than the Netherlands are only Eastern European countries, namely Slovakia, Lithuania, the Czech Republic and Slovenia according to the Eurostat data. However, the accuracy of the observed recycling data may be questioned due to the weak performance of Eastern European member states in waste management in the past. Furthermore, not only the quantity of recycling is essential but also the quality. One has to take a close look at the application of the recycled material. The extensive promotion of recycling carries the danger that rates are vehemently increased to be able to report higher recycling rates, disregarding the goal of environmental protection and the quality of the recycled material. At the end, recycling should be about the environmental benefit while saving resources and energy.

7. Defining the barriers on the road towards a Circular Plastics Economy

The circular economy concept has become widely discussed as a response to climate change and resource scarcity. However, various barriers on the road to a circular plastics economy can be identified, which will be elaborated in this chapter.

Environmental economists defined current resource prices as a major obstacle to a more circular economy. Generally, resource prices do not take into account the triggered negative externalities such as pollution and are too low to inspire change. Therefore, subsidies are needed to support recycling efforts (Hopewell, Dvorak, and Kosior 2009b, 2121). Secondly, frequently taxes, subsidies, regulations or policies constitute obstacles to a more circular economy. For instance, although in terms of the waste hierarchy, incineration is a more favourable option than landfilling, it might compete with recycling or reuse (EU-Umweltbüro 2016, 15).

Furthermore, another difficulty is faced when trying to close the loop and using waste as an input for another product. Here the quality of materials plays a key role and it must be secured that no harmful substances are present. Hazardous materials could contaminate the cycle and have negative effects on human health. Therefore, it is essential that the circular economy does not lead to the substitution by an inferior substance. Frequently suppliers do not inform businesses sufficiently about the exact composition of secondary materials, making their inclusion in the cycle questionable and risky (von Weitzel-Mudersbach 2016).

Moreover, perfect processes that neatly “close the loop” are implausible since components of production cycles will not feed into each other without creating waste. Nevertheless, collaboration and transparency about production processes among industries on the international scale can support the use of waste as a resource (Zimmermann and Muirhead 2016).

Furthermore, the creation of a circular economy should be focused on reduced resource extraction in the first place. Higher recycling rates do not necessary guarantee lower resource consumption, taking into account the growing resource demand. In other words, even if all recycled products were reintegrated into the economy this would not lead to a closed loop as the resource demand exceeds the recycling potential. Considering the waste hierarchy, waste prevention should be the top priority in a circular plastic policy. In the light of that, the European Commission has recently taken first steps by publishing a proposal targeting a final ban of single-use plastic products. This initiative is a vital measure to achieve a more circular economy by decreasing the use of virgin plastic material.

Although the Action Plan compromises some ambitious recycling targets, it needs binding reduction targets on resource consumption. Reuter suggests a reduction of 30% until 2030. One could for example introduce economic incentives for sustainable circular products (EU-Umweltbüro 2016, 14). The binding primary resource reduction targets are essential to achieve a circular economy. Nevertheless, an implementation of such targets would be rather difficult in practice as the European economy is based on economic growth, which stands in conflict with decreasing consumption.

As many projects that aim to protect the environment, the Circular Economy Package struggles with insufficient investment sources and requires the use of realistic business models. Businesses usually have a short-term vision in regards to investment and profits and circular projects might be regarded as too risky and unfeasible.

Furthermore, there are no targets focusing on mandatory re-use only. The reuse option of the waste hierarchy needs legally binding targets in order not to be totally displaced by the third hierarchy option, namely recycling. Economic incentives for increasing the re-use option would be an option (Neitsch 2016).

Moreover, the provided data on specific recycling targets is rather poor across Europe, as the example of discussed post-consumer plastic packaging waste treatment illustrated. It is particularly challenging to find specific waste data on Eastern European countries. Even if data is provided, it is often unclear which definitions and calculation methods have been used for data such as recycling rates. The data problem became prevalent when comparing the statistics provided by Eurostat and Plastics Europe. Additionally, the accuracy and availability of the data leaves much to be desired.

As the EC's policy proposals put their focus on higher recycling targets it is substantial to find a common definition at which point in the waste management chain the recycling quantity is to be measured. So far a common definition has not been laid out in European legislation yet (Van Eygen, Laner, and Fellner 2018). Differing definitions on how the recycling rate is measured might also explain why various recycling rates were found for the same year and country. In most cases it was unclear how the indicator values were calculated in different countries (Haupt, Vadenbo, and Hellweg 2017).

Therefore, there is the need for harmonised rules on measurement or at least the requirement to indicate how and at which point in time of the waste management chain recycling rates were measured. In fact, the European Commission has acknowledged the definition problem, proposing that the recycling targets must be based on the input waste entering the final recycling process (European Commission 2015c).

Nevertheless, when focusing on the input to the recycling plant, it might decrease the purity of the materials, while decreasing the actual quality of the recyclates as the system encourages to account for higher output amounts after the sorting plant (Van Eygen, Laner, and Fellner 2018, 62). Van Eygen et al. (2018) therefore suggest putting the calculation point for the recycling rate towards the end of the recycling chain as this reflects the actual amount of granulate produced. This could, however, also negatively influence the quality of the re-granulate produced.

By any means, it is important to have a common definition as the calculation method influences the actual rate immensely. Especially new legal obligations on increased recycling rates make this issue more prominent than ever.

