Swedish Waste Streams in a Circular Economy

–A study of the perception change of waste flows when reviewing waste recycling target for the EU proposed Circular Economy Package

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Dokumenttitel och undertitel

Svenska avfallsströmmar i en cirkulär ekonomi
En studie om hur uppfattningen av avfallsströmmar förändras relaterat till lagförslaget om ändringar i Europeiska Unionens avfallsdirektiv, inkluderat i det cirkulära ekonomipaketet

Sammandrag

I juli 2014 föreslog Europakommissionen ett cirkulärt ekonomipaket som skulle bidra till att göra EU mer resurseffektivt genom att recirkulera resurser in i det ekonomiska systemet. En cirkulär ekonomi syftar till att tillvarata värdefulla naturresurser samtidigt som man motverkar behovet av att extrahera nya. Det föreslagna paketet innehöll bland annat ändringar i avfallsdirektiven, höjda återvinningsmål samt en ändring av beräkningsmetoden för återvinningsmål. Denna studie undersöker hur förslaget om ändringar i avfallsdirektiven, skulle påverka uppfattningen av Sveriges avfallssystem. Studien visar hur de föreslagna mätmetoderna skulle förändra den svenska avfallsstatistiken och sätter detta i relation till höjda återvinningsmål. Det cirkulära ekonomipaketet drogs tillbaka av kommissionen i början på 2015, ett nytt förslag är under utveckling och ska presenteras i slutet av 2015.

Resultaten för denna studie visar att Sverige återvinner 42 % av det totala kommunala avfallet, detta beräknat med metoden i förslaget om ändringar i avfallsdirektiven. Studien visar även att om man endast redovisar insamlat material ger det en missvisande bild av avfallssystemets uppbyggnad då det även går stora avfallsströmmar mellan de olika behandlingsmetoderna. Exempelvis är endast 17 % av de totala 4 % som hamnar på deponi av det kommunala avfallet insamlat för att skickas direkt dit. Studien visar även att återvinningsgraden är beroende av definitioner av begrepp och var i återvinningsprocessen mätningen sker.

En projektion för 2030 gjordes med antagandet att målet 70 % återvinning uppnåtts. Denna visar bland annat att 84 % av allt kommunalt avfall skulle behöva samlas in för materialåtervinning för att uppnå att 70 % slutligen blir återvunnet.

En fallstudie av plaståtervinningssystemet visar på ett komplext system där många aktörer suboptimerar sina egna processer. En brist på öppenhet och kommunikation inom branschen står i vägen för möjligheten att få en överblick av plaståtervinningssystemet. Återvinningsgraden av plastförpackningar kommer sjunka från 65 % till 41 % beräknat med nuvarande metod respektive metoden i det föreslagna paketet. Effektiviteten i återvinningsprocesserna kan variera mellan 75- 90 %.

I studien dras slutsatsen att införandet av mätmetoden i ovan nämnda förslag skulle ge en tydligare och rättvisare bild av det svenska avfallshanteringssystemet genom att rejekten från de avfallsbehandlings-metoder som rör sig genom systemet blir synliga. Genom att följa rejekten kan utnyttjandet av resurser lättare maximeras samt återföras in i systemet och därigenom kan en cirkulär ekonomi uppnås.

Nyckelord

Cirkulär ekonomi, Återvinningsgrad, Återvinningsgrad, Avfallsströmmar, Svensk avfallshantering, EU direktiv, EU:s ramdirektiv om avfall

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Swedish Waste Streams in a Circular Economy

A study of the perception change of waste flows when reviewing waste recycling target for the EU proposed Circular Economy Package

Abstract

In order to become more resource efficient and circulate resources back into the economic system, the European Commission adapted a circular economy package in 2014. This is in line with the idea of a circular economy. This study investigates how *the legislative proposal to review recycling and other waste-related targets in the EU*, which was a part of the proposed circular economy package, would affect the perception of the waste system in Sweden. The study seeks to answer how the proposed measuring method would change Sweden's waste management statistics and to put this in relation to the raised recycling targets included in the proposal. The circular economy proposal was withdrawn but the investigation is relevant, as a new proposal is currently under development and will be presented by the end of 2015.

The results shows that Sweden recycles 42% of the entire produced municipal waste, according to calculations based on the measuring method described in the legislative waste proposal. The results also shows that only reporting which treatment method the waste is collected for gives a misleading picture of the system, as there are large waste flows also between the treatment methods. One example is that out of the total 4% of the municipal waste which ends at a landfill, only 17% was collected for this purpose. The study shows that the recycling rates are very dependent on the concept definitions and where along the recycling chain the measurements are done.

A scenario for the year 2030 was constructed assuming full compliance with the proposed 70% recycling target. According to the study, 84% of all municipal waste would have to be collected from material recovery for the 70% target to be reached

The case study of the plastic recycling system showed a complex system where many actors are sub-optimizing their processes. There is a lack of openness and communication, which inhibits an overview of the full plastic recycling system. It showed that the recycling rates for collected plastic in Sweden are difficult to calculate and the 75% value used for this study's calculations of the overall waste system is hard to verify. The recycling rate of the plastic packaging put on the market will decrease from 65%, calculated with the current method, to 41% using the method from the proposal, accounting for the rejects. It is also shown that the recycling efficiency rate of the recycling process may vary between 75 and 90%.

The study concludes that using the measuring method from the legislative proposal to review recycling and other waste-related targets in the EU, would give a more accurate picture of the waste system. It also concludes that rejects will flow through the system from a treatment method to another. Tracing the flows will make it possible to maximize the utilization of each resource, making sure that it is restored into the system creating a circular economy.

Keywords

EU directive, Swedish waste management, Recycling rate, Recycling target, Waste framework directive, Circular economy

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Thank you!

Contents

List of Abbreviations

CE - Circular Economy

EC - European Commission

FTI - Förpacknings- och Tidningsinsamlingen, Packaging and Newspaper Collection Service

GHG – Greenhouse Gas

IA - Impact Assessment

LPW - Legislative Proposal to review recycling and other Waste-related targets in the EU from 2014

MS - Member States

MW – Municipal Waste

PiW - Plaståtervinning i Wermland

SAH 2014 - Svensk Avfallshantering 2014

WFD - Waste Framework Directive

ÅI – Återvinningsindustrierna, The Swedish Recycling Industries' Association

1 Introduction

1.1 Background

The environmental boundaries of the planet are being exceeded. A common strategy for industrialization is to form a linear economy, where raw materials are used to produce, use and discard products. This linear way of maintaining a good economy is resulting in shortages of the planets finite resources, such as forests, minerals and fossil fuels, while resulting in increased waste as an end product (Ellen MacArtchur Foundation, 2013). The modern human lifestyle is creating numerous problems for the environment and the planet, such as climate change, the spread of toxins and pollution, and resource scarcity. The Intergovernmental Panel on Climate Change has again concluded in their newly published report in 2014, that “Human influence on the climate system is clear, and recent anthropogenic emissions of green-house gases are the highest in history” (IPCC a, 2014). IPCC (2014) also states that the effects of climate change could have an impact on human health, the economy, and ecosystems, among other areas.

Waste and its management contributed to climate change with 3-5% of the total anthropogenic emissions in 2005 (UNEP, 2010). Waste is a steadily increasing source of emissions of greenhouse gases. Fischedick et al. (2014) reports a nearly two fold increase in the emissions from the waste sector between 1970 and 2010. Of the municipal solid waste about 20% is recycled, 13, 5% is recovered as energy and the rest is disposed at landfill sites globally (Fischedick, et al., 2014). Fischedick et al. (2014) also state that a development in waste treatment technologies and energy recovery can significantly reduce the share of emissions at the waste disposal stage. During the time period 2000-2009, the energy production from energy recovery of waste and biogas increased with 50% and 270% respectively. During the same time period, a decrease with 19.4% of emissions from solid waste treatment was detected. Waste incineration and other waste management methods compose a relatively small share of emissions compared to solid waste disposal (Fischedick, et al., 2014). In addition to Fischedick et al. (2014), The United Nations Environmental Programme, UNEP, (2010) also concludes that the treatment method of waste and emissions of green house gases (GHG) are strongly connected to each other (UNEP, 2010).

In addition to direct emissions from waste disposal, emissions are rising when extracting and producing resources for manufacturing of products and materials. These emissions are also contributing to the climate change and are attributed to the fast consuming society where products are quickly discarded and then replaced (Fischedick, et al., 2014). By avoiding the use of virgin materials, their contribution to climate change can decrease. Thus the need to change and decrease the amount of virgin material used is important not only for the sake of the emissions from fossil fuels but also from the perspective of resource scarcity. By recirculation of already existing material a decreased amount of virgin material could be extracted. This can be accomplished by approaching waste in a new way and looking at it not only as discarded objects but as a resource i.e. by switching to a circular economy (Ellen MacArtchur Foundation, 2013).

The European Union is striving toward becoming a more sustainable economy as is evident by its ten-year growth strategy, *The Europe 2020 Strategy*. The strategy includes all aspects of the economy by approaching areas such as research, environment and employment. One aim of the strategy is to close the economic circle, preventing the copious amounts of natural resources and energy losses to the surrounding environment, which emerges with a linear economy, and to bring the resources back into the economy. Adopting and implementing the 20-20-20 targets is a way to facilitate transition to a more resource efficient society which would boost the economy by decreasing the use of expensive raw material (European Commission d, 2015). A resource efficient society needs to generate as little waste as possible and regenerate resources out of used material instead. The foundation of this is a well functioning and developed waste treatment system, where each used product is treated with the most fitting and efficient method (UNEP, 2010).

As a part of the transition to resource efficiency, the European Commission presented a strategy towards a circular economy called the Circular Economy Package, in the summer of 2014 (European Commission i, 2015). One of the main goals of this strategy was to make sure that the large amounts of municipal waste (MW) generated in Europe every year, 481 kg/capita, would be allocated back into the economic system as effectively as possible (Eurostat, Statistics Explained, 2015; European Commission h, 2015). The package included both a policy on circular economy and a Legislative Proposal to review recycling and other Waste-related targets in the EU (LPW). However, by the end of 2014 the package was withdrawn by the newly elected commission (COM(2014) 910 final, 2014). The incentive of the withdrawal was to take the upstream value chain into account in addition to the downstream product chain i.e. the waste management (European Commission c, 2014). A new proposal is expected to be presented by the end of 2015 (European Commission e, 2015).

The LPW included in the Circular Economy Package presented new higher recycling targets, clearer definitions and a better harmonized method for measuring recycling. The LPW measuring method clarifies that the reject from a recycling process should be taken into account. The LPW measuring method would make the calculation of recycling more comprehensible to interpretation, as the rate of recycling would be based on what is actually recycled. This is in contrary to the current system, where there are four different measuring methods to be chosen from, making it difficult to compare results. In addition, there are different interpretations of the current four measuring methods, where some European countries, e.g. Sweden, have based their recycling rate calculations on what is sent to a waste treatment facility (Ulvang, 2013).

The outcome of the LPW measuring method, for countries basing their recycling rates on what is collected to waste treatment could be to start measuring these rejects from recycling processes, thus adding a new measuring point. The new measuring point might modify the visualized waste system with respect to waste flows, in those countries calculating the recycling rates based on collected waste.

It is natural to assume that the implementation of the suggested package, including the suggested LPW measuring method, on the current waste data, would result in decreased reported recycling rates in comparison with current reported rates. Thus, proposed higher recycling targets along with the LPW measuring method, leads to the necessity of an investigation on what the result of an implementation of the package in a European waste system would be. Furthermore, the current measuring method used in Sweden is presenting a misleading picture of the waste system since the reject flows are not included in the waste statistics[1]. The misleading picture of waste system increases the difficulty of a transition to a circular economy (COM(2014) 398 final/2 , 2014).

With respect to possible modifications in the way of viewing the waste management system and the altered calculation of recycling rates, due to implementation of the circular economy package, this report aims to execute a survey on how the statistics change the viewing of the waste system in

[1] Jakob Sahlén, Technical Adviser on Energy Recovery, Avfall Sverige, Personal Communication 2015-22-01

Sweden. The focus of the investigation is municipal waste flows and recycling rates with the approaches submitted in the proposed circular economy package.

