Bachelor Thesis

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Title:

“Assessment of plastic waste management practices with a focus on the reduction of negative externalities – a German approach”

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Abstract

Throughout the last decades, the production of plastic has increased drastically on an international level. At the same time, this implies an increase in the amount of occurring plastic waste. In this context, the global awareness of negative effects of plastic waste is peaking as well, inspiring campaigns and protests against the waste of this material especially focusing on the harm the waste does to marine wildlife.

Focussing on Germany, this thesis provides an overview of the current plastic waste landscape and regulations in place and thereafter assesses the effectiveness of plastic waste management methods regarding the reduction of said negative effects on society and third parties also having a closer look at the cost-benefit ratio that is achieved by pre-treatment measures and the methods applied.

As a matter of fact, the current structure aligns with the waste hierarchy implemented and the current EU strategy. Nevertheless, there is still room for improvement especially regarding the international level of standardisation and trade in plastic waste.

Keywords: plastic waste management, negative externalities of plastic waste,
German plastic waste landscape, efficiency of waste management practices

JEL classification: Q53, Q56, Q28

I. Outline

II. List of tables and figures

III. List of abbreviations

CO2	Carbon dioxide
EU	European Union
KrW- /AbfG	Kreislaufwirtschaft- und Abfallgesetz
PET	Polyethylene terephthalate
REACH	Regulation on the registration, evaluation, authorization and the restriction of chemicals
UN	United Nations
VerpackG	Verpackungsgesetz
VerpackV	Verpackungsverordnung

1. Introduction

1.1 Research problem

Plastic is a material that is used worldwide for several causes. Throughout the last century, its production has increased steadily resulting in a large pile of plastic waste. One of the challenges faced in this context is that if plastic waste is not managed effectively, it might also be littered into the environment causing environmental pollution which might have an impact on human health. It is being discussed whether these negative externalities resulting from the consumption of plastics need to be reduced actively in order to hold off severe damages.

Thus, the issue is being addressed by the implementation of plastic waste management measures, that focus on the reduction of those negative externalities. In addition to that, there are certain regulations of the European Union (in the following EU) and national laws in place in Germany that shall prevent those negative externalities from being ignored. Thereby, the long history of recycling and waste management offers different kinds of treatment for plastic waste many of which are used in Germany as well.

The question remaining from this status quo analysis is whether those measures used in Germany are efficient in reducing negative externalities of plastic littering in such a way that their advantages outweigh the additional costs that have to be buried by the government and in the end will be passed on to the consumer.

Therefore, this thesis aims to illustrate how plastic waste is currently managed in Germany regarding the reduction of negative externalities assessing both, the effectiveness and the efficiency of measures in use, in a world where plastic production is increasing steadily, and its waste management is lacking efficiency worldwide. It evaluates the overall reduction of negative externalities and the cost-benefit relationship of different methods used to treat plastic waste.

1.2 Research method

This paper addresses the role of German plastic waste management practices to the issue of the compensation of negative externalities in the usage of plastics in times of permanently increasing production and usage of the material applying a literature based theoretical approach. Therefore, a description of the current situation in

Germany as well as the evaluation of the effectiveness of applied methods of plastic recycling regarding the reduction of negative externalities is necessary. A sophisticated outcome can be provided by comparing several literature devices by different authors to create coherence.

1.3 Course of investigation

In order to achieve coherence, the thesis starts with chapter 1 as an introduction to the aim and for an understanding of the approach.

The second chapter clarifies the general topic of negative externalities of plastic usage defining the term negative externalities itself and then projecting it on the context of plastic.

The third chapter aims to grasp the current plastic waste management landscape of Germany explaining the legal foundation on both national and EU level and then depicting the status quo of used methods. These methods will be assessed and evaluated upon their effectiveness regarding the reduction of negative externalities of the waste and their cost efficiency.

The fourth chapter will focus on the question whether the collection and treatment of plastic waste are designed in an efficient way evaluating the costs emerging throughout the process of treatment with the benefit of reduced externalities.

In chapter 5 the research question of chapter 1.1 will be answered within a summary of the declared remarks. Moreover, potential restrictions to the outcome of the term paper as well as a possible forecast of the expansion will be stated.

2. Assessment of negative externalities of plastic consumption

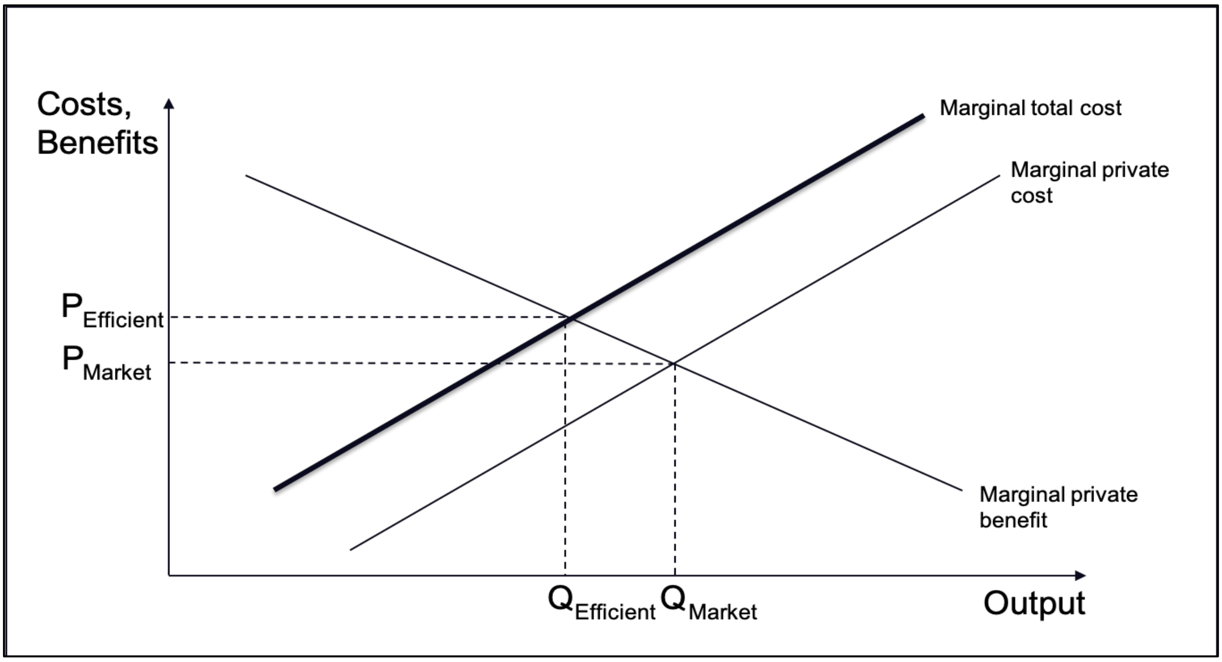
2.1 Definition of negative externalities of business transactions

In order to understand why there is a need for plastic waste management, it is important to create an understanding for the impact of the consumption as well as the production of plastic on society and the environment. In this context, the term negative externalities plays an important role which is why this chapter will focus on explaining it in greater detail in order to build the foundation for understanding the issue of plastic waste.

Externalities in general are defined as the imposition of costs or benefits on third parties due to the production or consumption of goods and services which are not reflected in the product prices (Centre for Co-operation with European Economies in Transition 1993, p.44). Subsequently, externalities often imply that the market allocation of goods is inefficient as market prices do not reflect costs or benefits for society (Stiglitz, Walsh 2010, pp.290).

In the case of negative externalities, companies or individuals do not pay the appropriate price for producing or consuming a certain good but the costs only represent a part of the total costs (Krugman, Wells 2010, pp.595). The total costs are compiled of private costs, which are buried by the producer or the consumer, and external costs, which arise due to the production or the consumption of a good or a service such as the environmental impact, negative impact on the health of third parties as well as on other industries or companies which suffer from certain actions, which are usually not reflected in a product price (Woll 2011, pp.137). This effect leads to market disfunctions as companies can sell products or services at a lower price than the total costs would suggest and therefore the goods or services are demanded at a higher quantity than the actual market conditions would imply (Hubbard, O'Brien 2017, pp.148).

Figure 1: Market inefficiencies due to negative externalities



Source: Own source based on Hubbard, O'Brien, 2017 pp.148

This discrepancy between the efficient market situation and the situation realized due to negative externalities is depicted in figure 1 above. As the graphic indicates, the marginal total costs which include both private and external costs is neglected when the market forms an equilibrium, selling a higher quantity for a lower price than economically efficient. The marginal private benefit is therefore higher than in an efficient market situation, but this also implies that the complete external costs have to be borne by society as they are not reflected in the market price.

The remaining question is how negative externalities should be treated as those negative effects do not regulate themselves because neither producers nor consumers voluntarily change those conditions since they both profit from higher income and cheaper prices (Stiglitz, Walsh 2010, pp.290). Therefore, a society can either decide not to intervene and accept the status quo or the government can impose regulatory measures introducing new taxes, regulations, penalties and subsidies for the application of best practices avoiding those effects or innovations preventing negative externalities to arise amongst other methods (ibid.).

Even though regulating markets in order to design them more efficiently can have a positive overall effect on total benefit, in general it is important to reflect on how in an internationalized world government interference that is restricted to a country's borders can lead to a competitive disadvantage for the economy or certain industries of that country as international competitors do not have to internalize negative externalities in the same way (Krugman, Wells 2010, pp.595). Another important factor in the consideration process for governmental interference is to what extent it is efficient to further reduce negative externalities (Hubbard, O'Brien 2017, pp.148). This aspect will be addressed in chapter 4.1 in greater detail.