As outlined above, Europe faces multiple barriers in the transition to a circular economy such as lack of data and harmonised rules. The idealism of the concept of a circular economy with its focus on closing the loop is also problematic. Moreover, the difficulties in plastic recycling are one of the major barriers on the road towards a more circular plastics economy and will be elaborated in the following chapter.

7.1 The Challenges in Plastics Recycling

Recycling is a key tool in the creation of a more circular economy. Recycling offers various environmental benefits, such the reduction of carbon dioxide emission and waste generation (Hopewell, Dvorak, and Kosior 2009a). However, there are also various difficulties faced concerning plastics recycling, which will be discussed in this chapter.

Plastics consist of polymers made of small molecules (monomers), which are linked with chemical bonds. Depending on what monomer is repeated in the chain and their connection, plastic forms various structures (Hahladakis and Iacovidou 2018, 1396).

Based on the way the chains are connected, the distinction between thermoplastics and thermosets can be made. Thermoplastics are held together by weak chemical forces and can be recycled by heating, shaping and cooling the materials without changing much of their mechanical properties. Examples for thermoplastics are Polyethylene Terephthalate (PET), Polyvinyl-Chloride (PVC) and Polycarbonate (PC). Thermosets plastics, on the other hand, have chains that are cross-linked together and undergo a chemical change when heated. After being heated and formed, these types of plastics cannot be re-melted/recycled. Examples for thermosets are unsaturated polyester, silicon and polyurethane (PUR) (Hahladakis and Iacovidou 2018, 1396; Plastics Europe 2018).

Thermoplastics resins are typically used to make plastic packaging, which consist of various polymers. Following types of thermoplastics are mainly used for plastic packaging (Hahladakis and Iacovidou 2018, 1396):

- Type 1: Polyethylene terephthalate (PET)
- Type 2: High-density polyethylene (HDPE)
- Type 3: Polyvinyl chloride (PVC)
- Type 4: Low-density polyethylene (LDPE)
- Type 5: Polypropylene (PP)
- Type 6: Polystyrene (PS)

- Type 7: Others (which are usually not collected for recycling)

The environmental performance is different for each polymer (Van Eygen, Laner, and Fellner 2018, 56). Type 1-6 can be collected and reprocessed into flakes or pellets that can be used as input for new products. The thermoplastics used for packaging have different characteristics and are therefore used for distinctive applications. PET, for instance, is used for beverage bottles due to representing a barrier to flavours, its hard nature and stability (Hahladakis and Iacovidou 2018).

The various plastic types used in plastic packaging influence the recyclability and can lead to contamination when mixed during recycling. For instance, a small amount of PVC present in a PET recycling stream can degrade the stream substantially leading to the development of hydrochloric acid gas (Hopewell, Dvorak, and Kosior 2009b, 2119). If packaging contains only one plastics type, the recycling process is relatively easy (Dahlbo et al. 2018, 54). The more dissimilar the chemical characteristics of polymers are, the higher is the effect on the chemical properties (Brouwer et al. 2018, 71).

There are three main categories of plastics recycling methods. The first category refers to mechanical recycling in **closed loops**, which upholds the quality of materials. An example is recycling PET bottles into PET bottles. Single-polymer recycling can be used to produce food-grade re-granulates.

The second category is mechanical recycling in **open loops**, which is the most frequently applied and referred to as downgrading. Here the quality of materials is lowered and non-food grade re-granulate is produced, for example, when recycling PET into fleeces. The third category is **chemical recycling or feedstock recycling**. This refers to breaking down polymers into its chemical constituents, which can be used to create new polymers. These chemical methods are, however, rather costly and therefore not than common. Feedstock recycling is frequently used in the steel industry (Bourguignon 2017, 3; Hopewell, Dvorak, and Kosior 2009b, 2118; Van Eygen, Laner, and Fellner 2018, 56).

As discussed before, global plastic packaging recycling rates are quite low. If recycling takes place, plastic packaging is frequently down-cycled into lower grade products. Closed-loop recycling is challenging due to the presence of various polymers in packaging and only possible if polymers can be separated from contamination and stabilised against degradation. In the UK, for instance, only PET bottles and HDPE milk bottles are usually recycled in a closed loop manner. In fact, around 80% of recycled PET bottles are transformed into polyester fibres used in clothing, carpets or other applications. Conventionally recycled post-consumer plastics are therefore bends (Brouwer et al. 2018, 72; Hahladakis and Iacovidou 2018, 1398; Hopewell, Dvorak, and Kosior 2009b, 2118).

Concerning plastic packaging design, clear plastics are the preferable option when it comes to recycling because they can be dyed easily. Compared to other polymers, PET and HDPE have a high market value, as they can be easily recycled. Nevertheless, their recovery rate is only around 30%. Coloured and opaque plastics, on the other hand, have lower economic value, as they can only be used to produce plastics in darker shades and cannot compete with virgin materials on the market. Therefore, pigmented plastics are frequently disposed instead of recycled (Szaky 2015). Consequently the, design of plastic packaging and the polymeric composition of the packaging play a key role in the recycling process (Brouwer et al. 2018, 72).

While there is much discourse on the concept of a circular economy, the policies and business models frequently fail to take into account the technicalities, such as consumer behaviour, lack of infrastructure, plastics composition and functionality. The remaining functionality of materials to be recovered, reused or recycled depends on the quality. A high quality standard allows the reprocessing industry to ensure credibility on the market, to safeguard steady supply and reduce the risk related to resource demand and prices. The quality of plastic packaging depends on material properties, reprocessing and design (Hahladakis and Iacovidou 2018).