1.2 Purpose

The purpose of the study is to investigate the waste management system in Sweden as a result of the implementation of the legislative proposal to review the European recycling targets, included in the European Commission proposed circular economy package from 2014. This paper seeks to answer how the system would be affected, qualitatively and quantitatively, by the new LPW measuring method as well as how the system would be affected by higher recycling targets in the proposed European circular economy package.

1.3 Research Questions

The following questions are the basis and focus of this study.

- How does the perception of the overall system change when applying the proposed LPW measuring method?
- How does the recycling rate change with the LPW measuring method compared to the current measuring methods?
- What data is missing for Sweden to be able to show compliance to the suggested targets concerning recycling, using the LPW measuring method? In the plastic recycling system and in the system as a whole.
- What is the consequence of the lack of reliable data?

1.2 Delimitations

The study focuses only on the waste system in Sweden and the borders of Sweden are the limiting boundary. Given that the circular economy package addresses municipal waste (MW) the study is as well limited to address MW.

The investigation covers a general perspective on the overall waste system based on a treatment distribution template (see chapter 2.3.2 for further information). Since the treatment distribution template is not fully reliable[2] further investigation to confirm the figures included in the template is desirable. Therefore a detailed study is also executed. The detailed study is however limited to cover the municipal plastic waste due to the time frame of this report.

The plastic fraction was chosen for the detailed study because of its big share in the total amount of MW. Plastic waste is also sent to both recycling and energy recovery treatment making it interesting to survey the end treatment of the plastic waste flows. In addition, the knowledge about the overall plastic fraction and its system is inadequate[3].

The data, regarding waste statistics, used in the report is from 2013, meaning that the waste statistics is based on amounts of waste that has been collected and treated during year 2013. The data from 2013 is

[2] Carl Jensen, Climate and Sustainable Cities, IVL Swedish Environmental Research Institute, e-mail 2015-23-02

[3] Anna Fråne, Climate and Sustainable Cities, IVL, personal communication 2015-13-03

used since the statistical data for the Swedish waste management from 2014 was not fully processed, hence not available, when the work with the report started. The statistics used in the report only concerns waste generated in Sweden.

1.3 Outline of the Report

The report starts with a method chapter (chapter 2) describing the general method of the study and a more detailed methodology for different parts of the study. This is followed up by a theoretic part, presented in chapters 3-4, where essential information about circular economy and the Swedish and European legislation and frameworks on waste is outlined.

Chapter 5 presents the circular economy package proposed by the EU commission in 2014, the background to the proposal including the impact assessment, the content of the proposal and a timeline for the development of the proposal including its current status.

Chapter 6 is following up with significant information about the municipal waste system in the EU and in Sweden. This includes waste generation and management, waste treatment actors and waste treatment targets. Chapter 6 also presents some basic background of plastics and the recycling of plastic.

Chapter 7 shows the calculated results for the implementation of changes in the waste directives in the overall municipal waste system in Sweden. It shows for example the final distribution of treatment methods in Sweden. It also presents a projection of a scenario with 70% recycling in Sweden showing how much waste which would have to be collected for recycling in order for 70% to actually be recycled.

Chapter 8 presents a case study investigating the plastic recycling system in Sweden in more detail. It shows the information collected from various actors during the survey and presents composed maps of the system.

In chapter 9 the presented information and results from the full report is analyzed and it is discussed in chapter 10. Chapter 11 is the final chapter of the report and it presents the main conclusions of the report by answering the research questions.

2 Method and Assumptions

2.1 Basic Implementation of the Study

This study is carried out in co-operation with the Swedish Waste Management and Recycling association, Avfall Sverige, and performed as a master thesis at the institution of Energy- and Environmental Systems at Lund University -Faculty of Engineering, LTH.

The study was done from the starting point of the 2014 proposed circular economy package where a new calculation method was presented. The report focuses on applying the LPW on the Swedish waste management system through a recalculation of the Swedish municipal waste statistic according to the LPW measuring method. A case study of the plastic recycling system is also made in order to investigate in further detail what data and information that is lacking to be able to achieve the implementation of the LPW.

The study includes both qualitative and quantitatively data. As the starting point and foundation of the study is the CE package, a thorough qualitative examination of the concept of the circular economy package was performed. The source and content of the whole CE package and the LPW, and in particular parts regarding the application on the Swedish waste management system, such as changes in definitions, was focused on. In order to support the study with fundamental theory, an analysis of the existing literature for the legislation in the European Union and Sweden, the concept of CE and the MW system of Sweden has also been performed. The current waste legislation was reviewed and interpreted with the perspective of the LPW.

For the recalculation of the statistics and the case study, an investigation of the overall waste system and the plastic recycling system of Sweden was executed. The investigation included surveys on; how the system is constructed, how the waste flows affect each other and where the waste is finally treated. The recalculation was done by; adapting the Swedish waste statistics to the LPW, adapting a *Treatment distribution template,* that is indicating the actual distribution of the waste treatment methods from each collected fraction, and finally using the treatment distribution template on the adapted statistics.

To understand how the application of the LPW will affect the perception of the waste system, a projection for the scenario of realizing a material recycling rate of 70% in 2030 was made. The projection is based on the result for the current waste treatment system in Sweden.

The method for the recalculation part could be specified and concretized to the steps accordingly:

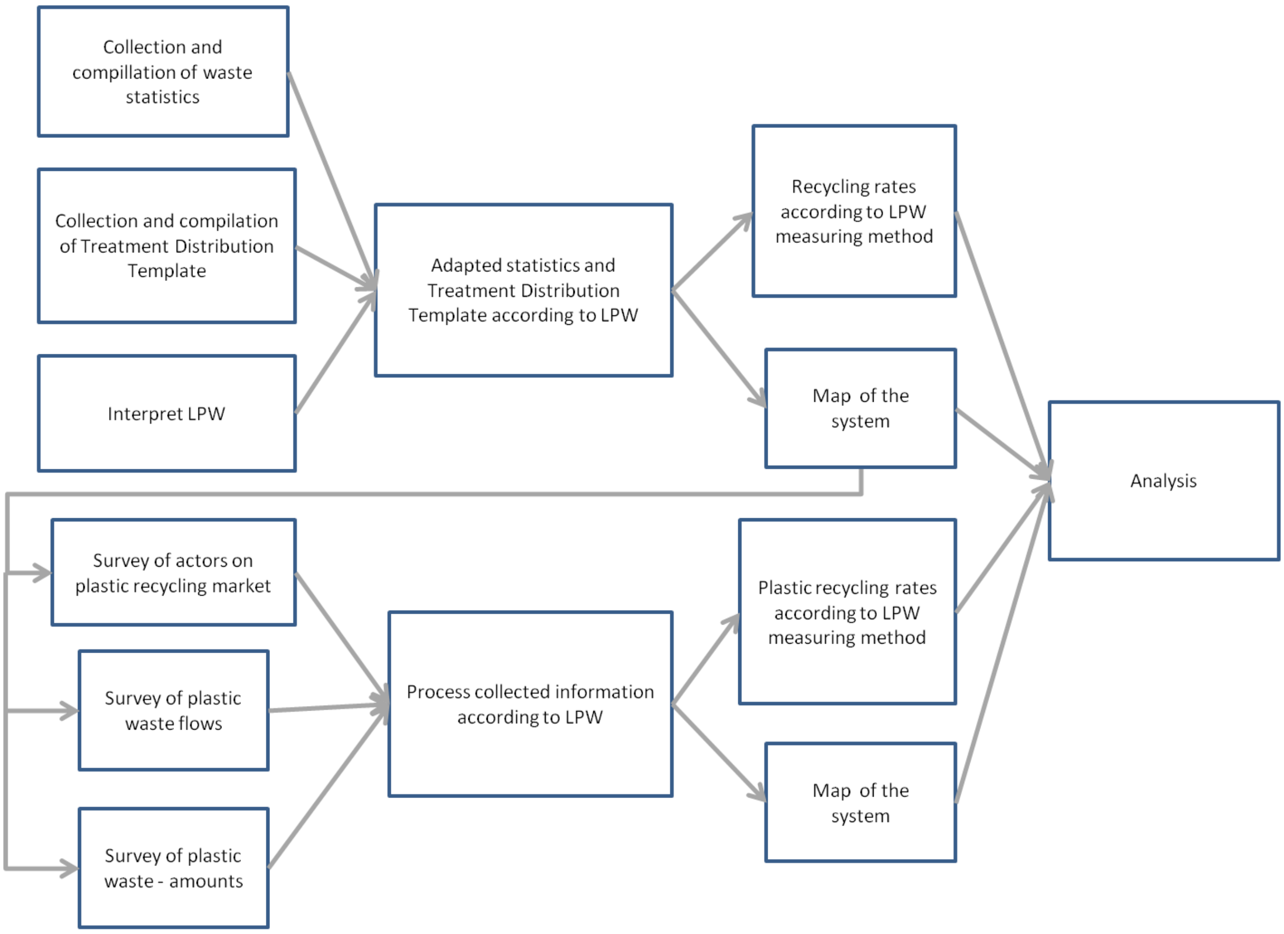
- Collecting statistics
- Adapting the Swedish statistics to the “real “situation i.e. include all the waste flows
- Treatment distribution template
- Adapting treatment distribution template to apply the adopted statistics
- Use the treatment distribution template on the adopted statistics to see “how the system really looks like”
    - Calculating recycling rates
    - Mapping the system
- Projection

The case study of the plastic recycling market focuses further on investigating the waste flows, the distribution rates used in the Treatment Distribution Template and the elements affecting the distribution and recycling rates for the plastic waste.

The method for the case study could be specified and concretized to the steps accordingly:

- survey actors on plastic recycling market
- survey of plastic waste flows
- survey of plastic waste statistics- amounts
    - calculating recycling rates
    - mapping the system

The method for the investigation could be summarized according to the scheme below. The underlying foundation for the implementation analysis is compiled of the theoretical study. It is not shown in the scheme but the steps presented are based on the interpretations, knowledge and conclusions made during the examination of the theory.



The information was retrieved through thorough combing of current databases as well as by correspondence via email and personal communication with experts within the field. Additionally organizations, entrepreneurs and recycling companies have been contacted. Information vital to the study has also been provided through participation at a conference with Avfall Sverige Action Group on Economic Instruments under the Working Group on Energy Recovery, 29-30th January 2015, and an expert workshop on the European Reference Model on (Municipal) Waste, European Environmental Agency (EEA) in Copenhagen, 26-27th March 2015.

2.2 Definitions

2.2.1 Terms Related to Waste Management

Definitions regarding waste management terms in the report are in concurrence with those as defined in the LPW (COM (2014) 397), the LPW Annex VI and in the Waste Framework Directive 2008/98/EC. The definitions are presented below:

Municipal Waste - household waste and similar waste

Household waste - waste generated by households

Similar waste - waste in nature and composition comparable to household waste, excluding production waste and waste from agriculture and forestry

Municipal Waste - includes household waste and waste from retail trade, small businesses, office buildings and institutions (such as schools, hospitals, government buildings) similar in nature and composition to household waste, collected by or on behalf of municipalities.

Waste from sewage network and treatment, including sewage sludge, construction and demolition waste is not included in the term MW.

Recovery -any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations;

Material recovery - any recovery operation, excluding energy recovery and the reprocessing into materials which are to be used as fuel

Recycling -any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;

Backfilling - any of the following types of recovery:
(i) recovery where waste is used in excavated areas such as underground mines or gravel pits for the purpose of slope reclamation, safety, or for engineering purposes in landscaping
(ii) recovery where waste is used for the purpose of construction, stowage of mines and quarries, for re-cultivation, land reclamation, or landscaping and where the waste is substituting other non-waste materials which would otherwise have been used for that purpose

The expression the **LPW measuring method**, used in this report, equals the measuring method for reporting compliance for the targets as described in the legislative proposal to review recycling targets, see Eq 2.1 and Eq 2.2 (COM(2014) 397 final, 2014).