As this chapter explains, it is important to reflect on the negative externalities caused by the production or consumption of a good or a service in order to describe its monetary impact on society. If a government decides to intervene in order to reduce arising costs, it is necessary to reflect on the marginal benefit of intended measures and the international competitiveness before restricting a free market.

2.2 Negative externalities of plastic

After introducing negative externalities and explaining the impact they have on market efficiency, this concept can now be applied to the consumption of plastic, focussing on plastic waste. This chapter will explain in how far the negative externalities of plastic consumption affect further industries, third parties and society as a whole.

In order to create coherence, it is important to understand the characteristics of plastics and its application for assessing the negative implications of its production as well as its consumption. The source material of plastic is usually a crude oil, which is a scarce raw material (OECD, 2018). The main component of plastic thereby is synthetically produced or processed carbon, which is contained in crude oil, and in a next step is transformed from a monomer to a polymer, most likely through technical polymerization (Brandsche, Piringer 2007, pp.9). As this founds the basis for the production of plastic of any kind, it is also important to understand that plastic is a collective term for a range of different materials with different properties and applications (UNEP 2014, pp.15). These different materials are used for several purposes and can be found in the production process for products such as bottles, textiles, food packaging, window frames, medical products and automotive parts (OECD 2018, p.30).

This wide range of application reflects upon the fact that the material itself is beneficial in many contexts and its usage is not necessarily solely connected with negative implications (UNEP 2014, pp.15). The usage as food packaging in many cases leads to food waste prevention as food can be stored for a longer time (ibid.). Also, the usage in the medical sector helps supporting the health state of many humans, which also should be taken into consideration (OECD 2018, pp.30). Moreover, in 2012, the plastic industry accounted for about 1.4 million employees in Europe alone providing an income for those people that otherwise might be unemployed (UNEP 2014, pp.15).

Plastic is often used because it is cheap and convenient and therefore especially for packaging purposes an easy solution for companies to profit from its characteristics (Vikolainen 2018, p.1). Even though these positive characteristics of plastic have to be considered when taking decisions regarding the material to be used in a product, plastic also has its downsides due to its negative impact on the environment occurring at both stages, the production and the consumption concerning the end-of-lifecycle momentum when plastic turns into waste. Both can lead to severe economic forfeits if not managed properly (Saito 2016, p.40, p.48).

Evaluating the production process, it has to be taken into account that the raw material, which in most cases is crude oil, is irreversibly transformed and, if not recycled properly, lost (UNEP 2014, pp.15). Moreover, throughout the process emissions occur in form of greenhouse gases and other chemicals which especially have a negative impact on climate change and the environment (Schulte, Simon 2017, p.22). Focussing on the consumption of plastic, the negative externalities are broadly diversified being reflected in direct costs and costs borne by independent industries in the form of loss of revenue (ibid.). This is implied by the fact that the release of plastic waste into the wider environment has a negative impact on society and the ecosystem in general (OECD 2018, p.15). One industry that is especially affected by the plastic waste occurring due to plastic littering is the fisheries industry. Fishermen have to face the issue of the occurrence of plastic as by-catch as well as the decease of certain species which both leads to losses because the amount of fish caught decreases (Jahn, Stickel, Kier 2012, pp.15). Especially the latter is caused by the ingestion of microplastics and smaller plastic parts and the entanglement in abandoned fishing nets, so called ghost nets, that are usually disposed by fishermen themselves (UNEP 2014, p.17). Another problem occurring with marine littering of plastic waste that affects not only the fisheries industry but also the shipping industry and any other industry using motorised boats or vessels is that also the propellers of ships crossing the oceans can get entangled by said plastic nets and other plastic products. Owners then have to face high repair costs, losing crucial time at sea as the fixing might take a rather long time (Jahn et al. 2012, pp.15).

Tourism is another industry affected by the negative externalities of marine littering of plastic. With coasts being flooded by plastic waste, many touristic areas become less appealing to visitors as they do not want to face the garbage littered into the environment (Lippelt 2017, pp.62). Often, beaches need to be cleaned up in order not to threaten anyone’s health and to make beaches more appealing to tourists, which also costs government and private beach owners as well as other involved parties a large amount of money (ibid.). But plastic waste does not only make it less appealing to go to beaches, but some attractions such as whale watching or diving become less popular as many species are critically endangered and become extinct in some areas (Jahn et al. 2012, pp.15).

Only focussing on the marine ecosystem concentrating on those three industries mentioned above, the Asia-Pacific Economic Cooperation estimates the yearly losses due to the improper management of plastic waste at 13 billion US Dollars worldwide (UNEP 2014, p.18). This same publication indicates that about ten to twenty million tons of plastic waste are littered into the sea annually (ibid. p.17). Using these numbers as a benchmark for estimating the external costs of plastic waste, one tonne would cost about 650 to 1300 US Dollars depending on the actual amount littered into the oceans. As this number is only focussing on specific costs imposed on the marine ecosystem it should be used with caution and as estimation only. This is reinforced by the fact that these figures are already difficult to measure in the first place due to a lack of transparency and inaccuracy because of projections.

Another factor describing the negative externalities of plastic waste is the material loss considering that petroleum is a scarce raw material. Worldwide, about 95% of the material value of plastic is lost due to littering into the environment, improper treatment and value loss throughout the recycling process assuming a worldwide recycling rate of 14%. This loss is valued at an estimated 80 to 120 billion US Dollars in 2016, anticipating a material value of 1,100 to 1,600 US Dollar per tonne and a value preservation rate of recycled plastic of 30% (World Economic Forum 2016, p.12). Even though the actual numbers are difficult to be determined, these estimations give a broad overview of how important an effective plastic waste management can be in order to reduce the costs that are not internalised into the price of plastic sold on the market.

What also has to be taken into consideration is that the natural decay process for plastic takes up several hundreds of years depending on the specific kind of plastic. Therefore, the negative externalities of unmanaged disposal of plastic waste are often underestimated as the timescale of decay postpones many of the problems arising. Therefore, society often forgets how the amount of waste piles up, aggravating the effects of newly disposed plastic waste (OECD 2018, pp.22). The emergence of secondary microplastics, which are plastic particles that are one micrometre to five millimetres in size occurring through the decay of larger plastic products, for example takes up a long time so the negative consequences are not valued properly (ibid.).

The emerging problems due to microplastics are another issue that has to be considered when assessing the negative externalities of plastic consumption in itself.

Besides the secondary particles, often microplastics are also used intentionally by certain industries as for example in cleaning gels or shampoos as a cheap ingredient or they occur whilst using a product as it is the case for tyre abrasion (Lippelt 2017, pp.64). For those particles though it is technologically not feasible to filter them out of the environment or the tap water as at this point of time there is no filtration system in place that could remove them from the cycle (Betker 2015, pp.130). This problem might not be solvable by plastic waste management methods currently in use, but it shall indicate how important this issue is when taking into account that sized in the nanometre scale, it was found that the ingestion of microplastics can lead to cell damage in the case of marine wildlife, yet to be determined which impact it might have on human health (Lippelt 2017, pp.64).

This and other possible impacts of plastic waste on human health are not researched in detail yet which is why it is not possible to quantify it at this point of time, but studies supporting the possibility of cell damage due to microplastics and the fact that often hazardous additives are used in the production process suggest that there is a negative impact that should be further investigated into (ibid.; OECD 2004, pp.31). Besides the fact that plastic waste might affect public health, another reason that increases the need for governmental interference and the introduction of a waste management system is the fact that plastic production and therefore the occurrence of plastic waste is increasing steadily (ibid., p.43). This is amongst other reasons due to the growth of worldwide population, the process of urbanisation and the emerging industrialisation. Another reason is a change in lifestyle, especially in high income countries, as it becomes more common to be single, which causes the need for smaller portions and hence a larger total amount of plastic packaging (Ruth 2018, pp.3).

3. Plastic waste management practices in Germany

3.1 Definition of waste management

After discussing why it is important to address the issue of plastic waste, this chapter will focus on how to do so introducing the concept of waste management and its implementation in Germany. Hence, this subchapter focusses on the introduction of the definition of solid waste management that is used as a foundation for this thesis.

The general understanding of waste management is the identification of a safe and economical way of disposing waste in order to prevent negative consequences of littering into the environment (Günther, 2019). In order to achieve this goal, the identification of the best practicable option of treatment has to be accomplished considering either the most beneficial method for society and third parties or the one causing the least damage on the environment as well as citizens, both at acceptable cost in order to grant the application of an efficient method (Barton, Dalley 1996, pp.35). These considerations have to be both, long and short term (ibid.). This definition considers the design, upgrade and operation of waste management processes aiming at increasing the rate of material or energy recovery (Pohjola, Pongrácz 2004, p.148). The approach includes the collection, transport, recovery and disposal of waste as well as the monitoring and after-care processes for the method applied (Council Directive 75/442/EEC status as of 1975, Art. 3-7).

However, the approach mentioned above does not consider the aspect of waste prevention as it is solely focussing on reducing the physical contact between environment and the waste produced, trying to minimise the negative implications of pollution and littering. (Pohjola, Pongrácz 2004, pp.150). Even though many modern concepts also indicate that waste prevention should be the most desirable method of coping with waste, often the strategies of avoiding waste are not part of the definition of waste management or are not methodologically defined or quantified (ibid.; Barton, Dalley 1996, pp.35). Therefore, this thesis will focus on the methods used after waste is produced, applying the more narrow definition but keeping in mind that the reduction of the amount of waste is considered to be the most purposeful way leading to the reduction of negative externalities.

