Comparative Analysis of Plastic Packaging Recycling in Portugal and Sweden

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Abstract
Current concerns for how unsustainable plastic packaging waste management is and how it negatively affects the environment, combined with the fact that it does not promote a circular economy has given origin to a strategy for plastics in a circular economy defined by the European Commission, in 2018. Thus, this study intended to compare and analyse two different plastic packaging waste recycling systems, in Portugal and in Sweden. Mainly since recycling this kind of waste is one solution pointed out in the published strategy on plastics. Ultimately, the study seeks to find possible obstacles in the recycling systems and solutions that promote the increase of plastic packaging recycling rates. This is accomplished by focusing on some actors from the plastic recycling value chain.

The study presents the plastic packaging recycling rates in 2016, 42% in Portugal and 50% in Sweden. However, the acquired knowledge on each country's plastic packaging recycling system was not enough to draw solid conclusions on what are the reasons for the different plastic packaging recycling rates from each country. This was because the systems are highly complex, with many actors playing different roles and relating with each other in different manners.

In addition, the study was highly dependent on published information like definitions and statistics that weren't always available or clear about their meaning or how they were calculated.

Nevertheless, the study showed that many solutions could be drawn, both from lessons learned from each country and practices not currently applied in either of them. Some of them were landfill bans for recyclable waste, higher landfill and incineration taxes, as well as sorting plastic packaging waste from the unsorted waste stream and sending non-packaging plastic waste for recycling. Additional solutions could be extracted from the plastic producer's feedback. For example: investments in recycling processes and technologies that contribute to higher quality of recycled plastics; better design that allow high recyclability of plastic packaging products; reduce multi-material plastic products; a collection scheme that increases the quality and traceability of the recycled plastic; increase correct source-sorting by consumers and implement regulation that demands a certain fraction of recycled plastic in plastic products.

Keywords
plastic packaging waste; recycled plastic; waste management; circular economy; recycling rate; market; target; legislation; collection; sorting

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Abstract

Current concerns for how unsustainable plastic packaging waste management is and how it negatively affects the environment, combined with the fact that it does not promote a circular economy has given origin to a strategy for plastics in a circular economy defined by the European Commission, in 2018. Thus, this study intended to compare and analyse two different plastic packaging waste recycling systems, in Portugal and in Sweden. Mainly since recycling this kind of waste is one solution pointed out in the published strategy on plastics. Ultimately, the study seeks to find possible obstacles in the recycling systems and solutions that promote the increase of plastic packaging recycling rates. This is accomplished by focusing on some actors from the plastic recycling value chain.

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Contents

1. INTRODUCTION 4

1.1. BACKGROUND 4
1.2. OBJECTIVES 6
1.3. DELIMITATIONS 7
1.4. OUTLINE OF THE REPORT 7

2. METHODS 8

3. PLASTICS PRODUCTION 9

3.1. MANUFACTURING 9
3.2. AVAILABLE FEEDSTOCKS 9
3.3. TECHNOLOGIES 10
3.4. WORLDWIDE PRODUCTION 10
3.5. EUROPE'S PRODUCTION 10
3.6. TYPES OF PLASTIC 10

4. SWEDEN'S WASTE MANAGEMENT SYSTEM 12

4.1. GENERAL FACTS ON SWEDEN 12
4.2. WASTE QUANTITIES 12
4.3. WASTE DESTINATION 13
4.4. ACTORS INVOLVED 14
4.5. COLLECTION AND TRANSPORT 16
4.6. LEGAL FRAMEWORK 17
4.7. NATIONAL TARGETS 17
4.8. COSTS AND FINANCIAL INSTRUMENTS 18

5. PORTUGAL'S WASTE MANAGEMENT SYSTEM 19

5.1. GENERAL FACTS ON PORTUGAL 19
5.2. WASTE QUANTITIES 19
5.3. WASTE DESTINATION 20
5.4. ACTORS INVOLVED 22
5.5. COLLECTION AND TRANSPORT 23
5.6. LEGAL FRAMEWORK 24
5.7. NATIONAL TARGETS 25
5.8. COSTS AND FINANCIAL INSTRUMENTS 25

6. SWEDEN'S PLASTIC PACKAGING RECYCLING 27

6.1. PRODUCTION OF PLASTIC PACKAGING 27
6.2. ACTORS INVOLVED 27
6.3. REGULATIONS 29
6.3.1. Plastic Packaging and PackagingTargets 29
6.3.2. Deposit Return Systems for Plastic Bottles 29
6.4. RECYCLING GUIDELINES 30
6.5. RECYCLING SYSTEM 31
6.5.1. Collection Systems for Plastic Packaging Waste 31
6.5.2. Collected Amounts 33
6.5.3. Sorting and Recycling Processes 34
6.5.4. Sorting Companies 34
6.5.5. Sorting and Recycling Technologies 36
6.5.6. Recycling Rate 42

6.6. Costs and Financial Instruments 43
6.7. Plastic packaging market 45
6.8. Waste Management Company: Sysav 48

7. PORTUGAL'S PLASTIC PACKAGING RECYCLING 50

7.1. Production of Plastic Packaging 50
7.2. Actors Involved 50
7.3. Regulations 51
7.3.1. Plastic Packaging and Packaging Targets 51
7.4. Recycling Guidelines 52
7.5. Recycling System 53
7.5.1. Collection Systems for Plastic Packaging Waste 53
7.5.2. Collected Amounts 54
7.5.3. Sorting and Recycling Processes 55
7.5.4. Sorting Companies 56
7.5.5. Sorting and Recycling Technologies 56
7.5.6. Recycling Rate 58
7.6. Costs and Financial Instruments 59
7.7. Plastic packaging market 61
7.8. Waste Management Company: ValorSul 64

8. COMPARISON BETWEEN WASTE MANAGEMENT AND PLASTIC PACKAGING RECYCLING SYSTEMS 66

8.1. Waste Management System 66
8.1.1. Waste Quantities 66
8.1.2. Waste Treatment 66
8.1.3. Financial Instruments 67
8.1.4. Organization of actors involved 67
8.1.5 Legal Framework and Targets 68
8.1.6. Costs 69
8.2. Plastic Packaging Recycling System 70
8.2.1. Plastic Packaging Collection 70
8.2.2. Plastic Packaging Recycling 72
8.2.2.1. Recycling Rates 72
8.2.2.2. Recycling Targets 73
8.2.2.3. Actors Roles and Interactions 74
8.2.2.4. Sorting Technologies and Efficiencies 78
8.2.2.5. Economic Costs and Financial Incentives 78
8.2.2.6. Market for recycled plastic waste 80

9. DISCUSSION 82

9.1. Lessons from each country 82
9.2. Solutions for both countries 82
9.3. Limitations and uncertainties 84

10. CONCLUSION 86

11. FURTHER STUDIES 88

12. REFERENCES 89

13. APPENDIX I - TABLES 97

14. APPENDIX II - DEFINITIONS 100

List of Abbreviations

EU - European Union

FTI - Förpacknings- och Tidningsinsamlingen

SPV - Sociedade Ponto Verde

HDPE - High Density Polyethylene

LDPE - Low Density Polyethylene

PP - Polypropylene

PET - Polyethylene Terephthalate

PS - Polystyrene

PAYT - Pay-As-You-Throw

SGRU - Sistema de Gestão de Resíduos Urbanos

STEPS - Sustainable Plastics and Transition Pathways

NAFTA - North American Free Trade Agreement

GDP - Gross Domestic Product

SEPA - Swedish Environmental Protection Agency

EGF - Environmental Global Facilities

SCB - Statistiska Centralbyrån

1. Introduction

1.1. Background

Plastic has become a major resource due to its unique characteristics that allow for packaging, building and construction, transportation, renewable energy, medical devices and others (Plastics Europe, 2017). The use of plastics has increased twenty-fold in the past half century and it is estimated to double in the upcoming 20 years (Ellen MacArthur Foundation 2016). Plastic packaging is the main application of plastic within the industry (Plastics Europe, 2017). Plastic packaging represents 39.9% of total plastics production in Europe, followed by building and construction (19.7%).

Plastic products can differ in its composition, properties and characteristics and not all have the same life time of consumption or shelf life. Some plastic products are only used for less than one year, while others can be used for more than 15 years or even several decades (Plastics Europe, 2017).

When plastic waste is not recovered, it has the potential of becoming a serious source of pollution. That could lead to plastic littering in the environment that will often end up in the ocean (Milios et al, 2018). In fact, by 2050 there will be more plastics in the oceans than fish if we continue with the business as usual (Plastics Recyclers Europe). Furthermore, marine litter affects biodiversity, by entering the food chain with a possible impact on people's health.

Hence, the correct management of plastic waste is of major importance. The new circular economy package on plastic waste supports an increase of plastic packaging recycling rates, by establishing ambitious targets. According to Antoon Emas from Plastics Recyclers Europe 'recycling is one of the key answers to efficient waste management. It saves resources, reduces GHG emissions and reduces waste. It also brings an answer to Europe's high dependence on the rest of the world when it comes to natural resources'. Mechanical recycling is the most common method for recycling plastic waste (Ragaert et al, 2017) and 'has emerged as the most economical, as well as the most energetic and ecologically efficient option' (Maris et al, 2018).

Recycling of plastic waste leads to a complex value chain (Figure 1) which includes several actors and processes, starting with the consumer that produces the waste. This plastic waste is processed and turned into a resource again and thus can re-enter the value chain, promoting a circular economy.

Figure 1 shows that plastic waste recycling starts with source-sorting by the consumer, followed by the collection of plastic waste. Unfortunately, the amounts of collected plastic packaging waste (see appendix II – definitions) for recycling don't often correspond to the amounts of waste that

are recycled. This can be explained by the fact that not all packaging waste is separated at source, hence it does not always end up in the recycling system. Also, the plastic packaging might be too contaminated, or it might be composed of different polymer types that cannot be separated. That type of plastic packaging waste is often sent to energy recovery (see appendix II – definitions) or landfill (Willén, 2018; Fråne et al, 2015).

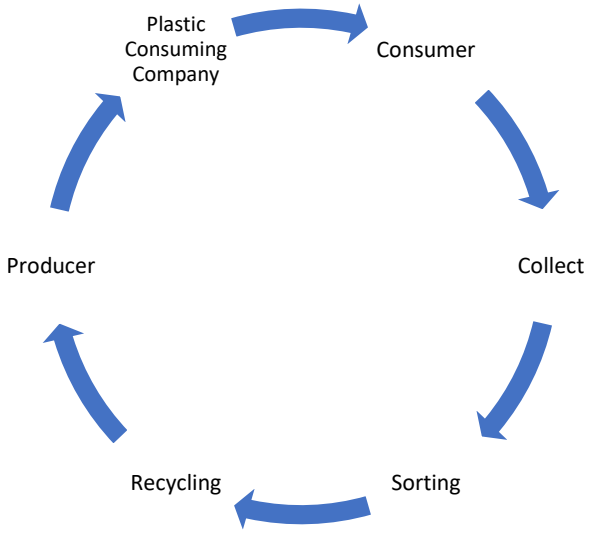


Figure 1 – Plastic waste recycling value chain, adapted from Milios et al, 2018

Requirements regarding collection and recycling systems to provide recycled plastics of high-quality that can be used as a raw material should be made (Fråne et al, 2015). This would be of great importance to improve the market for plastic waste as a secondary raw material and circular economy. In addition, "the challenge to recycle more and to fully implement the waste hierarchy model, with prevention, reuse, recycling, recovery and disposal as the least preferable option, remains." (Plastics Recyclers Europe)

"A circular economy could increase the efficiency of primary resource consumption in Europe and the world. By conserving materials embodied in high value products or returning wastes to the economy as high-quality secondary raw materials, a circular economy would reduce demand for primary raw materials. This would help to reduce Europe's dependence on imports, making the procurement chains for many industrial sectors less subject to the price volatility of international commodity markets and supply uncertainty due to scarcity and/or geopolitical factors" (Fråne et al, 2015).

In January 2018, a communication from the European Commission was published, which defined a strategy for plastics in a circular economy (European Commission 2018). Before that, in 2015, the Commission had already published the EU Action Plan for a circular economy where plastics had already been identified as a priority. In the new strategy focus is given for action among the private sector, national, regional and international authorities and citizens.

Some of the challenges described were the fact that less than 30% of plastic waste produced in Europe is recycled; landfilling and incineration rates of plastic waste remain high (31% and 30% respectively) in Europe; demand for recycled plastics accounts for only 6% of plastics demand in Europe; plastics production and incineration of plastic waste contribute to approximately 400 million tonnes of CO_2 emissions each year; alternative types of feedstock represent a very small share of the plastics market; and in the EU 150 000 to 500 000 tonnes of plastic waste enter the oceans every year (European Commission, 2018).

To tackle these challenges, the strategy defines targets for 2030 and measures that envision a more sustainable plastics industry with emphasis on design and production that increases reuse, repair and recycling, helps create jobs and economic growth and helps reduce EU's greenhouse gas emissions and dependence on imported fossil fuels (European Commission, 2018). The targets for 2030 are: recycling rates of urban waste of 65%; recycling rates for packaging waste of 70%; reduce landfill disposal to a maximum of 10 percent of all types of waste; forbid landfill disposal of recyclable waste (APA 2016).

Finally, the extended producer responsibility (Directive 2008/98/EC) indicates that waste collection and disposal of waste is the responsibility of the producers, this waste must be sent to recycling to comply with national targets. It includes recovered paper, packaging waste, electrical and electronic equipment (WEEE), tyres, cars, batteries and pharmaceuticals and is aimed to encourage producers to develop products that are more suitable for recycling in a cost-effective way. To sum up, this regulation has the following purposes: packaging shall be manufactured in such a way that their volume and weight are limited to the level required to maintain a good level of safety and hygiene; manufacturers shall take responsibility for packaging when it becomes waste; packaging waste shall be disposed of in a healthy and environmentally acceptable manner.

1.2. Objectives

The main goal of this study is to compare and analyse two different plastic packaging recycling systems, in Portugal and in Sweden. Therefore, a number of questions were defined:

- How is the waste management and plastic packaging recycling systems of both countries organized?
- How is the plastic packaging waste recycling system financed?
- What are the annual costs of plastic packaging waste recycling?
- What are the legal frameworks and targets on plastic packaging waste recycling?
- What is the plastic packaging recycling rate in each country?
- What are the main obstacles for higher recycling rates?
- How is the market for recycled plastic?

- What are the methods and technologies used for collection and sorting of plastic packaging waste in each country?

The answers intended to better understand each countries' waste management and plastic packaging recycling systems, hence providing sufficient knowledge to fulfil the objective. Furthermore, the acquired knowledge would be gained by assessing current and non-current practices. Thus, this should allow to determine solutions that help increase recycling rates of plastic packaging waste in both countries.

1.3. Delimitations

This report focuses on mechanical recycling, since it is the most widely type of recycling applied in both countries and hence possible to study. However, there are other types of recycling, namely feedstock and chemical recycling. In addition, the analysis is made with statistics from 2016, since they were the ones available for both countries at the time of the study.

1.4. Outline of the Report

After the Introduction, a section defining the methods used to develop this work is presented (Section 2). Then, there is a short section on plastics' production, that cover its manufacturing, feedstocks, technologies, main plastic types and its current worldwide situation (Section 3).

Sections 4 and 5 describe the waste management systems in Portugal and in Sweden. Both sections include waste quantities and treatment, the main actors involved, collection methods, legal framework and targets, as well as costs and financial instruments at the time of the studied period.

Sections 6 and 7 present each country's plastic packaging waste recycling system. These sections approach some of the same topics as Sections 4 and 5. In addition, the sorting and recycling processes, plastic waste market and two waste management companies are described. These sections also include the summarized answers from the interviews.

Section 8 focuses mainly on comparing the most relevant topics of the previous sections and provides some analysis of that comparison. Section 9 provides a discussion of the findings from Section 8, as well as solutions for both countries and the main obstacles found during the development of this work. Finally, Section 10 presents some possible further studies that could complement this work and Section 11 presents the main conclusions of the report.

2. Methods

This master thesis was mainly conducted at the Energy and Environmental Systems division at Lund University, LTH. It was done in cooperation with the University of Lisbon, especially regarding the last phase of the study.

The study came up as a result from the issues raised in the publication by the European Commission in the beginning of 2018 that defined a strategy on plastics in a circular economy (European Commission, 2018).

The focus of this report is to study the plastic packaging recycling systems, namely plastic packaging waste from households in Portugal and in Sweden, in order to compare and analyse both countries. For a more complete analysis, a brief description of each country's waste management system is present in the report. As a theoretical support of the study, several articles and reports, published by recycling and waste related organizations were assessed. In addition, current waste legislation of each country was briefly analysed.

Furthermore, as part of the data collection for the study, several interviews with representatives at different companies were conducted. These were done via email or personal communication (phone or physical meeting) mainly with employees and experts from recycling and waste management companies and organizations and plastic producers. Likewise, visits to waste management companies, Sysav and ValorSul, and to two other recycling companies, Swerec and Extruplás, took place.

To sum up, the approaches to this study were: enquiries to the actors involved and consultation of literature, like articles, reports, including published statistics and legislation.

The participation at the STEPS, a research programme, annual meeting also provided some additional knowledge, important to understand the context of plastics in a circular economy, as well as more sustainable alternatives for the plastic industry.

3. Plastics Production

3.1. Manufacturing

Plastics are organic compounds made of elements such as carbon, hydrogen, oxygen, nitrogen, chlorine and sulphur. Usually plastics have a high molecular weight, since each molecule that is part of its structure may have thousands of bonds. Plastics are also commonly known as polymers and they can be produced by conversion of natural products or by synthesis of chemicals derived from oil, natural gas or coal (American Chemistry Council, 2005).

Plastics are often based on the carbon atom that can make connections with hydrogen, oxygen, nitrogen, chlorine or sulphur. When long chains are formed the polymer is known as a thermoplastic. Thermoplastics are mostly characterized by the fact that they are meltable, which grants the ability of these plastics to be heated and cooled multiple times (Sciencing 2018). About 92% of plastics are thermoplastics (American Chemistry Council, 2005). The other type is the thermoset polymer that when exposed to a certain amount of heat, it experiences an irreversible molecular change. This type of polymer is commonly used for permanent structures and composite materials.

Furthermore, additives may be present in polymers according to the desired properties for a product. These additives mainly improve mechanical, physical or chemical properties.

3.2. Available feedstocks

Plastics can be made from fossil feedstock, like the ones previously announced, which can be fossil-based and non-biodegradable or fossil-based and biodegradable. Additionally, they can be made from biomass and are divided into two types of plastic: bio-based and non-biodegradable or bio-based and biodegradable.

Bio-based and non-biodegradable plastics are currently the more produced type of bioplastics and can be derived from sugarcane for instance. Examples of products derived from this kind of feedstock are milk cartons and PET beverage bottles. The bio-based plastics can be chemically identical to fossil-based plastics and have similar properties therefore. As for the bio-based and biodegradable plastics, polylactic acid is the most common source that can be produced from sugars and starch and has similar properties to the thermoplastics (Palm and Myrin, 2018).

Other possibility for producing plastics from a renewable feedstock is producing it from carbon dioxide. This kind of production though is still small, and the main disadvantage is the high energy requirements for the process, which does not allow for competitive prices of plastics from this type of feedstock (Palm and Myrin, 2018).

Moreover, and as it is the focus of this work, another possible feedstock for plastics production is plastic waste, through recycling processes that will be further described and analysed in the following sections. The plastic packaging waste is then seen as a resource and acts as a secondary raw material for production of plastic products.

3.3. Technologies

To produce plastic a refining and cracking process takes place, in which the lighter hydrocarbons are cracked into smaller building blocks like ethylene and propylene through exposition to high temperature, that are later used in polymerisation. In the polymerisation process there is the production of long molecular chains of monomers, which can either be done by poly-condensation or poly-addition (Palm and Myrin, 2018). Poly-condensation is a polymerisation process in which the growth of polymer chains is due to condensation reactions between molecules (Polycondensation 2018). As an example of poly-condensation there is the polymerisation of PET. Poly-addition can be defined as a polymerisation technique where unsaturated monomer molecules are added to a growing polymer chain one at a time (Polyaddition 2018). As examples for poly-addition, the two most common plastics are PE and PP. A difference between both polymerisation processes is that poly-condensation needs at least two reactive groups on the monomer and polyaddition, in contrast, needs a double bond (Palm and Myrin, 2018).

3.4. Worldwide Production

In 2016, 335 million tonnes of plastics were produced, including thermoplastics, polyurethanes, thermosets, adhesives, coatings and sealants. China was the largest producer of plastics materials followed by Europe and North America (NAFTA) which corresponded respectively to 29%, 19% and 18% of the total plastics produced (Plastics Europe, 2017).

3.5. Europe's Production

In 2016, about 60 million tonnes of plastic were produced in Europe (EU28+NO/CH). The most demanded plastics by resin type were PP with more that 10 million tonnes demand, and PE about 6 to almost 9 million tonnes (Plastics Europe, 2017).

3.6. Types of plastic

Most of the consumer plastics are thermoplastics. Hence, the most common types of thermoplastics are PE and PP which represent respectively about 17.5% and 19.3% of the total demand for plastics' polymers (Plastics Europe, 2017). Polyethylene, more specifically LDPE can be used for production of reusable bags, trays and containers and HDPE for toys, milk bottles,

shampoo bottles and others. PP is often used for food packaging, sweet and snack wrappers, hinged caps, microwave-proof containers and others.

In addition, PET represents about 7.4% of the polymer types demand and PS represents about 6.7%. PET is commonly used for water bottles, soft drinks, juices, cleaners and others and PS is for instance used for egg trays, plastic cups, eyeglasses frames and others (Plastics Europe, 2017).

4. Sweden's Waste Management System

4.1. General Facts on Sweden

In 2016, Sweden had a GDP of approximately 440 trillion euros and the population was about 10 million people, more precisely 9 995 153 people. The country's surface area is about 438 600 square kilometres, with a total of 290 municipalities (SCB 2018a; SCB 2018b).

4.2. Waste Quantities

In more recent years, in 2015 and 2016 total mass of household waste (see appendix II – definitions) treated was 4.70 million tonnes and 4.67 million tonnes respectively, the equivalent to 478 kg/person and 467 kg/person. It is possible to verify that there was a reduction in treated waste from 2015 to 2016 of about 37 tonnes of treated waste (Avfall Sverige 2017a).

Figure 2 presents an overview of the waste flows in Sweden. This figure shows the different inputs and outputs of waste. As inputs there are the imported waste, secondary waste and total waste generation of the country and as outputs there are mainly exports.