When using the term **measuring point** in the report it is meant, the point in the recycling process where the waste is measured to be used in the calculation of recycling rates, see point f in Figure 1.

Since there are different views on when a material is recycled, plastic is in this report regarded as recycled when the plastic waste has gone through a recycling process i.e. a sorting process where the plastic waste is sorted into different plastic types. After the sorting process the plastic is regarded as recycled raw material and could either be comprised of baled loose material, grinded flakes or processed granulate.

2.2.2 Recycling rates

In the literature and statistical sources utilized for the study, the term **recycling rate** is commonly used when calculating the quantity of recycled waste. There is an issue that there is no standard protocol for making these types of calculations nor is there an adequate explanation of which approach is used, in the literature. This generates a source of confusion and makes it unfeasible to compare the different rates. For example in the current waste framework directive, (Directive 2008/98/EC), there are four different methods for calculating the recycling rate, see chapter 4.1.2.1, making a comparison inadequate. The LPW measuring point, defines a new way of explaining the recycling rate. Therefore the definitions explained below, see equations 2.1-2.6 and Figure 1, are used in this report for simplified comparison.

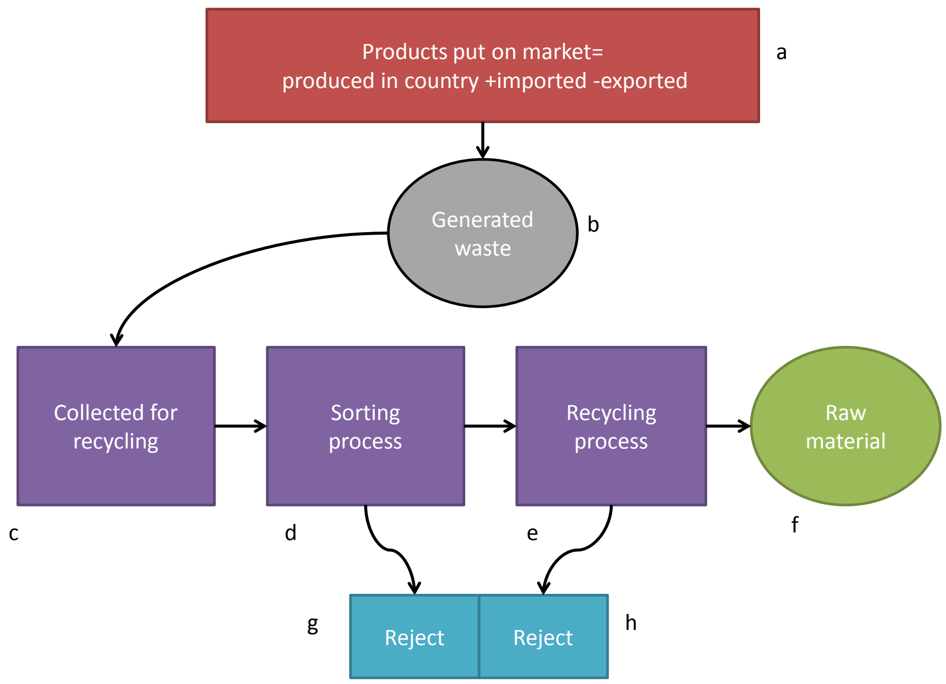


Figure 1.Schematic figure of a recycling process, produced with the purpose of clarifying expressions related to MW management rates.

The recycling rates, Eq 2.1 and Eq 2.2, equals the LPW measuring method presented in the circular economy package (COM(2014) 398 final/2 , 2014). The recycling rate for MW and packaging waste differs according to directive 2008/98/EC and directive 94/62/EG. The collection and recovery rates, Eq 2.3 and Eq 2.4, equal the current measuring methods used by some EU countries. The recovery rate used in this report, Eq 2.4, is inspired by Rankin (2011) who discusses different terminology used in situations related to recycling. Rankin uses the term recovery rate as the quantity of collected material divided with the quantity of material available. In this report the material available is equally to the material put on the market. The loss rate, Eq 2.5, equals the one used for rejects in the impact assessment written by Gibbs, et al b (2014). At last, the recycling efficiency rate, Eq 2.6, shows the share of waste that is processed into new raw material.

$$\left.\begin{array}{ll} Recycling\ rate\ MSW = \frac{c-g-h}{b} = \frac{f}{b} & Eq\ 2.1 \\ Recycling\ rate\ packaging = \frac{c-g-h}{a} = \frac{f}{a} & Eq\ 2.2 \end{array}\right\} \textit{LPW measuring methods}$$

$$\left.\begin{array}{ll} Collection\ rate = \frac{c}{b} & Eq\ 2.3 \\ Recovery\ rate = \frac{c}{a} & Eq\ 2.4 \end{array}\right\} \textit{Current measuring methods}$$

$$Loss\ rate = \frac{d-g}{c} = \frac{e}{c} \qquad Eq\ 2.5$$

$$Recycling\ efficiency\ rate = \frac{e-h}{d} = \frac{f}{d} \qquad Eq\ 2.6$$

2.3 Implementation of Changes the Waste Directives

The collection and adaption of statistics are explained below in section 2.3.1. To apply the LPW measuring method, see Eq 2.1, on the Swedish waste statistics the final distribution between the treatment methods need to be known i.e. amount of waste being material recycled, sent directly and as reject to energy recovery, disposed on landfills and used as backfilling. A treatment distribution template put together by SMED, IVL, Profu and Avfall Sverige was used to distribute the tonnage for each collected fraction. The template was produced for another project concerning waste indicators in Avfall Web. Section 2.3.2 explains the treatment distribution template and the distribution rates are shown in Table 1.

2.3.1 Adapting of statistics

The Swedish waste statistics did not include all the waste streams needed to implement the LPW and was therefore adapted to fit the LPW. Most of the data was provided by Avfall Sverige but was in some cases complemented with statistics from further data sources.

The total amount of waste collected to each treatment method, measured in weight, was foFund in the reporting system of Avfall Sverige, Avfall Web. These data were compared to the national data Avfall Sverige reported for 2013 in “Svensk Avfallshantering 2014“ (SAH 2014), where the reported waste streams are adjusted after comparison with FTI and El-kretsen. The amounts that were used as collection data is shown in appendix 3 and in a simplified version in Table 9.

In the cases where the figures did not correspond between the statistics in Avfall Web and the official statistics by Avfall Sverige presented in SAH 2014, it was further assumed that the figures in SAH 2014 were accurate and in turn used in the model. The data were closely compared and differences and uncertainties were discussed with the statistical expert Jenny Westin at Avfall Sverige. In the cases where statistics were not included in SAH 2014 the numbers in Avfall Web were assumed to be representative.

The total amount of MW generated in Sweden presented by Avfall Sverige for 2013 was 4 447 880 tons. In the calculations made for this report this number is replaced with 4 537 392 tons as grease trap residues, frying grease and cooking oil is included. These fractions are defined as MW according to the Waste Framework Directive 2008/98/EC, but were not included in the statistics presented in SAH 2014[4].

The waste stream for packaging, including both household packaging waste and similar packaging waste, were not divided into the separate fractions paper, metal, plastic and glass in SAH 2014. In order to obtain the relation between each separate fraction, the distribution between these fractions was assumed to be the same as presented in the statistics for household packaging. The distribution was thereafter used to divide the total amount of paper, metal, plastic and glass packages between the different fractions.

Regarding cans and bottles covered by the deposit system, the statistics were not included in the waste statistics provided by Avfall Sverige. These figures were instead provided by Erik Ebbeson at Returpack.

2.3.2 The Treatment Distribution Template

The template indicating the actual distribution of the waste treatment methods from each collected fraction was produced in preparation for the introduction of “waste indicators” in Avfall Web. The template indicates for example that; of all the electrical waste that was sent to a material recovery operation only 67% was actually material recovered, 17% was energy recovered and the remaining 17% of the treated WEEE ended up on a landfill (Sundberg, et al., 2014). The template values are shown in Table 1.

The template in Table 1 was produced based on information from recycling companies and environmental reports. The focus of the investigation, in which the template was produced, was not to produce these templates, but rather on developing waste indicators showing development in the waste management system over time. The template values for the distribution of the final destinations of the waste streams are therefore often rough estimates and of a low accuracy[5]. In many of the fractions the included rejects are based on rejects which arise during the waste sorting process. In the case of plastic for example, only rejects produced at the recycling facility of the company Swerec are included, while losses due to reprocessing are not. Moreover, data from other plastic recycling plants were not considered thus the reject data from Swerec were applied on all plastics. The sources used by IVL for deciding each template can be found in Table 23 in appendix 3.

[4] Jenny Westin, Avfall Sverige, Statistical Expert, personal communication 2015- 03- 02
[5] Carl Jensen, Climate and Sustainable Cities, IVL Swedish Environmental Research Institute, e-mail 2015-19-02

Table 1. Treatment distribution template based on (Sundberg, et al., 2014)

Waste fraction	Material recovery	Energy recovery	Landfilling	Backfilling
Corrugated board	70%	30%	0%	0%
Scrap metal	92%	2%	1%	5%
Plaster	90%	0%	10%	0%
Flat glass	100%	0%	0%	0%
Plastic, non-packaging	75%	25%	0%	0%
Textile	90%	10%	0%	0%
Other (bulky) material for recycling	92%	2%	1%	5%
Glass packaging	95%	0%	5%	0%
Paper	70%	30%	0%	0%
Paper packaging	70%	30%	0%	0%
Plastic packaging	75%	25%	0%	0%
Metal packaging	85%	15%	0%	0%
WEEE	67%	17%	17%	0%
Car batteries	85%	15%	0%	0%
Portable batteries	55%	11%	34%	0%
Oil filters	50%	50%	0%	0%
Water-based paint	50%	50%	0%	0%
Food waste to co-digestion plants	74%	26%	0%	0%
Food waste that undergoes anaerobic digestion at wastewater treatment plants	74%	26%	0%	0%
Food waste grinded in a garbage disposal unit	100%	0%	0%	0%
Food waste that undergoes anaerobic digestion at farm-based plants	74%	26%	0%	0%
Grease trap residues	100%	0%	0%	0%
Frying grease and cooking oil	100%	0%	0%	0%
Food waste to central composting plants	97%	3%	0%	0%
Garden waste to central composting plants	97%	3%	0%	0%
Food waste for home composting, one family homes	0%	0%	0%	0%
Food waste, home composting, multiple family homes	0%	0%	0%	0%
Small chemicals	0%	100%	0%	0%
Solvent based paint	50%	50%	0%	0%
Impregnated wood	0%	83%	9%	8%
Residual waste	1%	78%	5%	16%
Garden waste to incineration	0%	83%	9%	8%
Other (bulky) waste to incineration	1%	78%	5%	16%
Straight to Landfill	0%	0%	100%	0%

The cans and PET-bottles collected with the deposit system are not included in the distribution template from Avfall Sverige (Table 1), and were complemented with rates received during the investigation. According to Ebbeson the fractions are very clean and there are no losses during the sorting process. However, there may be losses during the recycling and production process[6]. During the study of the plastic recycling system it was found that the reject from the recycling process is 88%. The distribution for PET-bottles was hence put to be 88% to material recycling and 12% to energy recovery. No further information was collected concerning the cans and the recycling rate was therefore set to 100%.

2.3.3 Recalculation of Statistics- Using the Template on the Adapted Statistics

The Swedish waste statistics were recalculated using the adapted statistics and the treatment distribution template. The recalculation determines recycling rates that are based on the LPW measuring method. The calculation was performed with a simple excel model which was put up based on the assumption that the treatment distribution template provided by Avfall Sverige is accurate.

Regarding the modeling, the definitions presented in the LPW has been used. In the basic model backfilling (see chapter 2.2 for definition) is not included as recycling whilst all biological treatment is included as recycling.