3.2 Legislation and governmental initiatives

3.2.1 Regulations of the European Union

In order to understand the legislative landscape in Germany regarding the management of plastic waste, it is important to also consider which EU laws are applicable with regards to the topic. As Germany is part of the EU, there are certain legislative approaches that have to be integrated into national law and some guidelines that apply consecutively to the publication of the European Parliament.

The EU is a treaty-based union that provides legislation for in total 35 areas of policy making in order to align standards across Europe, actively influencing the rules applicable in all 28 member states (European Commission 2018, pp.7). Member states have democratically decided to give up on their sovereignty in those areas in order to support harmonisation across the continent (ibid.). There are several different ways of introducing new legislative content to the member states with regulations and directives usually being the most used ones. Regulations represent directly applicable law for all members of the EU whereas directives have to be implemented and ratified into national law, strictly having to convey the same goal as the directive itself but if necessary adapted to the cultural and individual situation of a country (ibid., p.53). As one of the fields the EU is introducing laws for is climate action and sustainability, EU law also plays an important role in the context of plastic waste management as those practices intend to reduce negative externalities and therefore aim at protecting the environment (ibid., p.25). In the following, the most important aspects as well as the most recent developments in this field will be depicted.

The first directive published addressing packaging waste and therefore also plastic waste stems from 1994 and already indicated the first targets for recycling and waste management (EPRS 2017, pp.5). One of the targets was a recycling rate of 22.5% of packaging waste raising the awareness of the importance of the matter (Directive 94/62/EC, status as of 1994). These targets were amended in 2015 by a limit of annual per capita consumption of carrier bags made out of lightweight plastics of 40 by 2025 and the introduction of charges for those bags after December 2018 (Directive 2015/720, status as of 2015). In a next step, in the context of increasing export rates for plastics, the EU also published a regulation on the shipment of waste in 2006 focussing on the procedures regarding the international trans-border waste transport, also including the transportation routes to third countries. The main goal of this directive was to make waste trade more transparent and therefore more sustainable, granting the traceability of waste so it can be ensured that waste is treated in alignment with EU standards (Regulation (EC) No 1013/2006, status as of 2006). Moreover, after it was noticed that often hazardous additives are used in the plastic production that would be exposed to the environment when littered, the regulation on the registration, evaluation, authorisation and restriction of chemicals (in the following REACH) was also introduced in 2006 (EPRS 2017, pp.5). This regulation does not necessarily address plastic waste management methods and their application, but it is an important step towards a product design that makes it easier for plastic products to be recycled.

In 2008, the waste framework directive was introduced by the European Parliament, which focussed on, but wasn't limited to, further establishing a waste hierarchy

(Directive 2008/98/EC, status as of 2008). According to the hierarchy, the best way of handling waste should be the prevention of producing it. The next best way would be the preparation for re-usage, followed by recycling, (energy) recovery and disposal in this order (EPRS 2017, pp.5). This hierarchy is broadly accepted and implemented as a standard worldwide as it also promotes the development of a circular economy (Barton, Dalley1996, pp.35). Another topic addressed by the framework is the extended producer responsibility (Directive 2008/98/EC, status as of 2008). This passage focusses on how producers should be held responsible for organizing or paying the emerging environmental costs arising throughout the entire product lifecycle and to internalise these expenses into the market price of a product which shall reduce the external costs imposed on society (EPRS 2017, pp.5). Also, plastics and the treatment of plastic waste were identified as a priority topic in the EU action plan for the circular economy (ibid.). The treatment methods should get aligned with the sustainable development goals of the United Nations (in the following UN), focussing especially on the recyclability of produced plastics, the promotion of biodegradable substitutes, the reduction of usage of hazardous substances as well as of marine litter (COM (2015) 614, European Commission 2015, pp. 2).

This focus on the reduction and re-usage of plastic materials is also reflected in rules on single-use plastic products and other products littered into the ocean adopted by the European Parliament in March 2019 (European Commission, 2019). The main content of the constructed limitations in plastic usage consists of a ban of the ten most used single-use plastic products as well as abandoned fishing gear and further targets of incentivizing the reduction of plastic consumption in general (ibid.). These ideas and restrictions are closely aligned with the waste hierarchy approach implemented in 2008, applying a broader definition of waste management as defined in chapter 3.1. In connection with further recycling rules such as a target of 90% separate collection of plastic bottles by 2029, the rules are expected to save 3.4 million tons of carbon dioxide (in the following CO2) equivalent emissions as well causing a reduction of environmental damage accounted at an estimated value of 22 billion Euro by 2030 improving the plastic waste treatment after its occurrence (ibid.).

Even though not all of the regulations and directives mentioned above have a direct influence on plastic waste management methods that are assessed in this thesis, they illustrate that the overall topic is relevant for the EU and needs to be addressed. Also, it shows the complexity of the issue and that the recyclability of plastic materials is of importance in order to achieve the targets set.

3.2.2 National legislation in Germany

National law in Germany has to be aligned with the EU directives and has to take into consideration the regulations published as they are overruling the national law of any EU member state as indicated in chapter 3.2.1. However, Germany's attempts to reduce negative externalities of plastic waste are not limited to complying with institutional legislation from the EU but it is proactively targeting even more extended goals itself.

One of the first steps in Germany towards a more sustainable waste management approach focusing on packaging waste was the introduction of the so-called Verpackungsverordnung (in the following VerpackV) in 1991 leading to Germany being one of Europe's first countries to introduce a law that copes with the fair allocation of costs arising from the incurrence of waste (Wacker-Theodorakopoulos 2000, p.628). Moreover, it has laid the foundation for the dual system in Germany, focusing on the producer responsibility in the context of waste incurrence (Deutsches Bundesamt 1998). This concept introduces a second system for waste collection and treatment besides the municipal waste management system already in place before the presentation of the VerpackV, reacting to the increasing amount of waste produced which the public system would not have been able to dispose (Wacker-Theodorakopoulos 2000, p.628). This approach is represented by the brand Grüner Punkt which belongs to the company Duales System Deutschland and initially was intentionally formed as a monopoly acting as an administrative and intermediary connector between companies producing primary or secondary waste due to the packaging of their products and companies providing services in the waste industry such as collection, transportation and recycling (ibid.; Dehio, Rothgang 2018, p.4). The entire concept is based on royalties that have to be paid by participating producers in order to use the branding of Grüner Punkt and to be registered as having complied with the concept of producer responsibility regarding their plastic packaging (Rahmeyer 2004, pp.14).

Even though this dual system approach has solved the initial problem of coping with an increasing amount of waste, critics claim the cost calculations for plastic waste introduced by Grüner Punkt are not transparent and the initial monopolistic approach reduces the efficiency from a long-term perspective (ibid.). In order to address these concerns, the German government decided to adjust the law several times throughout the last decades trying to enable stronger competition for Grüner Punkt to establish fairer market conditions (ibid.). The latest change to the regulatory landscape of packaging was the introduction of the Verpackungsgesetz (in the following VerpackG) having entered into force on January 1st, 2019 replacing the VerpackV (Schulze 2019, p.6). The two main differences comparing it to the VerpackV are the introduction of a central institution for registering packaging in order to grant more transparency throughout the pricing process and also that the required recycling rate of plastic, amongst other materials, will be increased in two steps in 2019 and 2022, overall changing from 36% to 63%, focusing on following the waste hierarchy implemented (Wissenschaftliche Dienste des Deutschen Bundestags 2018, pp.8,10). Furthermore, the VerpackG shall provide incentives to increase the recyclability of produced packaging – the specification of the measures taken in order to incentivize is to take place in the near future (ibid.).

As for the increase in recycling rate, the new goal is ambitious not only because it almost doubles the initial percentage, but also because at the moment the input of material arriving at plastic waste recycling facilities with the purpose of being recycled is considered for identifying recycling rates, but this definition will soon be harmonized across the EU only taking into account the actual weight of output of those facilities (Schulze 2019, p.6).

In addition to the VerpackV, Germany has furthermore introduced the Kreislaufwirtschafts- und Abfallgesetz (in the following KrW- /AbfG) in 1996, which concentrates on the waste hierarchy having the same structure as the order promoted by the EU (Rahmeyer 2004, p.8; cf. chapter 3.2.1). Even though the reduction of waste is considered to be the most expedient measure according to the waste management hierarchy, the law does not implement any clauses allowing the quantification or introducing a certain target regarding this topic (ibid.). As the conservation of natural resources is in the center of this law, article five obligates producers and processors of waste to utilize it if technologically possible and economically reasonable (ibid., p.9). In the following years, as a reaction to the waste framework EU directive from 2008, Germany has introduced the Kreislaufwirtschaftsgesetz 2012, which replaced the KrW- /AbfG but mainly has the same content (BGBI. S. 212).

As the above-mentioned laws imply, on a national level, Germany has a similar role influencing national waste management as the EU has, because the national ministry of environment has to develop an overall strategy setting priorities and defining requirements, but it does not plan any particular waste management measures (EEA 2009, pp.38). The implementation and the achieving of set targets is the responsibility of the federal states and local authorities, which define in detail which costs have to be borne by which party and which collection methods to apply (Rahmeyer 2004, p.5). Therefore, this thesis does not further go into detail on an implementation level as this varies due to significant differences between federal states and even on a municipal level.