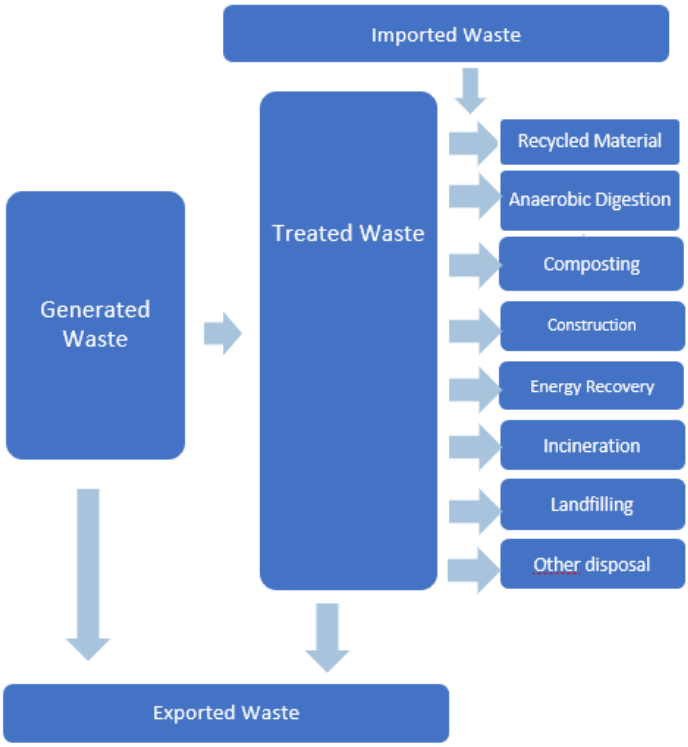


Figure 2 – Waste flows in Sweden, adapted from Naturvårdsverket 2014

4.3. Waste Destination

There are essentially four methods for treating waste in Sweden: material recycling, biological treatment, which includes anaerobic digestion and composting processes, energy recovery and landfill (Avfall Sverige 2017a).

In 2016, 34.6% of waste produced went to material recycling (see appendix II – definitions), the equivalent to 162 kg/person. Biological treatment was the destination for about 16.2% of generated household waste and energy recovery for approximately 48.5% of that waste. Meaning almost half of produced household waste was sent to energy recovery. Finally, 0.7% of total household waste went to landfill (Avfall Sverige 2017a).

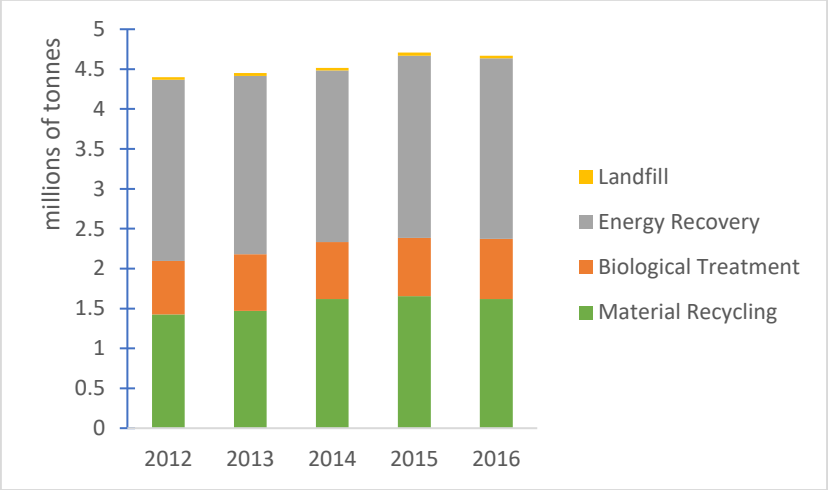


Figure 3 – Waste destinations' distribution in Sweden between 2012 and 2016, Avfall Sverige 2017a

Material Recycling, in this case, refers to the following fractions of waste: return paper, packaging waste, electrical waste, portable and car batteries, oil waste, water-based paint, other hazardous waste and bulky waste (Westin, 2018). The packaging waste is further described in Section 6.4.

From 2012 to 2016 there has been an effort in increasing material recycling as see in Figure 3. Biological treatment has also been increasing and both energy recovery and landfill have been decreasing at a slower rate. Overall, Sweden has been trying to focus more on the upper levels of the EU's waste hierarchy, since for example recycling rates have been continuously increasing. Moreover, looking at previous years (Figure 4), since 1975 the country has been very effective in limiting landfill usage as much as possible and on transforming waste into a resource by investing in operations that allow the recovery of material, energy and nutrients from waste (Avfall Sverige 2017a).

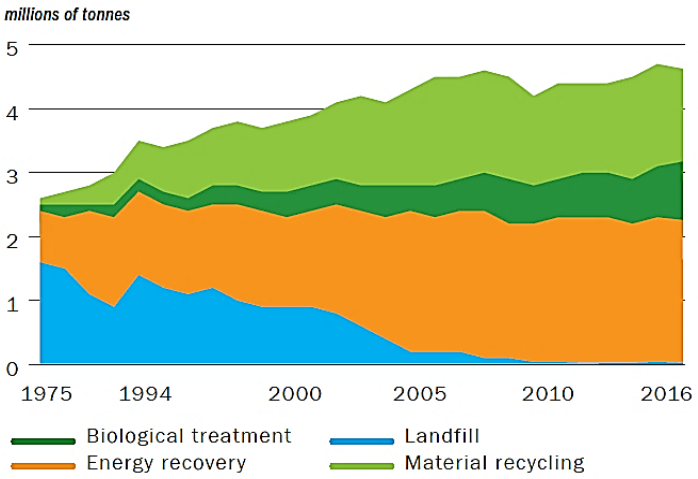


Figure 4 – Evolution of waste destination in Sweden between 1975 and 2016, Avfall Sverige 2017a

Furthermore, in 2016 35 municipalities had an incineration plant in Sweden. There were 10 plants producing compost and 34 digestion plants (Avfall Sverige 2017a).

4.4. Actors involved

In the Swedish waste management system, several actors are involved. The actors can be divided as those responsible for collection and disposal of waste and those responsible for informing and making publications on waste management plans, waste prevention programmes and reports on up to date statistics on waste production and management. Some of these actors, namely municipalities have both responsibilities. (Naturvårdsverket 2014; Avfall Sverige 2017a)

For collection and disposal of household waste actors involved are: municipalities, producers and households. The municipalities are the main responsible ones, unless the waste is covered by producer responsibility. Municipalities also are required to follow a waste and sanitary ordinance that demands the execution of a waste plan and regulations towards its management (Chapter 15, Section 11 of the Environmental Code). In addition, they have the obligation to inform about their waste management, related plans and about the responsibility of producers. Municipalities are also responsible for the disposal of bulky household waste.

Municipalities can organize themselves into four types of organizational structures: self-administration; municipal enterprises, wholly or partially owned; joint boards or municipal associations. Waste treatment can, therefore, be carried out by the municipality or municipal enterprise or by a private contractor which can be another municipality, municipal enterprise or a private company.

Figure 5 and Table 1 show the organizational structure of waste management distribution among Swedish municipalities. Both figure and table allow to conclude that almost half of the municipalities have chosen to be ran by self-administration, until 2016.

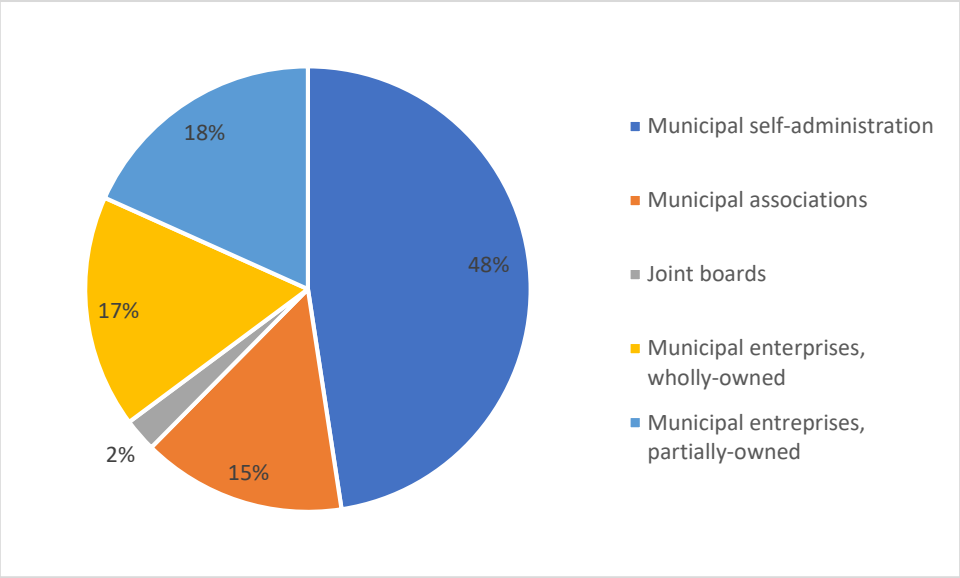


Figure 5 – Distribution of organizational structures of waste management distribution in Sweden, Avfall Sverige 2017a

Table 1 - Organizational structures of waste management distribution in Sweden, Avfall Sverige 2017a

Organizational structure	Number of municipalities
Municipal self-administration	138
Municipal associations	43
Joint boards	7
Municipal enterprises, wholly-owned	49
Municipal entreprises, partially-owned	53

On the other hand, households are responsible for separating and placing the waste at its proper collection points, as well as follow municipality's rules on waste management.

Statistics about waste flows in Sweden are published by the SEPA. These publications are then used to ascertain whether measures and objectives are being fulfilled and how are they being so. The waste statistics are shared with the EU. Avfall Sverige (Waste Sweden), the Swedish waste management and recycling association, and material companies, the organizations that manage producers' waste collect some of the statistics, on behalf of to the SEPA.

4.5. Collection and Transport

There are several systems available for collection and transport of household waste. Residual waste (see appendix II – definitions) from single-family households is usually collected every two weeks and waste from apartment blocks is often collected on a weekly basis (Avfall Sverige 2017a). Yet, the collection frequency differs from municipality to municipality according to the number of people living in the households, available resources for collection and others (Westin, 2018). Kerbside collection (see appendix II – definitions) is the most common system for collection of residual waste chosen by municipalities (Myrin, 2018) and bring systems (see appendix II – definitions) are also available for the sorted fractions.

A survey done by Avfall Sverige showed that households in a single-family household produce more waste than the ones in apartment buildings, but the waste is better sorted (Avfall Sverige 2017a).

Some municipalities hire private companies for collection of household waste (Figure 6). In 66% of the country's municipalities, the collection of food and residual waste is carried primarily by private contractors, 28% of municipalities deal with collection themselves and the remaining 6% use a combination of private contractors and in-house collection services.

The most frequently contracted company is Suez covering about 23% of municipalities, followed by Ragnsells with 16%, Reno Norden with 15% and Ohlssons with 9% (Westin, 2018). These four entrepreneurs collect household waste from two thirds of the municipalities. (Avfall Sverige 2017b). For the remaining 37%, about 16 companies are contracted by 2 to 10 municipalities the equivalent to about 27% of the municipalities and 20 companies are contracted by only one municipality, the equivalent to 10% of the municipalities.

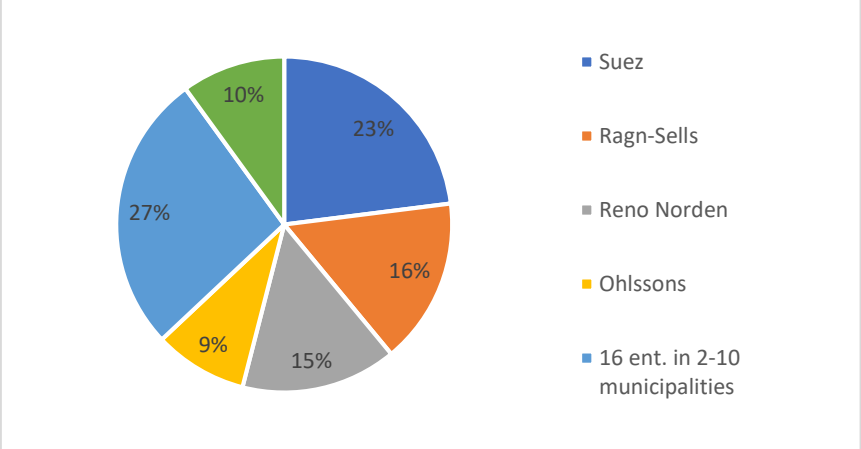


Figure 6 - Distribution of municipalities for the collection of food and residual waste by number of municipalities, 2016; Avfall Sverige 2017b

In some places in Sweden waste collection relies on technologies like vacuum waste collection and underground container systems. With these technologies it is now possible to avoid any heavy

manual handling of waste in the collection phase. Vacuum waste collection allows the reduction of needed transport by automatically transporting the waste through a vacuum system to a common point where it will be collected (Avfall Sverige 2017a). Underground container systems are positioned below surface level which allows essentially for reduction of needed space and prevents odours coming from the waste, due to lower temperatures that are less suitable for bacteria growth.

4.6. Legal Framework

The Environmental Code is a very important tool that contains the Swedish legislation, including waste regulations in Chapter 15. It defines rules that are essentially based on EU's Waste Directive (Directive 2008/98/EC). Regulations on waste can also be found in the waste SFS 2011:927, which contains information on the collection, transportation and treatment of waste (Naturvårdsverket 2017).

Within the Swedish waste legislation there are instruments like bans, taxes and the producer responsibility principle that aim to promote a more efficient management of waste and resources, reduce environmental impact and ultimately increase recycling.

When it comes to waste incineration, requirements can be found in the SFS 2018:537. This legislation has its basis on the Directive 2010/75/EU and only refers to industrial emissions. In this regulation maximum allowed emissions to air and water are stipulated as well as necessary requirements for the design of the incineration plant (Naturvårdsverket 2017). Apart from industrial incineration, it wasn't possible to find any current legislation specifically for household waste incineration in Sweden.

As for the packaging waste legislation, it can be found in SFS 2014: 1073 that has been recently amended in SFS 2017:167.

4.7. National Targets

The SEPA has stipulated milestone targets on waste. It specifies targets for 2018, like biological treatment of at least 50 percent of food waste from households, catering services, shops and restaurants and at least 40 percent of that waste should have its energy recovered (Avfall Sverige 2017a).

Up until 2016, a target was also established to reduce waste to landfill by about 35% in comparison to 1995 amounts of waste sent to landfill, which derives from an EU's target (Hedenstedt, 2009).

Concerning packaging waste, SFS 2014:1073 on producer responsibility establishes that for all packaging waste the recycling rate should be at least 55% by 2020 and about 65% after the first of January of 2020, this is further approached in the following sections.

4.8. Costs and Financial Instruments

Waste management costs are covered by a waste collection charge or a charge on the product depending on who has the responsibility, the municipality for the unsorted waste or the producer for the sorted waste. Services like waste planning, informing, customer service and services provided by recycling centres (see appendix II – definitions) are included in the costs and should be covered by the charge. The total cost on average for waste management to municipalities is about SEK 787, the equivalent to 78.7 EUR per person each year, with VAT not included (Avfall Sverige 2017a).

On top of a fixed basic charge some municipalities have added a weight-based charge. This charge means that households should pay an additional amount for each kilogram of collected waste. In 2016, 30 out of 290 municipalities had a weight-based charge (Avfall Sverige 2017a). The charge differs between municipalities according to their waste management needs (Westin, 2018).

Sweden has implemented two landfill bans, one on sorted combustible waste, in 2002 and one on organic waste, in 2005. The first one aims to divert from landfilling waste that can be incinerated with energy recovery. The second ban forbids all organic waste from being landfilled. This encourages biological treatment allowing both energy recovery, by producing biogas and organic recovery in the form of compost for instance. The landfill bans can be found in Sections 9 and 10, in SFS 2001:512. This regulation contains other provisions regarding the waste that is to be landfilled, such as the conditions it must comply with. In NFS 2004:4 there is basic regulation and advice on the management of combustible and organic waste, made available by the SEPA.

Besides the landfill ban there are other supporting instruments that intend to promote recycling like the landfill tax. The landfill tax is currently about SEK 500 or 50 EUR per tonne of waste (Nahibina et al 2006; Avfall Sverige 2017a). The tax on landfill disposal together with the landfill ban has shown a successful reduction in landfill disposal (SEPA 2012). Furthermore, currently there is no incineration tax in Sweden for household waste (Willén, 2018).

5. Portugal's Waste Management System

5.1. General Facts on Portugal

In 2016, Portugal had a GDP of about 185 trillion euros and a population of about 10.3 million people, more precisely 10 309 573 people with a total of 308 municipalities (População residente 2017). The country's surface area is about 92 200 square kilometres.

5.2. Waste Quantities

In 2016 the production of urban waste was 4.89 Mt, the equivalent to 474 kg/hab year. Moreover, there was an increase in waste production in recent years, contrarily to the objectives of waste prevention that intend to achieve a reduction in waste production (APA 2016).

Figure 7 shows the different paths waste can follow. This depends on the kind of waste stream, unsorted or sorted waste, but also the composition of the waste itself in terms of material. Additionally, this figure doesn't show imports and exports of waste, but such flows also exist in Portugal.

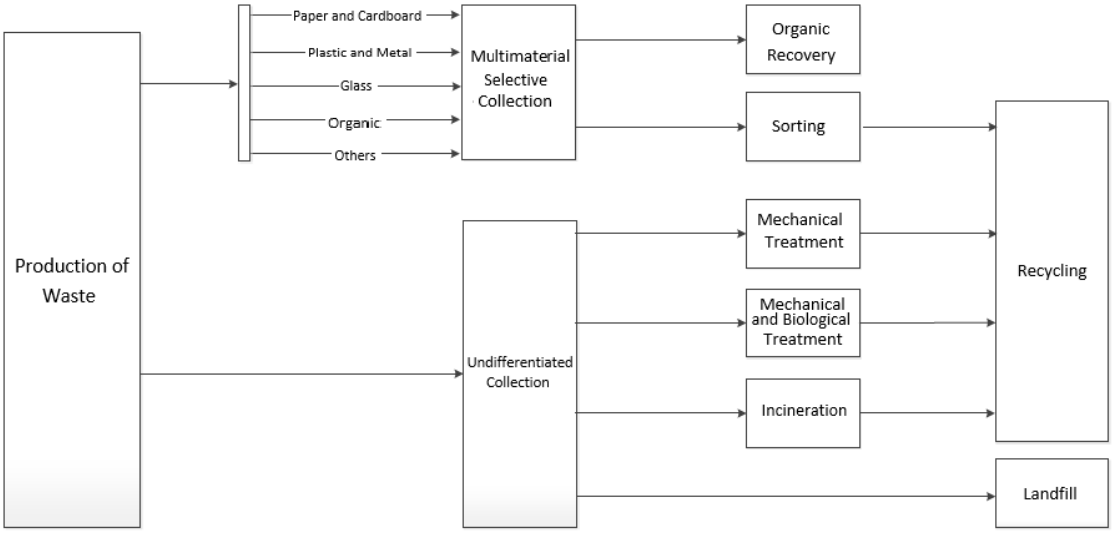


Figure 7 – Main waste flows in Portugal, Ministério do Ambiente, 2014

Figure 8 informs about the physical characterization of the urban waste produced in 2016. From that same figure, it is possible to see that plastic represented about 11.3% of total waste, which is still a large proportion when comparing to the other types of produced waste.

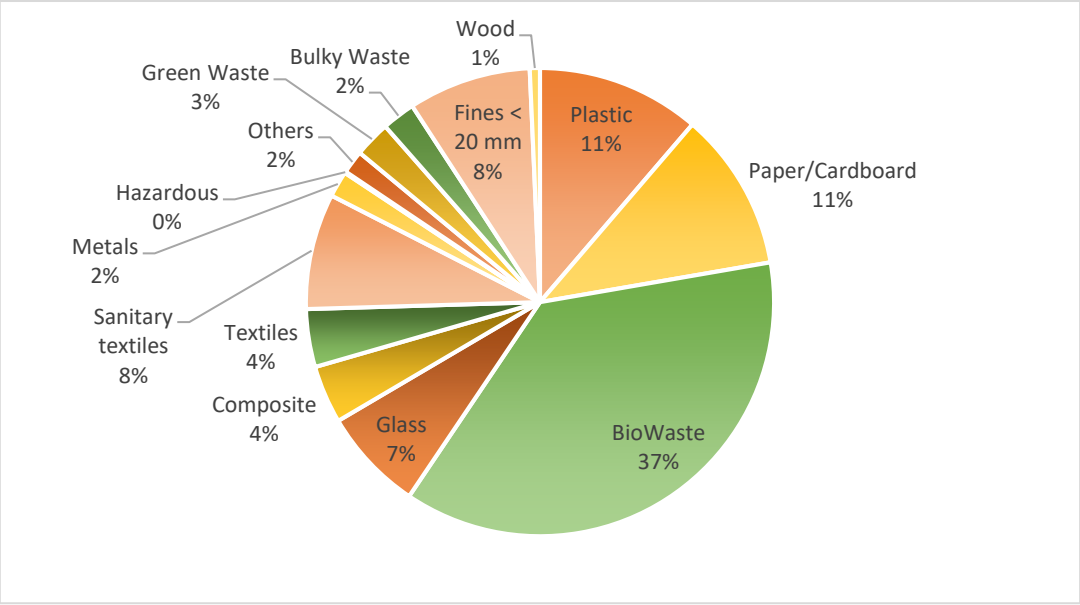


Figure 8 – Physical characterization of waste produced in 2016 in Portugal, APA 2016

5.3. Waste Destination

In 2016 the distribution in terms of waste destination (Figure 9) was the following: 10% for material recycling, 16% for organic recovery or biological treatment, 23% for incineration and 51% to landfill (ERSAR 2017).

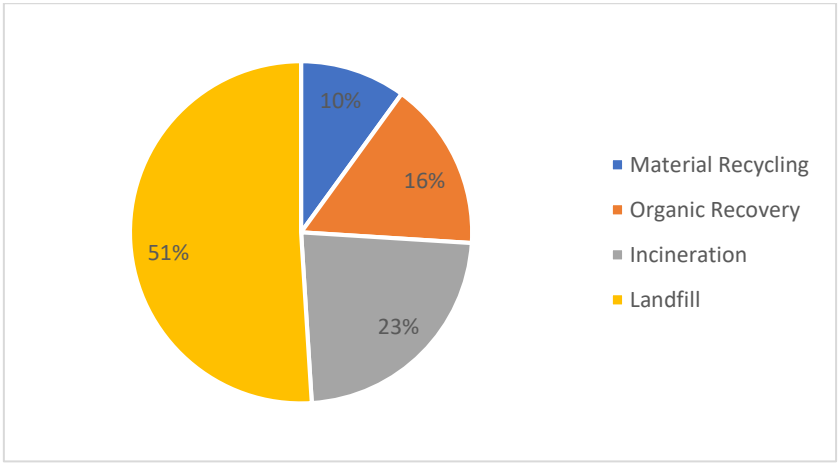


Figure 9 – Waste destinations' distribution in 2016 in Portugal, ERSAR 2017

Material recycling, in this case, has as an input the urban waste that is sent to sorting facilities and the waste that correspond to the codes 15 01 and 20 (Environmental Protection Agency 2002).