A visualization of the Swedish waste management system was done according to the current perception on the waste system and the perception on the waste system when implementing the LPW. These charts present the waste streams movement through the system but do not indicate the amount of waste in each stream, nor the relation between the streams regarding the amount of waste. These are seen in Figure 9 and Figure 10 in chapter 7.1.1 and 7.1.2.

In the study the complete waste system and the waste flows are mapped out visually according to the adapted treatment distribution template and the recalculation of the statistics. The distribution between the treatments methods in the Swedish system are also visualized in diagrams from Excel. This was done for both collected amounts and for final treatment methods. The distributions of waste within each method are also shown in the diagrams. Further, was a special case investigated where the consequences of differentiating between production of bio-fuel and bio-fertilizer from the anaerobic digestion.

The calculations for the 70% recycling rate scenario were based on the assumption that the rate of waste collected to be disposed on a landfill is the same as the current rate and in addition that none of the treatment processes increases in efficiency. It was also assumed that the relation between material recycling and biological treatment stays the same and the biological treatment was included as material recycling in the calculations. The calculations were based on the results and relations between treatment methods and rejects in the system of today.

2.3.4 Case Study of Plastic Recycling System

The study of the plastic recycling system is mainly a qualitative research focusing on surveying the plastic recycling market. Actors on the plastic recycling market have been contacted to collect information regarding plastic recycling and plastic waste flows. This was made in order to confirm recycling efficiency rates used in the treatment distribution template and understand the system accurately. An interview with IVL, the Swedish Environmental Research Institute, was set up to gain understanding about the common level of knowledge of the Swedish plastic recycling market and about relevant actors to be contacted. The correspondences with the various actors have been executed both via e-mail and personal communication over the phone.

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[6] Erik Ebbeson, Customer Manager, Returpack, e-mail 2014-13-04

A study concerning changes in recycling rates when implementing the LPW was also made regarding plastic packaging waste. In order to execute the study of changed recycling rates, the recycling efficiency rate understood from the treatment distribution template, for recycling of plastic was needed to be confirmed. The template shows the distribution of the final treatment methods of the collected plastic packaging. Under the heading *material recycling* in Table 1, a recycling efficiency rate of 75% for plastics can be seen. The recycling efficiency rate for plastics presented in the treatment distribution template was provided by Swerec, via IVL. An attempt was made to confirm this template by investigating literature, contacting recycling facilities such as Swerec, Plaståtervinning i Wermland and Cleanaway PET Svenska AB.

Schematic visualizations were also made for the plastic recycling system in Sweden. These charts are presenting the waste streams movement through the system but do not indicate the amount of waste in each stream, nor the relation between the streams regarding the amount of waste. These are seen in Figure 19. Flow chart showing the overall plastic waste flows from collection to treatment. in chapter 8.

The selection of actors contacted was based on the member companies of Återvinningsindustrierna, on the plastic market. ÅI, or in English "The Swedish Recycling Industries' Association, is an organization of Swedish companies working within the recycling field" (Återvinningsindustrierna, 2015). In addition to the companies collaborating with ÅI, three more companies were contacted, which were encountered during the original interviews. The contacted companies are presented in Table 2.

Table 2. Overview of contacted companies within the plastic recycling market

Company	Business concept	Managing plastic from MW	Plastic packaging waste	Non packaging plastic waste
Ekmaco Reagro AB	Entrepreneur	No	-	-
Hans Andersson Plastics AB	Entrepreneur	No	-	-
IL-Recycling	Entrepreneur	Yes	Yes	Yes
Miljösäck i Norrköping AB	Manufacturing	Yes	Yes	Yes
Ragn-Sells AB	Entrepreneur	Yes	Yes	Uncertain
Sita Sverige AB	Entrepreneur	Yes	Yes	Yes
Stena Recycling AB	Entrepreneur	Yes	Yes	No
Swerec AB	Recycling	Yes	Yes	Yes
Plaståtervinning i Wermland AB	Recyling	Yes	Uncertain	Yes
Rondo/Polykemi	Manufacturing	No	-	-
Polyplank	Manufacturing	No	-	-
Returpack	Material company	Yes	Yes	No
FTI	Service organization	Yes	Yes	No
TMR	Service organization	Yes	Yes	No
Cleanaway PET Svenska AB	Recycling	Yes	Yes	No

In several cases the contacted actors expressed recycling of plastic as one of their business services. It was also unclear what kind of plastic waste, e.g. residual from industry or MW, which was handled by the company. Thus before contacting the actors, it was unknown if the company managed plastic originating from MW and if they actually recycle plastic i.e. owned a recycling facility. See appendix 6 for interview questions asked. When contacting some of the companies it was found that they did not manage MW and no further investigation was executed. Therefore their answers are not included in the report.

Three manufacturing companies that use recycled plastic as raw material were contacted in order to retrieve information on the manufacturing process e.g. is there a necessity for additional sorting or does reject emerge during the process.

Miljösäck was contacted since it is both a manufacturing and a recycling company. Miljösäck produces plastic bags of recycled plastic and granulate of plastic waste. The raw material and plastic waste used in the manufacturing and recycling processes is mainly from industrial residual. However, a smaller amount of the plastic waste is MW. When it was discovered that Miljösäck recycles plastics, and that an additional sorting process is needed prior to the manufacturing process, due to contamination of other plastic types, the company were included in the report.

3 Circular Economy

The expression circular economy (CE) has been developed since the late 1970's. The concept origins from several design applications and ideas of shifting the economical model. It is evolved by researches and academics (Ellen MacArthur Foundation, Editorial Team, 2013). Among other ideas, is cradle to cradle one of the ideas commonly mentioned when talking about CE. It was introduced by Walter Stahel in 1970's as he demonstrated that it is economically profitable for economic actors to work in a loop economy instead of a linear economy. A loop economy could have impacts on job creation, resource savings, economy and waste prevention (Product -Life Institute, Geneva, 2013).In 1981, Stahel wrote the report *Product -Life Factor.* The conclusion was drawn that by using a loop economy, where less amount of virgin material is used and replaced with recycled material, the amount of generated waste could decrease (Product -Life Institute, Geneva, 2013)

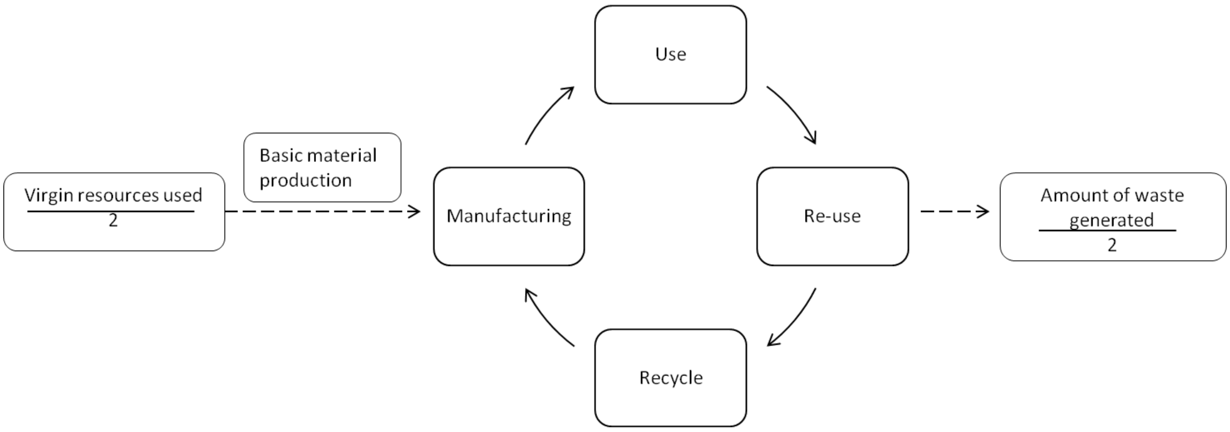


Figure 2.The idea of a cradle to cradle system, based on (Product-Life Institute, Geneva, 2015)

Researchers and organizations such as Ellen MacArthur Foundation, believe that a transition to a CE can result in development in markets as product design, research, service and food. In addition it can increase the economic growth and simultaneously decouple it from resource use (Ellen MacArthur Foundation, Editorial Team, 2013). It also creates a resilient system that will last for a long period of time, this in comparison with the current linear economical model where finite resources are being used and disposed. This chapter explains the idea of CE, some history and what is commonly included in the concept.

3.1 History and origin of Circular Economy

According to projections made by the United Nations Population Fund the world's population will increase from 7,1 billion to about 9 billion by the year 2050, where the middle class is projected to increase from 1.9 billion to 4.9 billion in 2030 (United Nations, Department of Economic and Social Affairs, Population Division, 2013; Pezzini, 2012). An increased middle class would result in greatly increased rates of consumption. The consumption rates in the developing economies will also shift from consumption of unbranded merchandise, such as products bought in bulk, to more packaged goods. This change in consumption behavior will lead to a higher intensity of material use (Ellen MacArtchur Foundation, 2013)

Resources efficiency alone is not enough to reach a sustainable society. As expressed in Ellen MacArthur Foundation's report (2013), written by McKinsey, "Efficiency can lower the amount of energy and materials used per dollar of GDP, but fails to decouple the consumption and degradation of resources from economic growth" (Ellen MacArtchur Foundation, 2013).

The now commonly used economic model where resources are extracted, used and then thrown away is not sustainable since the humanity are using more and more of our limited resources. A linear consumption model causes stacks of waste in the end of the line. A new economy, where resources are recycled and full potential of the resources are being used, is required according to the European Commission (European Commission i, 2015). A sustainable economy can be achieved by transitioning into a circular economy. CE is a concept and model for accomplishing a cradle to cradle system. A cradle to cradle system does not have an end and therefore does not generate waste. The concept of CE is a tool for developing a sustainable future. By reconsidering what is defined as waste, products that are now referred to as waste can instead be recycled back to new products and resources (European Commission i, 2015).

In civilizations where poverty is widespread, a CE model is often naturally practiced. Scarcity of resources obligates for economizing with what is available and often lead to a circulation of materials. For example clothes are repaired, reused and inherited while excess food could be used as animal feed (Ellen MacArtchur Foundation, 2013).

The Club of Rome has published a report *The Circular Economy and Benefits for Society, Swedish Case Study Shows Jobs and Climate as Clear Winners*, written by Wijkman and Skånberg (2015), where the effects of shifting to a circular economy and increasing resource efficiency is examined. The focus has been to look on the societal benefits surrounding carbon emissions and employment. The results showed that carbon emissions and the number of jobs would decrease and increase respectively, while the trade balance would be improved (Wijkman & Skånberg, 2015)

Wijkman and Skånberg (2015) argue that a circular economy creates employment and increases the economic growth. Furthermore they state that with a circular economy and an industry comprised of repairing, reusing and recycling is more labor-intensive than a linear economy where products are produced, consumed and thrown away, "(…) caring for what has already been produced- through repair, maintenance, upgrading and remanufacturing- is more labor-intensive than both mining and manufacturing (often highly automated and robotized facilities)" (Wijkman & Skånberg, 2015).

3.2 The concept of Circular Economy

The aim of steering towards a CE, according to Ellen MacArthur Foundation (2013), is to decouple economic growth from consumption of finite resources and therefore avert the negative consequences associated with it. The expression cradle to cradle is both a concept of circulation and a designing model where the purpose is to mimic nature in the manner of recirculation of nutrition. The model of cradle to cradle is based on a lifecycle approach developed by Michael Braungart and the Environmental Protection Encouragement Agency, EPEA. It approaches the designing of products and the idea is to produce products that contain natural material which can either be composted or recycled when becoming waste, or easily be taken apart, repaired or reused (EPEA a, 2015).