On a more general level, Germany has introduced several laws regarding waste management with the purpose of protecting the environment and in this context reducing the negative externalities of (plastic) waste mentioned in chapter 2.2. One of the most current publications besides the VerpackG is the five-point plan from 2018 that indicates how the material loop can be closed (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2018, p.1). Aligned with the predicted next steps of the EU, the main aspects of the plan are the reduction of redundant products and packaging, which goes hand in hand with the EU directive concerning single use plastics that is currently discussed, the more economically friendly design of packaging and products in general, the increase of recycling rates and the usage of recycled materials, the avoidance of plastic in biodegradable waste, as well as the international commitment to reduce ocean plastics (ibid. pp.3). For the last point, Germany has decided to invest 50 million Euro from its energy and climate fund for exporting technology against littering throughout the next ten years, indicating that the negative externalities of plastic littering are a global problem (ibid. p.2).

3.3 Plastic waste management landscape in Germany

3.3.1 Scope of plastic waste in Germany

After having discussed the different externalities of plastic consumption and depicting the legal situation in the EU and Germany, this chapter will focus on illustrating the scope of plastic production in Germany as well as the amount of waste produced annually that has to be coped with throughout the plastic waste management process.

During the past 70 years, the worldwide plastic production has drastically increased from 1.6 million tons in 1950 to 348 million tons in 2017 (PlasticsEurope 2018 pp.8). In Europe, the number increased from 0.35 million tons to 64.4 million tons throughout the same time span (ibid.). These numbers show how important plastic became over the past couple of years being a versatile material which is important for not only single use consumption, but also several other causes as mentioned in chapter 2.2. Not only are the volumes increasing, but so is the revenue in this industry. As table 1 illustrates, the production level in Germany was rather stable over the last three years whereas the revenue increased steadily. The plastics industry can be considered to be of great importance for the German economy as in 2017, German production accounted for roughly one third of the production level of the EU comparing the numbers mentioned above.

Table 1: Plastics industry in Germany – revenues and production

Indicator	2016	2017	2018
Revenue (in bn. EUR)	24.2	27.1	27.4
Production (in mil. tons)	19.2	19.9	19.3

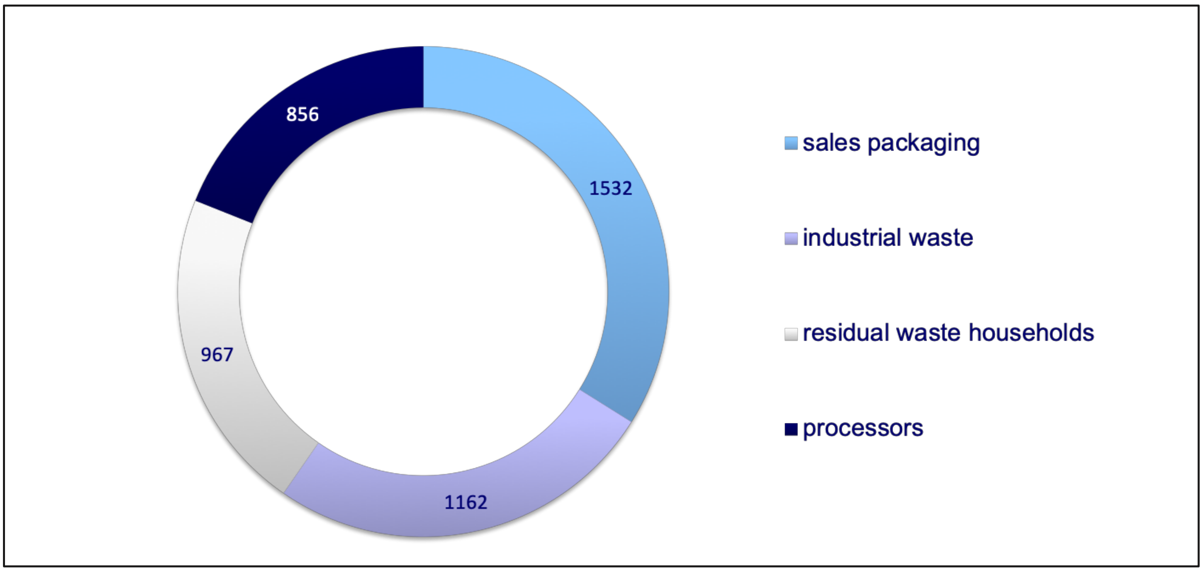
Source: Own source based on PlasticsEurope, 2019 p.15

The entire industry including but not limited to the production of plastics in 2018 was composed of about 3.430 companies making up about 419.000 employees and generating 101 billion Euro revenue in total in Germany alone (PlasticsEurope 2019, p.27). The industry itself can therefore be claimed to be a strong stream of income for German economy with the most important sectors being panels and foils, packaging, building materials and the production of the plastic material itself (Statistisches Bundesamt 2018).

As described in chapter 2.2, plastic furthermore is a crucial material in several sectors in order to improve product design. The problems that have to be addressed by plastic waste management measures though are arising from the end-of-lifecycle momentum when it is important to prevent littering from happening (cf. Chapter 2.2).

Therefore, it is important to reflect upon the amount of waste produced annually in order to further break down the issue faced by the German government, so the measures taken to reduce negative externalities of plastic consumption can be assessed. In total, in 2017 6.15 million tons of plastic waste occurred in Germany that had to be managed (PlasticsEurope 2019, p.36). The most common source thereby was sales packaging, followed by industrial waste, residual waste of households and processors in that order as illustrated in figure 2. In 2016, Germany was ranked 5th in the EU with regards to per capita plastic waste production in kilogramme counting at 37.62 kilogramme per person with only Ireland, Luxembourg, Estonia and Iceland producing more (Eurostat 2019).

Figure 2: Plastic waste in Germany according to source in tons as of 2016



Source: Own source based on Statistisches Bundesamt 2018, p.30

As these numbers and statistics show, the management of plastic waste in Germany is of great importance considering the scale of it connected with the possible consequences of uncontrolled littering of plastic waste into the environment (Ruth 2018, pp.2). These figures also justify and explain the implemented regulations mentioned in chapter 3.2.1 and 3.2.2 and their planned expansions especially with regards to the dual system in place in Germany as figure 2 illustrates that about one third of occurring plastic waste in Germany stem from sales packaging.

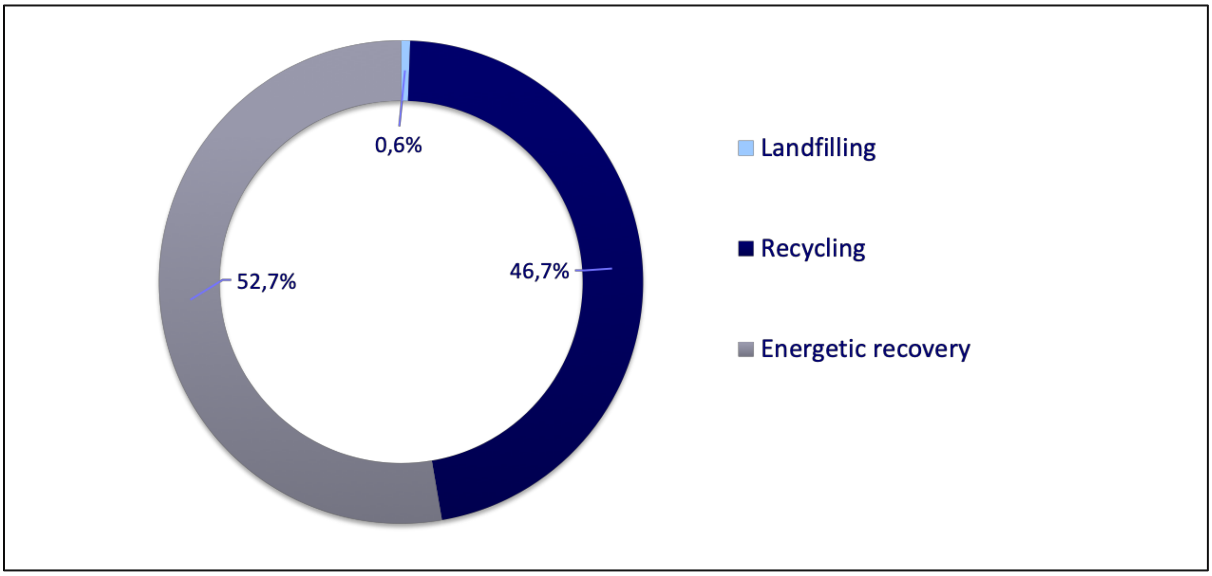
3.3.2 Treatment methods in use

3.3.2.1 Overview of methods applied

As pointed out in the chapters above, the amount of plastic waste produced in Germany needs to be managed in order to reduce negative externalities of the plastic consumption. Illustrating the scope of annually incurring plastic waste in chapter 3.3.1, the section shed light on how crucial an effective waste management system is in order to tackle the issues arising from uncontrolled littering. This chapter introduces to the measures applied in this context in Germany, giving an overview of the current landscape of plastic waste management measures before the methods are explained and assessed regarding their effectiveness in the following chapters.