According to Pivnenko et al. (2015), the quality of the material is influenced by the "polymer cross contamination, presence of additives, non-polymer impurities, and polymer degradation" (p.7). Contamination can occur in all phases of the plastic value chain[9]. Therefore, all steps need to be considered, when undertaking quality control. However, most contamination takes place in the manufacturing process, which includes product design and labelling. For instance, design choices can help to reduce the

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[9] Including extraction, production, manufacturing, use, segregation, collection, sorting, re-processing and upgrading.

number of contamination by reducing the number of polymers used or decreasing the presence of additives (Pivnenko et al. 2015).

When analysing the concentration of chromium (Cr) in virgin plastics, waste plastic, recycled plastics, Pivnenko et al. found that the difference in Cr concentration between waste plastics and recycled plastic was insignificant, which points towards an inefficient removal of Cr during the plastics recycling. It was not identified in which stage the contamination occurred (Pivnenko et al. 2015). The result raises concerns, as it could lead to an accumulation of Cr in recycled products.

To improve the properties of plastic packaging various chemical additives[10] are added to the polymeric structures, affecting its performance and ageing (Dahlbo et al. 2018, 59). The ability of additives to pollute soil, water and food is of great concern. The contact between food and recycled packaging can be problematic if hazardous substances are present (Hahladakis et al. 2018). Further research is required to understand the impact of additives in plastics in order to ensure the food safety, the protection of human health and the environment (Pivnenko et al. 2015).

Another major barrier to increased recycling rates and a strong secondary resource market is the cheap price of virgin plastics. The price of virgin plastics is largely dependent on the oil price. Downgrading, for instance, is usually uneconomic due to low virgin material prices and the comparably high costs of the plant and the recycling process (Patel et al. 2000). Therefore, political and regulatory actions are needed to support the market for secondary materials.

Besides the chemical, technical and economical obstacles, there are also barriers in regards to social behaviour. Consumers tend to be confused which types of plastics need to be separated for recycling. Therefore, they might mix different materials, which can cause contamination of the recycling stream, affecting the quality negatively. Contamination can destroy the overall macroscopic properties. For instance, when minor amounts of PVC are present in a PET recycling stream this results in the PET

[10] such as plasticizers, flame retardants, antioxidants, acid scavengers, light and heat stabilizers, lubricants, pigments, antistatic agents, slip compounds and thermal stabilizers

becoming brittle and yellowish when recycled. Contaminated streams will most likely end up in landfills or be incinerated (Dahlbo et al. 2018, 59).

Currently it is impossible to recycle all plastics types into the same product in an efficient manner because of the chemical properties of the materials. Therefore, recycled plastic packaging is mostly converted into non-packaging products and non-food packaging applications (Brouwer et al. 2018, 72). It was estimated that the maximum possible recycling share for plastic packaging could be 80% in 2020 and 85% in 2025 (Dahlbo et al. 2018, 54). Naturally these numbers depend on the available technologies and type of resins used.

Yet, it is necessary to underline that recycling rates should not be increased at all costs. Some products should not be recycled to avoid contamination of the plastic stream and negative health effects. Therefore there is the need for rules on the maximum allowed concentrations of foreign polymers in certain plastics applications (Brouwer et al. 2018, 72). Furthermore, studies like Brouwer et al. are important to analyse the waste composition and adapt the recycling process. MFAs and life-cycle assessments can be useful methodological tools to determine the recyclability and the flow of products within a system (Reuter and van Schaik 2012, 339).

This chapter gave a brief insight into the challenges that exist in plastics recycling. Although plastic recycling plays a key role in creating a more environmentally friendly plastics economy, a closed loop plastics economy is unattainable. Policy proposals frequently disregard that technical, environmental, social and economic limits to recycling exist. Due to these barriers, reaching the newly suggested recycling targets will be challenging (Pivnenko et al. 2015). Nevertheless, recycling numbers have increased substantially during the last decades. There have been improvements in recycling technologies in regards to recognition software improving automatic sorting. As recycling is a dynamic area, improvements and innovations in technology, systems and reprocessing could make considerable contributions in regards to higher recycling numbers and efficiency (Hopewell, Dvorak, and Kosior 2009a, 2120).

8. Recommendations

This chapter provides recommendations on how to achieve a more sustainable plastics economy in Europe, while taking into account all aspects of the life cycle of a plastics item, namely production, consumption and waste management. In light of the current barriers, policies options will be discussed.

8.1 Reducing plastic consumption, preventing waste & the use of alternative materials

Before considering all stages of the life cycle of plastics, it is vital to again highlight the importance of plastic prevention. The Circular Economy Package fails to provide proposals on the reduction of plastic waste. As prevention is the preferable option in the waste hierarchy, it is a key policy in the creation of a circular economy. Thus, waste prevention ought to be a policy priority in the EU. Nevertheless, the European Commission has recently voiced its intentions to ban certain types of single-use plastic items, which would make a valuable contribution to waste prevention. However, it remains to be seen whether this proposal can overcome legal barriers and political resistance. Especially the use of alternative materials instead of plastic is a vital step to decrease the use of virgin plastic.

8.2 Establishing a dialogue between plastic product producers & recycling companies

When it comes to production, it was underlined that design choices matter. As was discussed in the previous chapter, the use of multiple polymers in packaging can render the recycling process rather challenging. Therefore, the use of polymers should be restricted for certain applications, thereby facilitating the recycling process. The use of polymers should be limited to those, which can be separated easily. Furthermore, indicating the used polymers and additives in the production process would facilitate recycling processes. New business models are needed that focus on services or offer quality products rather than the mass production of cheap plastic products, which have a short life-time or are used only once.