In Portugal, there are unit operations like mechanical and mechanical and biological treatment (see appendix II – definitions) where there is sorting of waste with potential for recycling, such as paper/cardboard, glass and packaging waste, which includes plastic and metal. Such operations

also allow separation of the organic fraction that can proceed to composting, for example, and separation of the refuse waste that can be used for producing refused derived fuel.

Figure 10 shows that between 2011 and 2016 efforts have been made to decrease landfilling of waste. There has also been an effort and investment towards increasing mechanical and biological treatment, as more units for mechanical and mechanical and biological treatment have been operating. These efforts are also meant to increase the recycling rate and decrease greenhouse gases emissions. Even though statistics show a positive trend for upper levels in the waste hierarchy, there has been a stabilization of the fraction going to material recycling, an opposite trend to what is intended to achieve. Current efforts to increase sorted collection (see appendix II – definitions) have not led to acceptable results (APA 2017).

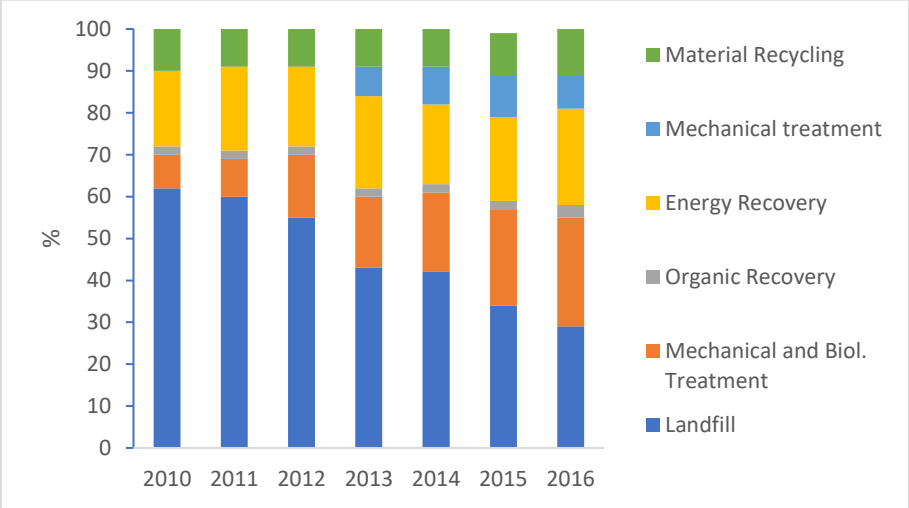


Figure 10 – Unit operations distribution from 2010 to 2016, APA 2016

In 2016 about 4, 89 Mt of waste was produced, 1.04% of reduction was achieved compared with 2012. The amount of organic waste sent to landfill was reduced by 41% when compared to the year of 1995. Also, in 2016 the recycling rate of waste was about 38% and the sorted waste was about 38 kg/habitant.year (APA 2016). Furthermore, the landfill fraction shown in Figure 10 refers only to waste that is being sent directly to landfill. This fraction increases to 51% (Figure 9) when summing the amounts of waste that are coming from treatment units, like mechanical and biological treatment, that also have as final destination landfill.

Table 2 – Number of waste management facilities in Portugal in 2016, APA 2016

Waste management facility	Number of facilities
Landfill	32
Mechanical Treatment Unit	6
Organic Recovery Centre (Undifferentiated Stream)	16
Organic Recovery Centre (Selective Stream)	5
Energy Recovery Centre	3
Sorting Station	30

Transfer Station	90
Eco-centre	197

Table 2 shows the number of waste management facilities there was in Portugal, in 2016. The main difference between sorting facilities and mechanical and mechanical and biological treatment facilities is how sorting is primarily done. In sorting facilities manual sorting is predominant and in the other units, mechanical sorting dominates.

5.4. Actors involved

Since 1995 the waste management sector in Portugal has evolved towards multi-municipal and inter-municipal systems. The responsible management entities are divided into two, the “high” management entity refers to an entity that manage waste treatment and the “low” management entity is responsible for managing the waste collection (APA 2016). These entities are also known as SGRUs.

In 2016, in Portugal’s mainland, there were 23 ‘high’ entities of which 12 were multi-municipal concessions and 11 were inter-municipal entrepreneurs (APA 2016). As for the ‘low’ entities there are 258 entities and at least 229 are municipalities, ran by self-administration (ERSAR 2017). The EGF operates 11 of the ‘high’ entities. The SGRUs operated by EGF are responsible for managing 64% of urban waste produced in the country. EGF owns 11 out of the 12 multi-municipal concessions of Portugal’s mainland. Figure 11 shows all SGRUs operating in Portugal (SPV 2017).

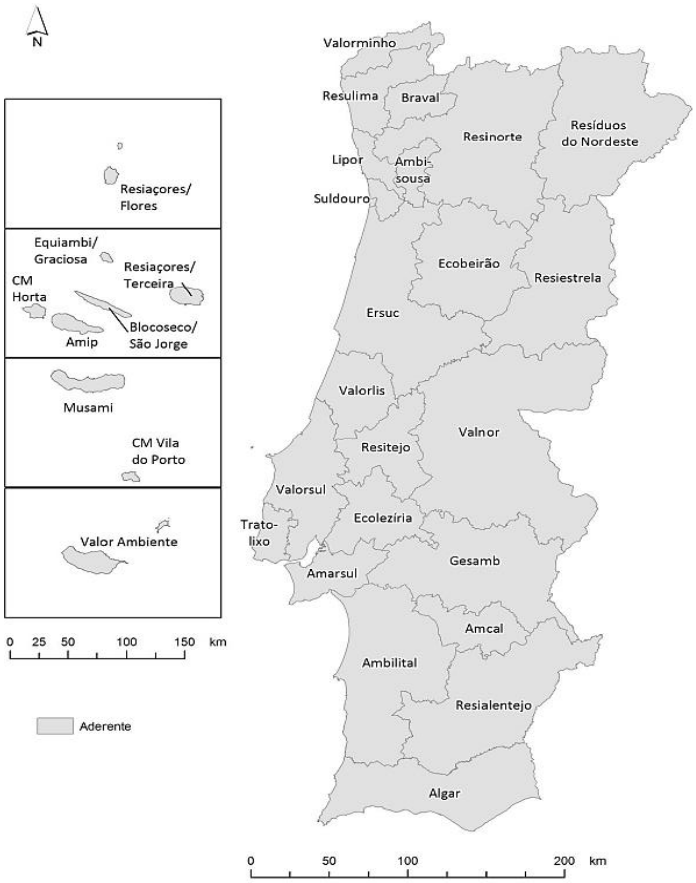


Figure 11 – SGRUs in Portugal, SPV 2017

Furthermore, Figure 11 shows the country's remaining SGRUs, the ones situated in the archipelagos. Multi-municipal concessions are owned by at least two municipalities and require the State's intervention, in matters of national interest. Inter-municipal systems and multi-municipal concessions, including municipal associations either ran by themselves or in partnership with the State should provide the necessary organization and management of the water and waste sector (APA 2016). In Portugal only 2 municipalities ('high entities') are ran by municipal self-administration.

The main responsible entity for publications about statistics and waste management in Portugal is the Portuguese Environmental Protection Agency. To determine whether and how measures and objectives are being satisfied annual reports are made available each year by the same entity. These waste statistics' reports are also shared with the EU.

5.5. Collection and Transport

In Portugal, the bring system is mainly composed of eco-points (see appendix II – definitions), surface containers for sorted waste, which are either located outside households or in eco-centres

(see appendix II – definitions). Eco-points outside households are placed in public areas near households and are used by more than one household. Eco centres allow for the concentration of waste from many points of the country and from here, this waste is then sent to a treatment facility. In the eco centres, besides the sorted waste disposed in the eco-points, other types of waste that cannot be dropped-off at eco-points, such as bulky waste can be disposed of in proper containers. The disposal of urban waste is often done inside plastic bags, except for paper/cardboard. These are often collected in a weekly basis. Nevertheless, the collection frequency varies between municipalities according to its available resources, production of waste and population density (Norte, 2018; Torres, 2018).

In addition, collection of waste can also be done through door-to-door collection or kerbside collection, in which a vehicle collects the waste directly from each household. This can apply for both the sorted and unsorted waste.

For the unsorted waste collection, vehicles are usually mono-compartmentalised. Even though, for sorted collection, mono-compartmentalised or multi-compartmentalised vehicles can be used. Multi-compartmentalised vehicles allow for collection of waste without mixing different waste streams. Investment costs for such vehicles are higher, but the collection costs are lower (Teixeira, 2004).

Then, urban waste is sent to treatment facilities, where separation of recyclable and inorganic waste from the unsorted and sorted waste stream takes place. In Portugal, collection of urban waste is essentially divided into two streams, the sorted and unsorted one. The unsorted waste should include organic and residual waste and the sorted should include three waste streams: paper/cardboard, packages and glass. These three sorted waste streams are further described in Section 7.4.

5.6. Legal Framework

Currently, the Portuguese waste management legislation is outlined in the Decreto-Lei n.º 73/2011 which is based on the Directive 2008/98/EC. It reinforces prevention of production of waste and encourages reuse and recycling as a mean to achieve a circular economy. Packaging waste was the first type of waste being regulated through Decreto-Lei nº 366-A/97, that was amended in the Decreto-Lei nº 71/2016 (ERSAR 2017).

In 2016, a licence which allow for packaging waste management of one new entity (Novo Verde, SA or New Green) was published and in 2017 another entity, Amb3E joined the packaging waste management as well. In Portugal, the extended producer responsibility as presented in the EU waste framework can be found in Directive 73/2011. In addition, in 2016 SPV's licence was renewed.

Technical characteristics or specifications of waste and requirements for landfill disposal are described in the Decreto-Lei nº 71/2016. These technical characteristics refer to those that waste must comply with before being sent to its final treatment.

In 2016, a waste management commission (Portaria nº 306/2016) was defined as an entity responsible for technical support and evaluation of sustainable policies for waste management. It is responsible for suggesting needed updates towards packaging waste technical specifications.

The Directive 2000/76/EC on waste incineration has been adopted in Portugal and can be found in the Decreto de Lei nº 85/2005. Furthermore, legal regulations concerning the waste management tax can be found in Lei nº 82-D/2014.

5.7. National Targets

National targets for 2020 related to landfill and recycling of urban waste are: reduce landfilling of biodegradable waste to about 35% related to 1995 (EU's target) and assure separate collection of waste to 47 kg/person.year (APA 2016).

To successfully achieve such targets, measures must also be satisfied. For instance, it is important to adopt financial and economic instruments like taxes, incentives and PAYT systems (APA 2016). Moreover, it's essential to improve institutional and operational capacities of the waste sector, by monitoring and revising current plans and organizations.

Each SGRU has also defined its own targets, that together must comply with the national targets. These targets established for the period between 2016 and 2020 vary according to production of waste in each municipality, as well as available resources like vehicles, equipment, infrastructures, technologies, as well as distances to be travelled when collecting waste (Despacho nº 3350/2015).

5.8. Costs and Financial Instruments

In 2016, total costs of urban waste collection in Portugal were about 409 million EUR and costs for treating it were about 345 million euros (ERSAR 2017).

The provisions obtained from the extended producer responsibility will support costs for the correct handling of the sorted waste including sorting, pre-treatment, recovery and disposal of waste. The total of these provisions is called Ecovalor (Ecovalue) and this should also cover communication, awareness campaigns and studies. This is further described in Section 7.6.

Another important financial instrument is the waste management tax (regulation 82-D/2014). This annual tax (Table 3) is charged according to the amount of waste and the chosen destination. If the destination is landfill the total tax is charged. If incineration, without energy recovery is chosen 75% of the tax is charged. Otherwise, if energy recovery is chosen 25% of the tax is charged. This

tax aims to cover administrative costs, encourage reduction of produced waste and help achieve national targets.

Table 3 – Waste management tax values since 2015 up to 2020, Regulation 82-D/2014

	2015	2016	2017	2018	2019	2020
Waste management tax (€/t)	5.5	6.6	7.7	8.8	9.9	11

Besides the waste management tax paid by the entities in the waste management sector, there is also a tariff for the urban waste management service which is paid by households. According to Deliberação nº 928/2014, the variable tariff for urban waste management can be applied in different ways: PAYT system, in which producers of waste pay according to weight or volume of waste produced or a tariff that varies according to the volume of consumed water.

The most common waste management tariff currently applied in Portugal is presented in the water bill and it is often the combination of a fixed tariff and a variable tariff. Therefore, the consumer pays according to the volume of consumed water during that month (Tarifas dos Serviços 2018). There aren't currently many examples of a PAYT system. In Portugal there has been some projects such as in Maia municipality and in Portimão for the PAYT system but in any of them it has been fully implemented. The municipality of Guimarães, along with Vitrus Ambiente and Resinorte implemented a PAYT system pilot project for the historic centre of the city. In this project citizens pay according to the amount of produced unsorted waste by paying for each necessary waste bag. Hence, the more waste they produce and the more they place sorted waste in the unsorted waste stream, the more bags they will have to buy and pay for. In fact, Guimarães municipality is the only municipality currently applying a PAYT system in Portugal (Lobo, 2018).

6. Sweden's Plastic Packaging Recycling

6.1. Production of Plastic Packaging

In recent years, between 2012 and 2016, it is possible to say that total amounts of plastic packaging put in the Swedish market have been increasing (Table 4). In 2016 it was estimated that a total of 238 500 tonnes of total plastic packaging were sold in the Swedish market.

Table 4 – Total plastics packaging put on the market (plastics excluding PET bottles), SCB 2018c

Plastics put in the market (t)	2012	2013	2014	2015	2016
Plastic packaging, excluding PET-bottles	191 900	199 200	203 100	206 100	212 500
PET-bottles	21 700	23 300	25 300	24 800	26 000
Total plastic packaging	213 600	222 500	228 400	230 900	238 500

In Table 4, PET bottles refer only to bottles that are included in the deposit return system (SCB 2018c).

The data chosen was published by the Swedish Statistics Institute (SCB), since it includes the results from all material companies, like FTI and TMR and from producers that are not members of any material company (Willén, 2018). These actors are responsible for reporting to the SEPA, that then shares the data with SCB.

6.2. Actors Involved

Since 1994 producers and importers of plastic packaging that is sold within the Swedish market are responsible for the collection and recycling of that plastic packaging waste. This has been implemented due to the producer responsibility on packaging, first established by the EU, and it is stated in the SFS 2006:1273. On the other hand, unsorted plastic packaging waste that ends up in the households' unsorted waste fraction is collected and managed by municipalities (Fråne 2014).

To answer producers' responsibilities on their waste management, a number of material companies were formed, including Plastkretsen, Svensk Kartongåtervinning, Returwell, MetallKretsen, Svensk Glasåtervinning and Pressretur. In the beginning four of the material companies, the companies responsible for material recycling, (Plastkretsen, Svensk Kartongåtervinning, Returwell and MetallKretsen) formed two organizations, Förpackningsinsamlingen ('Packaging collection') and Reparegistret AB (REPA). Förpackningsinsamlingen was responsible for managing collection systems and recycling stations

(see appendix II – definitions) and REPA would finance collection and recycling of plastic, paper/cardboard, corrugated boards and metal packaging waste. Since 2005, Förpackningsinsamlingen has been owned by FTI and in 2007 REPA also became part of FTI (FTI AB 2018e).

Currently Plastkretsen is one of the material companies that owns FTI and it represents plastic packaging producers. This is a not-for-profit company which ensures that the producer responsibility is applied for plastic packaging put on the Swedish market (FTI AB 2018e).

FTI advises producers by suggesting them plastic materials for packaging that are easier to sort and transform into a new raw material. FTI inform producers about the types of plastic that have higher demand in the market (Ström, 2018). The company has also developed a recycling guide for producers that aims to help them choose more recyclable materials for manufacturing new products. For example, PET (excluding PET bottles) can be efficiently collected and sorted and further transformed into a raw material. However, using it as a raw material implies a difficult process, since PET is very sensitive to humidity (Boss, 2018).Hence it is usually not a recommended material for plastic products. Furthermore, FTI evaluates the figures received by the sorting companies like Swerec through external and internal reviews (Ström, 2018).

In addition, FTI contracts private companies for the collection of packaging waste which is then transported to a sorting facility (Fråne 2014). Currently, FTI doesn't own any sorting facilities, they use existing sorting facilities that use NIR technology for automatic sorting, like Swerec. FTI offers a collection system (bring systems and kerbside collection) for packaging waste. This collection is financed by the producers, through a fee and it is further described in Section 6. 5.

There are other actors responsible for assuring the producers responsibility for plastic packaging such as TMR AB (Fråne 2014). TMR AB just like FTI provides collection and recycling systems for plastic packaging waste. This company was founded in 2005 and it offers both kerbside and bring systems for collection of plastic packaging waste by contracting waste collection companies. TMR owns a sorting facility where they produce mixed recycled plastic, but also sell the plastic packaging waste to external sorting facilities after compression. These external facilities take over the material and sort it, so it can go into recycling, which may include going back to TMR's recycling production. Along with FTI and municipalities, TMR has collection points in every municipality (Mellgren, 2018).

Nevertheless, there have been several municipalities that have chosen to set up a collection system for packaging through kerbside collection (Fråne 2014). About 40 out of 290 municipalities have set up a collection system for packaging waste from single-family households (Westin, 2018).

In addition, over the years there has been some difficulties in terms of delegation of responsibility of waste management when it comes to packaging waste between municipalities and material

companies. This has resulted in obstacles for a more efficient waste management, since there are no strategic discussions between actors meant to tackle and solve these obstacles (SEPA 2012).

Moreover, in Sweden PET bottles are regulated in SFS 2005:220 on deposit return system for PET bottles. The collection and recycling system for this kind of waste is different from the other plastic packaging waste. The deposit system for PET bottles is mainly managed by Returpack, a private company owned by Sveriges Bryggerier, Livsmedelshandlarna and Svensk Dagligvaruhandel. PET bottles are then sorted and transformed into flakes by Cleanaway Svenska AB. This is further explained in Section 6.3.2.

Hence, it is possible to summarize the most relevant actors as: importers and producers of plastic packaging, municipalities, consumers of plastic packaging, FTI and Plastkretsen, TMR AB, sorting facilities' owners, FTI's contracted collectors and the Swedish EPA.

6.3. Regulations

In Sweden, SFS 1997: 185 on producer responsibility was one of the first published legislations on packaging waste. It has its most recent update in SFS 2017:167.

6.3.1. Plastic Packaging and PackagingTargets

In SFS 2014:1073 on producer responsibility for packaging (Sections 15 and 23) targets for plastic packaging waste recycling rates have been established that refer to the period before the 1st of January of 2020 and the period after that (Table 5). In case of packaging waste, in general the target is that, before 1 January 2020, the recycling rate should be at least 55% and thereafter at least 65%. This can also be found in SFS 2014:1073.

Table 5 – Plastic packaging recycling targets, SFS 2014:1073

Type of plastic packaging waste	Until 1st January 2020	After 1st January 2020
Plastic packaging waste, excluding PET bottles	30%	50%
PET bottles	90%	

6.3.2. Deposit Return Systems for Plastic Bottles

SFS 2005:220 on deposit return system for plastic bottles in Sweden defines plastic bottle as a packaging made of mainly polymeric material. Therefore, this ordinance applies for PET bottles sold in Sweden as ready-to-drink beverages, excluding the ones containing dairy products or with

a content of juice or vegetables higher than 50%. The ordinance claims that products that fit into what was previously described should be included in an approved return system. The authority that gives approval to deposit systems is the Swedish Board of Agriculture. The ordinance also states that a plastic bottle part of a return system shall be marked as such. This indication informs the consumer about which return system the product is included, as well as the amount that is paid when the bottle or can has returned to the system.

6.4. Recycling Guidelines

The Swedish waste separation guide's description allows for better understanding how source-sorting is done. This is important for studying the collection and sorting of plastic packaging waste. The packaging waste in Sweden is divided into plastic packaging, paper packaging, metal packaging, glass packaging, magazines and newspapers, food waste, residual waste and electrical waste/electronics (FTI AB, 2018g).

Plastic Packaging consists of plastic bags, plastic tubs, plastic foil, bottles, plastic cans and others. Plastics that are used for other purposes other than packaging may have a different composition and content, as well as hazardous substances that should thus not enter this waste stream. Some of the non-plastic packaging waste are: plastic toys, plastic furniture, laundry baskets, PET bottles, video cassetes/VHS tapes, plastic folders, garbage bags and dog bags, catheters and other medical plastic items.

Paper packaging includes pasta boxes, milk or juice cartons, paper carrier bags, empty bags of sugar, shoe boxes, finished toilet rolls and cardboard boxes. This waste should be previously folded and flattened so less space is required. Items like envelopes and post it papers as well as magazines, brochures, flyers and writing papers should not follow this waste stream (FTI AB, 2018g).

Metal packaging includes tin cans and empty spray cans, tubes, bottle tops, dried tins of paint. They should be squeezed as much as possible and items that contain both metal and plastic materials, cans with paint residues, glue or solvents, metal-like bags containing plastic or paper, metal scrap, frying pans and other non-packaging products as well as electrical items should not go into this waste stream.

Glass packaging includes bottles and jars made of coloured or transparent glass. Metal tops or corks should be removed. The following items should not be sorted as glass packaging: metal cans within the deposit return system, porcelain, ceramics and other non-packaging waste, as well as light bulbs and florescent tubes and window glass or mirrors (FTI AB, 2018g).

Paper (‘returpapper’) includes newspapers, magazines, periodicals, catalogues, advertising flyers, brochures, writing/drawing paper and notebooks. Plastic covers should be removed, since they are plastic packaging. Envelopes and books, paper carrier bags and other paper packaging waste should not follow into this waste stream.

6.5. Recycling System

6.5.1. Collection Systems for Plastic Packaging Waste

In Sweden, the collection of plastic packaging waste for recycling is done either by kerbside collection of source-sorted plastic packaging waste or by bring systems (see appendix II), like recycling stations (Figure 12). Kerbside collection can be done through three different collection systems: in multi-compartment bins, in separate containers, transparent plastic bags or in coloured bags. The collection of plastic packaging waste is mainly done by contracted collectors hired by FTI.