Ellen MacArthur Foundation presents five principles for circular economy (Ellen MacArthur Foundation, Editorial Team, 2013):

- Designing out waste
- Building resilience through diversity

- Working towards using energy from renewable sources
- Thinking in ‘systems’
- Thinking in ‘cascades’

The idea of designing out waste is to increase resource circulation in society. Michael Braungart and William McDonough (2002) introduced the expression "waste equals food” to challenge peoples commonly held beliefs. The message is that people should see waste in the same cyclical way as nature, where waste becomes another species food source. Braungart and McDonough exemplified this as a tree dropping its leaves, as “waste”, supplies nutrients to the millions of organisms living in the soil (EPEA b, 2015). Furthermore, the energy used in society to transport, heat and produce products for consumption, should be derived from renewable sources such as wind or solar power, to create and maintain a CE (Ellen MacArthur Foundation, Editorial Team, 2013).

The CE addresses the overall system, meaning that every step in the system must be considered. In a linear economy a transformation or adjustment of a parameter affects only the subsequent step in the system, compared to a circular system where flows are interdependent and adjustments may address and affect several subsequent flows. The Ellen MacArthur Foundation (2013) explains that a CE is feedback-rich, meaning that they often contain a greater degree of interconnectedness. Complex systems can generate negative effects such as inertia and ineffectiveness. However, CE models are more resilient than linear systems. A linear economy is vulnerable because the product carries the entire economic value. If, for example, the price of the material increases, the cost difference threatens the whole product chain. When applying this scenario to a CE, there are many additional steps and materials that are valuable therefore less vulnerable to these types of fluctuations. It is not only the raw material put into the process that comprises value but also the ability to utilize the waste (Ellen MacArthur Foundation, Editorial Team, 2013). Finally, the idea of thinking in cascades refers to the many usage areas that one product or material could be used. One product could have many different application areas and should be utilized in each application area before being disposed, in order to use resources more efficiently.

3.3 How to Achieve a Circular Economy

By focusing on some areas, such as developing services instead of product goods and product design, the transition towards a circular economy could be accomplished. One area of focus with great importance is the maintenance of the value of resources. Separating biological and technical materials into two separate material loops where the biological material is filtered into the biosphere while the technical nutrients are put into a so called technical cycle (EPEA c, 2015). The principle behind the biological loop is that it contains products or materials that are either decomposable or able to be recycled. The products circulating in the biological loop are called consumption products and could for instance be packaging materials or clothing. On the other hand the technical cycle would contain the components of products constructed from synthetic materials, designed for longevity. In relation to the consumption products these products are entitled as products for service. In the technical cycle products for service should be easy to take apart and to repair. Products should be designed with modular components which could be easily replaced or re-used (EPEA c, 2015). By making these a service, it becomes a situation of not owning a product. More like renting it, with modular parts it can be easily fixed and thus the company that rents it to you is providing you a service. It would also be beneficial by having it easily fixed so it can be repaired and rent again later. The desirable outcome of having separate streams in the two cycles is to obtain the materials easily and in the purest form possible. It is important that they are not polluted or contaminated with chemicals allowing them to be able to be recycled multiple times while preserving their intrinsic material value. To accomplish separate material cycles or to attain uncontaminated materials actions addressing the value chain upstream and the designing of products are required. Furthermore, efficient use of materials and optimized material flow through the consumption chain further increase the movement towards a CE.

The increase of green house gas emissions is one of the consequences of using fossil fuels. A CE addresses every part in the consumption chain and provides a method for closing the circle for green house gas emissions. There could be an incentive to capture CO_2 emissions and use it as a resource instead of as waste. Michael Braungart and Douglas Mulhall (2012) suggest that this may be a way of fostering economic growth while steadily decreasing greenhouse gas emissions. By treating greenhouse gas emissions as a resource instead of a problem a new industry could be born. Research being conducted on maximizing the CO_2 uptake is currently in development. The emissions could for example be used for cultivating crops in rooftop greenhouses (Braungart & Mulhall, 2012).

Therefore, capturing CO_2 and utilize it on big scale in agro-industry processes is also part of the solution of the new way of thinking of emission as a resource. Braungart and Mulhall present some more examples of these industrial processes such as using large-scale algae cultivation which use CO_2 as the energy source. In addition, there are schools in New York setting up greenhouse on the rooftops where polluting CO_2 from classroom is used as a tool for science teaching (Braungart & Mulhall, 2012). In 2011 Walter Stahel wrote an article on the depletion of taxation on labor and that it could be a contributing act to a circular economy (Stahel, 2011). He believes that human labor is a renewable resource and that it should be free of taxation. A removal of taxation on renewable resources could increase and exhilarate the transition into a sustainable society.

3.4 Energy Recovery in a Circular Economy

Material recycling is the third step of the EU waste hierarchy (Figure 3) above energy recovery. Material recycling is, in the perspective of climate change, a better waste treatment method than energy recovery (Sundberg, 2015) However, as describe further in section 6.8, energy recovery might be a better treatment method than material recycling in other environmental perspectives such as circulating pollutions.

The report *Increased material recovery - What role will energy recovery play?* (Sundberg, 2015) discusses the correlation between material recycling and energy recovery as treatment methods. One conclusion made is that countries that have a well developed waste management also have a combination of waste treatment methods with a large share of material and energy recovery. Due to the large share of waste treated with material and energy recovery the share of waste disposed on landfills is low, meaning that the total emissions from waste management is low. A high share of material and energy recovery also indicates that a high amount of virgin material used for production of goods and fuel used for energy production could be replaced.

Energy recovery offers a possibility to utilize combustible rejects from the material recycling process, combustible material that for any reason was not sorted correctly, and combustible material which have too low quality for recycling. By recover the energy of these materials ensures that also these resources are brought back into the economy as electricity and heat replacing other fuels (Sundberg, 2015). Sundberg (2015) also points out that waste contains toxic substances and material which should be destructed in order to remove them out of the material recycling loop. This will be done in a safe way trough incineration.

4 Legislation and Frameworks

This chapter presents the waste legislation in the European Union and Sweden. The submitted legislative parts are presented both to acquire background knowledge of the current waste legislation and knowledge of legislation related to the legislative proposal to review the recycling targets.

4.1 European Legislation

The European Union has several types of legal acts and there is a certain hierarchy between them. A binding legal act will always stand above a non-binding one. The five types of acts are in order of priority; regulations, directives, decisions, recommendations and opinions (EU-Upplysningen, 2015). Regulations are binding legislative acts which will apply across all member states as national laws as soon as they are put into force by means of publication in the European Official Journal. EU regulations stand above any national laws no matter their content of former applications.

A directive sets up goals and targets which the member states are obligated to achieve, but they are free to implement them using an approach decided on a national level. If a MS already has a law ensuring achievement, the country will not have to change anything. One example of this is the waste hierarchy which in Sweden already is implemented through for example the environmental code (1 chapter 1§ MB and 2 chapter 5§ MB). However, if a MS has not applied any laws that comply with the EU directive by the deadline presented, the directive may take the place of the absent law. The legal act type which this report will mainly focus on is directives.

A decision is directed directly towards a legal person, such as one or more specific member states or one or more individual companies. It is a binding act and will be applied as soon as it goes into effect. Recommendations and opinions are not binding acts and the member states are therefore not obligated to follow them. They may however be used in other ways, such as by allowing institutions to make their views known or suggest lines of actions without imposing legal obligations. They may also be used by the EU-court of justice when reinterpreting the EU-law (EU-Upplysningen, 2015; European Union, 2015).

4.1.1 Legislative Process

There are three main actors in the European law making process. The European Commission, the Council of the European Union and the European Parliament. The European Commission consists of a member from each state, while the Commission represents and act on the interests of the European as a whole. The current president of the Commission (2015) is Jean-Claude Junker. The Council on the other hand represents the governments of the member states and the presidency is here shared on a rotating basis. The parliament is directly representing the citizens after they are directly elected into office (European Union, 2015).

In principle, the legislative process begins with the Commission proposing a new law. This should be done for the purpose of protecting the interests of the EU and its citizens, while trying to satisfy the widest possible range of interests. According to the subsidiary principle, the EU should not interfere on issues that can be dealt with effectively on a national, regional or local level. In the development of a proposal the European Commission holds public consultations and consults experts through various committees and groups (European Union, 2015; EU-Upplysningen, 2015).

Following the standard approach, a proposal is produced at one of the Commission's various departments. It is put forward only after at least 14 of the 28 Commissioners agree on it. It will then be sent to the Parliament who will discuss it and may suggest amendments to it, before it is sent to the Council. The Council will decide on the proposal and on the parliament's standpoint. They may also make their own amendments. If the proposal does not pass, as the parliament approved it, the new version will be sent back to the parliament for a new review session. When the Parliament and the Council are in agreement, the law will be adopted. This must happen within three rounds of reviewing between the Parliament and the Council or the proposal will not pass (EU-Upplysningen, 2015).

4.1.2 The Waste Framework Directive

The Waste Framework Directive (WFD), 2008/98/EC, is the current directive on waste. It describes some of the most significant terms used in waste management. This includes, among other things, definitions regarding waste, recycling, and recovery. Equally important definitions such as when waste ceases to be waste and becomes a secondary raw material as well as the difference between waste and by-products are also included. The WFD also lays down some basic waste management principles and introduces the *waste management hierarchy* which can be seen in Figure 3.

Figure 3. The waste hierarchy (European Commission, 2015)

The directive (2008/98/EC) introduces *extended producer responsibility*, which aims to support a responsible design and production, taking fully into account the efficient use of resources through the whole life cycle. It also contains the polluter-pays principle which is working for that the waste producer and the waste holder will manage the waste in a way that guarantees a high level of protection of the environment and human health.

The WFD includes obligatory targets for the different categories of waste management which must be achieved by all EU members by year 2020 (European Commission a, 2015). Below are the current MW target for 2020 as described in article 11, § 2a, Directive 2008/98/EC.

> "(a) 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;"

Article 11 (Directive 2008/98/EC) also states that the European Commission must review the targets and possibly present a proposal with new or different targets at the latest by the 31st of December, 2014. The same article also states that MS shall report their current statuses every third year. If the targets are not being met, the MS will become under scrutiny as to why the targets have not been met. They will be required to file a report to the European Commission defending falling short of the targets and how they are planning to catch up.

Terms and concept related to waste management used in the WFD are further defined in the Commission Decision (COM 2011/753/EU). The decision also sets up rules and calculation methods on how to approach the targets set in the WFD which are described in greater detail in section 4.1.2.1 below. Some of the important details in the directive, which are relevant for this study, are presented and compared to the circular economy package in Table 5 and in appendix 1.

4.1.2.1 Calculation Methods for Fulfilling of the Set Targets

The Directive 2008/98/EC, allows for the MS to choose one of four methods to calculate their directives targets and prove that they have been met. These methods are closely described in the Commission Decision (COM 2011/753/EU) and in Table 3. The expressions "preparing for re-use" and "recycled" are used here as described in the directive 2008/98/EC:

> "16. 'preparing for re-use' means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing;
>
> 17. 'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;" (Directive 2008/98/EC)

This means that 'recycling' may allow including the rejected materials produced during the recovery operation.

Each country may choose which of these methods they want to use for verification of their compliance with the recycling targets in the waste framework directive. As confirmed through Sweden's Directive 2008/98/EC Implementation Report (issued to the European commission in the fall 2013), Sweden has chosen to use calculation method two (Gibbs b, et al., 2014).

Table 3. The four allowed alternative methods according to Directive 2008/98/EC. Table inspired by: (Ulvang, 2013) and (Sundqvist, 2013)

Calculation Method	Numerator	Denominator
Method 1	Recycled amount of paper, plastic and glass household waste	Total generated amount of paper, metal, plastic and glass household waste
Method 2a, Only waste from households	Recycled amount of paper, metal, plastic, glass waste and other single waste streams from households	Total generated amount of paper, metal, plastic, glass waste and other single waste streams from households
Method 2b, Waste from households and similar waste streams	Recycled amount of paper, metal, plastic, glass waste and other single waste streams from households or similar waste streams	Total generated amount of paper, metal, plastic, glass waste and other single waste streams from households or similar waste streams
Method 3	Recycled amount of household waste	Total household amounts excluding certain waste categories
Method 4	MW recycled	MW generated

4.1.3 The Packaging and Packaging Waste Directive

The EU directive for packaging and packaging waste, Directive 94/62/EG, was created to harmonize national measures concerning prevention and reduction of environmental impacts from the management of packaging and packaging waste. This was initiated by several member states, which introduced their own measurements to address their environmental concerns. It introduces an information system to facilitate identification and classification and it aims to prevent obstacles to trade, distortions and restrictions of competition for the purpose of ensuring a functioning internal market (European Commission j, 2015).