A policy dialogue between producers and recyclers would help to clarify what is needed for a more sustainable end-of-life option. The EU could provide subsidies to companies producing "circular plastics products" or to products replacing single-use plastics to incentivise a transition towards a more circular economy.

8.3 Reducing single-use plastics, implementing a take-away deposit systems in major European cities & raising awareness among citizens

The reduction of single-use plastics is necessary, as they constitute the vast majority of beach/marine litter. As the "take-away" culture and "on-the-go" consumption is increasing, infrastructure and new business ideas are required. Returnable take away food containers would considerably reduce single-use plastic waste, if introduced in major European cities. A deposit system could be used to incentivise consumer to return the reusable containers at any restaurant participating in the system. The success of the proposed system goes hand in hand with behavioural patterns of consumers. Bringing a reusable bag when going shopping is clearly not the only part consumers play in the creation of a more sustainable plastics economy. Although ecological awareness has increased during the last years, many people are uninformed about the role they are playing in recycling and waste management. The environmental consequences of our plastics economy remain unknown to the majority of the world's population. Especially Asian countries, which are a huge source of marine litter, need to strengthen their education about the environmental consequences of plastic use. Increasing public awareness, which is taught from kindergarten-age onwards, has the ability to spur policy change and create the demand for environmentally friendlier products. Moreover, universities are especially important when it comes to innovations in waste management and waste technologies (Fischer and Simic 2016) and should therefore be supported financially for their research concerning circularity.

8.4 Offering standardised labelling & hindering "green-washing" practices

To avoid consumers' confusion with regard to recycling, the EU and producers must provide clear information about products. Well-defined labelling about exact polymer presence in a plastic item and on the disposal of the product should be stipulated. Furthermore, labels provide consumers with the possibility to make a more informed decision and can help to promote more sustainable consumption behaviour. Moreover, labels should provide information about the recyclability of a product and about the presence of harmful substances (European Commission 2013, 13). As consumers are getting more environmentally conscious, frequently firms use unwarranted claims of sustainability to highlight the environmental friendliness of their products. In many cases this practice is disguised "green-washing", which serves a mere marketing strategy (Dahl 2010). Therefore, trustworthy and reliable labels on the real sustainability of a product should be developed.

Standardised eco-labels can help to provide reliable and comparable consumer information and help to improve the environmental performance of products. Another option that may change consumer behaviour is the introduction of environmental taxes and charges. They can help to provide an incentive for waste reduction and the use of recyclable plastics. Nevertheless, it is difficult to decide on the exact rate of the tax. Also, political players and the fossil industry will show resistance and revolt against the introduction of such fees (Ren 2003, 37).

8.5 Discouraging landfilling & defining a common EU wide definition on recycling rates

With regard to waste management, which was the highlight of the case study, it is important to discourage landfilling practices globally. This might be possible with a substantial tax on landfilling. With respect to recycling, a common legal definition of the measurement of recycling and sorting rates is of utter importance, as was discussed in the previous chapter. It is useless to have common targets on recycling, if there is no binding way on how to measure the amount. Besides this, detailed waste management data is required in many European countries, particularly in Eastern European states. For instance, for plastics packaging the proposed target of 55% will be difficult to achieve as many countries lack the data to examine the status quo. Therefore those countries will struggle to evaluate the necessary technical improvements and examine the necessary financial input to meet the target.

8.6 Implementing rules on the maximum contamination of recycled materials

Moreover, recycling targets should not be increased at any costs, as this could lead to a lower quality of the recyclates. Rules in regards to a maximum contamination of a recycling stream by foreign polymers would provide clarity on the future use of the recycled material and the human health concerns.

When putting the focus on recycling, increased targets should focus on closed loop recycling, which is most likely to result in to the reduction of the consumption of virgin plastic materials.

8.8 Summary & Conclusions

Although waste management plays a vital role in creating a more sustainable plastics economy, consumer choices and increased environmental awareness are equally important. The establishment of a new plastics economy requires the transformation of all life-cycle phases of plastic, reaching from the design and the production, to the end-of-life treatment. Especially economic incentives for circular products and research are essential to spur a shift towards increasing environmental protection.

9. Conclusion

This Master's Thesis was concerned with the research question: *To what extent can the European Union become a Circular Plastics Economy by 2030?* To answer the question the legal and political context with regard to plastic in Europe was critically examined. It was highlighted that the EU Plastic Strategy was clearly a response to China's decision to ban the import of certain types of plastic waste, which went into force in January 2018. Whereas discussing all stages of the plastic lifecycle, the main focus of the Plastic Strategy is waste management. In fact, the strategy outlines the ambitious aim for all plastic packaging on the EU market to be recyclable or reusable by 2030, thereby creating a circular European plastics economy. To attain this goal, the European Commission (EC) has proposed to amend the Packaging and Packaging Waste Directive, raising plastic packaging waste recycling rates from the current 22.5% to 55% by the end of 2025. Presently, the suggested proposals have not yet been translated into binding legal obligations.

The importance of adhering to the waste hierarchy, including prevention, reuse, recycling, recovery and disposal, was underlined in the transition to a more sustainable economy. It was found that neither the Circular Economy Package nor the Plastic Strategy put sufficient emphasis on waste prevention, which is the most favourable option for the environment. In fact, reduction targets are clearly missing in the EC's legal proposals. While concentrating mainly on increased recycling targets for plastic packaging, the waste prevention is rather disregarded. However, the recently published proposal to ban certain types of single-use plastic items was a favourable step towards a circular economy.