Figure 12 – FTI’s recycling station, Västblekinge Miljö AB 2018

In multi-compartment bins different waste fractions have their own compartment in the same bin, usually the bin contains four fractions. Each household often has two bins with a total of eight fractions of waste (food waste, residual waste, coloured glass packaging waste, newsprint, paper packaging waste, plastic packaging waste, transparent glass packaging waste and metal packaging waste). Figure 13 shows an example of how waste can be divided into two bins.

Figure 13 – Bins with possible disposition of waste fractions, Fråne 2015

For the bin that contains food waste and residual waste there is a common collection frequency every second week. For the other bin, collection is about once a month. This frequency will depend greatly on the municipalities and private collectors. This type of collection is more oriented towards single-family homes. In Sweden this type of collection is available in 27 municipalities (Fråne 2015). Moreover, this kind of collection is done by rear-loaded vehicles that contain four compartments (Figure 14).

Figure 14 – Multi-compartment vehicle, Direct Industry, 2018

Separate containers or transparent plastic bags are more common in densely populated areas where apartment buildings and multi-family housing dominate. Thus, separate bins for plastic packaging waste are the most common option for apartment buildings in Sweden. The containers or plastic bags are kept either indoors or outdoors, frequently in the same place where containers for residual waste are located. As said before, collection frequency can vary a lot depending on the residential area. Nevertheless, transparent bags collection is usually done at least every fourth week (Fråne 2015).

Coloured plastic waste bags are all disposed in the same container and then collected by a single-compartment vehicle. In the sorting facility, the plastic bags are subjected to optical readers that

identify each colour and sort them into the type of waste. Afterwards, these bags are sent to further sorting. In Sweden only one municipality, about 20 000 households uses this type of collection system (Fråne 2015).

Bring systems are used for collecting packaging waste fractions, including plastic packaging waste. This kind of collection system is widely used in Sweden in all 290 municipalities (Fråne 2015). Bring systems are essentially recycling stations in Sweden. For example, FTI has about 5000 unmanned recycling stations, spread all over the country (Ström, 2018).

Moreover, FNI is part of FTI and it is essentially a type of kerbside collection system that is most commonly known as a property-close collection where households can leave their packaging waste in containers close to their accommodation facilities. The waste is then collected by a waste contractor and FTI ensures that the material is recycled. According to FTI 1,6 million households are offered kerbside collection, which corresponds to roughly 35% of plastic packaging waste collected (Ström, 2018). The remaining is collected through a bring system, FTI's recycling stations.

In the residual waste fraction there is always a small fraction of plastic packaging waste. In average between 13 to 15% of the residual waste is plastic packaging. This fraction is not sorted out from the residual fraction and ends up in energy recovery. Still there is no data on the fraction of plastic packaging waste that ends up in residual waste (Westin, 2018).

6.5.2. Collected Amounts

Every year, in February or March FTI publishes last year's collected amounts of packaging waste. These statistics include both kerbside collection and the bring system. All waste received by FTI is further sent to sorting facilities. In 2016 7,19 kg/person of plastic packaging waste the equivalent to 71 865 tonnes was collected by FTI,

Table 6 – Collected Amounts of plastic packaging waste sent for recycling in 2016, SCB 2018c

Type of plastic packaging	Collected Amounts (t)
Plastic Packaging (excluding PET bottles)	99 700
PET bottles	21 300
Total Plastic Packaging	121 000

The total amount of collected plastic packaging waste in Sweden in 2016 (Table 6) was 121 000 tonnes, including PET bottles received by the deposit return system. The total plastic packaging waste, excluding PET bottles was 99 700 tonnes which is higher than the number reported by FTI,

since it includes other organizations also responsible for collecting plastic packaging waste, like TMR and other plastic producers that are not members of any of those organizations (Willén, 2018).

6.5.3. Sorting and Recycling Processes

After the waste is collected, it is transported to transfer stations (see appendix II - definitions) before being sent to sorting facilities. The recycling system implies a large logistics system. In every county there are bailing sites where the plastic packaging waste is transformed into bales before it is sent to sorting facilities (Ström, 2018).

The soft and hard plastic packaging waste are collected together. Nonetheless both fractions are then separated using air. The resulting material is then shredded to flakes and is washed and refined. Afterwards these washed and refined flakes are melted and shaped into pellets which results in recycled plastic, also known as secondary raw material (see appendix II – definitions) (FTI AB, 2018h). This will be further explained in Section 6.4.5.

Hard plastic packaging is mainly composed of HDPE and PP. It is possible to have uncoloured and coloured fractions of such waste. Fractions of mixed colours and quality can be transformed into shelves or pallet blocks for instance (FTI AB, 2018h). Soft plastic packaging is mainly composed of LDPE and is mainly transformed into new bags, carrying cases and cable protections.

Three different processes are available for treating plastic packaging waste that will depend on collection and plastic type. The first one starts with compression followed by sorting and further compression of the sorted fraction that will finally be recycled as new material. The second option is pre-sorting followed by compression, moulding, washing and recycling. Finally, as a third option, first there is compression of waste and then, pre-sorting, washing and recycling. The sorted plastic packaging waste that is recovered by TMR's sorting plant is then sold to recyclers, in a global market. The non-recoverable part is sent for energy recovery (Mellgren, 2018).

6.5.4. Sorting Companies

Swerec is a plastic packaging recycling company that receives plastic waste from industries, municipalities and waste contractors like FTI and TMR. In return, Swerec sells the recycled plastic as raw material to other companies. This company receives most of the collected plastic packaging waste that falls into the producers' responsibility managed by FTI. Recycling processes that take place in Swerec's facilities will be further addressed and explained in Section 6.4.5. The facilities of this company are situated in Lanna, Värnamo municipality since 1992 and the services provided range from sorting, washing and baling or shredding (Thisted and Anderberg, 2015).

The market for recyclable plastic in Sweden is mainly dominated by Swerec (Norden 2015). Its sorting plant receives approximately 45% of plastic packaging waste produced by households, which corresponds to 50 000 tonnes of waste. The remaining is sent to German facilities Kedenburg, Tönsmeier and Eing (Ström, 2018). The waste received by Swerec comes from FTI, TMR and municipalities. Swerec also sells its sorted plastic packaging waste to a Germany company, Morssinkhof Rymoplast, and a polish company, Tradepol, by contracting about 5 or 6 different transport companies that deliver such waste to those companies. In Tradepol, the plastic waste is mixed with other plastic waste from other companies to obtain an optimum mixture for manufacturing a good quality raw material. Besides plastic packaging, Swerec receives rigid plastic from households and industries which is separated from the other type of plastic waste once it reaches the sorting facility. Moreover, they receive plastic packaging waste from Iceland (Karlsson, 2018).

About 65% of the plastic packaging waste received is recoverable, but only about 40% in weight is recycled. This is due to losses, that may be caused by moist and dirt mixed with the plastic packaging waste fraction. The remaining 25% of the waste received is mainly non-packaging waste and is sent to energy recovery. About 50% of the unrecovered plastic waste is sent to a cement company, HeidelbergCement that uses the recycled plastic as fuel to make the cement (Karlsson, 2018).

In a project recently developed with ICA, Swerea and Novoplast, Swerec sent their plastic flakes to Novoplast that makes granulates and along with Embalattor, a bottle was made with 100% recycled plastic.

Besides Swerec's sorting facility, FTI has made plans for the construction of a new sorting plant in Motala. The plant should be ready by the end of 2018 and fully operational by the beginning of 2019 (FTI AB 2018a).

Cleanaway PET Svenska AB is part of the Veolia Umweltservice GmbH group and is a market leader in PET bottle recycling. It receives its input material by the Swedish organization Returpack AB. Cleanaway PET Svenska AB recycles about 28 000 tonnes of PET bottles each year (Ottosson, 2018; Thisted and Anderberg, 2015). This company offers essentially 6 types of plastics granulates as plastic raw materials that vary according to the plastics' composition and colour. It has no reusing process, only recycling. The input capacity of its facility is 28 kt/y and about 85% of the input waste is mechanically recycled. They only receive PET bottles from the return deposit scheme. Additionally, they perform lab analysis for all batches of recycled material that are being continuously produced. The main buyers and consequently converters of recycled PET from the company are bottlers and sheet producers (Ottosson, 2018).

6.5.5. Sorting and Recycling Technologies

In Swerec's sorting facility when the plastic packaging waste arrives it is first baled by a compactor with a steel wire (Figure 15). Then, the bale is opened, and a front loader carries the bale into the facility where it throws it up in the air so that when it hits the floor the plastic materials become more lose. Sometimes the compacted waste doesn't become lose because of food residues or cleaning products that stick the plastics together, that waste is usually sent to incineration. This shows that compaction is a good solution for facilitating transport since it allows to transport higher amounts of waste at once, but it may lead to losses in terms of what is going to recycling.

Figure 15 – Compacted plastic packaging waste in the form of bales (on the right)

After the material is loser it goes into a bag opener (Figure 16), a machine with an inside rotor that is intended to tear the waste plastic bags (Figure 17). When sorting plastic packaging waste at households, people are supposed to empty their waste and put the remaining plastic bag in the same plastic packaging waste stream. Though it often happens that when the nearest recycling station is 500 metres way from households, people tie the waste bag before going there and consequently dispose of it in that way. When the plastic waste bags don't open in the bag opener, they will either be sent for energy recovery or they will follow the mixed plastic waste stream, where the plastic waste in those bags has a chance to be recovered. Swerec does a second sorting of the mixed plastic waste to obtain higher amounts of sorted plastic packaging waste, this is included in the 40% recycled plastic (Karlsson, 2018).

Figure 16 – Bag opener

Figure 17 – Old bag opener rotor

After the bag opener, the waste follows into a machine containing air blowers that allow the separation of plastic films from the remaining waste plastics with higher density. Hence, in that step the plastic waste gets separated into two streams. Along the tube system there are additional air blowers that are connected (Figure 18). These allow for further separation of the lighter fractions of plastic waste. The heavier plastic waste stream will then go through rotating sieves that separate smaller particles of plastic from the other particles. Those smaller particles originate from hard PET materials or HDPE and PP bottles that have broken in the initial compaction or baling process. These are sent to energy recovery, since the NIR (Near Infra-Red) station is not able to detect such small particles. This corresponds to a loss in terms of plastic waste that could otherwise be recycled.

Swerec uses the UniSort® NIR system technology for sorting plastic packaging waste. This sorting system can detect plastics with grain sizes up to 4 mm. The system allows for separation of different types of plastic found in the plastic packaging waste stream, and for separation of mixed plastics from electronic scrap (WEEE), for example. This sorting system uses high-precision particle detection followed by a burst of compressed air to separate the detected particle. It uses the materials' property of absorbing characteristic wavelengths. These absorbed wavelengths are in the infrared region of the spectrum and they determine the material's specific molecular

structure. Hence, the system analyses the radiation reflected from the material, the molecular structure, and is sorts accordingly. Through hyperspectral imaging technology the high-resolution spectrometer can carry out very fast material recognition.

Figure 18 – Air blowers

The system separates HDPE from LDPE or PP and PET from polyamide (PA) and polycarbonate (PC). Additionally, the system can distinguish between ABS (Acrylonitrile butadiene styrene) and PS (Near Infrared Unisort 2018).

Moreover, at Swerec's sorting facility HDPE and PP plastic waste is washed twice. These plastic types pass through a sink and float process and are then shredded, in the form of flakes with a size of 8-10 mm (Figure 19), also twice. These steps are followed by a final drying process and then stored in bags (Figure 20), as they are ready to be sold as secondary raw materials. PVC also ends up in the sorting facility and must be removed from the waste stream since this type of plastic is not included in the producer responsibility scheme (Norden 2015). Therefore, to sum up, the plastic types recovered are PP that is mostly sold in the form of bales, although some are

turned into flakes, HDPE that is sold in form of flakes, PET, plastic films and LPDE that are sold in the form of bales.

Figure 19 – Sample containing plastic flakes

Figure 20 – Bags with HDPE and PP recycled plastic flakes

Figure 21 shows the containers that store the sorted plastic packaging waste, resulting from the process described above.

In addition, in the beginning of the process, a sample from a plastic waste bale so that an overall analysis of the type of plastic waste, as well as moisture and dirt content is conducted. Once a month a company comes and collects two samples from two randomly selected trucks. These tests show that about 15 to 20 percent in weight of that sample is mainly moisture and dirt.

Currently for Swerec HDPE and PP are the plastic packaging waste materials with higher value in the market. Plastic films also have value in the market, if they are transparent and cleaned. The mixed film has no value, since it doesn't get colour sorted in Swerec's sorting plant. PET doesn't have that much value anymore, since most PET is in the form of bottles that are collected through the deposit return system. Hence, the PET that ends up in Swerec is a hard material that easily breaks in the baling process which leads to losses in the recycled plastic waste amount. The

mixed plastic had market value before the recent China's Import Waste Ban on Plastic Waste, since they were the main purchaser of such waste.

Figure 21 – Containers for each recycled plastic type

In the plastic packaging waste stream, certain types of waste can cause problems in the machinery. Video cassettes sometimes follow into this stream, even though they are not plastic packaging and so the tapes (Figure 22) can get tangled in the machines and cause problems in the process. Hence Swerec has developed a machine that helps solving this problem by removing that type of waste (Figure 23).

Furthermore, biodegradable plastics mixed with other types of plastic may contaminate the remaining plastic. That is more noticeable as granulates are produced, since a high content of biodegradable plastics in those can alter the plastic product's characteristics, if such is used as a raw material (Karlsson, 2018).

Figure 22 – Tapes from the plastic packaging waste stream

In addition, plastic packaging waste that is received and sorted by Swerec is not allowed to be transformed into food packaging. It is instead used for manufacturing other products like packages for cleaning products, floor and garbage bins.

Figure 23 – Machine that separates tapes from the plastic packaging waste stream

The recycling process for PET bottles applied by Cleanaway PET Svenska AB is the URRC process. This process starts with a bale feed, in which the PET bottles are pre-sorted and materials like metals, tins and others are separated. Then they are separated by colour and the clear PET bales go to a bale dissolver, where the bottle caps pass through a drum sieve that separates them. A staff member then examines the PET bottles and removes the remaining contaminants. These bottles are then sent to a grinder that transforms them into flakes. This is followed by a hot washing process that cleans the flakes by removing remaining labels, drink residues and dirt particles. After that PET flakes are separated from other types of plastic flakes, based on their different densities, since HDPE and PP plastics float while PET sinks. Hence, they are separated into different types of plastics. The material is then dried and passed through an air classifier for further elimination of unwanted particles. The dried flakes pass through a caustic soda treatment and a surface cleaning with vacuum treatment to be then rewashed and dried. Finally, the flakes are sieved and sorted one last time by a laser sorting system that recognizes unwanted particles. The final materials are stored in bags and ready for transportation. The products are: CleanPET® FK, CleanPET® FK light-blue, CleanPET® GK, CleanPET® WF clear, CleanPET® WF colored, CleanPET® PO (Cleanaway PET Svenska AB).

Swerea is a Swedish research group that works in materials sciences, manufacturing and product engineering that promote sustainable growth. Swerea IVF is the research institute responsible for studying materials properties and applications for ceramic, polymer and textile materials. In this institute, plastic recovery and recycling expertise has been developed, especially for the cable industry. Swerea has some projects on plastic packaging recycling that are done as a partnership with plastic producers or recycling companies along with universities (Boss, 2018).

Swerea provides with several technologies like extruding, injection moulding, melt spinning, testing equipment, depolymerization. These technologies allow for material characterization and studies about the processability of the material that allow for assessing the polymers' properties.

Swerea develops depolymerization of plastic waste, that allow its transform into new plastic products and studies bio-based plastics as an alternative for virgin feedstock.

Plastic waste like PE and PP can be recycled at least two or three times, possibly more if it is to be made into new plastic packaging products. Therefore, in the future focus should be given in improving plastic products design and avoid multi-layer plastic products which make disassembly of such products for recycling nearly impossible (Boss, 2018).

6.5.6. Recycling Rate

In Sweden, the plastic packaging recycling rate hasn't had a stable evolution since 2004, as shown in Figure 24. Only in more recent years, since 2013 there has been an increasing trend of this rate.

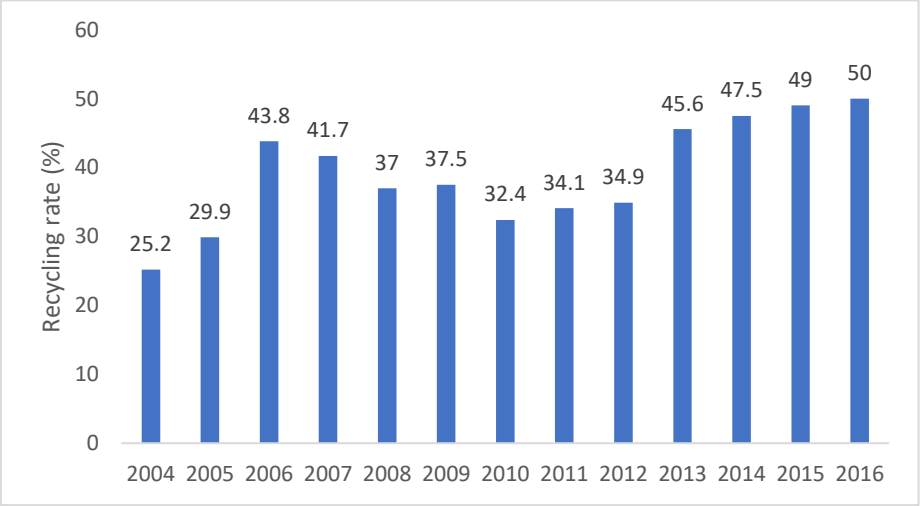


Figure 24 – Plastic packaging rate recycling rate evolution between 2004 and 2016 in Sweden, Eurostat a and SEPA

In 2016, the recycling rate of total plastic packaging was approximately 50% (Table 7). In Table 7, a big difference can be seen between the recycling rate of PET bottles, about 82% and the remaining plastic packaging, 47%.

The recycling rates are calculated with the amounts of collected plastic packaging waste sent for recycling, that is the amounts of plastic packaging sent to the recycling companies, divided by the amounts of plastic packaging waste put on the market. In Sweden the amounts of plastic packaging waste sent for recycling refer to the amounts prior to any sorting process (Ström, 2018).

Table 7 – Recycling rate of plastic packaging in 2016, including produced and recycled amounts, results from Sections 6.1 and 6.4.2

Type of plastic packaging	Produced Amounts (t)	Recycled Amounts (t)	Recycling Rate (%)
Plastic Packaging (excluding PET bottles)	212500	99 700	47
PET bottles	26000	21 300	82
Total Plastic Packaging	238 500	121 000	50

Table 8 shows the published amounts of produced plastic packaging that are reported to FTI by its members. These members are the producers of plastic packaging that put their products on the Swedish market and are obligated to report such amounts to FTI (Ström, 2018). The difference seen in produced and collected amounts in Table 7 and Table 8 is because Table 7 presents national amounts. which include reported amounts by FTI, TMR and the remaining producers that are not members of any of such producer responsibility organizations.

Table 8 - Recycling rate of plastic packaging in 2016, FTI AB 2018d

	Produced Amounts (t)	Recycled Amounts (t)	Recycling Rate (%)
Plastic Packaging	196 908	83 044	42

6.6. Costs and Financial Instruments

To cover collection and recycling of plastic packaging costs, FTI as a not-for-profit organization has established some packaging fees that should cover such costs. Companies that are affiliated with FTI and consequently under the producer's responsibility must pay these fees (Table 9) which vary according to the amount of packaging products put on the market.

Table 9 – Packaging fees required by FTI (FTI AB 2018b)

Type of packaging	Material	Until Mars 31, 2017 (SEK/kg)	From April 1, 2017 (SEK/kg)
Household packaging	Paper	1.35	1.18
	Plastic	2.15	2.33
	Aluminium	2.21	2.35
	Steel plate	3.59	3.90
Commercial Packaging	Paper	0.01	0.01
	Plastic	0.03	0.03
	Aluminium	0.01	0.01
	Steel plate	0.16	0.16
	Barrels	0.04	0.04
	Steel plate, wire	0.28	0.28
Manufacturer's Packaging	Paper	1.22	1.06
	Plastic	1.94	2.10
	Aluminium	1.99	2.12

Most of FTI's costs relate to collection of packaging waste from households. The remaining costs are associated with consulting with municipalities and reporting to the Swedish EPA. Kerbside collection in apartment buildings is also financed by the property owner and consequently its residents. The same arrangement applies for kerbside collection, for households in collaboration with FTI. In the cases where municipalities have set up their own collection system for plastic packaging, they may sell the plastic waste on a free market afterwards. (Fråne 2015).

The collected material by FTI is sold to Swerec and others. The income from the sale plus the packaging fees should cover the following activities: establishing, operating, cleaning and collecting from recycling stations, as well as subsidize kerbside collection services for households, transportation, sorting and recycling, information campaigns, administration and information about the recycling system (FTI AB 2017). FTI is considering having different fees on plastic packaging waste, in which good recyclable products shall pay less, so as to create an incentive for making packaging more recyclable (Ström, 2018).

As for PET bottles, grocery stores and shops must pay a deposit per bottle, 1 SEK for small bottles and 2 SEK for bigger bottles, as well as an administrative fee. When buying these bottles consumers are charged the deposit and so the shop is refunded the amount they had previously paid to the producers. Nevertheless, this is only so if the bottle is not returned to the deposit system by the consumers. This deposit is charged by the breweries and importers when selling their ready-to-drink beverages in PET bottles to grocery stores and shops.

Returpack finances the collection and recycling system of PET bottles by selling the sorted PET fractions to recycling companies, in this case to Cleanaway PET Svenska AB which then sells the PET flakes to bottle producers (Fråne 2015).

Moreover, municipal recycling centres are also financed through waste management fees already introduced in Section 4.8.

6.7. Plastic packaging market

A market for recycled plastics is essential for completing the plastic recycling value chain and promote circular economy. Hence, the demand for recycled plastics should be high enough to enable its circularity. In the Swedish market there are already some companies that use recycled plastics in their products, at some extent (Plastic Recyclers Europe 2018).

Electrolux claims that "the use of recycled materials in our products will receive renewed focus to ensure that we achieve our objectives". Two of Electrolux goals for 2020 are to replace virgin materials with recycled materials in their products and increase the annual volume of recycled plastic to 20 000 tonnes. Recycled plastics are presently being used to produce vacuum cleaners and white goods at this company. Their latest vacuum cleaner is made of 70 percent recycled plastic. Furthermore, Electrolux, recycled 5 640 tonnes of their plastic waste in 2017 (Electrolux 2017).