The directive 94/62/EG states that MS should introduce return and collection systems for used packaging in order to achieve the targets laid out in the directive. The following targets are set from the directive:

- By June 2001, 50-60% reduction by weight and by the end of 2008 should 60% by weight of the packaging waste be recovered or incinerated at waste-to-energy plants.
- By June 2001 should 25-45% reduction by weight and by the end of 2008 should 55-80% by weight of the packaging materials contained in packaging waste be recycled with a minimum of 15 % by weight for each material.
- By the end of 2008 should the following targets, for packaging waste to be recovered or incinerated at waste-to-energy plants, be attained:
- – 60 % for glass, paper and board
- – 50 % for metals
- – 22.5 % for plastics and
- – 15 % for wood

The directive 94/62/EG has been revised a couple of times since it first went into effect. The definition of packaging was clarified and the recovery and recycling targets has been raised. It was later revised to allow transitional periods for some MS and an extended list of examples of *non-packages* was also revised to clarify the definition (European Commission j, 2015). The entire list of relevant definitions is available in appendix 1.

4.1.4 The Landfill Directive

The aim of directive 1999/31/EC is to prevent the negative effects of disposing waste on landfills, on the environment, with special focus on emissions to water, soil and air. Mitigation of green house gas (GHG) emissions to air is central in the directive. It seeks to prevent and reduce all risks to human health, during the entire course of a landfill's life cycle. The directive includes relevant technical requirements and specifications for the management of landfills. In addition it creates standard protocol for the acceptance of waste and a list of prohibited materials to avoid risk. On this list is; liquid waste, flammable waste, explosive or oxidizing waste, hospital and other clinical waste which is infectious, used tires and any other type of waste which does not meet the acceptance criteria laid down in the 1999/31/EC directive annex 2. In the inert landfill the waste must be expressly included under the directive's definition of inert waste.

The directive specifies that the MS are obligated to reduce the amount of biodegradable MW going to landfills to 75 % by 16 July 2006, to 50 % by 16 July 2009 and to 35 % by 16 July 2016. This reduction is calculated for each country on the basis of the total amount of MW produced in 1995. The MS have been adopting different strategies to reach this target such as composting, incineration and pre-treatment, such as mechanical-biological treatment (Eurostat a, 2015).

4.2 Swedish Legislation

This chapter presents parts of the Swedish waste legislation and also includes Sweden´s recycling targets. The Swedish law is adapted after the EU directives. Regulations in the WFD are implemented into the existing environmental legislation called *Miljöbalken*. There are regulations and constitutions in the Swedish legislation which the EU directives are implemented through. Examples of these are the waste regulations, the regulations on producer responsibility for different products and the regulation on landfill.

4.2.1 The Swedish Environmental Code – Miljöbalken

The legislation regarding the environment is governed in the Swedish environmental code, Miljöbalken, (SFS 1998:808). The aim of the law is to support sustainable development and to make sure that future generations can live and have access to a wealthy and thriving environment. It is divided into 7 parts with 33 chapters. Chapter 15 regulates questions regarding waste such as the municipal collection and disposal obligations and the producer responsibilities. The regulation also defines terms related to waste management. Waste is defined identically to the WFD (Directive 2008/98/EC). Household waste is defined as "(…) waste generated by households and comparable waste from other sources "(SFS 1998:808).

In article 8 in WFD, *extended producer responsibility* is outlined and states that it is optional for the MS to take legislative or non-legislative measures to ensure that the producers act according to the extended producer responsibility. Sweden has selected to take legislative measures to ensure the producer responsibility. The main legal framework for extended producer responsibility in Sweden is laid out in Miljöbalken, (SFS1998:808), chapter 15, 6 §:

> "…the duty of producers to ensure that waste is collected, removed, recycled, reused or removed in a manner that satisfies the requirements for acceptable waste management in terms of health and the environment."

One of the objectives of the extended producer responsibility is to drive development during the production phase towards a more resource efficient and sustainable market. The ambition is to have long lasting products that are easy to recycle when necessary (Directive 2008/98/EC).

In the Swedish legislation there are also a MW collection and disposal obligations outlined in chapter 15, 8 §, which states (SFS 1998:808):

> "Unless other provision is made pursuant to 6§, municipalities shall ensure that: household waste generated in the municipality is transported to a waste treatment plant where necessary in order to protect human health and the environment and safeguard private interests; and household waste generated in the municipality is recycled or removed."

According to 8 § the municipalities are the actors which bear the main responsibility to take care of the generated household waste. They may outsource this externally to private companies to control the collection and management of the waste.

4.2.2 The Regulations on Waste, Incineration and Landfill

Regulation (SFS 2011:927) on waste is the overall guideline on waste, and develops the set of laws outlined in the environmental code, Miljöbalken. The regulation includes the main definitions and requirements outlined in the WFD.

The regulation on incineration (SFS 2013:253) describes and characterizes concepts related to waste and incineration. It states that an *incineration plant* is a construction (6 §, SFS 2013:253);

1. that is intended for incineration of waste with or without energy recovery,
2. where incineration of waste is made in a way that the main objective with the plant cannot be consider to be production of energy or material.
3. where more than 40 percent of the generated heat is from incineration of hazardous waste or
4. where other household waste than waste according to appendix 4 to the regulation on waste (2011: 927) covered by any of the waste types in chapter 20 01 and is separated at source or covered by any of the waste types in chapter 20 02, is incinerated.

In addition to incineration plants there are also so called *co-incineration plants*, which is described in 7 § (SFS 2013:253) as:

> An incineration plant that is: mainly intended for production of energy or material but where waste is used as normal fuel, additional fuel or treated with heat with the purpose of being disposed, and is not a waste incineration plant.

According to 37 § (SFS 2013:253), the heat produced in an incineration plant should be recovered to the greatest extent possible. The regulation also includes requirements on how the measurement of emissions to air and water should be conducted.

The regulation on landfills outlines rules and standard practice for the operation of landfills and harmonizes the existing laws with the WFD (Directive 2008/98/EC). For example it stipulates what kind of waste is permitted into the landfill, as well as any required prerequisite treatment steps. Ones put into the landfill the law further covers the compulsory steps for the final coverage and after treatment, which may include supervision and performing checkups for up to 30 years after the landfill is closed (SFS 2001:512). Landfills are separated in three categories, as in the WFD: landfill of hazardous waste, landfill of non-hazardous waste and landfill of inert waste. In addition to the list of non-permitted waste there is also a landfill ban on collected and sorted residual waste and organic waste (SFS 2001:512).

4.2.3 The Regulations on Producer Responsibility

The extended producer responsibility in Sweden addresses eight product groups. In the Swedish legislation there are regulations according to the types of products e.g. batteries, medicals, cars, electrical products and packages (Swedish Environmental Protection Agency, 2015). This section accounts for producer responsibility of packaging and packaging waste since it is relevant to this report.

The legislation for producer responsibility for packaging is regulated in SFS 2014:1073. The objective for the regulation is that: the producers should take responsibility for the products when they become waste. The waste should be taken care of in a way that is safe to both health and the environment, while the goals for recycling should be reached. The aim for the regulation of packaging and packaging waste is also to limit how packaging is used in the industry by making requirements as to the weight and volumes of the package (SFS 2014:1073).

Commonly used terms relating to packaging in terms of recycling and waste are also defined WFD (Directive 2008/98/EC). As one of the objectives of the regulations is to make sure that the recycling targets are reached, the regulation implements directly the targets from the packaging and packaging waste directive (Directive 94/64/EC). The Swedish legislation is more ambitious than the European with its higher recycling targets. They are presented in 15-23 § (SFS 2014:1073) for packages. Some of the targets are also presented in Table 4. The targets consist of recovery rates and contain benchmarks that should be achieved before the 1st of January 2020 and further reductions thereafter.

Table 4. Recovery rates for packages of different material and recycling paper (SFS 2014:1073, SFS 2005:220 and SFS 2014: 1074).

	2020	**After 2020**
All packaging waste	55%	65%
Packages of board, cardboard, corrugated cardboard and paper	65%	85%
Packages of plastic except for plastic packaging used for beverages	30%	50%
Packages of glass	70%	90%
Packages of metal except for metal packaging used for beverages	70%	85%
Recycling paper	75%	90%
Metal packaging used for beverages	90%	
Packages used for beverages consisting of polymeric material (plastic)	90%	

The regulation also introduces the producer responsibility for collecting and managing the packaging or recycling paper waste. The producer, importer or seller of packaging in Sweden is responsible of providing a system for collection and managing packaging waste or make sure that another waste management actor does so (SFS 2014:1073, 37 §).

The regulation on deposit system for plastic bottles and metal cans (SFS 2005:220) present regulations stating that, all beverages bottles and cans should be included in the Swedish deposit system. A deposit system can generate an opportunity to have a greater collection rate which in turn provides a higher recovery rate.

5 Circular Economy Package Proposal

This chapter presents the proposed circular economy package submitted by the European Commission, the background and contents of the proposal are presented.

5.1 Background to the Proposal

Globalization and a challenging economic situation drove the EU´s head of state and the governments of its MS to act upon making Europe "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion" (Committe of the Regions, n.d.). The European council met in Lisbon in spring 2000 to establish the Lisbon Strategy, to reach this ambitious goal. The strategy was at first only applicable to economic and social issues but the environmental concerns were also included just one year later. The Lisbon Strategy has resulted in the European Union adopting a ten-year growth strategy and renewing it every decade in order to achieve this goal (Committe of the Regions, n.d.; European Parliament, 2000; Europa summaries of european legislation, 2005). The ten-year growth strategies contains numerous of policies, initiatives and frameworks, Figure 4.

Europe 2020 is the current ten-year growth strategy in EU. It aims to create a smart, sustainable and inclusive growth by approaching five working areas: climate and energy, research and development, social inclusion and poverty reduction, employment, and education. Specific targets have been set for each of these working areas (European Commission c, 2015). For climate and energy sustainability the following targets have been set:

- greenhouse gas emissions 20% (or even 30%, if the conditions are right) lower than 1990
- 20% of energy from renewables
- 20% increase in energy efficiency

Seven flagship initiatives were identified by the Commission in order to work towards the agreed upon targets. They are divided into the three main parts: smart growth, inclusive growth and sustainable growth. In the category of sustainable growth the flagship initiative, Resource Efficient Europe is presented (European Commission, 2012). It is a framework developed to support action taking and policy making for a more resource efficient and low-carbon economy.

To be able to implement the initiative a series of policy plans, so called roadmaps, are being or have been composed. The Roadmap for a resource efficient Europe is already adopted and used while other roadmaps are still in the progress of being developed. A strategy for making the EU a circular economy is one of these which are currently under development. The CE proposal focus on a recycling focused society where waste is being used as a resource according to A Resource Efficient Europe initiative (COM(2011) 21 , 2011).

The Seventh Environmental Action Program (7th EAP) commenced in January 2014 and is developing the main ideas of the commission's roadmap to a Resource Efficient Europe from 2011 (COM(2014) 398 final/2 , 2014). It is supposed to be guiding the European environmental policies towards 2020 but also beyond by setting long term targets for 2050. For this mission it sets out three key objectives; "to protect, conserve and enhance the Union's natural capital, to make the union a resource- efficient, green and competitive low-carbon economy and to safeguard the Union's citizens from environmental-related pressures and risks to health and wellbeing" (European Commission b, 2015).

The EAP sets Europe on a path to decrease waste generation and for it to be decoupled from GDP growth. It aims at phasing out recoverable waste disposed on landfills, limiting incineration of non-recyclables and to bringing reuse and recycling to the highest level feasible (COM(2014) 398 final/2 , 2014).