In Chapter 6, the plastic waste treatment in the European Union was examined. Special attention was paid to plastic packaging, as it constitutes the vast majority of plastic waste. In a general analysis of all European member states it was concluded that waste management among member states differs substantially. Indeed, the recycling rates of plastic packaging were located between 23% and 63%. However, waste management data needs to be studied with caution due to differing definition of recycling rates, the lack of data and insufficient accuracy of statistics. The data problem became especially apparent when comparing the recycling data of three different sources (Eurostat, Statista and Plastics Europe). Surprisingly, the Eurostat data set for the recycling rates of plastic packaging waste in 2015 represented Slovenia, the Czech Republic, Bulgaria, Lithuania and Slovakia (in descending order) as the top recycling countries. The inconsistency of recycling rates for plastic packaging was underlined when pointing out the completely different order provided by Plastics Europe. For instance, while Plastics Europe represents Bulgaria as one of the European countries with the lowest recycling rates in 2016, it is the country with the 3rd highest recycling rate according to Eurostat data for the year 2015. Still, overall it could be observed that landfill rates for plastic have been decreasing in recent years, whereas recycling and energy recovery rates are on the rise. Indicating progress in plastic waste management, for the first time, the recycling portion was higher than the landfilling share for plastic and plastic packaging waste in Europe.

To comprehend the national context of plastic packaging recycling systems, five country case studies (Austria, Finland, Spain, Germany and the Netherlands) were analysed with regard to plastic packaging waste data and treatment. Although the variability of data collection methods only allowed for a broad comparison, it was found that all of the countries, except for Germany and the Netherlands, would face substantial challenges when increasing the plastic packaging recycling minimum target of 55%. A closer look at national recycling data revealed that even highly advanced recycling nations convert most of their recycled plastic items into lower quality items. These results highlight the unfeasibility of establishing a closed loop recycling system. Furthermore, it was observed that the introduction of landfill bans frequently lead to a sharp increase in energy recovery rates, resulting to a certain "lock-in effect".

For plastic a closed loop circular plastic economy in which no waste arises is unfeasible, due to the complexity of the system and the material itself. While there is much political discourse, the policies and business models frequently fail to take into account the technicalities, such as consumer behaviour, the lack of waste management infrastructures, the mixed plastics compositions, the quality of the material and the lack of demand for recycled plastic. Plastic recycling, for instance, struggles with the use of various polymers, additives and substances, which can contaminate recycling streams. An increased dialogue between manufactures and recycling companies would help to reduce challenges in recycling when introducing design modifications. Producers need to create recyclable products and move far away from single-use plastic applications, which make up the vast majority of beach litter.

When creating a more sustainable plastics economy it is vital to concentrate on all phases of the life cycle of a plastic item. While waste management plays a significant role in the creation of a more circular economy, it cannot be left alone with this immense task. The prevention of waste is probably one of the most essential measures, which begins with increasing environmental consciousness among citizens. After all, globally speaking, there is an urgent need for a paradigm shift away from the mass production, single-use application and the overconsumption of plastic, a material that is frequently perceived as worthless, while causing immense costs for the environment.

Bibliography

Asendorpf, Dirk, Fritz Habekuss, Paul Middelhoff, Robert Pausch, Mathias Peer, and Petra Pinzler. 2018. 'Für immer Dein'. *Die Zeit*, 19 April 2018.

Balke, Verena. 2018. 'How China's Ban of Plastic Waste Imports Can Help Us Beat Pollution'. *UN Environment*. http://www.unenvironment.org/news-and-stories/story/how-chinas-ban-plastic-waste-imports-can-help-us-beat-pollution. Accessed May 15, 2018.

Bourguignon, Didier. 2016. 'Circular Economy Package: Four Legislative Proposals on Waste'. European Parliamentary Research Service. http://www.europarl.europa.eu/EPRS/EPRS-Briefing-573936-Circular-economy-package-FINAL.pdf. Accessed May 13, 2018.

———. 2017. 'Plastics in a Circular Economy: Opportunities and Challenges'. European Parliamentary Research Service. http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/564398/EPRS_BRI(2015)564398_EN.pdf. Accessed April 21, 2018.

Brivio, Enrico, and Iris Petsa. 2018. 'European Commission - Press Release - Plastic Waste: A European Strategy to Protect the Planet, Defend Our Citizens and Empower Our Industries'. 16 January 2018. http://europa.eu/rapid/press-release_IP-18-5_en.htm. Accessed January 20, 2018.

Brouwer, Marieke T., Eggo U. Thoden van Velzen, Antje Augustinus, Han Soethoudt, Steven De Meester, and Kim Ragaert. 2018. 'Predictive Model for the Dutch Post-Consumer Plastic Packaging Recycling System and Implications for the Circular Economy'. *Waste Management* 71 (January): 62–85. https://doi.org/10.1016/j.wasman.2017.10.034.

Browne, Mark Anthony, Phillip Crump, Stewart J. Niven, Emma Teuten, Andrew Tonkin, Tamara Galloway, and Richard Thompson. 2011. 'Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks'. *Environmental Science & Technology* 45 (21): 9175–79. https://doi.org/10.1021/es201811s.