Nolato has also established as a target the increase in usage of recycled and, or renewable raw materials. This company produces pharma packaging, laboratory products, protection plugs and others- In 2017 the company used about 400 tonnes of recycled plastic and they claim that projects concerning the increase of usage of recycled materials are being developed. Moreover, Nolato recycled approximately 64 percent of its waste in 2016 (Nolato 2016).

Plaståtervinning i Wermland AB also makes use of recycled plastics as secondary raw materials. They have developed composite sleepers for railway and in the manufacturing process of these, recycled material from the household's plastic packaging was used. In addition, they managed to make their sleepers completely recyclable (Plaståtervinning i Wermland AB 2018).

NPA Plast uses recycled materials and makes products from recycled PE. They also try to make products using less water and energy consumption which results in less carbon dioxide emissions. One example of NPA Plast's products made of recycled plastic is their bags from the STRONG series (NPA Plast AB 2018).

Trioplast works to develop products that use more recycled materials. They produce a "climate smart carrier" (plastic bag) made of up to 80% recycled plastic. About 25% of 200 000 tonnes of plastic's raw material used in Trioplast factories is recycled plastic (Trioplast Industrier AB 2018).

Polyplank AB uses as raw material recycled thermoplastics (excluding PVC) and wood fibers. They make products such as noise barriers and balconies. Polyplank AB's ambition is to become the Nordic region's largest manufacturer of a material composite made of recycled thermoplastics and organic fibers (Polyplank AB 2018).

Flextrus owns AR Packaging AB which produces plastic packaging. AR Packaging AB is a leading company in the packaging sector in Europe. Their packaging products are meant to be used for healthcare and food. For their food packaging, the company focuses on high food safety and sustainability standards. The lightweight and flexible packaging produced is increasingly being produced from recycled material (Flextrus AR Packaging Group AB 2018).

Other companies like Plaståtervinning i Strömsbruk AB and IKEA are worth mentioning. Plaståtervinning i Strömsbruk AB receives hard plastic packaging from households, which is then transformed into cable protections, pipes and plastic sheets (Plaståtervinning i Strömsbruk AB 2018). As for IKEA, it claims to look for new ways to use recycled, recyclable and reused materials in their products. One of IKEA's products worth mentioning is the TOMAT bottle that is made from recycled plastic (IKEA Group 2017).

The next paragraphs in this section present a summary of the plastic producers responses from the conducted interviews.

Trioplast feedback took in consideration the whole group, including their factories outside Sweden. This company uses about 25 % in volume of recycled plastics, both post-consumer and pre-consumer, as secondary raw material. As for recycling of their own products, they are not certain about its final destination, since it is hard to follow their products as waste. At least 90 % of their products is fully recyclable and design for better recyclability is part of their strategy. They mainly use PE which is fully recyclable, although some products in which they laminate the PE film with other materials are non-recyclable. They incorporate the recycled material in their products by co-extrusion or as a mix with virgin material. The company argued that the supply of post-consumer recycled plastic packaging waste is very limited, adding that that they don't receive any from Sweden, it is all imported. When asked about the price difference of virgin and recycled plastic, the company answered that is was approximately 5:1, meaning that recycled plastic price on market is only about 20% of the virgin source. Although there is a major difference in price, the company still uses a low percentage of recycled plastics, since their customers often don't accept untraceable material sources and also the quality is often unpredictable. The company agreed on further creation of quality standards and certification schemes for plastic recyclers, claiming this is an absolute need, since it would increase the supply. The quality of the reived recycled plastic is done either by tests done using equipment available in their French facilities or incoming quality tests. The company actively works to increase the content of recycled plastics, both internally through sustainability strategies, like eco-design set goals and externally by communicating with customers. Their food plastic packaging products don't have any recycled

plastic content in its composition. As for future improvements in plastic products recyclability, the company says that it's necessary that secondary raw material's suppliers refine their materials to reduce the need of combining them with other primary raw materials for the final. In addition, not all products need the same high-quality demand to fulfil their function. Finally, the customer acceptance needs to increase, and the recycling processes should improve to allow better quality and traceability of the recycled material (Olofsson, 2018).

Flextrus uses post-consumer PET, flakes from recycled PET bottles, which represents 20 to 25% of their PET production. That recycled content is used in flexible packaging materials. They don't know exactly how much of their products are recycled once they become waste. The company is constantly looking for alternatives and tries to influence their costumers on choosing a sustainable material for their products. On the other hand, they argue that for a food packaging to efficiently protect its content, several layers of plastic are necessary and although less layers would improve recyclability, it could potentially decrease protection of food and increase food waste. The company claims that they don't use higher content of recycled PET, because the supply of food grade flakes, as in sufficient quality to be used as food packaging, is low. Hence, they are looking for solutions that allow using lower grade of post-consumer material. The company argues that recyclers should find ways to add more value into their materials, but also investments should be made into facilities and technologies that will enable usage of lower quality recycled materials like inline purification and drying stations. The company is currently involved in a national project that aims to build awareness on how to increase recyclability of plastic packaging. The quality of the received plastic waste is tested by the supplier, in this case Returpack. Since the supply of high quality is lower than the demand, the company is currently interested in improving their own facilities and production processes, that will make possible to use lower quality materials. This providing that then they improve themselves the quality during production. In the future, efforts should be done for better eco-design of products, but also to improve the entire value chain, by looking into what drives recycling and why some streams are more valuable than others. According to the company, currently the most valuable plastic material is PE (Persson, 2018).

Polyplank claims to use only recycled plastic in their plastic products. They also claim to recycle almost all of their plastic products, once it becomes waste. The company uses recycled HDPE and LDPE. Nevertheless, it claims that recycled plastic can have huge variations on its quality and possibly create problems during production. They don't assess the quality of the recycled materials as they expect their suppliers to do this. As for future improvements the company mainly thinks that improvements should be done in the packaging products, by not mixing different types of plastic in the same product, since this affects its recyclability (Aldentun, 2018).

6.8. Waste Management Company: Sysav

Sysav is a waste management company, responsible for managing waste from the southern west part of Skåne, which corresponds to 14 municipalities. It collects and treats waste from both households and industries. In 2017, Sysav received 841 400 tonnes of waste, about 175 900 tonnes was sorted waste collected at the recycling centres. About 97.2% of the sorted waste was recovered by material and energy recovery. Besides, 60% of the district heating in Malmö and Burlöv is supplied by Sysav's energy recovery plant. Also, the equivalent to 3.2 million litres of gasoline was produced in the form of biogas and about 145 300 sacks of plant soil, fertilizer obtained from composting was sold in that same year (Sysav 2018b).

Sysav has 15 recycling centres destined for private waste from households, there people can leave their waste, including hazardous waste. Apart from their recycling centres they own and manage 4 waste facilities (Spillepeng, St Olof/Måsalycke, Hedeskoga and Trelleborg). At these sites various operations take place, like composting, intermediate storage and reloading, as well as sorting and handling certain waste fractions, not including plastic. Trelleborg has an old landfill that is no longer used and at Spillepeng there is currently a landfill. An intermediate storage or reloading facility can also be found in Lund. They offer awareness campaigns that are available for public consultation in their website.

Sysav operates a bring system through their recycling centres that are situated in all of its municipalities. In 3 municipalities there is kerbside collection since 2017, it covers both apartment buildings and single-family houses. Sysav owns the vehicles for this collection. Private contractors are in charge for transporting the waste not fit for recycling to the incineration plant (Lindblad, 2018).

Sysav receives several types of plastic waste, plastic packaging is one of them. For plastic packaging waste there is a designated space in the recycling centre (Figure 25) that belongs to FTI. Thus, FTI then collects that plastic packaging waste, since they are the ones responsible for managing it. The plastic packaging fraction that ends up in the residual waste stream does not get sorted, it goes directly to incineration. Sysav also collects plastic bags, a from of plastic packaging, and since these are not allowed to go for energy recovery, they must be emptied by the citizens and placed in the plastic bag compressor for recycling (Figure 26). In addition to this, Sysav also receives rigid plastic (Figure 27) in two recycling centres. Rigid plastic does not have a market value though, since it is mainly composed of mixed plastics. It is very expensive to send these types of material for recycling and Sysav must pay the recycling companies to recycle such plastic waste. The collected plastic bags are sold to recycling companies and the plastic packaging waste collected for FTI is owned by them and thus Sysav does not get any further compensation for this, besides renting the place for FTI's containers in the recycling centres (Lindblad, 2018).

Figure 25 – Recycling containers that belong to FTI

Figure 26 – Plastic bag compressor on the left and organic compost on the right

Sysav does not make any extra sorting in addition to the one already done by the customers, they only collect and send the waste to the recyclers. The rigid plastic waste received by Sysav is sent to Swerec which then does the sorting and cleaning. Sysav also owns some waste transfer stations and collects waste for reuse (Lindblad, 2018).

Figure 27 – Rigid plastic waste

7. Portugal's Plastic Packaging Recycling

7.1. Production of Plastic Packaging

The producers and importers of plastic packaging must declare the plastic packages produced that are put in the national market. This information is transmitted to SPV that publishes it in their annual reports. In 2016, the amount of declared produced or imported plastic packaging was 195 902 tonnes (Table 10). Since 2012, the increasing trend of plastic packaging put on the market hasn't always been stable, with a minor decrease in 2013, followed by a constant increase until 2016.

Table 10 – Declared amounts of plastic packaging put on the market from 2012 to 2016 (SPV 2017)

Amounts declared to SPV	2012	2013	2014	2015	2016
Plastic packaging (t)	189 420	184 862	186 228	191 371	195 902

It was not possible to gather data from the Portuguese Statistics Institute as to the amounts of plastic packaging put on the market.

7.2. Actors Involved

The packaging waste integrated system in Portugal (SIGRE) was created to provide the legal obligations and check if such are being fulfilled for the recovery and recycling of packaging waste by recycling companies.

In 1997, SPV was made responsible for managing packaging waste, including plastic packaging (APA c) as states the extended producer responsibility defined in the Portuguese Decreto-Lei n.º 73/2011. This is a private not-for-profit organization that aims to promote sorted collection of waste, as well as its recycling at a national level. SPV manages both the urban and non-urban packaging waste flows.

Besides the producers of plastics, SPV must deal with the recyclers, the SGRUs and waste management operators and also hotels, restaurants and cafes (HORECA establishments). Waste management operators are economic operators responsible for sorted collection, transportation, storing, sorting and, or recycling of packaging waste that have contract with SPV for the non-urban waste flow. There are currently 24 plastic packaging waste recyclers with a valid contract with SPV. Furthermore, a SGRU is defined as an operator, in which municipalities hold share capital that collects and or sorts urban waste (SPV 2017).

For the plastic packaging waste from the urban waste flow, the most influential actors are the producers of plastics, SPV, the recyclers and the. Moreover, the SGRUs must deliver a guaranty about the destination of packaging waste to SPV.

The main SPV's shareholders are Embopar, that represents the packaging companies and importers, Dispar which represents commerce and distribution companies and Interfileiras, that represents companies that produce packaging and packaging materials (SPV 2017), Plastval is one of the packaging associates of Interfileiras and represents plastic packaging. Thus, it is the most relevant actor in terms of recycling plastic packaging, since it represents actors from the plastic packaging value chain, like raw material producers (Interfileiras 2018). Plastval covers almost entirely the plastic packaging value chain. However, since 2017 the organization acts as a consortium of companies and no longer represents producers of plastic packaging waste.

In 2016, Novo Verde was also licensed to manage packaging waste. Amb3e also obtained a license for managing packaging waste in 2017. Amb3e is currently managing three different waste streams: electrical equipment, batteries and packaging. These organizations as well as SPV shall be responsible for managing primary and secondary packaging, any packaging designed to group the same product, which may be purchased by the consumer individually or multiple quantities, and service packaging, packaging intended for the storage or transport of products to or by the consumer (SPV 2016b).

7.3. Regulations

In Portugal, Decreto-Lei nº 366-A/97, the transposition of the Directive 2004/12/EC first defined the principles and norms on packaging and packaging waste and it had its most recent alteration in Decreto-Lei nº 152-D/2017. The organizations responsible for plastic packaging such as SPV, Novo Verde and Amb3e have a license which defines responsibilities and can be found in Despacho nº 14202-E/2016, Despacho nº 14202-D/2016, and Despacho nº 6907/2017 respectively.

7.3.1. Plastic Packaging and Packaging Targets

The targets for each type of material recycling defined in the renewed license of SPV are the same as for 2011. Thus, the minimum target for plastic packaging recycling is still 22,5%, as it is also stated in the Decreto-Lei nº 92/2006. As for general recycling targets of packaging waste, also presented in Decreto-Lei nº 92/2006, a minimum of 55% and maximum of 80% were defined. Additionally, a more recent national target has been defined which says 70% in weight of packaging waste should be recycled (Ministério do Ambiente 2014). Besides these national targets, targets have been established for each SGRU regarding recycled amounts of packaging

waste with origin in sorted collection. These are defined in Despacho nº 3350/2015 (see appendix I, Table 24). Different SGRUs have different targets according to the installed capacity, thus a minimum and maximum target have been established.

7.4. Recycling Guidelines

In Portugal there are essentially four urban waste streams that are identified by different colours. The yellow stream, also known as lightweight packaging (see appendix II – definitions) waste stream (Rodrigues et al 2016) is mainly for plastic, metal and drinking cartons packaging. In this waste stream people should dispose of juice, detergent and water bottles, cooking oil bottles, plastic bags, butter packages, food and beverage's cans, dairy products' packages, as well as sphincter and aerosols packages. Non-packaging plastic waste should not follow this stream and the packages should be cleaned and compacted before being disposed of (SPV 2018).

The blue stream is destined for paper and cardboard packages, as well as journals, magazines, pamphlets, toilet paper rolls and paper bags. Waste like paper stickers or plasticised paper, handkerchiefs, napkins, toilet paper, diapers, cement bags and greasy paper should not follow into this stream. Before disposing this type of waste, it should be previously compacted, and efforts should be done in order not to wet or contaminate this waste (SPV 2018).

Finally, the green stream should receive only glass bottles and jars and not waste like lamps, mugs, plates and others. This waste should be cleaned in advance. Besides the mentioned streams it is also possible to sort batteries and electronic equipment, as well as tires, food oils and construction materials (SPV 2018).

7.5. Recycling System

7.5.1. Collection Systems for Plastic Packaging Waste

Since 1998, legislation towards an integrated system of packaging waste management has been created and since then SPV has been creating partnerships with municipal systems with the purpose of recovering packaging waste that is source-sorted, collected and treated by those. It was only in 2013 that SPV was able to cover the entire Portuguese territory and fulfilled to manage all the packaging waste produced in the country. (SPV 2017) The plastic packaging waste can come from: sorted collection, mechanical and mechanical and biological treatment units and the unsorted waste stream.

In Portugal there is essentially two types of collection for plastic packaging waste: kerbside collection and a bring system, also known as a drop-off system. The bring system is the most widespread and used system nowadays. In some municipalities both collection systems are present. Bring systems may include eco-centres owned by the municipalities or inter/multi-municipal systems eco-islands or eco-point (Figure 28). The eco-islands consist of bigger containers for the sorted and unsorted waste streams (Câmara Municipal de Lisboa). An eco-point is characterized by a set of containers of collective usage, usually placed above ground, although some can be underground, occupying less space (Lavita 2008). Eco-points are owned by the SGRUs.

Figure 28 - Eco-point, Ecoponto Santa Fé 2018

Figure 29 gives an overall picture of the evolution of the bring system (eco-points) since 2012. Thus, this kind of system has been increasing with the increasing installation of containers for that purpose. In 2016 there were 194 eco-centres (ERSAR 2017).

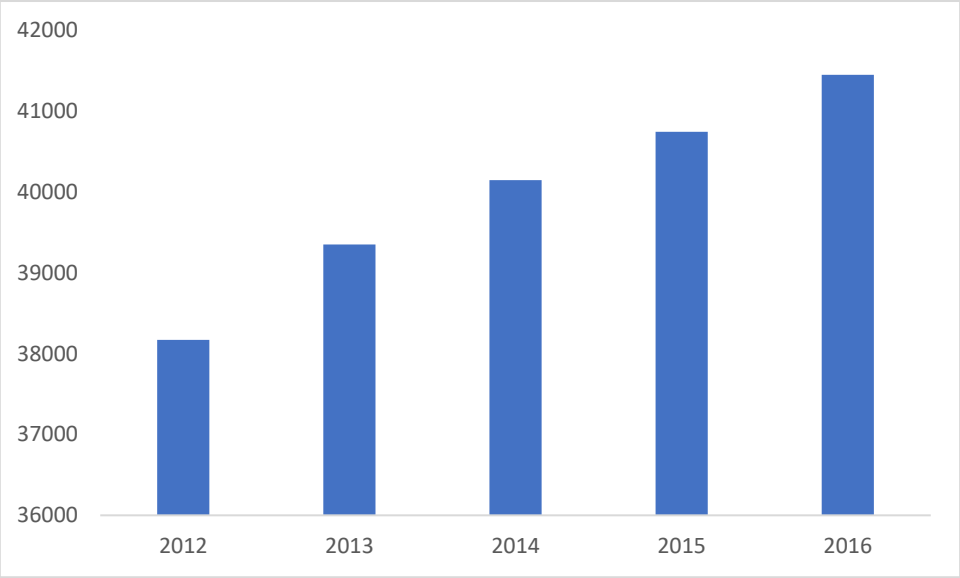


Figure 29 – Evolution of the number of eco-points between 2012 and 2016, ERSAR 2017

As for the kerbside collection, in apartment buildings usually, there is a 'waste house' in which there are coloured PE containers for the sorted and unsorted waste that have capacities between 120 and 800 litres. For smaller buildings, containers' capacities depend on the household's needs. There are also other options such as the usage of transparent bags for the sorted waste streams and black bags for the unsorted waste stream. In addition to this, one can opt for coloured ribbons in the waste bag that allow for identification of the type of waste stream. These last two types of deposition of waste are usually used in big buildings that do not have attached to it a 'waste house'. There is also a type of collection, called lateral collection, an automatic collection system that only requires one worker, the driver with the possibility of an extra worker that should collect waste that falls out of the vehicle, as the automatic collection takes place. Finally, there is also available a pneumatic system in Parque das Nações area which was built and installed by Envac, a Swedish company (Lavita 2008).

In Portugal, kerbside collection is characterized by surface emplacement containers in which waste bags are disposed of. The waste is then collected by a single compartment vehicle. The collection frequency for the yellow stream is usually once per week but it may depend on each SGRU (Norte, 2018).

7.5.2. Collected Amounts

In 2016, the amount of collected plastic and metal packaging waste (yellow stream) was about 92 640 tonnes (APA d). Since the amount of recycled plastic packaging was about 80% of the total amount of plastic and metal packaging (Norte, 2018) it is possible to roughly estimate the total amount of collected plastic packaging waste, resulting in 74 112 t, the equivalent of 7.56

kg/person. This collected amount does not include plastic packaging waste collected in the archipelagos which represent about 5% of the total population, according to the last population statistics from 2011, reported by the Portuguese Statistics National Institute (INE).

Nevertheless, it was possible to estimate the total of collected plastic packaging waste, including the archipelagos with a simple calculation. Hence about 78 013 t of plastic packaging waste were collected in total 2016.

The amount of plastic packaging waste collected in eco-points, about 52 576 t was also estimated by knowing that it corresponded to about 71% of total plastic packaging waste collected (APA d). The remaining was collected by door-to-door collection and special circuits (kerbside collection) and eco-centres. Hence, it is reasonable to estimate that 71% of plastic packaging waste is collected through a bring system. And even though eco-centres are part of the bring system, the amounts of plastic packaging waste received there should be very small, considering that these places are not mainly intended to receive that type of waste. Hence it was assumed that 29% of plastic packaging waste was collected by kerbside collection.

7.5.3. Sorting and Recycling Processes

Currently most of the municipal systems, in Portugal recover materials either from sorted collection or from the unsorted collection (see appendix II – definitions). The plastic packaging waste coming from the "yellow" waste stream is sorted from the remaining waste, like metal packaging and drinking cartons' packaging, in sorting facilities owned by SGRUs. The plastic packaging waste is further sorted into 5 categories, according to the technical specifications available for consultation in Despacho nº 21894-A/2009. The types of sorted plastic waste are: PET, HDPE, plastic films (LDPE and flexible HDPE), PS and mixed plastics. Some of the contaminants are removed, yet the SGRUs do not make the plastic waste go through any kind of washing process, this is only made by the recyclers (Norte, 2018).

In 2016, 11 SGRUs recovered sorted waste from the unsorted waste stream in mechanical and biological and mechanical Treatment Units. Nonetheless, until 2016 SPV was only responsible for managing plastic packaging waste coming from the sorted waste stream. Only recently in the renewed license of the organization the unsorted waste stream has been included as part of the recycled packaging waste (Norte, 2018).

7.5.4. Sorting Companies

In Portugal, sorting of plastic packaging waste is done by the SGRUs. These systems are responsible for then sending the sorted plastic waste to recycling companies that are presented in Section 7.7.

ValorSul is a waste management company, one of the SGRUs that owns two sorting facilities (Lumiar sorting facility and West sorting facility) where the three streams of sorted waste are sent for recycling. Furthermore, both ValorSul sorting facilities have eco-centres where people can drop off their recyclable waste.

The Lumiar sorting facility has a maximum annual capacity of 90 500 t and the West sorting facility a maximum capacity of 35 040 t/year. These capacities refer to total amounts of sorted waste. This facility has three sorting circuits, one for each sorted waste stream (ValorSul 2018b).

In 2016, ValorSul received 18 733 t of plastic and metal packaging and non-packaging waste (APA d). About 80% of that collected amount is only plastic (Norte, 2018), hence 14 984 t of plastic waste was collected by the company. The sorted amounts of plastic waste which were sold to recycling companies was about 9 967 t. These sorted amounts of plastic waste include non-packaging plastic waste (ValorSul 2018c). With these amounts it is possible to estimate that ValorSul sorts and consequently sells to recyclers about 66.5% of the incoming plastic waste, from sorted collection.

7.5.5. Sorting and Recycling Technologies

Currently there are 30 sorting facilities in Portugal, owned by the SGRUs. The technologies and equipment described and explained further ahead are the ones being used in one of the sorting facilities owned by ValorSul (Lumiar sorting facility).