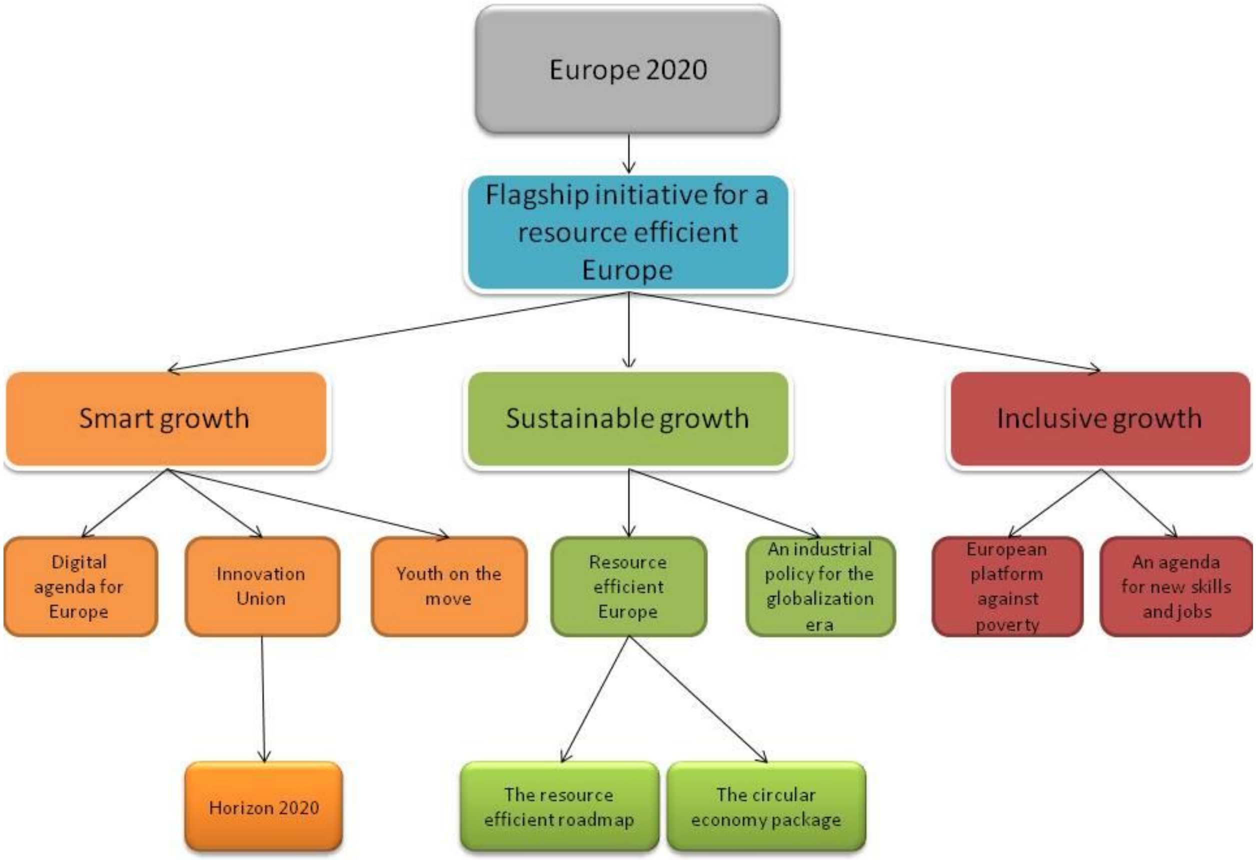


Figure 4. Schematic picture showing the relation between the EU initiatives based on information retrieved on the Europe 2020 Platform (European Commission c, 2015)

5.2 The Proposal, Presented and Withdrawn

In July 2014 the European Commission, led by José Barroso, presented a policy for moving towards a circular economy, called the circular economy package (European Commission e, 2015). The package contained a Commission Communication, COM (2014) 398, stating the policy, to the European parliament and the Council with arguments explaining the incentives of the proposal. It also contained a legislative proposal on changing some of the current waste directives (LPW) and three other initiatives in forms of Commission Communications on how to get the building sector more resource efficient, green employment, COM(2014) 446, and an action plan for small and medium enterprises (SMEs), COM(2014). The legislative proposals included e.g. new and harmonized definitions, higher targets on recycling and a new approach on how to measure these targets (European Commission h, 2015). The proposal aimed to regulate the waste treatment system and make sure that the member states are working their way up the waste hierarchy.

Horizon 2020, see Figure 4, is a research and innovation program that supports and implements the flagship initiative Innovation Union financially. It consists of several parts as Industrial Leadership, Societal Challenges and Excellent Science (European Commission g, 2015). Circular economy (EC) addresses each part of a products' life cycle and in order to implement a circular economy it is necessary to come up with new innovative technologies and ways for handling each of these steps. Annex to the Commission Communication (COM (2014) 398 final) explains, in a scheme, how the various parts and projects of Horizon 2020 can contribute to a circular economy.

The Commission Communication COM (2014) 398 "Towards a circular economy: a Zero waste program for Europe" reports that turning waste into new resources is an effective way of reducing virgin material inputs and thus reducing material costs for the European industry. The process of transitioning to a CE will cause new markets, businesses, recycling technologies to spring up around. Furthermore this will create new job opportunities leading to a sustainable economic growth approaching the Europe 2020. The CE would also introduce new business models and promote eco-design and industrial symbiosis which could move Europe towards zero waste. The commission stated, in the "Towards a circular economy: a zero waste program for Europe", that improved and more sustainable resource efficiency performance are reachable and can bring great economic benefits.

Sweden supported the proposal. A few member states were however negative as the targets were perceived as too ambitious and difficult to achieve[7].

As explained in section 4.1.1 Jean-Claude Juncker is the president for the new Commission and was elected in November 2014. He had an agenda for growth, jobs, fairness and democratic change. In his political guidelines he states, "I want a European Union that is bigger and more ambitious on big things, and smaller and more modest on small things" (Juncker, 2014). Juncker's Commission will work towards ten policy areas, for example towards a European Energy Union and for jobs, growth and investment (European Commission f, 2015).

When presenting the Commission's work plan for 2015, the commission explained that they had gone through all of the pending proposals. Proposals not corresponding with the Commissions´ agenda would be retracted and replaced by modified proposals. Juncker's Commission proposed to draw back the circular economy package with the explanation that they want to broaden the picture, as they think that the proposal only focuses on the end of life and waste treatment stages. The new commission feels the need to include an upstream perspective on, for example, products design (European Commission b, 2014). By also addressing the upstream product chain the Commission hopes to contribute to green growth and the subsequently added job opportunities which are directly in line with their objectives (European Commission c, 2014; COM(2014) 910 final, 2014). The reactions to the EU Commission's withdrawal of the circular economy package have been many and strong. The heavy criticism from member states, businesses and civil society lead (Wijkman & Skånberg, 2015) to the Commission committing to putting forward a new proposal by the end of 2015 (European Commission e, 2015).

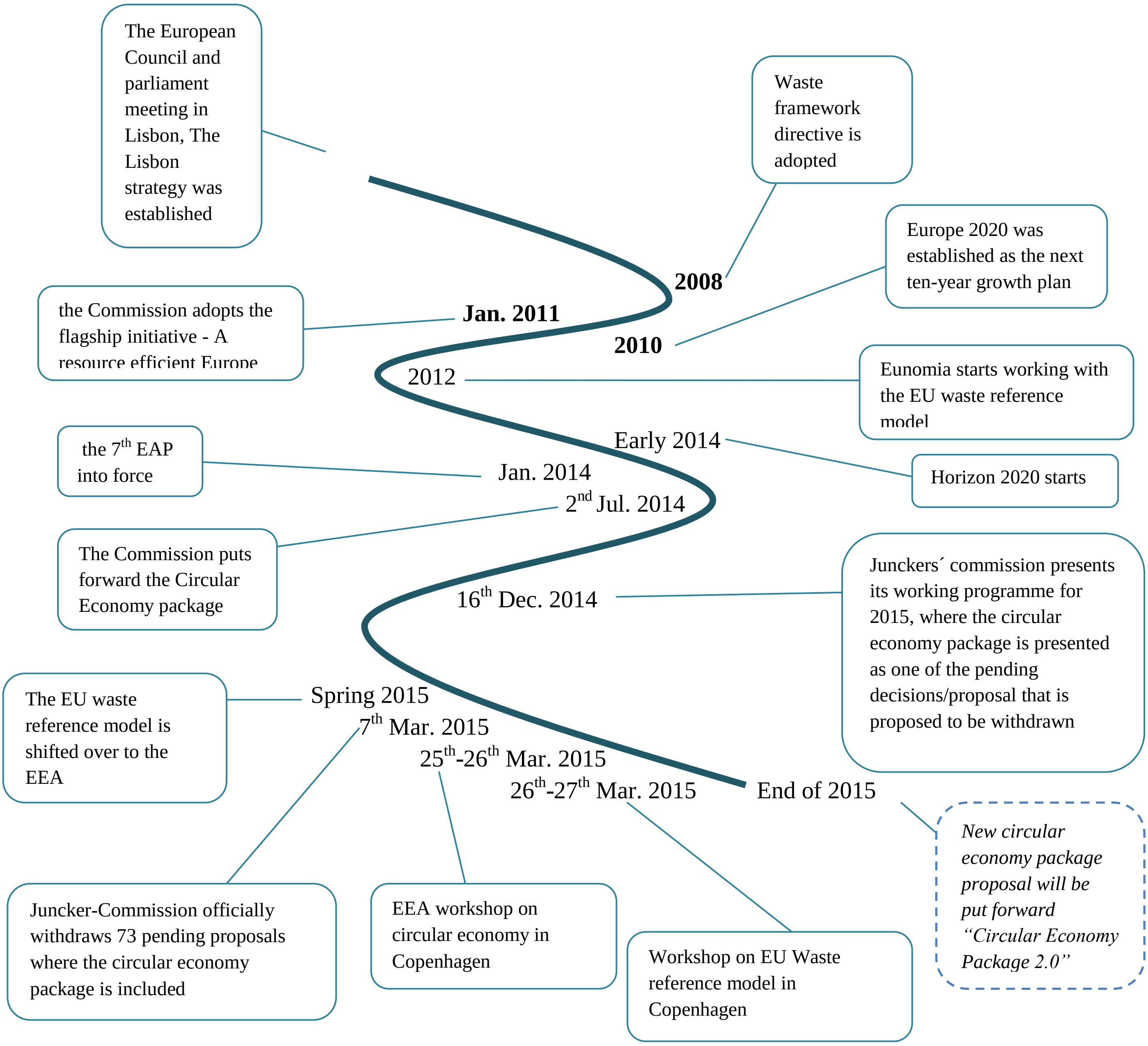
A workshop about CE and the new CE package was held in Copenhagen 25-26th March 2015. The message here was that the new package from the commission should be seen as a development of the old one that widens the prospective and is less waste focused. However the workshop gave the impression of a less enforceable and less detailed proposal concerning targets and recommendations. The workshop also addressed the need for new business models and the issue of a great knowledge gap concerning behavior[8].

[7] Jakob Sahlén, Technical Adviser on Energy Recovery, Avfall Sverige, personal communication 2015-22-05
[8] Jakob Sahlén, Technical Adviser on Energy Recovery, Avfall Sverige, personal communication 2015-31-03

For this study the “legislative proposal to review recycling and other waste-related targets in the EU” plays the leading role from the proposed circular economy package. This is the proposal to review recycling and other waste-related targets in the EU (LPW); Waste Framework Directive 2008/98/EC, the Landfill Directive 1999//31/EC and the Packaging and Packaging Waste Directive 94/62/EC and will be presented in a coming chapter 5.4.

5.3 Timeline

A timeline for the EU development process towards a circular economy is shown bellow.



5.4 Proposal to Change the Waste Framework Directive, the Packaging Directive and the Landfill Directive

5.4.1 Purpose of the Change

As a part of the proposed circular economy package the European Commission developed a proposal to change the current Waste Directives in different aspects as to more clear and direct definitions and new targets for waste management to be achieved by the year 2030 (COM(2014) 398 final/2 , 2014) This would help circulate the resources back into the system instead of losing them, as in the linear economy model of today.