CEWEP. 2017. 'Landfill Taxes and Bans'. http://www.cewep.eu/landfill-taxes-and-bans/. Accessed May 15, 2018.

Dahl, Richard. 2010. 'Green Washing: Do You Know What You're Buying?' *Environmental Health Perspectives* 118 (6). http://dx.doi.org/10.1289/ehp.118-a246.

Dahlbo, Helena, Valeria Poliakova, Ville Mylläri, Olli Sahimaa, and Reetta Anderson. 2018. 'Recycling Potential of Post-Consumer Plastic Packaging Waste in Finland'. *Waste Management* 71 (January): 52–61. https://doi.org/10.1016/j.wasman.2017.10.033.

DG Environment. 2016. 'Landfill Waste - Environment - European Commission'. 6 August 2016. http://ec.europa.eu/environment/waste/landfill_index.htm. Accessed April 15, 2018.

———. 2017. 'Breaking Bag Habits - Environment - European Commission'. Environment. 24 November 2017. https://ec.europa.eu/environment/efe/themes/waste/breaking-bag-habits_en Accessed April 20, 2018.

Dickinson, Kate. 2018. 'EU to Legislate on Single-Use Plastics by Summer'. *Resource Magazine*, 26 February 2018. https://resource.co/article/eu-legislate-single-use-plastics-summer-12437. Accessed March 15, 2018.

Directive 94/62/EC. 1994. 'EUROPEAN PARLIAMENT AND COUNCIL DIRECTIVE 94/62/EC of 20 December 1994 on Packaging and Packaging Waste'.

Directive 2015/720. 2015. 'DIRECTIVE (EU) 2015/720 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 April 2015 Amending Directive 94/62/EC as Regards Reducing the Consumption of Lightweight Plastic Carrier Bags'.

Dodick, Jeff, and Dan Kauffman. 2016. 'A Review of the European Union's Circular Economy Policy'. http://www.r2piproject.eu/wp-content/uploads/2017/04/A-Rview-of-the-European-Unions-Circular-Economy-Policy.pdf. Accessed March 15, 2018.

Ellen MacArthur Foundation. 2016. 'The New Plastics Economy: Rethinking the Future of Plastics'. https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics. Accessed February 15, 2018.

European Commission. 2013. 'Green Paper: On a European Strategy on Plastic Waste in the Environment'. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0123&from=EN. Accessed January 15, 2018.

———. 2015a. 'Closing the Loop - An EU Action Plan for the Circular Economy'. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614. Accessed October 1, 2017.

———. 2015b. 'Closing the Loop: Commission Adopts Ambitious New Circular Economy Package to Boost Competitiveness, Create Jobs and Generate Sustainable Growth'. 12 February 2015. http://europa.eu/rapid/press-release_IP-15-6203_en.htm. Accessed October 2, 2017.

———. 2015c. 'Proposal for a Directive of the European Parliament and of the Council Amending Directive 94/62/EC on Packaging and Packaging Waste.' http://eur-lex.europa.eu/resource.html?uri=cellar:b68494d2-999f-11e5-b3b7-01aa75ed71a1.0019.02/DOC_1&format=PDF. Accessed February 2, 2018.

———. 2016a. ‘Circular Economy Closing the Loop: Clear Targets and Tools for Better Waste Management’. https://ec.europa.eu/commission/sites/beta-political/files/circular-economy-factsheet-waste-management_en.pdf. Accessed January 20, 2018.

———. 2016b. ‘Circular Economy Closing the Loop: The Production Phase of the Circular Economy’. https://ec.europa.eu/commission/sites/beta-political/files/circular-economy-factsheet-production_en.pdf. Accessed January 20, 2018.

———. 2016c. ‘Directive 2008/98/EC on Waste (Waste Framework Directive) - Environment’. 6 September 2016. http://ec.europa.eu/environment/waste/framework/. Accessed January 21, 2018.

———. 2018a. ‘A European Plastics Strategy for a Circular Economy’. http://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf. Accessed January 20, 2018.

———. 2018b. ‘European Commission - Press Release: A European Strategy for Plastics’. 16 January 2018. http://europa.eu/rapid/press-release_MEMO-18-6_en.htm. Accessed January 21, 2018.

———. 2018c. ‘Press Release - Single-Use Plastics: New EU Rules to Reduce Marine Litter’. 28 May 2018. http://europa.eu/rapid/press-release_IP-18-3927_en.htm. Accessed May, 28. 2018.

Eurostat. 2015. ‘Packaging Waste Directive Targets’. http://ec.europa.eu/eurostat/statistics-explained/images/0/02/First_and_second_stage_targets_and_the_years_in_whcih_the_targets_must_be_achieved.JPG. Accessed May 10, 2018.

———. 2018a. ‘Packaging Waste Statistics’. http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics&oldid=371511. Accessed May 10, 2018.

———. 2018b. ‘Packaging Waste by Waste Operations and Waste Flow’. http://appsso.eurostat.ec.europa.eu/nui/show.do?query=BOOKMARK_DS-056956_QID_-A9A5CC1_UID_-3F171EB0&layout=TIME,C,X,0;GEO,L,Y,0;WASTE,L,Z,0;STK_FLOW,L,Z,1;WST_OPER,L,Z,2;UNIT,L,Z,3;INDICATORS,C,Z,4;&zSelection=DS-056956INDICATORS,OBS_FLAG;DS-056956UNIT,PC;DS-056956WASTE,W150102;DS-056956STK_FLOW,DOM;DS-056956WST_OPER,RCY_M;&rankName1=STK-FLOW_1_2_-1_2&rankName2=UNIT_1_2_-1_2&rankName3=WASTE_1_2_-1_2&rankName4=INDICATORS_1_2_-1_2&rankName5=WST-OPER_1_2_-1_2&rankName6=TIME_1_0_0_0&rankName7=GEO_1_2_0_1&sortC=ASC_-1_FIRST&rStp=&cStp=&rDCh=&cDCh=&rDM=true&cDM=true&footnes=false&empty=false&wai=false&time_mode=ROLLING&time_most_recent=true&

lang=EN&cfo=%23%23%23%2C%23%23%23.%23%23%23. Accessed April 15, 2018.