ValorSul sorting facilities receive sorted waste that is collected from eco-points and kerbside collection, only from the Lisbon region. The sorting facilities receive sorted waste from the three waste streams already presented in Section 5.9, paper/cardboard (blue stream), glass (green stream) and plastic and metal packaging, plus drinking cartons, or simply packaging waste (yellow stream). The Lumiar sorting facility has capacity for sorting 19 500 t/year of waste from the yellow stream.

After collected, the waste is transported by vehicles that unload it in the sorting facility (Figure 30). Before unloading the vehicles are weighed, which happens before the vehicles enter the sorting facility and as they exit. This weighing process allows for quantifying the amount of sorted waste that is coming in and out of the facility.

Figure 30 – Unloading area of packaging waste/yellow stream, ValorSul 2018c

The facility has a packaging waste sorting capacity of 4.5 t/hour. The sorting processes require mechanical equipment, like a rotating sieve, bag opener, ballistic separator (Figure 31), optical sorters and an aspiration system.

Figure 31 – Ballistic separator, ValorSul 2018c

The sequence of processes, mostly in terms of equipment is: sieve, bag opener, ballistic separator, ferrous separator, optical separator, manual sorting, induction sorting and baling (Figure 32). Afterwards the sorted waste is sent to the recycling companies (ValorSul 2017).

Induction sorting is done by 'using a conveyor belt with a series of sensors underneath. These sensors locate different types of metal which are then separated by a system of fast air jets which are linked to the sensors' (Waste Sorting 2018).

Ballistic Separators separate 2-D materials, from 3-D materials, such as bottles, cans, etc. Capable of achieving a three-fraction split with one machine, ballistic separators achieve separation by feeding material onto a deck with a series of 4-12 paddles. Material is then separated by a "walking" motion. The flat 2-D materials, such as film plastics walk on top of the deck while the round, rolling fraction of 3-D materials, such as aluminum cans and plastic bottles, move to the bottom of the deck. The third fraction of material, which is made of fine residues, falls through the holes in the paddles (McLanahan 2018).

Figure 32 – Baling, ValorSul 2018c

From the sorting process, ValorSul sorts the following plastic waste: PET and HDPE, film and mixed plastic (ValorSul 2018c).

7.5.6. Recycling Rate

Portugal has shown a tendency for increasing the plastic packaging recycling rate since 2004. This behaviour has been quite stable, except for some years where instead of an increase there was a stabilization of the rate, like from 2005 to 2007 and from 2009 to 2011 (Figure 33).

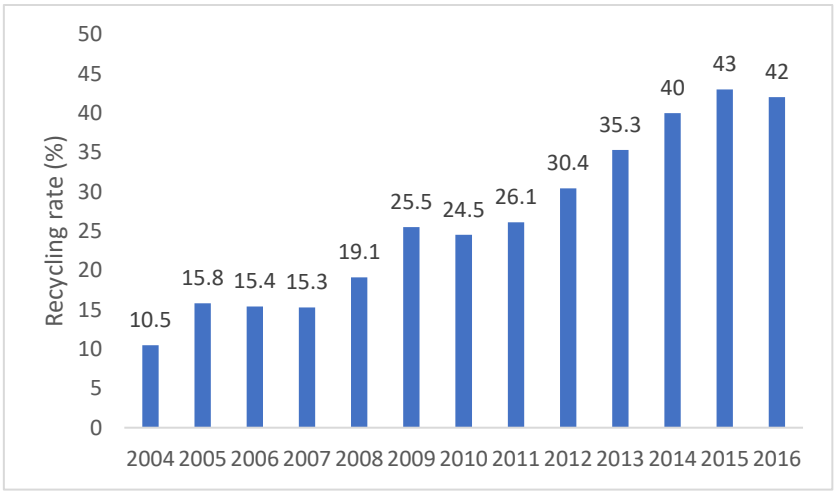


Figure 33 - Plastic packaging rate recycling rate evolution between 2004 and 2016 in Portugal, Eurostat a and APA 2017

In Portugal, the recycling rate of plastic packaging is calculated with the collected amounts sent for recycling divided by the produced amounts of plastic packaging. The collected amounts sent for recycling can refer to amounts that have gone through a sorting process, for plastic packaging this means that there is sorting of the different types of plastic before the plastic packaging waste

is sent to the recycling companies (Torres, 2018). The recycling rate of plastic packaging in 2016 was about 42% (APA 2017).

'The weight of recovered or recycled packaging waste shall be the input of packaging waste to an effective recovery or recycling process. If the output of a sorting plant is sent to effective recycling or recovery processes without significant losses, it is acceptable to consider this output to be the weight of recovered or recycled packaging waste' (Eurostat b). Hence, it is correct to consider the calculation of the plastic packaging recycling rate as mentioned above.

The recycled amounts shown in Table 11 correspond to collected amounts of waste reported by SPV and that are sent by the SGRUs to the recycling companies. The produced amounts refer to the amounts declared by the plastic packaging producers that are members of SPV. The resulting recycling rate reported by SPV is lower than the one reported previously as 42%. This is probably because the amounts that are being considered to obtain 42% refer to the entire country, which includes SPV and the remaining producers that are not a member of the organization.

Table 11 - Recycling rate of plastic packaging in 2016, SPV 2017

	Produced amounts (t)	Recycled amounts (t)	Recycling rate (%)
Plastic packaging	195 902	63 163	32

In 2016, about 34% of the total recycled amount of plastic packaging waste corresponded to LDPE and plastic films and mixed plastics corresponded to 42%. PET plastic waste was approximately 22% of the total recycled plastic waste and the remaining 1.3% corresponded to other types of plastic like PS.

7.6. Costs and Financial Instruments

Each producer of plastic that has transferred its responsibilities to SPV must pay a fee per unit of weight of packaging material put into the national market, this fee is commonly known as ecovalue (Table 12). Ecovlaues are divided into packages of high consumption products, industrial products and hazardous products. Since the focus of this work is household plastic packaging waste, emphasis will be given on high consumption products (SPV 2017).

Table 12 – Ecovalue for plastic packaging in 2016 and 2017, SPV 2017 and SPV 2016a

Type of packaging	Material	Year	Primary Packaging (€/Kg)	Plastic Carrier Bags (€/Kg)	Multipacks (€/Kg)
	Plastic	2016	0,2008	0,2008	0,1004

High Consumption Products		2017	0,2281	0,2281	0,1121

On Table 12 multipacks refer to plastic packaging that are used to hold together other products like metal cans or carton packages. Primary packaging means any packaging designed to constitute a unit of sale to the end user or consumer (SPV 2016b).

According to Despacho nº 8376-C/2015 the financial compensation values are compensations given by SPV, Novo Verde and Amb3e that vary according to the amounts of collected sorted waste, in weight from the urban waste stream, which production is not higher than 1100 litres. This waste is collected through the network of eco-points, eco-centres and door-to-door collection and must fulfil technical specifications, as well as be sent for recycling to specific recyclers. On the other hand, there are also compensation values for the unsorted collected waste. These are meant to cover costs related to mechanical and biological treatment and mechanical treatment (see appendix II – definitions), as well as sorting of packaging waste from that waste stream, composting and incineration.

The "retake" value is the value that SPV receives by selling packaging waste to the recyclers. This value is only applied for waste that is sent to recycling and that fulfils the technical specifications imposed by SPV that allow its acceptance as waste for recycling. Sometimes this value may be negative when SPV must pay to the recyclers instead, so that they recycle that waste (SPV 2017).

The counterpart value corresponds to the financial compensation that SPV gives to the SGRUs that should cover costs related to the collection of sorted waste. This value is defined by the ministry of economy and the ministry of environment. The value is attributed according to the amounts of collected sorted waste, which results in an incentive for recycling. Thus, the more the SGRUs collect sorted waste, including plastic packaging waste the more of such waste will be sent to recycling. The calculation method to obtain each value for each SGRU can be consulted in Despacho nº 14202-C/2016 (SPV 2017).

Finally, there is still the complementary information value which is voluntarily paid by SPV to the SGRUs as a compensation and incentive for the amounts of plastic packaging waste that has its source in complementary streams. Other streams besides the sorted collection can be for instance the mechanical and biological treatment (MBT) units (Table 13).

Table 13 – Complementary information value correspondent to the plastic waste from mechanical and biological treatment units in 2016, SPV 2017

Type of plastic packaging waste	Complementary information value from MBT (€/Kg)
Film	275

HDPE	275
PET	180
Mixed Plastics	220

7.7. Plastic packaging market

The recyclers and some of the plastic packaging producers using recycled plastic as a raw material that are presented in this topic are mainly the recyclers of plastic packaging waste in SPV 2017.

In 2016, in terms of the recycled quantities of mixed plastics, Extruplás has received a total of 18 590 tonnes of waste, about 75% of the total mixed plastic waste, followed by Ligeplás that received about 25% of the mixed plastic waste. Sirplaste was the recycler to accept the higher amounts of PEAD and plastic films, followed by Micronipol (Figure 34).

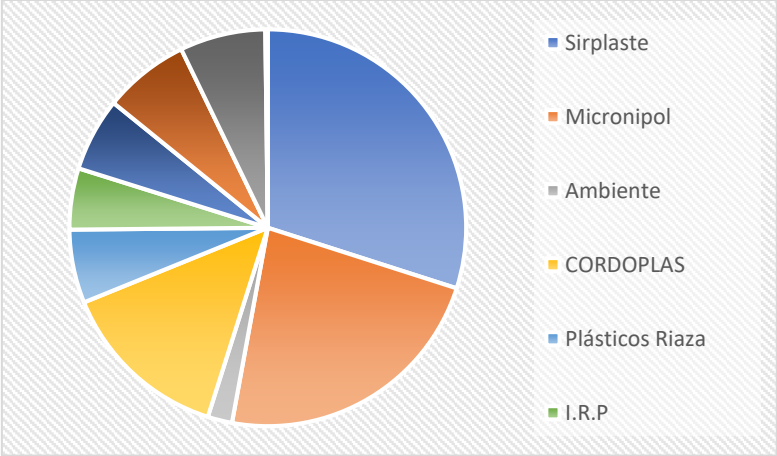


Figure 34 - Recycled PEAD and plastic film in 2016 distributed by each recycler, SPV 2017

As far as PET plastic waste is concerned, about 98% was recycled by the companies Evertis and Ecoibéria (Figure 35).

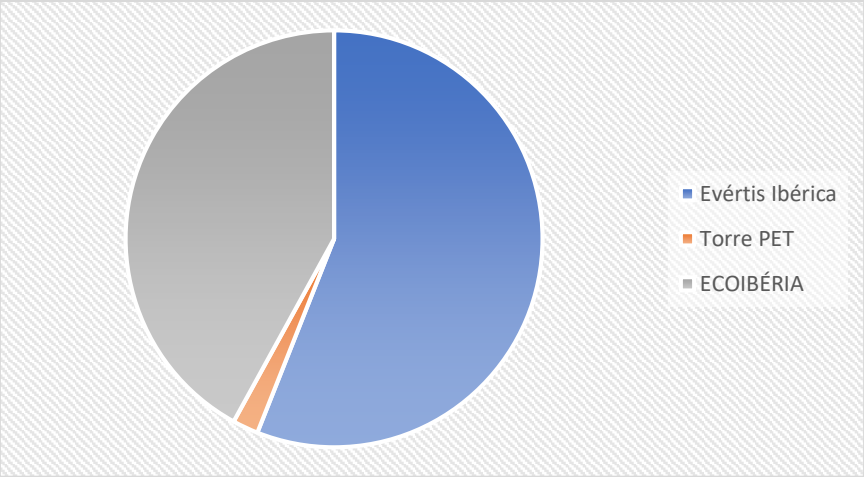


Figure 35 - Recycled PET in 2016 distributed by each recycler, SPV 2017

Recycled PS plastic waste was about 260 tonnes in total and was mainly recyled by the three companies from Figure 36, in which EPS20 FISHER recycled most of the total amount.

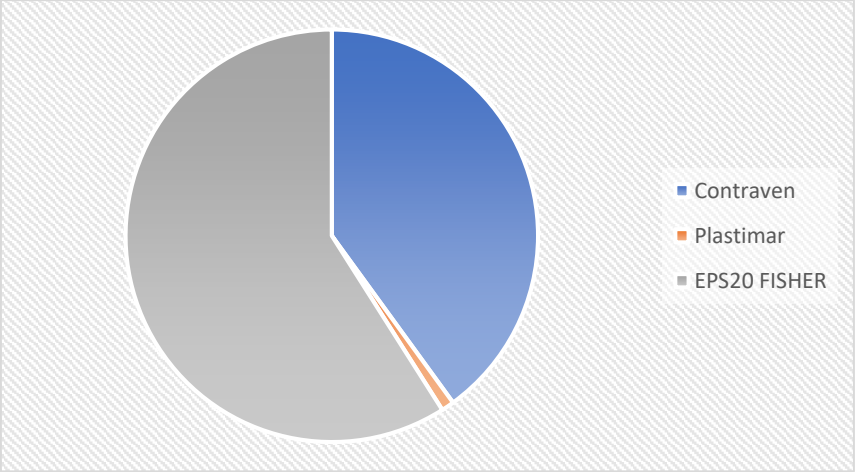


Figure 36 – Recycled PS in 2016 distributed by each recycler, SPV 2017

Extruplás is a company that has been established in 2000 which collects and recycles mixed plastic waste. It has two facilities in Seixal (headquarters) and Maia. From the mixed plastic stream, the company can manufacture products like tables and stools for garden, walkways and paving, sun loungers and parasols and structures like bridges (Extruplás 2018).

Sirplaste was established in 1974. This company receives waste plastic that undergoes inspection, sorting, crushing and washing, so it can then be extruded into granulates. The end product is then sold to their clients. Their products include plastic as second raw material such as LDPE, MDPE (medium-density polyethylene), HDPE and PP. They have an annual production of about 35 000 tonnes. (Sirplaste).

Micronipol recycles plastic packaging waste and was also been established in 2000. This company manufactures PE and PP from plastic packaging waste (Micronipol 2018).

Evertis is owned by the IMG Group, which is involved in the polymers industry since 1959. Evertis produces mono and multilayers semi rigid barrier films for food packaging and other packaging applications. They develop mainly PET packaging products. This company owns a recycling unit, where plastic packaging is recycled and converted into PET flakes that is then incorporated into Evertis produced packaging film (Evertis 2018).

Torrepet was founded in 2005 and has representatives in Spain and other european countries. This company performs bottle-to-bottle recycling of PET bottles. They do this by recycling the PET-PCR resin which is restored and used as a secondary raw material. They either sell the secondary raw material to the plastic industry or transform it into other PET bottles (Torrepet 2018).

Recipolymers SA is owned by Ambigroup SGPS SA and recycles plastic waste which then reintroduces into the plastic industry as secondary raw material. It holds one facility which processes plastics like ABS (Acrylonitrile butadiene styrene), PS, PP, PVC (Polyvinyl chloride), HDPE and another that recycles PE through an extrusion process (Recipolymers Reciclagem de Polímeros S.A.).

Logoplaste is an industrial that was founded in 1976. It manufactures rigid plastic packaging for plastic consuming companies, their products are manufactured to store food and beverage, personal care, household care and oil and lubricants. The company has 50 factories spread all over the world, including Portugal, where its headquarters are located. The company has made a commitment that involves 7 principles, some of them are reuse, promote the use of renewable resources, reduce the weight of their products and promote the use of recycled material, like HDPE and PET (Logoplaste 2018).

The next paragraphs in this section present a summary of the plastic producers responses from the conducted interviews.

Logoplaste manufactures plastic products using recycled plastic, some of them are produced exclusively from recycled plastic. When asked about improvements in the recyclability of their products, the company answered that design is essential, but the most important aspect is combine using as little plastic as possible with using materials that are fully recyclable. The company uses recycled PET and in their English facilities they also use recycled LDPE. According to the company, PET has the biggest supply amongst recycled plastics. PET can be used to produce primary packaging and fibres for textile applications, for instance. The company produces food grade plastic packaging using recycled PET and LDPE. Regarding the price of recycled plastic, this has continuously varied, usually following the same pattern as other recycled materials, states the company. When the supply is lower, the price is naturally higher, hence when supply increases the price is closer to the virgin plastic price. They added that in the case of recycled PET, it often has the same characteristics as the virgin material, apart from the colour.

The company believes that there is no need for significant reviews of quality standards and certificates for the recycling companies, instead action should be taken to improve collection, sorting and the supervision of such activities. The company keeps contact with recycling companies, only by sending their waste for recycling to those companies. They also claim that the encouragement for better strategies for collection and sorting of plastic packaging waste is always a part of their projects, though the final decision is not up to them. Finally, according to Logoplaste recyclability could be improved by educating consumers on a better source sorting of plastic waste, as well as compel waste management entities to ensure a proper collection of plastic waste. Additionally, since most plastic packaging is 100% recyclable, the problem is that the quantity and quality available from the recycling companies is not enough. Hence, instruments like creating incentives for correct sorting could be made, as well as oblige companies to use a certain content of recycled plastic in their plastic products (Machado, 2018).

Other companies like Gepack, Tutiplast and KLC were successfully contacted. Nevertheless, these companies claimed they didn't use any recycled content in their plastic products. When asked why that is, several reasons were presented. Those reasons were: the customer or plastic consuming company doesn't demand it; they can't use it for food grade plastic packaging products, due to food safety; lack of proper equipment or technology that allows combination of secondary and primary raw material; the quality requirements are not met by recycled materials, since they cause instabilities in the new manufactured product's properties.

7.8. Waste Management Company: ValorSul

ValorSul is a multi-municipal system responsible for the treatment and recovery of waste in 19 municipalities of the Great Lisbon and West Region. In 2016, ValorSul received about 935 394 t of waste, 73 888 t were sorted waste, 40 872 t were organic waste and the remaining was unsorted waste. In 2016, in the case of organic recovery, 1.1 t of compost were produced, and biogas production allowed for the production of 10.9 MWh. As for energy recovery from incineration 288,4 GWh were obtained (ValorSul 2017).

Table 14 shows the current ValorSul facilities for waste management. The eco-centres can receive both the plastic packaging waste, from the yellow stream and rigid/bulky plastic waste.

Table 14 – ValorSul waste management facilities, ValorSul 2017

Type of Facility	Number of facilities
Sorting	2
Energy recovery	1
Organic treatment and recovery	1
Treatment and recovery of rejects	1
Landfill	2
Transfer station	6
Eco-centres	8

The collection of the sorted waste is mostly done by the company, except for 5 municipalities that do this collection themselves. All municipalities are responsible for collecting their unsorted waste, ValorSul only collects sorted waste. Currently only 3 municipalities have kerbside collection for domestic sorted waste and other two municipalities have this kind of collection but only for business waste, which may include only the yellow or blue stream. The plastic packaging waste (included in the yellow stream) is usually collected once to twice a week in the case of kerbside collection. The collection frequency from bring systems and eco-points, depends on the vehicle's circuit and type of material waste. All municipalities are covered with eco-points. The packaging materials collected are sent to ValorSul sorting facilities. Once the packaging waste arrives to the sorting facilities, it is first separated from contaminants. After that, the waste is separated according to each type of material and sent to the recycling companies. To separate plastic types optical sorting is used. ValorSul currently does no extra sorting of the unsorted waste stream. Thus, the mechanical treatment and mechanical and biological treatment do not contribute to higher amounts of plastic packaging waste (Torres, 2018).

About 20% of the collected packaging waste in weight are contaminants. This fraction is either sent to incineration or landfill. The remaining collected packaging waste is sent for recycling. Furthermore, the non-plastic packaging waste that appears in the collected packaging waste stream is also sent for recycling (Torres, 2018).

8. Comparison between Waste Management and Plastic Packaging Recycling Systems

8.1. Waste Management System

8.1.1. Waste Quantities

Sweden and Portugal have similar numbers of population,10 million and 10.3 million people, respectively, as mentioned in previous chapters. Also, in 2016 Sweden produced the equivalent to 467 kg/person and Portugal produced 474 kg/person. Thus, the similar amounts of waste produced per capita should allow for a reasonable comparison of both countries' waste management systems.

8.1.2. Waste Treatment

As shown in Table 15 and mentioned in previous chapters, Portugal sent only 10% of its waste to material recycling and Sweden sent about 34.6%. Since the waste quantities produced per capita were relatively similar, it is possible to say that Sweden sent three times more of its waste to material recycling than Portugal. When comparison is done on the total amount of both landfill and energy recovery fractions, it is possible to estimate 74% for Portugal and 49.2% for Sweden. Thus, the main cause for such differences is that Portugal sent most of its waste to the least preferable level of the EU's Waste Hierarchy, landfill which accounted for 51%. On the other hand, Sweden sent almost half of its waste to energy recovery.

Table 15 – Proportion of municipal waste going to material recycling, energy recovery and landfill in Portugal and Sweden, in 2016, ERSAR 2017; Avfall Sverige 2017a

Unit Operation	Portugal	Sweden
Material recycling	10%	34.6%
Energy recovery	23%	48.5%
Landfill	51%	0.7%

Moreover, Sweden currently has more waste fractions for the same type of material waste compared to Portugal. According to the recycling guidelines presented in previous sections (4.9. and 5.9.) waste materials like plastic, paper, metal and glass have 5 waste streams in Sweden and 3 waste streams in Portugal. Paper in Sweden is divided into a paper packaging stream and a return paper waste stream (writing paper, magazines and newspapers). In Portugal there is the 'blue' bin which combines both those streams into one. Metal and plastic are part of the same stream, the 'yellow' stream and glass is referred as the 'green' stream. Whereas in Sweden plastic

and metal packaging are in separate streams. The higher amounts of waste fractions can possibly reduce costs and efforts for further sorting after collection. On the other hand, it may also mean to more than required one sorting facility for the different type of material waste received increasing costs.

Portugal has unit operations like mechanical and mechanical and biological treatment, mainly since unsorted waste goes to sorting facilities after the collection process, where separation of recyclable waste and inorganic waste takes place. In Sweden, the residual waste mainly goes to energy recovery (Myrin, 2018), hence there is no mention to mechanical and mechanical and biological treatment units.

8.1.3. Financial Instruments

The landfill taxes of both countries are shown in Table 16, it shows that the Swedish landfill tax is currently much higher than the Portuguese one. In addition to this, Sweden has implemented two landfill bans on both combustible and organic waste. Therefore, the lower tax for landfilling waste and absence of a landfill ban in Portugal contributes greatly for such a high rate of landfilling. This means that Sweden is making more efforts to divert waste from landfill, hence contributing for focus on higher levels of the EU's Waste Hierarchy.