To be able to compare the German landscape on an international level, the EU landscape will be depicted first. In 2014, the most common method in use in the EU including Norway and Switzerland was incineration with energy recovery (39.5%), followed by landfilling (30.8%) and recycling (29.7%) (EPRS 2017, pp.2). Compared to the plastic waste management hierarchy introduced by Germany and the EU, the overall share of landfilling is relatively high when looking at rates of recycling, which according to the regulation is supposed to be the predominant method to treat waste of any kind, and energy recovery (European Environment Agency 2009, pp.38). It also has to be taken into consideration that an estimated 50% of collected plastic waste in the EU in 2016 was exported to a wide range of countries which makes it difficult to keep track of regarding the further processing (EPRS 2017, pp.2).

Figure 3: Market share of plastic waste management methods applied in Germany in 2017



Source: Own source based on PlasticsEurope 2019, p.36

In Germany however, the recycling as well as the energetic recovery rates are much higher than the average rates in the EU (PlasticsEurope 2019, p.36). As figure 3 shows, almost none of the collected plastic waste is landfilled in Germany, which appears to be closely harmonised with the waste treatment hierarchy suggested by the EU (European Environment Agency 2009, pp.38).

3.3.2.2 Landfilling

After giving an overview of which methods are applied in Germany in order to reduce the negative externalities of plastic waste, in the following the methods in use will be assessed regarding their effectiveness also looking at the negative externalities that result from the application of the measures themselves.

According to the waste hierarchy that is applicable in Germany and the EU in general (cf. chapter 3.2), landfilling is the least favourable method to be applied from an ecological and environmental viewpoint. Therefore, Germany has decided to limit the usage of landfilling facilities in order to prevent further negative impacts to incur (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, 2018). The following paragraphs will focus on the question of whether the reduction of the usage of landfilling is also viable from an efficiency viewpoint.

The process of plastic waste landfilling starts with the collection, transportation and sorting of waste (Dvorak, Jefferson, Kosior 2009, p.2117). As explained in chapter 3.2.2, the sorting process is simplified due to the dual system in place in Germany, which encourages domestic waste separation by consumers. The method specific treatment starts after the waste arrives at the landfilling facility where usually the waste has to be treated before it can be disposed in an area (World Bank 2012, p.5).

There are several different kinds of landfilling facilities depending on the intensity of precautious measures for protecting environment and public health installed (ibid., p.29). The worldwide most common levels of landfills are semi-controlled dumps, controlled dumps, engineered or controlled landfills and sanitary landfills (ibid.). As the standards in Germany are high, this thesis will focus on sanitary landfills only as the other methods mentioned have a tremendous negative impact on the environment and therefore are not allowed to be used in Germany (Rahmeyer 2004, p.6). The standards for sanitary landfill are composed of different technologies like leak detection and leachate collection systems, which shall monitor and limit the environmental influence of landfilling of plastic waste (World Bank 2012, p.5).

In general, is broadly known that landfilling causes greenhouse gases and especially due to additives used throughout the plastic production process, the contamination of soils and the groundwater are common threats of the method (UNEP 2014, p.82). Moreover, it causes a linear material flow with no recovery processes (Dvorak et al. 2009, p.2117). It is possible to recover some of the energy throughout the flaring process related to the gas management, but this measure only recovers a small fragment of the energy that was used in the first place for producing the plastic materials (World Bank 2012, p.29). Considering the negative externalities of plastic waste mentioned in chapter 2.2, landfilling effectively prevents littering and its consequences, but it comes along with several problems of its own. Therefore, the overall trend is diverting from landfill as the waste management hierarchy suggests, which is also why the amount of plastic waste landfilled in Germany is negligibly low which was shown in the previous chapter.

3.3.2.3 Incineration with energy recovery

One alternative to the above explained method of landfilling is incineration, which is claimed to be favourable from an environmental view point according to the waste hierarchy implemented in Germany and the EU, that is if the method is applied using energy recovery measures (cf. chapter 3.2).

Just as for the process of landfilling, the first steps that have to be taken in the process of incineration are the collection, transportation and sorting of waste, resulting in having a sorted pile of plastic waste (United States of America Patentnr. 5,369,947 , 1994). As mentioned before, the expenses for the sorting process are limited in Germany due to household pre-sorting of municipal waste (cf. chapter 3.2.1). The general process of treatment in form of incineration following is very similar regardless of the specific method applied as the waste is heated up to a point where it decays to ash (United States of America Patentnr. 5,369,947 , 1994). There are different purposes this process can be used for dependent on the material and the function of the facility examined. Some of the most common usages are the regeneration of electricity, a combination of electricity and heat, the transformation into solid refuse fuel, the liquefaction to diesel fuel or the gasification of the material (Dvorak et al. 2009, pp.2117).

As the outcome significantly impacts the degree of energy recovery achievable, it is important to have a closer look on how the application of different approaches influences the effectiveness of incineration regarding the reduction of negative externalities of plastic waste (ibid.). One aspect that is influenced by the designated outcome of the process is the CO2 emission level. Even though the CO2 emissions of incineration are usually relatively high especially in comparison with landfilling, under certain conditions it is possible to achieve a negative CO2 balance (Eriksson, Finnveden 2009, p.908). If a high level of efficiency is achieved as well as a high electricity-to-heat ratio and the plastic waste is used to substitute fossil fuels as it is the case in some cement kilns, the emissions produced throughout the process might be lower than the emissions that would have been caused by using fossil fuels instead (ibid.). Also dependent on the intended outcome of the incineration process is the energy savings level, which is on average at a level of 32.6 gigajoule, which generally has a positive impact on the environment (Reid Lea 1996, p.296).

Besides the consideration of CO2 emissions, incineration, as landfilling as well, does address many of the negative externalities of plastic waste mentioned in chapter 2.2 as the waste does not get littered into the environment but instead is collected and treated so inadvertent ingestion by fish for example is not a problem anymore (UNEP 2014, pp.82). On the other hand, the process causes its own negative externalities as the air is polluted by the smoke resulting from incineration and the ash accruing throughout the process is considered to be hazardous waste and if not treated correctly, can have a negative impact on the environment with the latter being due to additives used in the plastic incinerated. Moreover, the plastic material which consists of a limited natural resource is inevitably lost (World Bank 2012, p.4).

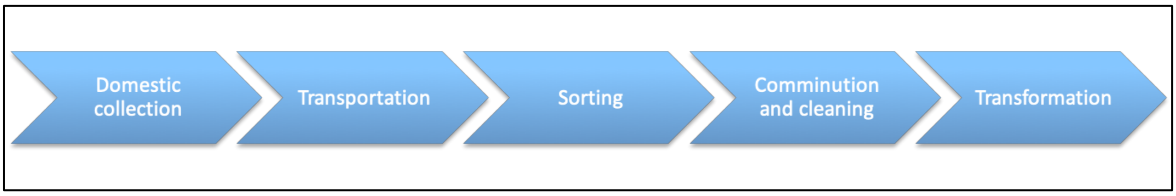
If energy is recovered, this process is still preferable to landfill as it leads to a reduction of the total waste volume and the material is not entirely wasted (UNEP 2014, pp.82). Also, incineration is especially an applicable alternative for recycling if the plastic material is not recyclable, which is the case for thermosets in general or thermoplastics of low quality (Eriksson, Finnveden 2009, p.907). As the method is robust with respect to the quality of plastic waste, this method is also a reasonable alternative for recycling for highly mixed plastics that cannot be separated completely with the current technological standards (Dvorak et al. 2009, p.2117).

3.3.2.4 Recycling

After describing the methods of landfilling and incineration with energy recovery and assessing their effectiveness regarding the reduction of negative externalities of plastic waste, the last measure to be considered in a German context is recycling. This measure is claimed to be the preferred one regarding the implementation of a sustainable waste management approach according to the waste hierarchy mentioned in chapter 3.2.1. This chapter will therefore focus on supporting this assertion regarding the effectiveness in reducing negative externalities while being resource oriented.

As any of the mentioned methods in chapter 3.3.2, the process of recycling also starts with the waste collection process followed by the transportation to the waste management facility, in this case a recycling plant (Dvorak, Jefferson, Kosior 2009, p.2119). From there on, the process is slightly different from the other strategies mentioned before as the sorting process does not only include the separation of plastics from other kinds of waste if still present in the theoretically already pre-sorted material taken to the facility, but it also comprises of the colour and material separation in order to prepare the upcoming recycling procedure (OECD 2018, pp.56). The latter is rather complex and requires either manual sorting or optical colour recognition camera systems or other technologies in order to be performed (Dvorak et al. 2009, pp.2119). In a next step, the coarsely separated plastic materials are washed or respectively cleaned so particles on the surface of the plastic get removed, and the material gets flaked, which is a process of size reduction making it possible to further process the plastic (OECD 2018, pp.56). Optionally, the already shredded plastic is sorted again in a next step, using different methods such as a sink/float separation or air elutriation depending on the recycling method that will be applied in the following (Dvorak et al. 2009, pp.2119). This process including the last step of transforming the plastic waste into recycled plastic, which is explained in the next paragraph, is illustrated in figure 4.

Figure 4: Process of plastic recycling



Source: Own source based on Dvorak et al. 2009, pp.2118

For the actual transformation of plastic waste into recyclate, there are three main approaches to do so (EPRS 2017, pp.2). The so-called primary recycling method describes mechanical recycling in closed loops, which is able to maintain the quality of the original material (Dvorak 2009, pp.2118). The most common type of plastic that is suitable for this method is the group of thermoplastics as the requirements for applying the method are that the material can be effectively separated from any other kind of plastic and that it can be stabilised against degradation throughout the process of the transformation, which is especially achievable for polyethylene terephthalate (in the following PET). However, these are very demanding prerequisites to meet because of additives, layered packaging and mixed materials (ibid.).