EU-Umweltbüro. 2016. ‘EUropaifno: Das Magazin Des EU-Umweltbüros’. http://www.eu-umweltbuero.at/assets/EU-Umweltbuero/Magazin-EUropainfo/EUropainfo-1-16.pdf. Accessed April 11, 2018.

FEVE. 2015. ‘Glass Recycling Hits 73% in the EU’. *The European Container Glass Federation*. 14 September 2015. http://feve.org/glass-recycling-hits-73-eu/. Accessed April 20, 2018.

Fischer, Wolfgang, and Danko Simic. 2016. ‘Umweltbildung Als Schlüssel Zu Höheren Recyclingquoten’ *EUropainfo* 16 (1): 18–19.

Freytas-Tamura, Kimiko de. 2018. ‘Plastics Pile Up as China Refuses to Take the West’s Recycling’. *The New York Times*, 11 January 2018. https://www.nytimes.com/2018/01/11/world/china-recyclables-ban.html. Accessed January 20, 2018.

Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. 2016. ‘A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems’. *Journal of Cleaner Production* 114 (February): 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007.

Hahladakis, John N., and Eleni Iacovidou. 2018. ‘Closing the Loop on Plastic Packaging Materials: What Is Quality and How Does It Affect Their Circularity?’ *Science of The Total Environment* 630 (July): 1394–1400. https://doi.org/10.1016/j.scitotenv.2018.02.330.

Hahladakis, John N., Costas A. Velis, Roland Weber, Eleni Iacovidou, and Phil Purnell. 2018. ‘An Overview of Chemical Additives Present in Plastics: Migration, Release, Fate and Environmental Impact during Their Use, Disposal and Recycling’. *Journal of Hazardous Materials* 344 (February): 179–99. https://doi.org/10.1016/j.jhazmat.2017.10.014.

Haupt, Melanie, Carl Vadenbo, and Stefanie Hellweg. 2017. ‘Do We Have the Right Performance Indicators for the Circular Economy?: Insight into the Swiss Waste Management System: Circular Economy: Do We Have the Right Indicators?’ *Journal of Industrial Ecology* 21 (3): 615–27. https://doi.org/10.1111/jiec.12506.

Hopewell, J., R. Dvorak, and E. Kosior. 2009a. ‘Plastics Recycling: Challenges and Opportunities’. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1526): 2115–26. https://doi.org/10.1098/rstb.2008.0311.

———. 2009b. ‘Plastics Recycling: Challenges and Opportunities’. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1526): 2115–26. https://doi.org/10.1098/rstb.2008.0311.

Konieczna, Aleksandra, Aleksandra Rutkowska, and Dominik Rachoń. 2015. ‘Health Risk of Exposure to Bishenol A (BPA)’, *Rocz Panstw Zakl Hig* 66 (1): 5-11.

Martin, Anne-Claude. 2014. ‘Plastics to Be Banned from European Landfill’. *Euractiv*, 27 November 2014. https://www.euractiv.com/section/sustainable-dev/news/plastics-to-be-banned-from-european-landfill/. Accessed March 10, 2018.

Mato, Yukie, Tomohiko Isobe, Hideshige Takada, Haruyuki Kanehiro, Chiyoko Ohtake, and Tsuguchika Kaminuma. 2001. ‘Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment’. *Environmental Science & Technology* 35 (2): 318–24. https://doi.org/10.1021/es0010498.

Morris, Jeffrey. 1996. ‘Recycling versus Incineration: An Energy Conservation Analysis’. *Journal of Hazardous Materials* 47 (1–3): 277–93. https://doi.org/10.1016/0304-3894(95)00116-6.

Neitsch, Matthias. 2016. ‘EU-Kreislaufwirtschaftspaket: Nutzen Für Re-Use?’ *Das Magazin Des EU-Umweltbüros* 1 (16): 20.

Ocean Conservancy. 2015. ‘Stemming the Tide: Land-Based Strategies for a Plastic-Free Ocean’. https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf.

Packaging Europe. 2018. ‘Plastic Packaging Waste Statistics 2016: Recycling Passed 40%’. Packaging Europe. https://packagingeurope.com/api/content/86fbf7ea-30ee-11e8-a195-121bebc5777e/. Accessed March 28, 2018.

Patel, Martin, Norbert von Thienen, Eberhard Jochem, and Ernst Worrell. 2000. ‘Recycling of Plastics in Germany’. *Resources, Conservation and Recycling* 29 (1–2): 65–90. https://doi.org/10.1016/S0921-3449(99)00058-0.

Pivnenko, Kostyantyn, L. G. Jakobsen, Marie Kampmann, Anders Damgaard, and Thomas Fruergaard. 2015. ‘Challenges in Plastics Recycling’. CISA Publisher. http://orbit.dtu.dk/files/118106943/Plastics_published.pdf. Accessed March 15, 2018.