Table 16 – Taxes on Landfill and Incineration in 2018, Lei nº 82-D/2014; Avfall Sverige 2017a

Tax (€/tonne)	Portugal	Sweden
Landfill	8.8	50
Incineration	6.6	-

Nowadays, Sweden has no tax on household waste incineration. As for Portugal the incineration tax is 6.6 €/tonne and 2.2 €/tonne, if there is energy recovery.

In Sweden, about 15.9 TWh out of 18.1 TWh of energy produced from waste was used in district heating systems and in published data from 2016 (Avfall Sverige 2017a). Furthermore, the share of final energy consumption in the residential sector in space heating was about 21.1% for Portugal and 55.3% for Sweden (Eurostat c). In Sweden heating is in fact the main use of energy produced in incineration plants that receive household waste (Avfall Sverige 2017a). In addition to this, Sweden had at least 35 incineration plants receiving household waste in 2016 and Portugal had only 3.

8.1.4. Organization of actors involved

Municipalities' role is the management of residual waste, including collection and treatment, both in Portugal and Sweden. Both countries' waste management systems are mainly organized into either municipal self-administration, municipal associations or municipal enterprises. Nonetheless,

in Sweden, about 48% of municipalities have chosen to manage their waste by municipal self-administration and in Portugal only 2 municipalities have chosen to do so, according to Section 5.4.

In Sweden, FTI is responsible for managing packaging waste that is covered by the producer responsibility. However, in Portugal, the collection and treatment of waste that falls under that regulation is still widely covered by the waste management systems, although under supervision of SPV. This will be further explained in Section 9.2.2. Hence, the waste management systems Sysav and ValorSul in Section 7.7 and 8.7 have different roles regarding packaging waste management.

8.1.5 Legal Framework and Targets

Both countries have transposed the waste framework (Directive 2008/98/EC) into their national regulations.

Targets defined by the EU must be accomplished by both countries and thus are the same for Portugal and Sweden. The most relevant targets defined by the EU, in this case are for landfill and recycling and they state the following: 'By 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight' and 'No later than 15 years after the date laid down in Article 18(1), biodegradable municipal waste going to landfills must be reduced to 35% of the total amount (by weight) of biodegradable municipal waste produces in 1995' (Directive 2008/98/EC; Directive 1999/31/EC).

However, the target concerning reduction of biodegradable waste going to landfill had different deadlines for each country. Sweden had to fulfil the target by 2016 and Portugal only by 2020. Currently both countries have fulfilled the target. Portugal has exceeded the target by 6 percent point, 41% in total (APA 2016) and Sweden has succeeded, by implementing the landfill ban on biodegradable waste and hence landfilling less than 1% of its waste.

As for the 2020 target on preparation for re-use and recycling, Sweden has already achieved the target, since its recycling rate on municipal waste in 2016 was 50.8%[1] (Waste Sweden Report, 2017). Portugal hadn't reached the target on 2016, since it had an equivalent recycling rate of 38% (APA 2016).

[1] Material recycling plus biological treatment

8.1.6. Costs

The published costs of waste management systems presented in Sections 4.8 and 5.8 could not be compared and further analysed, since for Sweden these costs refer to food and residual waste and for Portugal the costs include packaging waste management in addition to residual waste.

A PAYT system could help improve recycling rates by charging a tax on the amount of produced residual waste, since it implies that the more a household properly sorts its waste, the less recyclable waste will end up in the residual fraction. Efforts for implementing a PAYT system are more evident in Sweden, since 30 municipalities have implemented a weight-based charge. In Portugal, there is only one municipality that has implemented this kind of system. Nonetheless, both countries still show little interest in implementing this kind of system, considering that only 10% of Swedish municipalities have a weight-based waste charge.

In addition to this, in Portugal, the variable tariff for waste management payed by households is mostly based on the amount of consumed water. Thus, the tax does not depend on the amount of produced unsorted waste, which does not contribute to better source sorting. The substitution of this kind of tariff for a charge based on amount of residual waste produced could possibly improve the national recycling rate.

8.2. Plastic Packaging Recycling System

8.2.1. Plastic Packaging Collection

Table 17 shows the national total amounts of collected plastic packaging waste (including PET bottles) in Portugal and Sweden in 2016. It shows that Sweden had higher collected amounts of plastic packaging waste. It should be taken into account that Sweden also had higher produced amounts of plastic packaging.

Table 17 – Total collected amounts of plastic packaging waste in 2016, in Portugal and Sweden; estimate based on APA d; Naturvårdsverket 2018

Country	Collected amounts of plastic packaging, including PET bottles (t)
Portugal	78 013[2]
Sweden	121 000

Table 17 shows the different amounts of collected plastic packaging waste of both countries. The analysis of such amounts, makes it possible to say that the deposit return system in Sweden could be one of the factors contributing to higher collected amounts, about 21 300 t (Table 6, section 6.4.2) that corresponded to 17% of the total collected plastic packaging waste.

In both countries, Portugal and Sweden, all municipalities have a bring system. In Portugal, this system includes eco-centres and eco-points and in Sweden it includes recycling centres and recycling stations.

Eco-centres, in Portugal are very similar to the recycling centres, in Sweden, since both are owned by waste management companies and are usually destined for collecting bulky waste and other fractions that are not possible to deliver in eco-points or recycling stations. Nevertheless, these infrastructures won't be considered in the analysis since they are not mainly intended for collection of plastic packaging waste.

Both eco-points and recycling stations (Table 18) are intended for delivering sorted waste, including plastic packaging waste.

[2] This is total amount of plastic packaging waste collected, including the archipelagos, which means it includes the 5% that was missing before. It was obtained based on estimates of plastic packaging waste produced per person.

Table 18 – Number of Drop-off points (eco-points and recycling stations) and collected amounts of plastic packaging waste in Portugal and Sweden, ERSAR 2017; APA 2016; FTI AB 2018c

Country	Type of drop-off point (bring system)	Number of drop-off points	Collected amounts (t)
Portugal	Eco-point	41 449	52 620
Sweden	Recycling station	5 000	46 712[3]

Sections 6.4.2 and 7.4.2 present rough estimates of collected amounts from kerbside collection and from bring systems in both countries, which are shown in Table 19.

Table 19 – Collected amounts of plastic packaging waste and the distribution between a bring system and kerbside collection in both countries; APA 2016; FTI AB 2018d; Ström (2018)

Country	Collected amounts (t)	Bring system (%)	Kerbside collection (%)
Portugal	74 112[4]	71[5]	29[6]
Sweden	71 865[7]	65	35

Kerbside collection leads to higher amounts of recyclables collected per capita per day, when compared to an exclusively bring systems and mixed system (both kerbside and bring system). This shows that the more the investments in kerbside collection, the higher the collected amounts. "Higher material separation rates, higher recycling rates, and lower contamination rates" are obtained by using a mixed system, when compared with exclusive bring system which is mainly attributed to the its combination with kerbside collection (Martinho et al, 2017). Thus, the fact that Sweden has slightly higher amounts of collected plastic packaging waste through kerbside collection (Table 19) could be another factor contributing to consequently higher amounts of collected plastic packaging waste, even though this could be of minor difference, given the close collected amounts.

Furthermore, studies done for Norden (Nordic co-operation that includes Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland and the Åland Islands) have demonstrated that plastic packaging waste that is collected by kerbside collection systems rather than bring systems results in a more efficient collection, since it leads to higher plastic packaging

[3] This amount only refers to FTI's collected amounts in its recycling stations
[4] This accounts for collected amounts of 95% of total households in Portugal, assuming 80% plastic waste.
[5] This amount is an estimate obtained by summing collected amounts in eco-points.
[6] This amount was obtained by summing the amounts of sorted collection, that includes special circuits, recycling centres, eco-points and door-to-door collection and accounts for 95% of total households in Portugal. It was also assumed that 80% was plastic waste.
[7] This amount only refers to FTI's collected amounts which corresponds to 72% of total plastic packaging waste, excluding PET bottles collected in Sweden.

waste collection rates. This could be possibly explained by the lesser people's willingness and availability to travel to the public drop-off points to discard of their waste (Fråne 2015).

In addition to this, the frequency of collection could eventually play a major role in the comparison and analysis between both countries. However, this was not possible to do at a national level, since it varies from municipality to municipality and even from household to household in the case of property close collection. It would be more relevant to study this at a regional level.

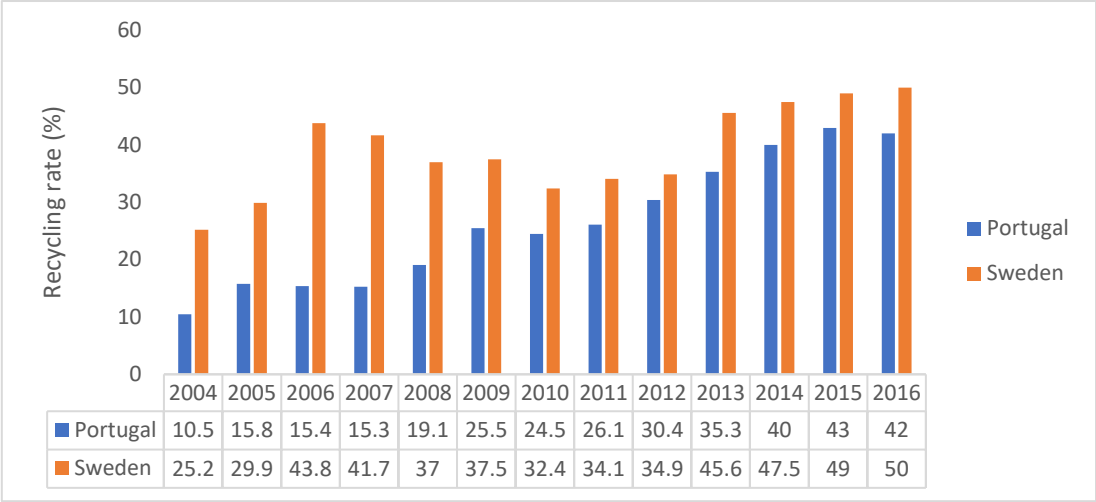
8.2.2. Plastic Packaging Recycling

8.2.2.1. Recycling Rates

Sections 7.4.7 and 8.4.7 show the recycling rates of plastic packaging waste. Sweden had a recycling rate of 50% and Portugal had a recycling rate of 42%. This difference in the recycling rates simply means that Sweden is collecting more plastic packaging waste that is to be sent for recycling than Portugal, because of the way this recycling rate is calculated. Unfortunately, the current recycling rate calculation method does not allow for comparison between sorted and produced amounts.

In the case of Sweden, the plastic packaging recycling rate is the combination of an open-loop recycling (see appendix II – definitions) system for plastic packaging, excluding PET bottles (47%) and a closed-loop recycling (see appendix II – definitions) system, exclusively for PET bottles (82%). Hence the deposit return system is contributing to an increase of 3 percentage point of the plastic packaging rate. This allows to conclude that a 3-percentage point difference between the Portuguese and Swedish plastic packaging recycling rate can be attributed to the fact that Portugal currently doesn't have a deposit return system.

The plastic packaging recycling rate has evolved differently in Portugal and Sweden. Portugal has had a steady increase and Sweden has had a very unstable evolution of the recycling rate as shown in Figure 37. Although Portugal had a much lower recycling rate in 2004 comparing to Sweden, in 2016 Portugal is much closer to the Swedish recycling rate. Hence, it is possible to conclude that in Portugal the efforts for increasing the plastic packaging recycling rate are more evident. The unstable evolution of the plastic packaging recycling rate in Sweden could have been possibly caused by choosing energy recovery over recycling during some years, but this is not clear and solid conclusions cannot be made for this. Especially if we consider that Sweden temporarily had an incineration tax on household waste from 2006 to 2010, the same period when there was a sudden decrease of the plastic packaging recycling rate.



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Portugal	10.5	15.8	15.4	15.3	19.1	25.5	24.5	26.1	30.4	35.3	40	43	42
Sweden	25.2	29.9	43.8	41.7	37	37.5	32.4	34.1	34.9	45.6	47.5	49	50

Figure 37 – Plastic Packaging Recycling Rate Evolution from 2004 to 2016 in Portugal and Sweden, Eurostat a; Naturvårdsverket (2018); ERSAR 2017

Results of plastic packaging recycling rates of both countries in 2016 were obtained from national statistics; the remaining was found in the Eurostat database.

8.2.2.2. Recycling Targets

Previously, in Sections 7.3.1 and 8.3.1 the recycling targets of packaging waste and plastic packaging waste of both countries are presented, as well as, where they can be found in national legislation. Table 20 shows whether the national targets had been fulfilled in 2016. The rates in green mean that the target has already been accomplished and rates in red mean they haven't yet been accomplished. Analysing Table 7 it is possible to say that in 2016, Sweden hadn't fulfilled the ambitious 90% PET bottles recycling target and Portugal hadn't fulfilled the most recent national minimum packaging waste recycling target of 70%. Nevertheless, both countries can potentially still reach those targets by 2020, since both are already close to the targets.

As for the plastic packaging recycling target, Portugal hasn't renewed its target since 2011 which could be negative, even considering that the 2011 target was already reached in 2009. In fact, Portugal hasn't established any recycling targets for any material waste for 2020, since 2011. This could eventually be interpreted as a lack of interest or effort in increasing the plastic packaging recycling rate.

As stated in Section 7.3.1 Sweden has already established a plastic packaging recycling target for 2020, of 30% and for 2030, of 50%. This fact shows that there might be more concerns in Sweden for recycling this type of waste than in Portugal. Nevertheless, the recent strategy published by the EU on plastics (European Commission 2018) will lead to new measures and targets that will motivate further improvements in plastic packaging recycling for both countries, including a 2030 plastic packaging recycling target for Portugal as well.

Table 20 – Recycling targets for 2020 and recycling rates of packaging waste and plastic packaging waste in 2016 in Portugal and Sweden; Ministério do Ambiente 2014; EUROPEN; SFS 2014/1073; Naturvårdsverket 2018; ERSAR 2017

<table>
<tr><th colspan="2"></th><th>Portugal</th><th colspan="2">Sweden</th></tr>
<tr><td rowspan="2">Packaging Waste</td><td>Recycling Target</td><td>Until 2020:
More recent minimum target of 70%</td><td colspan="2">Until 2020:
Minimum target of 55%</td></tr>
<tr><td>Recycling Rate in 2016</td><td>62%</td><td colspan="2">69%</td></tr>
<tr><td rowspan="4">Plastic Packaging Waste</td><td rowspan="2">Recycling Target</td><td rowspan="2">Until 2011:
Minimum target 22,5%</td><td>Excluding PET bottles</td><td>Until 2020:
Minimum target of 30%</td></tr>
<tr><td>PET bottles</td><td>Until 2020:
Minimum target of 90%</td></tr>
<tr><td rowspan="2">Recycling Rate in 2016</td><td rowspan="2">42%</td><td>Excluding PET bottles</td><td>47%</td></tr>
<tr><td>PET bottles</td><td>82%</td></tr>
</table>

8.2.2.3. Actors Roles and Interactions

The main actor within the management of packaging waste, including plastic packaging is the producer responsibility organization (PRO). This organization is owned by the producers, that rely on PROs for the waste management of their packaging waste. The PRO has the most significant influence on the other actors, as shown in Figure 38. However, the level of influence is likely to differ from country to country, as it happens for Portugal and Sweden.

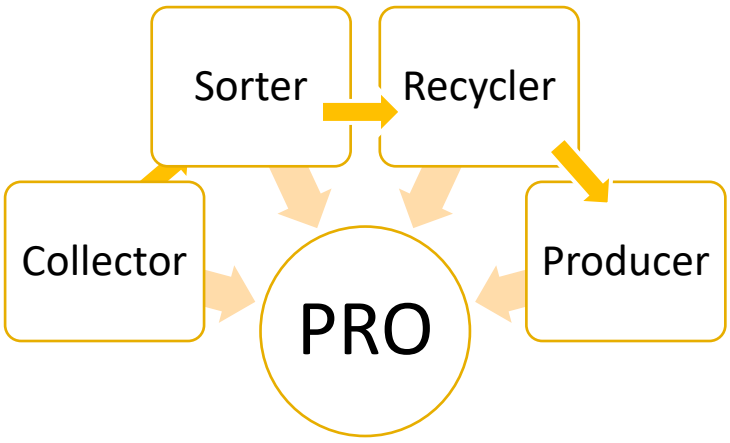


Figure 38 – Connections between the main actors involved in the plastic packaging recycling value chain

Table 21 shows an overview of who the actors part of the plastic waste recycling value chain are in each country, as well as their roles. The actors that were studied and presented in the plastic packaging recycling value chain (Figure 1, Section 1.1) do not include the consumer and the plastic packaging consuming company. In addition, in this study recyclers were considered as the companies that transform the sorted plastic waste into a secondary raw material and the producers' feedback are mostly from those that use recycled plastic as a raw material.

In the case of Portugal, SPV mostly has an indirect influence on the other actors and even though it can interact directly with them, it will mainly receive reported amounts by the actors involved. SPV's influence is more noticeable in the interaction with the SGRUs, which are responsible for the collection and sorting of plastic packaging waste. This is so, because SPV conducts inspections and based on these, it can confirm if the reported amounts are accurate. This also applies for FTI and the sorting facilities in Sweden. SPV also manages the financial costs of the entire plastic packaging recycling system. Thus, it manages the selling of the sorted plastic waste from sorters to recyclers and by that SPV can know the amounts of sorted plastic waste that are sold to the recycling industry. As for the producers, just like it happens in Sweden, the produced amounts are reported to the PRO and a fee is paid according to the amount of produced plastic packaging. This is used to support the costs of managing that waste, since the sorted plastic sales are not enough.

SPV has no direct influence or control over the collection of plastic packaging waste, contrarily to FTI, that hires the private collectors and decides on where the unloading of the vehicles takes place. In Portugal, this is controlled by the SGRUs that own the vehicles themselves. Nonetheless, sometimes this collection is done by the municipalities, although the SGRUs in Portugal and FTI in Sweden are the main responsible actors for that. Regardless of who does the collection, the plastic packaging waste must always be then returned to the SGRUs or the FTI. In Sweden, there's even the example of Sysav, a waste management company owned by municipalities that has an agreement with FTI, which collects plastic packaging waste in one of its recycling centres but must return it to FTI. Additionally, in Portugal there is also the case of the waste management company ValorSul, in which 5 out of the 19 municipalities collect their packaging waste.

In Sweden, the sorting of plastic packaging is done by private companies like the ones mentioned in Table 21, and in Portugal this is done by the SGRUs that are usually private-public or public companies. This contributes to the fact that Portugal has about 30 sorting facilities and Sweden only two (Swerec and Cleanaway PET Svenska). In Sweden, all sorting facilities make some transformation of the sorted plastic waste into a secondary raw material, even though Swerec mainly does this for HDPE, by transforming it into flakes. In Portugal, the SGRUs don't do any kind of transformation of the sorted plastic waste, this process is exclusively done by the recyclers (see Section 8.6). Hence, actors in Sweden, Swerec and Cleanaway PET Svenska and the German recycling companies shown in Table 21 are both sorters and recyclers. Nonetheless, there are

other recyclers that receive the sorted plastic waste from Sweden, these are for instance the ones Swerec sells its plastic waste to, which includes a German and Polish companies.

On the other hand, although currently in Sweden the sorting is not entirely done by national companies, this will change in 2019 with the construction of the new sorting plant in Motala, which will be owned by Plastkretsen (FTI). This will allow for Sweden to become independent in terms of sorting capacity of plastic packaging waste by 2019. The new sorting facility will be able to sort plastic packaging waste into more fractions (Ström, 2018). In Portugal the sorting is already done within the national market.

It should also be mentioned that in Sweden there is a deposit return system for PET bottles, and so Returpack appears also as a relevant actor. This actor is not mentioned on Table 21, since it doesn't match any type of the actors presented and even though it is more similar to a PRO, it is not a not-for-profit organization like SPV, FTI and TMR.

In addition to this, TMR should have the same role and interactions as FTI and in fact according to the company it works together with FTI in the collection of plastic packaging waste. Furthermore, as mentioned in Section 7.2 TMR owns a recycling facility where they produce mixed recycled plastic. They also sell some plastic packaging waste to external sorting facilities, like FTI.

Finally, regarding the producers, a clear difference is that in Portugal some of the plastic producers that use recycled plastic in their products are the same actors that transform the sorted plastic into raw material. This is usually not the case for Sweden, since the plastic producers mostly buy the secondary raw materials from the recyclers, with some exceptions, like Plaståtervinning i Strömsbruk AB.

Table 21 – Main Actors Involved in Plastic Packaging Recycling in 2016, in Portugal and Sweden

Type of actor	Main roles	Actors involved	
		Portugal	Sweden
Producer Responsibility Organization (PRO)	Producers' responsibilities on management of plastic packaging waste	SPV (Plastval)	FTI (Plastkretsen); TMR
Collectors	Collection of sorted plastic waste	Mostly waste management companies (SGRU); occasionally municipalities	Private collectors (hired by FTI); less frequently waste management companies or municipalities
Sorters	Sorting plastic packaging waste according to types of composition (PE, PP, PS, others)	Waste management companies (SGRU)	Swerec (Sweden); Kedenburg, Tönsmeier and Eing (Germany); Cleanaway PET Svenska
Recyclers	Transform the sorted plastic waste into secondary raw material	Mainly Portuguese and Spanish companies (see Section 8.6)	Swerec (HDPE flakes); Cleanaway PET Svenska; Kedenburg, Tönsmeier and Eing (Germany) plus Morsinkoff; Tradepol (Polish company)
Producers	Manufacture new plastic products and using secondary raw material	Sacos88; Extruplás; Grijótubos; Logoplaste	Trioplast; Polyplank AB; Flextrus and others (see Section 7.6.)

8.2.2.4. Sorting Technologies and Efficiencies

The comparison of the sorting processes and technologies between both countries were based on the sorting facilities owned by ValorSul (Portugal) and Swerec (Sweden), that have already been described in Sections 8.4.5 and 7.4.5.

In Portugal all three streams of sorted waste (yellow, blue and green) are collected and sorted by SGRUs, hence ValorSul receives in its sorting facility all three waste streams. Those waste streams will then go through separate sorting processes. Focus will only be given on the sorting of the yellow stream, of which the plastic packaging waste is part of. In Sweden, since plastic packaging waste is source sorted, Swerec only receives and sorts this kind of waste. According to each company, ValorSul sorts PET, HDPE, film plastic (including LDPE) and mixed plastic and Swerec sorts PET, HDPE, LDPE and PP. Mixed plastic in the case of Swerec is currently mainly sent for energy recovery, since it has lost most of its value on the market. The mixed plastic waste was previously exported to China, before its recent ban on imports of plastic waste.