The second type of recycling, also called the secondary approach, is also a mechanical based solution using an open loop approach leading to a reduction of quality of the transformed polymer (EPRS 2017, pp.2). Different to the primary method, the result of the transformation is no pure type of plastic, but it may contain a certain fraction of other polymers due to the fact that separation to a level of plain segregation is very cost intensive and sometimes not possible (ibid.). Since the output can usually not be reused for its initial purpose as the quality is lower, the resulting plastics are often utilised as synthetic wood presenting a cheap, long living alternative for timber or products with lower material quality standards. If this is the case, the material value is decreasing each time the plastic gets recycled leading to a decrease in the method's effectiveness in reducing the negative externality of the loss of a scarce raw material (Dvorak 2009, pp.2118).

The third of the most common ways of recycling plastic is a chemical variant throughout which polymers are broken down into monomers reversing the polymerisation process used for plastic production in the first place (EPRS 2017, pp.2). Applying this so-called feedstock recycling method, petrochemical constituents are recovered and can be remanufactured or used in order to produce other synthetic chemicals (Dvorak et al. 2009, pp.2118). This method is not used as frequently as the other two introduced beforehand because it is cost intensive and as the polymerisation is reversed, the intensive energy utilisation for producing plastics has to be repeated to make use of the monomers, resulting in a relatively low product value compared to the costs (ibid., EPRS 2017, pp.2).

Assessing the effectiveness of recycling methods, it has to be taken into consideration that not all types of plastics are recyclable and therefore the application of other methods might be mandatory (Dvorak 2009, pp.2119). If recycling is possible, it ensures the re-usage of the raw material incorporated into plastics, which from a sustainable viewpoint is a crucial advantage of the method as the occurrence of crude oil is limited (OECD 2018, p.41). If recycled properly, the secondary material retrieved from PET materials uses only about 10% of the energy used for the production of PET in the first place, about 5% of the water and per tonne of recycled PET bottles, there is a net benefit of 1.5 tons of a 100-year equivalent of CO2 emissions (Dvorak 2009, pp.2121). For the least favourable source of plastic to be recycled, mixed plastic, which is difficult to purify throughout the sorting process, the net benefit would still be 0.5 tons (ibid.). Just as it is the case for the other methods applied in Germany, a further positive effect of recycling is that the plastic waste is not littered into the environment where it would harm amongst others sea life, the tourism and fisheries industry and possibly human health as stated in chapter 2.2. Consequently, considering the aspects mentioned above, it can be said that recycling is effective in reducing negative externalities of plastic waste without establishing unreasonable negative externalities throughout the recycling process itself.

3.3.2.5 Export of plastic waste

Another method that is used in order to cope with plastic waste is the export of it. In order to judge this method regarding its ability to reduce the negative externalities of plastic consumption, it is important to understand to which extent this method is used globally and how far this method itself might come along with its own negative externalities for society.

The method of exporting plastic waste is not only applied in Germany but worldwide and comprised a trade volume of about 200 million tons in 2013 (Yamamoto 2016, pp.191). High income countries account for about 87% of the plastic waste exported since 1988 as of the year 2018 (Brooks et al. 2018, pp.2). This is mostly the case because proceeding fees in China, which was the largest importer of plastic waste until 2018, and other importing countries are usually lower than the relatively high costs for domestic management as certain standards have to be met in most developed countries for the management of plastic waste specifically (ibid.). Moreover, many modern countries do not want to have to face their plastic waste as it gets landfilled in their neighbourhood (OECD 2004, pp.31). Exporting waste therefore seems to be a quick fix as the plastic is leaving the field of vision for developed countries, but in fact it is only shifting the problem to another location without offering a solution.

Even though exporting plastic waste might sound like an easy way for coping with negative externalities caused by the occurrence of plastic waste, there are severe problems arising with this method. The biggest problem that has to be faced in this context is that in developing countries, informal sectors for recycling are emerging for recycling which leads to the inability of government to prohibit measures that might cause a neglection of negative externalities of the recycling process (Yamamoto 2016, p. 192). Some of the issues these countries have to face due to this informal treatment of plastic waste are directly connected to unsound disposal practices including disposal without any treatment which often threatens workers' health as waste is often sorted by hand (Kojima 2013, pp.5). Many of these circumstances lead to the treatment of plastic waste exported running counter to recycling policies of the country of origin of said garbage. However, in many cases the inadequacy of environmental monitoring leads to an even less accessible approach of environmental and social externalities of the plastic waste exported so that often it is impossible to prove that applied methods run counter to the standards of the country of origin (OECD, pp.31).

Often, waste is not only being improperly recycled or disposed, but it is simply littered into rivers and the sea (Kojima 2013, pp. 5). Taking China as an example, an estimated 1.3 to 3.5 million tons of plastic are entering the oceans annually through the coastlines of China which is a sign of an ineffective solid waste management structure (Brocks et al. 2018, p.3). As the country is still about to develop the infrastructure necessary for coping with incurring waste, the additional mass of waste imported from other countries leads to an overload of garbage the country is not able to manage in an effective manner which leads to littering (ibid.). Often, the only way to prevent the above stated problems from arising seems to be an import regulation such as an overall ban (Kojima 2013, p.1). As international trade codes for different kinds of plastic are not harmonized internationally yet, the ban of certain kinds of plastic waste is difficult to enforce as the market is rather opaque (Brocks et al. 2018, p.3).

For the case of China, the country has decided to reduce the maximum level of contamination of imported plastics to 0.5% starting from January 2018, which is a level unlikely to be achievable especially as primarily defiled waste got exported to China until the new standard was implemented (Dehio, Rothgang 2018, p.5). Therefore, this new standard functions almost like a ban for plastic imports having cut the amount imported drastically by 90% in total in the year of implementation (Greenpeace East Asia 2019, pp.2). This regulation has tremendously affected the international trade in waste, identifying a shortcoming in the domestic plastic waste management facilities especially in developed countries also directly affecting Germany (Dehio, Rothgang 2018, p.5). As an alternative, waste streams started focussing on East Asia including countries such as Thailand, where waste imports increased by 7000%, and Malaysia, where imports sextupled throughout the first months of 2018 (Greenpeace East Asia 2019, pp.2). Not having implemented the necessary capacities of facilities for the increase in waste imports, those countries were overwhelmed by properly processing the plastic leading to a fast development of an informal sector not regulated by the state and therefore not complying with minimum standards imposing threats to public health and the environment and resulting in stricter regulations on the import implemented in the second and third quarter of 2018 (Arkin 2019, pp.38). As this observation suggests, the short-term effect of the import ban of China leads to an even worse outcome indicating the sensibility and instability of the exporting solution and its inability to properly address the negative externalities occurring due to plastic waste. At the same time, from a medium- to long-term point of view, the Chinese regulation could lead to the implementation of more plastic facilities in developed countries and a reduction in overall plastic waste exports and therefore to a more sustainable approach worldwide (Dehio, Rothgang 2018, pp.6).

4. Efficiency approach of plastic waste treatment in Germany

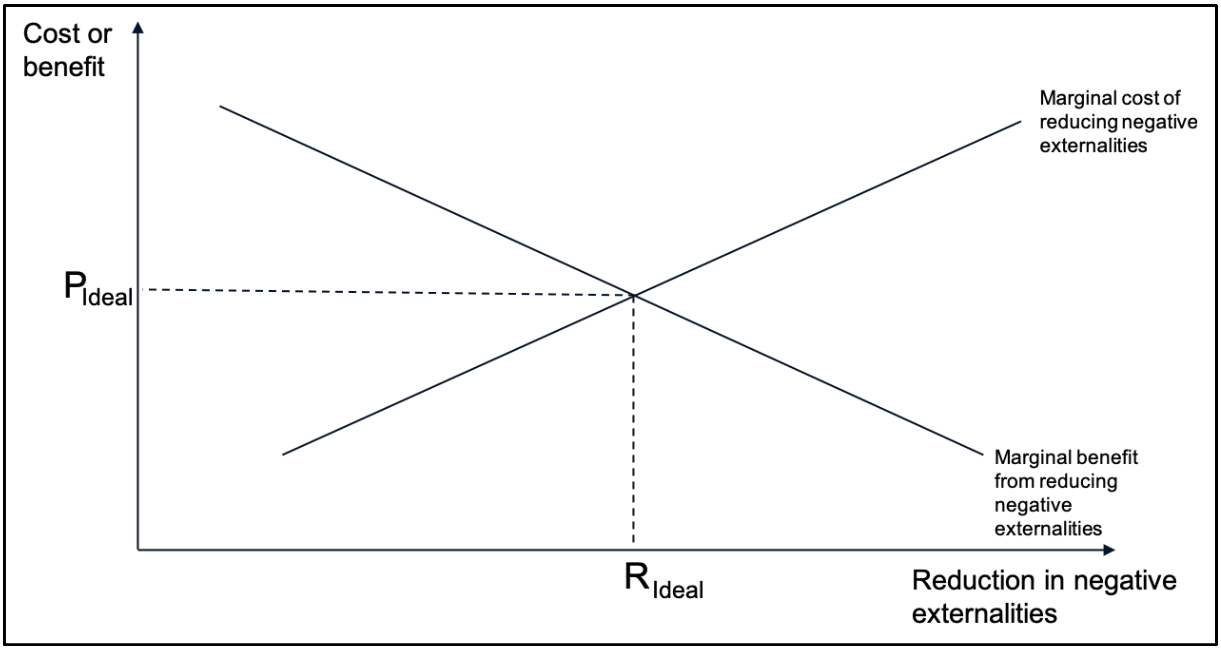
4.1 Characterization of efficiency for the reduction of negative externalities

In chapter 2.1, the introduction to the concept of negative externalities was given. In order to understand to what extent the reduction of those external costs is coherent with the market concept of efficient businesses, this chapter will give an overview of the definition for efficiency in the context of reducing negative externalities. This will define the criteria that have to be applied in the case of plastic waste in order to create an industry worth to invest in for the government and private companies.