Plastics Europe. 2011. ‘Plastics - the Facts 2010. An Analysis of European Plastics Production, Demand and Recovery for 2009’. https://www.plasticseurope.org/en/resources/publications/171-plastics-facts-2010. Accessed March 15, 2018.

———. 2014. ‘Plastics - the Facts 2013. An Analysis of European Latest Plastics Production, Demand and Waste Data.’ https://www.plasticseurope.org/en/resources/publications/103-plastics-facts-2013. Accessed March 15, 2018.

———. 2015. ‘Plastics - the Facts 2014/2015. An Analysis of European Plastics Production, Demand, and Waste Data’.

https://www.plasticseurope.org/en/resources/publications/95-plastics-facts-2014. Accessed March 15, 2018.

———. 2017. ‘Plastic - the Facts 2016: An Analysis of European Plastics Production, Demand and Waste Data’. https://www.plasticseurope.org/en/resources/publications/3-plastics-facts-2016. Accessed March 15, 2018.

———. 2018. ‘Plastics - the Facts 2017: An Analysis of European Plastics Production, Demand and Waste Data’. https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf. Accessed March 20, 2018.

Pozo, Beatriz Ferreira, César Aliaga Baquero, Juan Luis Martí Arbona, and Mercedes Hortal Ramos. 2012. ‘Plastic Waste Recovery in Spain: Overview of the Market and Applied Technologies’. http://www.vivis.de/phocadownload/Download/2012_wm/2012_WM_183_195_Ferreira_Pozo.pdf. Accessed March 20, 2018.

Quadrant. 2017. ‘REACH - Registration, Evaluation, Authorisation, Chemical Substances’. https://www.quadrantplastics.com/na-en/sustainability/reach.html. Accessed March 20, 2018.

Raynaud, Julie, James Richens, and Andrew Russell. 2014. ‘Valuing Plastics: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry’. *United Nations Environmental Program (UNEP)*. http://www.unep.org/pdf/ValuingPlastic. Accessed March 25, 2018.

Ren, X. 2003. ‘Biodegradable Plastics: A Solution or a Challenge?’ *Journal of Cleaner Production* 11 (1): 27–40. https://doi.org/10.1016/S0959-6526(02)00020-3.

Reuter, Markus, and Antoinette van Schaik. 2012. ‘Opportunities and Limits of Recycling: A Dynamic-Model-Based Analysis’. *MRS Bulletin* 37 (04): 339–47. https://doi.org/10.1557/mrs.2012.57.

Schüler, Kurt. 2017. ‘Aufkommen und Verwertung von Verpackungsabfällen in Deutschland im Jahr 2015’. Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2017-11-29_texte_106-2017_verpackungsabfaelle-2015.pdf. Accessed April 20, 2018.

Statista. 2018. ‘EU-28: Plastic Waste Generation 2015 | Statistic’. Statista. 2018. https://www.statista.com/statistics/817004/plastic-waste-generation-european-union-eu-28/. Accessed May 10, 2018.

Szaky, Tom. 2015. ‘The Many Challenges of Plastic Recycling’. *Sustainablebrands.Com.* http://www.sustainablebrands.com/news_and_views/waste_not/tom_szaky/many_challenges_plastic_recycling. Accessed April 15, 2018.

The Ecological Council. 2017. 'Consequences of the European Plastic Bag Directive'. https://www.ecocouncil.dk/en/releases-3/109-economy-and-politics/2568-consequences-of-the-european-plastic-bag-directive. Accessed April 18, 2018.

UNEP. 2005. 'Marine Litter: An Analytical Overview'. http://wedocs.unep.org/handle/20.500.11822/8348. Accessed April 14, 2018.

Van Eygen, Emile, David Laner, and Johann Fellner. 2018. 'Circular Economy of Plastic Packaging: Current Practice and Perspectives in Austria'. *Waste Management* 72 (February): 55–64. https://doi.org/10.1016/j.wasman.2017.11.040.

Velis, Costas. 2014. 'Global Recycling Markets: Platic Waste. A Story of One Player - China'. ISWA. https://www.iswa.org/fileadmin/galleries/Task_Forces/TFGWM_Report_GRM_Plastic_China_LR.pdf. Accessed May 14, 2018.

Watkins, Emma, Susanna Gionfra, Jean-Pierre Schweitzer, Mia Pantzar, and Charlotte Janssens. 2017. 'EPR in the EU Plastics Strategy and the Circular Economy: A Focus on Plastic Packaging'. https://ieep.eu/uploads/articles/attachments/95369718-a733-473b-aa6b-153c1341f581/EPR%20and%20plastics%20report%20IEEP%209%20Nov%202017%20final.pdf?v=63677462324. Accessed April 14, 2018.

Weitzel-Mudersbach, Mona von. 2016. 'Obtstacles to a Circular Economy'. *Das Magazin Des EU-Umweltbüros* 16 (1): 15–16.

Zero Waste Europe. 2017. 'Zero Waste to Landfill and/or Landfill Bans: False Paths to a Circular Economy'. https://zerowasteeurope.eu/2015/11/press-release-landfill-ban-a-false-path-to-a-circular-economy/. Accessed May 12, 2018.

Zimmermann, Lars, and Sam Muirhead. 2016. 'What Do We Mean When We Talk about an Open Source Circular Economy?' *Das Magazin Des EU-Umweltbüros* 16 (1): 16–17.

List of Figures

List of Tables