The equipment or processes that are common to both sorting facilities are: sieve, bag opener, optical sorting, ferrous or magnetic separator, manual sorting and baling. In ValorSul's sorting facility there is induction sorting that is related to the fact that the facility receives metal packaging waste. Furthermore, in Swerec there is a washing and drying process before baling, which does not take place in ValorSul. In Swerec, HDPE sorted plastic waste goes through grinding, a sink-float method, crushing and drying, and it is then stored in bags to be sold.

In Swerec the input of household plastic packaging waste is about 50 000 tonnes, about 45% of what is produced in Sweden. As mentioned in section only about 40% is sorted and further sent to recyclers. On the other hand, in ValorSul the input of plastic waste in 2016 was about 14 986 t and as mentioned in Section 8.4.4 about 66.5% was sorted and sent to recyclers. This shows that ValorSul had a higher sorting rate for household plastic waste than Swerec. This may be so, because ValorSul also sorts and sells non-packaging plastic waste, instead of sending it for energy recovery like Swerec. Nonetheless, it was not possible to make further conclusions on what are the specific amounts of plastic waste that are lost during its different phases. For example, plastic packaging waste that is sent for energy recovery in Sweden or sent for energy recovery or landfill in Portugal.

8.2.2.5. Economic Costs and Financial Incentives

The costs for managing plastic packaging waste, including collecting and sending it for recycling are paid by the producer responsibility companies. These costs should be covered by the fees ('ecovalue' for Portugal) presented on Table 22 and the sales of the recycled plastics ("retake"

value for Portugal). The fees are paid by the plastic packaging producers and are charged by SPV, in Portugal and FTI, in Sweden. The fees applied in both countries are quite similar, except for that in Portugal a lower fee is charged for multipacks, about half of the fee charged for other types of plastic packaging. These fees vary according to the amounts of plastic packaging produced by each producer.

Table 22 – Fees paid by the producers on plastic packaging charged by PROs in 2016 and 2017; SPV 2017; FTI AB 2018b

Portugal			Sweden		
Type of Plastic Packaging	2016 (€/kg)	2017 (€/kg)		2016 (€/kg)	2017 (€/kg)
Primary packaging + Plastic carrier bags	0.201	0.228	Household Plastic Packaging	2.15 or 0.215 SEK /kg	2.33 or 0.233 SEK /kg
Multipacks	0.100	0.112			

In addition, according to FTI the fees charged to producers shall vary according to the recyclability of the plastic packaging product in the future, in which the more recyclable the product is the lower will be the fee. This will be an incentive for producers to develop more recyclable products and ultimately increase the amounts of recycled plastic packaging waste.

Finally, the fees on Table 22 refer to 2016 and 2017, since it shows that the fee increased for both countries from one year to the other. This may be an indication of either a higher concern on better managing plastic packaging waste or the fact that the previous costs could no longer cover more recent costs.

Besides, in Sweden there is also a deposit for PET bottles as mentioned in previous sections. This deposit is 0.10 € (1 SEK) and 0.20 € (2 SEK) depending on the size of the bottle and is also meant to cover costs on management of PET bottles as waste. This acts as an incentive for consumers to return the used PET bottles to the store, this way they are not the ones paying the deposit, instead distributors of the product or the store in this case will be the one responsible for paying it.

In Portugal there are also incentives for recycling. These are monetary incentives, also known as compensation values (counterpart value and complementary information value) that are paid by SPV to SGRUs, that aim to encourage those systems to collect more sorted waste, since the value is paid according to the amount of collected sorted waste. These compensation values are further explained in Section 8.5 and as previously mentioned they are intended to lead to higher amounts of recycled plastic packaging waste.

8.2.2.6. Market for recycled plastic waste

Primary and Secondary Plastic Prices

Table 23 summarizes the average prices of primary plastics (virgin material) and secondary plastics (recycled material) on April 2018, which is based on Tables 25 and 26 (see appendix I). The table shows that primary plastics are much more expensive than secondary plastics, which had already been confirmed by one producer.

Table 23 – Average prices (€/t) of primary and secondary plastics on April 2018; average prices based on tables 25 and 26, appendix I

Type of plastic	Primary	Secondary
LDPE	1330	537
HDPE	1295	715
PP	1400	560
PS	1620	765
PET	-	245

However, both the price and quality of the secondary raw material appear to go through many variations, according to several sources (interviewed producers and Milios et al, 2018), which may occasionally lead to closer value prices of the secondary and primary raw material. Nonetheless, the 'quality for a product is considered much more important than the marginal gain from the lower price' (Milios et al, 2018). Moreover, in the cases where the plastic producers make quality testing to the incoming secondary raw material, it ends up being an extra cost, that leads to more similar costs for acquiring primary and secondary plastics.

Nevertheless, the plastic market is still mainly dominated by the primary raw material. Some of the reasons for such is the fact that there is a lack of traceability and transparency along the value chain of recyclables and general deficiencies when it comes to the recyclability of products (Milios et al, 2018). Also, there is a lack of demand for products made from recycled plastic. Overall plastic producers prefer to buy virgin plastic especially due to higher and clearly defined quality specifications.

In Sweden, it was possible to obtain valuable feedback on the recycled plastic market from three companies that use recycled plastic in their products (Section 7.6). These companies mainly used recycled PE (various types), including PET, HDPE and LDPE. In Portugal, one company responded claiming it uses recycled PET and LDPE.

Two of the Swedish companies and the Portuguese company didn't know the fraction of resulting plastic waste from their products that is recycled, since the market is not only national and it is difficult to follow the product along its life cycle.

The same two Swedish companies claimed to work on alternatives or improvements to increase recyclability of their products, which is more or less possible, depending on the application of the product. In the case of producing plastic packaging destined for storing food, like in Flextrus, the main focus is the protection of food, which according to the company implies using more layers of plastic (multi-material) which will reduce the recyclability of that product. The Portuguese company also produces food plastic packaging waste using recycled plastic and it answered that for the company the most important was to use as little plastic as possible in combination with recyclable materials. Overall producers from both countries said they encourage better strategies for collection and sorting of waste and they communicate with other stakeholders from the plastic recycling industry.

The responses related to virgin and recycled plastic prices were different, but they all agreed that the price varies. They mostly agreed on the fact that the quality of the recycled plastic also varies and that this may be influenced by the recycling system and by the fact that each time a plastic molecule is recycled, its polymer chain shortens, decreasing the quality of the recycled material. Hence, according to this a plastic material that has been recycled will always have a lower quality compared to a virgin material.

Several solutions to increase the recyclability of plastic products and recycling of plastic waste were presented by the plastic producers. To sum up, solutions from Flextrus, Trioplast and Logoplaste were: investments in the plastic value chain that motivate circular economy; study of the recycling system, as well as, the market value differences between each plastic type; reduce multi-material plastic products; review the quality of raw material needed for some plastic applications; increase customer demand for recycled plastic by increasing the quality and traceability of the recycled plastic; increase correct source-sorting by educating consumers; improve sorted collection of plastic waste and implement regulation that demand a certain content of recycled plastic in plastic products.

9. Discussion

First, some lessons and knowledge from each country's waste management system and plastic packaging recycling system are presented. These lessons aim to possibly complement current practices in each country's current system. Then solutions or practices that haven't been applied so far in either country are briefly exemplified, as well as, what problem they intend to solve. Finally, some of the main obstacles, limitations and uncertainties, that were experienced throughout the work are exposed with a few examples.

9.1. Lessons from each country

The comparison and analysis of the waste management systems and plastic packaging waste recycling systems allows to extract some lessons and knowledge from Portugal and Sweden.

The main lessons from Sweden that could be adopted by Portugal are the landfill bans on organic and combustible waste and the higher landfill taxes. In addition, a deposit return system for PET bottles would also be a suitable measure. These measures were considered the most relevant, since they have shown the highest potential for increasing plastic packaging recycling rates.

On the other hand, the fact that Portugal has an incineration tax on household waste could be further adopted by Sweden. And even though such tax didn't show efficient results in the past for Sweden, it could lead to a discussion on how to try to implement this instrument in a different manner. For example, perhaps only applying a tax to recyclable waste or not have a fixed tax, which would instead depend on the type of waste sent for energy recovery. Additionally, in Portugal there is some sorting of the residual waste intended to recover plastic packaging waste. Although it probably represents a minor fraction of the recycled amounts and only some SGRUs do this, it still has the potential to increase the plastic packaging recycling rate. Also, there is sorting of the non-packaging plastic waste that is sent for recycling. These Portuguese measures could possibly increase the plastic packaging recycling rate in Sweden.

9.2. Solutions for both countries

Furthermore, there are other practices that are not currently implemented in any of these countries. Those measures could be good solutions to possibly improve both countries' plastic packaging recycling rates. Such solutions can be divided in two, solutions identified in the analysis of the overall waste management, including plastic packaging waste and the ones extracted from the plastic packaging market analysis. The problems from the plastic packaging market that originated possible solutions will be further explained.

First, an incineration ban on recyclable waste, including plastic packaging waste could improve both plastic packaging waste recycling rate and the general waste recycling rate. Particularly if

this complements a landfill ban on recyclable waste. Furthermore, adoption of a PAYT system in more municipalities would probably also increase both the mentioned recycling rates, since people would feel more encouraged to better sort their waste.

Secondly, the main issues of the recycled plastics market that were briefly mentioned before are related to supply, demand and quality of the recycled plastics. The supply issue is strongly connected to the quality of recycled plastic, since there is often supply of recycled plastics within the market, but that supply doesn't always match the required quality of the plastic producer or the plastic packaging consuming company. Especially if it is to be used for food grade plastic packaging products. In addition, this quality is often unpredictable and hence its instability as a good source of raw material doesn't make it very attractive and ultimately preferred over a virgin source which steadily shows good quality. The demand issue is tightly related to the fact that customers or the plastic packaging consuming companies don't often ask or demand for a recycled content in their products, thus plastic producers often lose interest in using this raw material in their products. An additional possible explanation for that is the fact that secondary plastics are frequently untraceable, even more when they are sourced from household plastic waste. These problems were stated by producers of plastic that used recycled plastic in their products, but also others that don't use it, briefly mentioned in Section 7.7.

All these issues contribute to the fact that even though the recycled or secondary plastic price on market is usually much lower than the primary, it is still very often not the preferred option.

The combination of solutions already presented in Section 8.2.2.5 given by the interviewed plastic producers, with knowledge acquired from studying both countries' Plastic Packaging Recycling Systems allow for some possible solutions to boost and improve the secondary plastics market.

First of all, improvements should be made in the collection, sorting and recycling or transformation into raw material steps. For example, regarding collection, by studying better how to implement different collection schemes possibly at a regional level. There should more cooperation between municipalities and the producer responsibility organizations in both countries, which could be achieved through more frequent meetings, conferences and/or workshops. This could lead to higher amounts of collected packaging waste, if a collection scheme for sorted waste, particularly plastic packaging is made considering both actors potential contribution. As for sorting, there should be additional investments in more efficient technologies, for instance by improving efficiency of NIR technology, since it currently does not detect black-coloured plastics or by combining it with another technology that would allow this separation. However, this could also be resolved by educating producers on the problem of using this colour in their plastic packaging products. As for the transformation of the sorted waste into a raw material, a solution could be to replace the cold washing for a hot washing process of the material, which would potentially remove more contaminants and increase the quality of the raw material. This was based on the interview with Swerea.

To improve customers' demand for secondary raw material, possible solutions could be to educate on the environmental benefits from using this kind of raw material or simply establishing a regulation that demands a minimum required recycled content, as mentioned in Section 8.2.2.5.

Overall, a design that allows recyclability, a high content of recycled material, possibly combined with a closed-loop collection scheme or a collection scheme that increases traceability of waste and technologies that contribute to better quality of the recycled plastics, with clear and transparent standards should increase both demand and supply for recycled plastics.

9.3. Limitations and uncertainties

Throughout the development of this work, there were some limitations on what was comparable and analysed between both countries were found. Furthermore, such limitations led to uncertainties on results presented in the report. A major limitation was the lack of published information and data. For example, it was not possible to compare and analyse real costs of collection and sorting of plastic packaging waste, this would have enabled studying whether current fees and market values were enough. Likewise, it was not possible to compare produced, collected, sorted and recycled amounts, which would have made possible to understand the main losses occurring during the entire plastic packaging recycling system and in at what phase it was most significant. Nevertheless, with the available information major losses seem to take place between the production and collection of waste.

The uncertainties were mainly derived from the fact that some estimates had to be made. Since some amounts were not available in publications. For example, this was the case for the national plastic packaging collected and produced amounts in Portugal, as well as, bring system and kerbside collection fractions. Besides, for the bring system only recycling stations/ eco-points could be considered, since it was not clear how many recycling centres in Sweden also receive plastic packaging waste. This resulted in excluding the collected amounts at recycling centres and eco-centres collected amounts. Additionally, since each country often used different terminologies when referring to the same, such terms should have been either properly defined in national legislations or in EU legislation, hence avoiding different terminologies and making comparisons easier. An example of this was the fact that none of the consulted reports or legislation clearly defined material recycling or material recovery, or clearly defined the inputs used to calculate material recycling rates, at the time of consultation. This is currently better defined on the new amendments of EU directives, published on 30th May. These directives amended the waste, landfill and packaging and packaging waste directives and are defined in: Directive (EU) 2018/851; Directive (EU) 2018/850 and Directive (EU) 2018/852. In these new directives new targets can be found for 2025 and 2030. Directive (EU) 2018/851 has inserted a definition for material recovery (see appendix II), which is identical to what is being considered as material recycling in this report.

In addition, it was difficult to draw solid conclusions on the current market situation for secondary plastics, since different sources, literature and interviewees, sometimes reported conflicting information. Finally, it was also inconclusive how the different organizations and interactions of the actors involved in each country were influencing the plastic packaging recycling rate.

10. Conclusion

The Portuguese and Swedish waste management systems have been working towards reaching higher levels of the waste hierarchy. Nonetheless, a significant fraction is still going to the least preferred levels like landfill and energy recovery. This shows that there are still obstacles to overcome in order to reach higher levels of the waste hierarchy, as well as improve and encourage recycling, the waste hierarchy level that most significantly contributes to a circular economy of resources.

Over the years, Portugal and Sweden have been improving their plastic packaging waste recycling rates, which shows that both countries are working towards a circular economy of their plastic waste. Hence, nowadays plastic waste is starting to be seen more as a resource. However, the analysis and comparison of both countries' plastic packaging recycling systems revealed that there are still many improvements to be done if both countries want to reach future EU targets and fully integrate plastics into a circular life cycle.

Furthermore, the analysis of the recycled plastic market and feedback from the plastic producers made clear that there are still many problems in using this kind of raw material which affect its supply and demand. Some solutions were drawn and derived mainly from the producers' feedback. The main solutions were: a design that allows recyclability; regulation that obliges the use of a certain content of recycled material; a collection scheme that increases traceability of waste and technologies that contribute to better quality of the recycled plastics, with clear and transparent standards.

Naturally, there is not only one solution due to the complexity of the system and diversity of actors involved that influence the entire system performance. Hence, several solutions can be applied in both countries that should solve issues related to the collection, sorting and recycling of plastic packaging waste, as well as potentially increase the supply and demand of recycled plastics.

Even though there were some difficulties related to lack of published information and transparency of what was being reported at times, the main objective was fulfilled by answering the initial proposed questions at some extent.

Lessons from each country were pointed out. The lessons drawn from Sweden that can be implemented in Portugal were: landfill bans on organic and combustible waste and higher landfill taxes, as well as a deposit return system for PET. Lessons possible to extract from Portuguese practices were: an incineration tax on household waste, with the possibility of only applying it for recyclable waste or being dependent on the type of waste; sorting of the residual or unsorted waste to retrieve further plastic packaging waste, as well as sending non-packaging plastic waste for recycling. Likewise, these could be implemented in Sweden.

Nonetheless, more research should be done to complement this work. Focus should also be given in studying each country separately to allow for conclusions on how individually they can both contribute to an improved management of plastic waste, a global issue.

Finally, the recent strategy on plastics in a circular economy published by the European Commission and the EU directives published on 30th May of 2018 that establish 2025 and 2030 targets on waste, landfill and packaging waste should allow for better results in plastic packaging recycling and waste management, in a near future.

11. Further Studies

The development of this work has raised additional questions besides the ones initially developed. However, some of the initial questions were not fully answered to, due to inconclusive findings or lack of published information, like what the annual costs of plastic packaging recycling are or the main obstacles for higher recycling rates. Thus, further studies could be developed to better understand these issues and answer those questions.

For instance, it would be interesting to assess the environmental benefits and costs of a plastic packaging product made with a virgin source and another made with exclusively recycled plastics or with some content of recycled plastics. This could eventually raise awareness amongst plastic producers and promote better choices of the raw material.

Moreover, it was not possible to study the influence of all actors in the plastic recycling value chain. Therefore, a study of the consumers or households' awareness and motivations to improve source sorting, as well as, the importance of the plastic consuming companies' engagement in plastic packaging recycling would probably lead to a better comprehension of each actors' roles in the value chain. Ultimately, this could potentially allow an increase of the plastic packaging recycling rate in each country.

In addition, a study on the differences in source sorting (yellow stream and plastic packaging stream) between Portugal and Sweden and how it influences the collected amounts of plastic packaging waste and their quality would be interesting, since no conclusions were possible to obtain on that.

It was also not possible to determine losses of the plastic packaging waste in each step of the recycling process on a national level. Hence a study on this could identify changes that would promote more efficient processes of collection and sorting.

A study on the imports and exports of plastic packaging waste in each country and how the recent China ban on imports of plastic waste will influence plastic packaging recycling in each country and in Europe could also be an interesting study in the future. This could not be tackled, since there were no data on imports and exports of plastic packaging waste in either country.

Finally, a study on the supply and demand of each recycled plastic type could provide more knowledge on how the recycled plastics or secondary plastics' market work.

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13. Appendix I - Tables

Table 24 – SGRUs' 2020 targets of amounts of resold waste from selective collection, Despacho nº 3350/2015

SGRU	2020 target (kg/ person/ year)
Algar	71
Amarsul	45
Ambilitial	48
Ambisousa	32
Amcal	55
Ecobeirão	29
Braval	53
Ecoleziria	27
Ersuc	46
Gesamb	48
Lipor	50
Resialenetejo	43
R.Nordeste	42
Resiestrela	40
Resinorte	41
Resitejo	55
Resulima	45
Suldouro	45
Tratolixo	49
Valnor	54
Valorlis	42
Valorminho	47
Valorsul	49

Table 25 – Primary plastics prices on April and March 2018; Plasticker 2018

Prices (€/t)	April 2018	March 2018
LDPE film grade	1260 - 1400	1300 - 1400
LLDPE film grade	1240 - 1380	1280 - 1380
HDPE injection moulding	1260 - 1310	1260 - 1310
HDPE blow moulding	1280 - 1330	1280 - 1330
HDPE average	1270 - 1320	1270 - 1320
PS crystal clear	1540 - 1600	1660 - 1720
PS high impact	1640 - 1700	1760 - 1820
PS average	1590 - 1650	1710 - 1770
PP homopolymer	1350 - 1400	1350 - 1400
PP copolymer	1400 - 1450	1400 - 1450
PP average	1375 - 1425	1375 - 1425
Average Price	1371 - 1446	1411 - 1476

Table 26 - Secondary plastics prices on April and March 2018; Plasticker 2018

Prices (€/t)	April 2018	March 2018
HDPE regrind	590	590
HDPE regranulates	840	930
HDPE average	715	760
LDPE bale goods	270	240
LDPE regrind	580	660
LDPE regranulates	760	780
LDPE average	537	560
PP bale goods	250	200
PP regrind	530	550
PP regranulates	900	800
PP average	560	517
PS regrind	540	580
PS regranulate	990	960
PS average	765	770
PET bale goods	200	170
PET regrind coloured	330	320
PET average	265	245
Average Price	568	570

14. Appendix II - Definitions

Bring system: a system that provides containers of different sizes and shapes, where residents are required to deliver recyclables, also known as drop-off points (Rodrigues 2016).

Closed-loop recycling: when the recycled plastics are used to produce the same product, they were originally recovered from. The new product can be made up entirely from recycled plastics, or a mixture of recycled plastic and virgin material (Maris 2018).

Eco-point: voluntary collection drop-off points, made of a set of large containers that are used for sorted collection of waste (Ecoponto 2018).

Eco-centre: it is a park equipped with large containers that receives sorted waste that is sent to recycling (CM-Ilhavo 2018).

Energy recovery: includes incineration with production of energy for heat and electricity, as well as anaerobic digestion for biogas production (European Commission, 2013).

Household waste: shall mean waste generated by households and comparable waste from other sources, the same as municipal or urban waste (Ds 2000: 61).

Kerbside collection: Collection where containers like bins, racks, sacks and bags are allocated to individual families, very near to the source of waste generation. The homeowner is responsible for placing the containers to be emptied at the curb on collection day and for returning the empty containers to their storage location (Rodrigues 2016).

Lightweight packaging: includes all plastic, metal, and composite materials, such as liquid packaging cartons or LPCs (Martinho 2017).

Material recycling: 'means any recovery operation, other than energy recovery and the reprocessing into materials that are to be used as fuels or other means to generate energy' (Directive (EU) 2018/851). Materials are reprocessed into products, materials or substances for their original use or other purposes and thus re-injected to the economy (Plastics Recyclers Europe).

Mechanical and biological treatment: waste treatment that includes sorting and biological treatment, like composting and anaerobic digestion (Wikipedia 2018d).

Mechanical treatment: Treatment where workers remove waste like glass, plastic, paper and aluminium that may damage the equipment further ahead and mechanical sorting processes occur (Caracol 2016).

Packaging waste: shall mean all products made of materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer. 'Non-returnable' items used for the same purposes shall also be considered to constitute packaging (Directive 94/62/EC).

Open-loop recycling: occurs when the recycled plastics are used for a different product than the one they were originally recovered from. This does not necessarily imply that the new application is of lower 'value' (Ragaert 2017).

Recycling centre: facility where people can leave most of their household waste, including hazardous waste and bulky waste, which is equipped with many containers (Sysav 2018a).

Recycling station: is a stationary facility for returning essentially packaging waste (Wikipedia 2018a).

Residual waste: is non-hazardous waste which is not source sorted at households (What is residual waste fact sheet 2018), also referred as unsorted waste.

Secondary raw material: shall be defined as raw material that has its source on recycled material.

Sorted collection: collection of recyclable waste that has been source-sorted (Wikipedia 2018b).

Transfer station: is a facility for temporary storage of waste before it is sent to a final destination (Wikipedia 2018c).

Unsorted collection: commonly designated garbage collection, it means collection of waste that was not source-sorted (CM-Odemira 2018).