There are several instruments that can be deployed in order to reduce negative externalities, but before doing so, it has to be assessed whether the overall benefit of the measure is outweighing the costs (Nordhaus, Samuelson 2010, pp.418). As the marginal costs of developing measures to reduce negative externalities rise with each unit that has already been eliminated, at one point the costs will surpass the societal benefit resulting from the reduction (Hubbard, O'Brien 2017, pp. 148).

Figure 5 below shall indicate this ratio between marginal costs and marginal benefit stated above. In order to achieve the ideal investment amount that should be pursued by government, in a first step it is important to quantify the costs arising from the reduction of negative externalities, pointing out the single steps that have to be taken in this process, and to assess the monetary benefit for society as a whole (Nordhaus, Samuelson 2010, pp.418). The problem with this analysis is that in many cases, the concrete numbers are not available as there is little research done in this context and often the future impact is inaccessible at this point of time, which is the case for most environment related negative externalities (ibid.).

Figure 5: Efficient reduction of negative externalities



Source: Own source based on Nordhaus, Samuelson, 2010 p. 421

However, this illustration also indicates that it is usually not efficient for a government to completely eliminate the negative externalities the production or consumption of a product or service implies (Woll 2011, pp.137). As the marginal benefits of decreasing negative externalities is most likely decreasing by the unit, the marginal costs increase as the necessary technology and personnel to check upon whether regulations are complied with is getting more cost intensive by the unit (Hubbard, O'Brien 2017, pp.148). If a government decides to spend more money than efficient for a society on the reduction of costs, the monetary effect on society will be higher than without taking any action (Nordhaus, Samuelson 2010, p.420). This fact often makes it difficult to assess the quality of a government initiative when considering that some negative externalities are difficult to quantify and therefore decisions have to be made based on broader estimations (ibid., pp.419).

4.2 Efficiency assessment of pre-transformation processes

Considering the importance of the efficiency in the process of the reduction of negative externalities as one crucial factor to the success of implemented methods, in the following the measures applied in Germany will be assessed from an efficiency viewpoint with this chapter focussing on the non-method specific phases before treatment takes place, considering collection, transportation and pre-sorting procedures. Thereby, the costs for those processes have to be taken into account when assessing the treatment methods as well in order to fully assess a cost benefit calculation.

According to OECD, in 2015 the average collection costs of plastic waste accounted at 181 US Dollar per tonne in the EU27 countries, pre-treatment costs at 222 US Dollar per tonne and transport for about 2.4-18 US Dollar per tonne, depending on the infrastructure and the population density adding up to 405.4 to 421 US Dollar per tonne (OECD 2018, pp.87). Generally said, waste collection in suburbs is usually more economical as collectors can make use of economies of scale leading to higher efficiency (Dvorak et al. 2009, p.2122).

The costs for collecting are composed of labour force, the investment in waste collection vehicles and the development and expansion of infrastructural systems allowing for an efficient way of collection (World Bank 2012, p.6). The already highly mechanised process developed by municipal-led schemes in Germany account for comparably low collection costs in a European context (Dehio, Janßen-Timmen, Rothgang 2017, p.57).

The system applied in Germany is a kerbside model, which means that household waste gets collected by vehicles rather than inhabitants having to transport their waste to the closest collection facility, which is a service households have to pay a fee for in order to compensate the collectors which, besides government payments, represents the benefit for collection companies and implies an internalisation of negative externalities at the source (ibid.). This process of plastic waste collection is easier for industrial waste as it is collected in large containers by companies themselves and usually directly transported to treatment facilities which does not impose costs for society or private households (OECD 2018, pp. 60).

In Germany however, the collection process is partially centralised and facilitated due to the implemented deposit return scheme for PET bottles, which is one way of cutting costs and enforcing extended producer responsibility (ibid., p.59). This method also reduces transportation costs and characterises a strategy for consequently separating different types of plastics granting the purity of waste which value will be discussed in the following chapter in more detail (World Bank 2012, p.6).

Focussing on the last phase of pre-transformation processes, the primary sorting of waste, this step usually accounts for a larger part of the governmental budget used for plastic waste management compared to collection and transportation, at least in developed countries (World Bank 2012, p.5). As for Germany, the overall sorting costs of waste are reduced due to the introduction of the dual system mentioned in chapter 3.2.2. As the separation of municipal solid waste already takes place in households, the effort to ensure the absence of any other material in plastic waste sent to treatment facilities is relatively low compared to single-stream systems (Dehio et al., p.53). This does not only have a positive impact on the cost structure of plastic waste management, but as a side effect, the costs for waste management of any kind are reduced because of the multi-stream approach and the absence of unwanted products in waste (ibid.). As this dual system with Grüner Punkt in the centre mediating between waste producers and partners in the waste industry entail administrative expenses, usually they would have to be considered as costs of the plastic waste management cycle (Wacker-Theodorakopoulos 2000, p.628). However, in fact, these costs are absorbed by companies through a licensing scheme, internalising a small part of negative externalities allocating the costs at the source with an average cost of 130 Euro per tonne in 2010 (Dehio et al. 2017, p.53).

As this subchapter shows, the applicable laws and the plastic waste management measures introduced on a national as well as a federal and municipal level do already take into account the importance of efficiency trying to implement methods to save costs and incentivise waste separation. Nevertheless, the inefficiencies of the dual system itself with its intended monopoly design and lack of transparency as mentioned in chapter 3.2.2 and other possible inefficiencies also have to be taken into consideration in order to draw a conclusion regarding the efficiency of the German plastic waste collection, transportation and pre-sorting system.

4.3 Efficiency factors of treatment methods in use

After the waste is collected and pre-sorted, it is treated applying one of the methods mentioned in chapter 3.2.3. Considering the waste hierarchy introduced in chapter

3.1.1, from an environmental viewpoint, recycling is the most favourable form of treatment followed by incineration with energy recovery trying to divert from landfilling. The remaining question is whether the methods in use are efficient in reducing negative externalities or whether their focus solely lies on reducing the environmental and human health impact of plastic waste littering.

In addition to the previously stated pre-transformation costs, each method applied has further costs that have to be considered in a cost-benefit analysis. The costs of landfilling in this context consist of the private equity costs of the facility itself, the implementation of precautious and monitoring measures like leak detection mentioned in chapter 3.3.2.2, as well as labour costs for maintaining and managing the installation (Dvorak et al. 2009, p.2117). The average costs in 2015 for landfilling in the EU27 member states accounted at 88 US Dollars per tonne, which has to be interpreted in the context that not all countries apply such high standards as Germany, which probably leads to higher costs (OECD 2018, pp.87). Adding the above-mentioned pre-processing costs of 405.4 to 421 US Dollar per tonne, the overall costs would amount at 493.4 to 509 US Dollar per tonne. Comparing this number to the minimum estimated costs arising from negative externalities that can be addressed by landfilling of 650 to 1300 US Dollar per tonne mentioned in chapter 2.2, the expenses caused by plastic waste landfilling seem to be outweighed by the societal benefits. Even though the process itself might be designed as efficiently as possible and some of the negative externalities of the occurrence of plastic waste can successfully be limited, the additional costs arising from negative externalities caused by landfilling and the fact that there is no beneficial outcome reversing the loss of energy or the plastic material itself, this method is rather expensive and does not lead to the desired outcome of the plastic waste management system in place in Germany (Dvorak et al. 2009, p.2117; Wacker-Theodorakopoulos 2000, p.628).

As for incineration with energy recovery, the overall costs per tonne in 2015 in the EU27 member states accounted at approximately 89 US Dollars (OECD 2018, pp.87). Costs that have to be taken into consideration are the property needed for the incineration plant as well as the plant itself, labour costs regarding the management of the facility, the treatment technology and supply needed as well as the costs arising from the treatment of the hazardous incineration ash (World Bank 2012, p.4). As the expenses for this method are only one US Dollar above the prices for landfilling per tonne, compared with the estimation from chapter 2.2 the outcome of this method seems to be efficient as well. The output however can be seen as a benefit as energy, in whatever form, is a valuable good that can be used or sold to third parties (Reid Lea 1996, p.296). Nevertheless, for this method the efficiency level is also dependent on the method applied as there are large differences (Eriksson, Finnveden 2009, pp.907). Therefore, an overall assessment of the efficiency of incineration with regards to the reduction of negative externalities of plastic waste occurrence is rather difficult, also keeping in mind that the negative externalities reasoned by incineration such as CO2 emissions also largely depend on the method applied and the desired outcome (ibid.). However, the method does offer certain benefits and under certain circumstances, as stated in chapter 3.3.2.3, has the potential to be applied in a perceived efficient way even though the quantification of negative externalities of plastic waste is not possible (cf. chapter 2.2).

For the case of plastic recycling, the assessment of its efficiency is more difficult than for the other methods mentioned above as there is a secondary market for recyclates involved (Saito 2016, p.40). Considering the transformation process of plastic waste into recycled plastics, the cost intensity depends on the quality of the input as it determines the further processing steps and the sorting needed in order to achieve recyclability (Dehio et al. 2017, p. 33). For applying a mechanical recycling approach in closed loops, the material has to be purified which is rather cost intensive whereas recycling in open loops is less sensible to the quality of the input but at the same time the output is of lower quality (Dvorak et. Al 2009, pp.2118). Chemical recycling has not been economically viable yet because the costs of reversing the polymerisation process causes the output to be of less value than polymers while being more cost intensive (OECD 2018, p.68). Considering the differences in expenses, the largest cost driver for recycling is the technology in use which causes a high market entry barrier and therefore disrupts the free market concept (Dehio et al. 2017, p.33).

From a societal viewpoint, recycling reduces the negative externalities of plastic waste taking into account the prevention from uncontrolled littering and resource wasting while producing relatively low negative externalities of its own limiting the CO2 emissions to a fraction of the emissions of incineration (ibid., p.53). According to a publication conducted by the European Parliamentary Research Service, recycling rates of 80% within the EU would lead to an estimated amount of savings of 700 million Euro as secondary plastic materials are an estimated 10% cheaper than primary supplies, taking into account the overall costs of the entire process, which could incentivise companies to be more resourceful and limit the occurrence of negative externalities of plastics in general (EPRS 2017, pp.6).

On average, the additional costs for recycling in the EU27 countries in 2015 accounted at 535 US Dollar per tonne, which adds up to about 940.4 to 953 US Dollar per tonne when considering the pre-processing steps (OECD 2018, p.87). As marine littering and its negative consequences are prohibited due to the process of recycling, the in chapter 2.2 mentioned 650 to 1,300 US Dollar per tonne would be the social benefit of recycling just as for the two other methods assessed in this chapter. In addition to that, the resource value is partially recovered, which again leads to a social benefit, recovering an average of one third of the initial worth of virgin plastic (World Economic Forum 2016, p.12). According to the World Economic Forum, the original value per tonne lays at 1,100 to 1,600 US Dollar, which implies an average recovered value by recycling of 363 to 528 US Dollar per tonne assuming the above mentioned 33.3% are correct. This would mean that the total average social benefit of recycling would be reflected in 1,013 to 1,828 US Dollar per tonne, keeping in mind that these figures do not necessarily represent all negative externalities prevented through recycling and its success and value being highly dependent on the input and method used. Comparing these numbers to the average costs of recycling, the benefits seem to outweigh the expenses. Even though it is difficult to quantify those external costs in the first place, recycling seems to be an efficient method for reducing them (Dehio et al. 2017, p.48).

Besides the general consideration of the costs of plastic recycling and the benefit it implicates for society, another aspect that has to be assessed is the question whether the market for secondary plastics is efficient and in how far the material can compete with primary polymers (OECD 2018, p.68). The market price of re-processed plastic is composed of several different components one being the virgin plastic prices, which are relatively fluctuating due to the dependency on crude oil prices (ibid., p.83). As the price for virgin feedstock reflects the price ceiling for recycled plastic even though the production costs and the process remain the same regardless of fluctuations, this leads to an unstable market situation (Dvorak et al. 2009, p.2123). This especially has a huge impact because compared to the plastics industry, the recycling industry has a small output of considerably lower quality which is why recyclate suppliers do not have any chance to exert price pressure (Dehio et al. p.49). Another issue is the demand for recycled content. As the quantity and quality of recyclate is uncertain, companies tend to use primary plastics instead of recycled materials for quality assurance reasons

(OECD 2018, pp.85). However, current trends of increases in environmental customer awareness and the accompanying effect of higher demand for recycled materials that are supported by current policy decisions is shifting this behaviour towards a more resourceful and sustainable approach of companies (ibid.). This development shows that besides current inefficiencies, the market for recycled plastic has a large potential for future expansion (ibid.).

Another factor influencing the market efficiency of secondary plastic material is the export of plastic waste to developing and emerging markets for the purpose of recycling (Yamamoto 2016, pp.192). One aspect of the issue is that the concentration of recycling plants to only a few countries, especially countries that are not considered to be politically and economically stable, leads to higher insecurities and scepticism of companies on the demand side (OECD 2018, pp.94). Another aspect is the smaller marginal costs resulting from the informal recycling market in developing and emerging markets that do not reflect a proper consideration of negative externalities and the environmental damage caused throughout the process of transformation (Yamamoto 2016, p.192). If there are no sufficient political regulation and monitoring measures in place, neither exporting countries nor the local government can reconstruct what exactly happens to the imports after arriving in the country of destination (ibid.). Even though the export of plastic waste might seem like an attractive alternative to local treatment because of low cost haulage of containers especially from Asia that otherwise would be send back empty, the long-term costs would be higher and potentially the reduction of negative externalities could get reversed due to illegal littering leading to an inefficient plastic waste management (OECD 2018, p.88).

5. Conclusion

5.1 Summary

The occurrence of plastic waste brings along societal costs that are not internalised in the pricing of products containing polymers. Some of these so-called negative externalities are CO2 emissions, ingestion of microplastic by and entanglement of aquatic animals, the entanglement of ship propellers as well as landscape pollution resulting in monetary burdens for industries such as fishery, shipment and tourism.

In order to limit the economic costs of plastic disposal and especially its littering, the EU as well as the German government itself have introduced measures to reduce the usage of plastics and rules to treat occurring waste properly, focussing on the recycling of the scarce material of crude oil in form of plastics. This is especially necessary considering the steadily increasing amount of waste incurring due to various factors such as population increase, urbanisation and economic growth.

Besides recycling, which is the most favourable method for plastic waste treatment according to German legislative, incineration with energy recovery and landfilling are also techniques applied in Germany with the further two making up 99% of the industry whereas the latter is vanishingly rarely used. This is because through landfilling, the entire potential of plastic materials is lost whereas incineration and recycling partially recover the energy or the material itself. Even though recycling remains the best option regarding its effectiveness, incineration is highly applicable in case a certain material cannot be recycled, which is the case for thermosets and low-quality thermoplastics.

In order to be able to completely assess the methods in use, their efficiency should be taken into consideration as well. The usually high costs of collection, transport and pre-sorting of waste are reduced in a German context due to a dual collecting system for plastic waste which enforces extended producer responsibility, the introduction of a deposit return system for PET bottles as well as the separation at source by private households.

Adding the methodological costs of each of the introduced methods in use in Germany, as a result it can be claimed that landfilling is not the optimal solution from an efficiency viewpoint whereas there are some circumstances under which incineration with energy recovery could be regardless of the relatively high CO_2 emissions usually caused by the method. For recycling, mechanical methods might be efficient depending on the quality of waste but another obstacle for it to be economically reasonable would be the improvement of secondary material markets. Currently, they are not designed in an efficient way with the export of plastic waste to developing and emerging markets aggravating the situation of implicit societal costs.

5.2 Critical acclaim

Analysing a topic with a literature-based approach always means that the precision depends on the chosen information. As the negative externalities of the consumption of plastics is not easy to grasp, there is little evidence on the exact economic impact they have on society and certain industries. Also, research on the health implications and long-term problems of plastics in the ocean are not explored in depth yet which is why the information on these fields is limited in this thesis. Moreover, conducting valid statistics for this field of research is not only difficult, which leads to estimated numbers only, but it also takes a long time to evaluate data, so the used sources might be perceived as being not recent enough to address the current landscape. Especially the quantification of different approaches and their costs as well as the negative externalities are generally hard to be conducted in the context of plastic waste.

As documentation is poor for most of the countries worldwide and the negative impact of plastic littering in general, it is questionable in how far it is even possible to grasp the negative externalities of plastic waste. Because of the fact that the expansion of the length of this thesis was limited, the entirety suffers regarding the assessment of the effectiveness as well as the efficiency of the used methods in Germany, but the thesis rather gives an overview of issues that have to be taken into consideration.

5.3 Outlook

After describing the status-quo of the plastic waste management landscape in Germany, it will be interesting to observe how the environment will change over the next decades. Especially the legislative structure will probably become stricter when it comes to the usage of plastic, which is already indicated by the ambitious goals for 2030 set by the EU as well as the UN agenda from 2015. Besides the development in Germany, it will be worth taking a closer look at international agreements upon the tackling of waste problems occurring worldwide. As the export of plastic waste is not necessarily solving the problem but rather increasing the negative impact on the environment, the problem has to be addressed using global consensus about what the proper way of tackling the problem could be.

Another interesting aspect regarding the reduction of negative externalities of plastic consumption will be the question of whether there will be an alternative introduced to the market, which has the same benefits as plastic does but does not harm the environment and society as a whole. It is still to be found out in how far the government will subsidise the research regarding plastic alternatives and whether this might be a solution to the problem of the occurring issues with plastic waste.

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V. Declaration of originality

“I hereby declare that this thesis and the work reported herein was composed by and originated entirely from me. Information derived from published and unpublished work of others has been acknowledged in the text and references are given in the list of references.”

____________________ ________________________

Place, Date Signature

VI. Declaration of consent

I hereby

❍ agree,

❍ do not agree,

that my bachelor thesis will be included in the department’s library.

____________________ ________________________

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