One purpose of changing the directives is to simplify and clarify the measuring methods connected to the EU objectives. It is therefore important to define and adapt central expressions as well as develop and update the requirements. The proposal was also aiming to simplify the reporting process parallel with improving the waste statistics. This would be done with the focus on the targets and on an early warning system. Furthermore the proposed directive had the objectives to (SWD(2014) 208 final , 2014) :

- Simplify EU waste legislation by clarifying and simplifying measurements methods related to targets, adapting and clarifying key definitions, enhancing consistency in target setting, removing obsolete requirements and simplifying reporting obligations.
- Improve monitoring by improving the quality of waste statistics, particularly as regards targets, and anticipating possible implementation problems through an "early warning" procedure.
- Ensure optimal waste management in all Member States by promoting dissemination of best practices and key instruments such as the economic instruments, and ensuring a minimum level of harmonization of Extended Producer Responsibility (EPR) schemes.
- Establish mid-term waste targets in line with EU ambitions regarding resource efficiency and access to raw materials.

These objectives reflect the ambitions of the EU's seventh Environmental Action Program, which was adopted by both the council and the parliament and set into force in January 2014.

5.5 Content of the Waste Proposal put forward by the Commission July 2014

The proposal concerning changes to the waste management scheme as a part of the circular economy package suggested changes in recycling and other waste related targets in the EU Waste Framework Directive 2008/98/EC, the Landfill Directive 1999//31/EC and the Packaging and Packaging Waste Directive 94/62/EC. On EG Environments homepage they present what they themselves believe are the main elements of the proposal (European Commission k, 2015):

- Recycling and preparing for re-use of MW to be increased to 70 % by 2030;
- Recycling and preparing for re-use of packaging waste to be increased to 80 % by 2030, with material-specific targets set to gradually increase between 2020 and 2030 (to reach 90 % for paper by 2025 and 60% for plastics, 80% for wood, 90% of ferrous metal, aluminum and glass by the end of 2030);
- Phasing out landfilling by 2025 for recyclable (including plastics, paper, metals, glass and bio-waste) waste in non hazardous waste landfills – corresponding to a maximum landfilling rate of 25%;

- Measures aimed at reducing food waste generation by 30 % by 2025;
- Introducing an early warning system to anticipate and avoid possible compliance difficulties in Member States;
- Promoting the dissemination of best practices in all Member States, such as better use of economic instruments (e.g. landfill/incineration taxes, pay-as-you-throw schemes, incentives for municipalities) and improved separate collection;
- Improving traceability of hazardous waste;
- Increasing the cost-effectiveness of Extended Producer Responsibility schemes by defining minimum conditions for their operation;
- Simplifying reporting obligations and alleviating burdens faced by SMEs;
- Improving the reliability of key statistics through harmonized and streamlined calculation of targets;
- Improving the overall coherence of waste legislation by aligning definitions and removing obsolete legal requirements.

The proposal contained several proposed changes that in some way affect this study and to make the overview of these more perspicuous a table has been compiled below, see Table 5. It shows what the current directives have outlines, followed by the suggested changes. The green field indicates that it is proposed to be added or inserted under that paragraph or article. The orange field indicates that the current point is replaced by the proposal. An extended version of the table is to be found in appendix 1.

Table 5.Table showing current framework directive next to the proposal to change it

Article	§	Current waste framework directive	Proposal to change
3 Definitions	1	1.'waste' means any substance or object which the holder discards or intends or is required to discard.	(1a). "MW" means waste as set out in Annex VI*.
3 Definitions	15	15. 'recovery' means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations.	15(a). "material recovery" means any recovery operation, excluding energy recovery and the reprocessing into materials which are to be used as fuel*.
3 Definitions	17	17.'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.	(17a). "backfilling" means any of the following types of recovery: (i) recovery where waste is used in excavated areas such as underground mines or gravel pits for the purpose of e.g. slope reclamation, (ii) recovery where waste is used for the purpose of e.g. construction, land reclamation or landscaping and where the waste is substituting other non-waste materials which would otherwise have been used for that purpose*.
11 Re-use and recycling	2	(a) 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.	(a) by 1 st January 2020 at the latest, recycling and preparing for re-use of MW shall be increased to a minimum of 50% by weight**. (c) by 1st January 2030 at the latest, recycling and preparing for re-use of MW shall be increased to a minimum of 70% by weight***.
11 Re-use and recycling	4	4. By 31 December 2014 at the latest, the Commission shall examine the measures and the targets referred to in paragraph 2 with a view to, if necessary, reinforcing the targets and considering the setting of targets for other waste streams. The report of the Commission, accompanied by a proposal if appropriate, shall be sent to the European Parliament and the Council. In its report, the Commission shall take into account the relevant environmental, economic and social impacts of setting the targets.	4. For the purpose of calculating whether the targets laid down in paragraph 2(a) and (c) have been achieved, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process less the weight of any materials which were discarded in the course of that process due to presence of impurities and which need to be disposed of or undergo other recovery operations. However, where the discarded materials constitute 2% or less of the weight of the waste put into that process, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process**.
11 Re-use and recycling	5	5. Every three years, in accordance with Article 37, Member States shall report to the Commission on their record with regard to meeting the targets. If targets are not met, this report shall include the reasons for failure and the actions the Member State intends to take to meet those targets.	5. For the purpose of calculating whether the targets laid down in paragraph 2(b) has been achieved, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process less the weight of any materials which were discarded in the course of that process due to presence of impurities and which need to be disposed of or undergo other recovery operations. be understood as the weight of the waste which was put into a final preparing for re-use or recycling process**.
37 Reporting	4		4. For the purpose of verifying compliance with Article 11(2)(b), the amount of waste used for backfilling operations shall be reported separately from the amount of waste prepared for re-use or recycled or used for other material recovery operations. The reprocessing of waste into materials that are to be used for backfilling operations shall be reported as backfilling.

To get a clearer picture of how they are connected, Figure 5 has been created. The map shows that material recovery and energy recovery both fall under the definition for "recovery". Backfilling is a kind of material recovery (and therefore a kind of recovery) but is not included in the definition of energy recovery or recycling. It may be noted that recycling, backfilling and energy recovery all are different kinds of recovery.

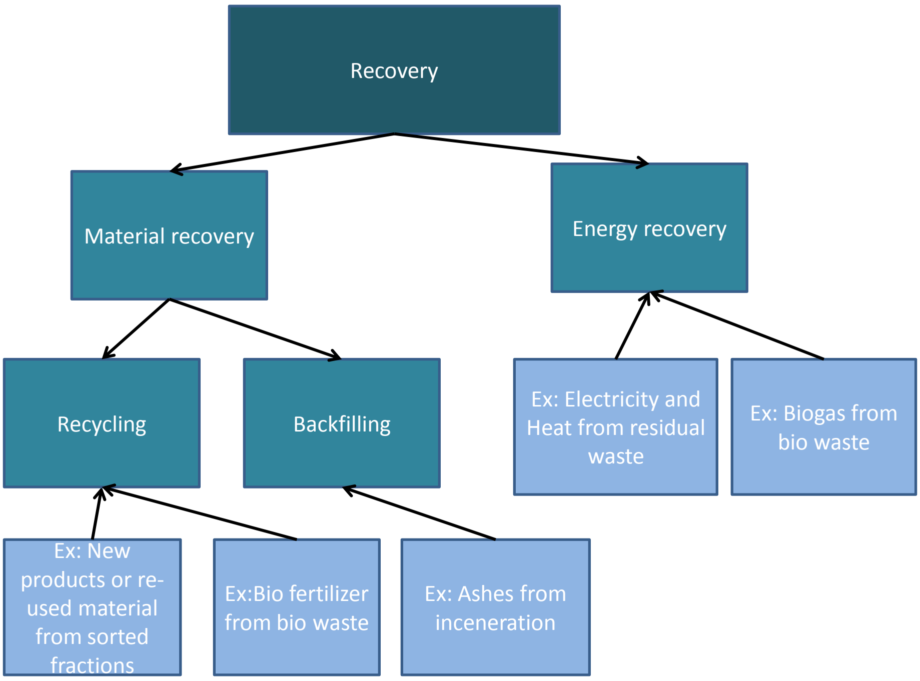


Figure 5.The map shows which definitions fall under each other. It is made according to the definitions in the directive proposal. It also shows examples of the different concepts.

5.5.1 Harmonization of Measuring Method and Definitions

One of the more relevant changes brought up in the proposal, both for this study and for the future work with waste management in Sweden, is the harmonized measuring points. As of now the EU allows four different calculation methods to be used whilst calculating compliance with the targets. This has been described more in detail in chapter 4.1.2.1. The proposal brought forward one single calculation method to be used by all member states and it was described as follows (COM(2014) 397 final, 2014):

> “For the purpose of calculating whether the targets laid down /.../ have been achieved, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process less the weight of any materials which were discarded in the course of that process due to presence of impurities and which need to be disposed of or undergo other recovery operations. However, where the discarded materials constitute 2% or less of the weight of the waste put into that process, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process.’”

What this part of the proposal says is that only the waste actually prepared for re-use or actually recycled shall be reported as such. The rejected material must now be counted as treated with the treatment method where it finally ends up.

This means that Sweden and many of the other member states would have had to adopt a new reporting system.

It is stated, in the target review project made for the proposal (appendix 9) that the key objectives for harmonization of the reporting would be to ensure that the MS are reporting the same thing. It is pointed out that (Hogg a, et al., 2014) :

> "If a target is intended to refer to 'recycling', and if 'recycling' is defined as "any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes", then it should be expected that this is what is reported on (and not what is 'collected for recycling', which, /../, may exaggerate the amount actually recycled by as much as 100 % (depending on the material, the collection method used, the nature of communications with users, the sorting process, etc.)"

The reason behind harmonizing definitions is presented in appendix 9, target review project. A waste stream which is referred to in a target must have a clear definition, so that the same waste stream is reported on in all countries. If this is not done, the *impact assessment* made for the LPW states that, there is no reason for countries not to adapt their reporting to make the achievements of the target easier. If the harmonization of definitions is not well executed there is no ensuring of the effectiveness of the established policies (Hogg a, et al., 2014).

5.6 Impact Assessment (IA)

5.6.1 The basis of the IA

Before the proposed changes to the waste directives were adopted, an impact assessment (IA) was executed. This was done to give a clearer picture of what changes could be done in the European Union and of what the effects of the proposed changes would be. Several alternative courses of actions (see appendix 2) were proposed and the assessment was done for each of these, with the help of a model made in Microsoft Excel 2010. This model was meant to be maintained by the EEA, but was developed and used in a primary stage by the consulting firm Eunomia. The outputs were then summarized in two modules which together include the following (European Commission a, 2014):

- Summary of Cost-Benefit Analysis results
- Assessment of the distance to European waste directive targets
- Indicators relating to resource efficiency
- An evaluation of anticipated impacts on employment

This was investigated for a few different courses of action. For example, no changes in the targets but full compliance among all MS, different versions of increased recycling targets and harmonization of definitions. Appendix 2 includes the different options studied in the IA.

For the collection of data, relevant officials from each of the member states were identified and sent questionnaires. For missing data or when further information was necessary, member states were visited in person (Gibbs b, et al., 2014).

The impact assessment concluded that the most cost effective alternative which also creates the most job opportunities, were those changes which would contribute to the largest reduction of GHG emissions. These alternatives included the 70% reuse/recycling target by 2030, the increase of targets for packaging waste (80% overall reuse/recycling) and the phasing-out of landfilling of recoverable MW. An overview of the modeled scenarios and the results of the modulations, presented in the IA, are shown in appendix 2. The directive that in the end was proposed by the commission was in accordance with the IA results.

5.6.2 The European Reference Model on (Municipal) Waste

The Model used for the IA is an advanced Microsoft Excel 2010 model, developed and run by Eunomia. It is a socio-economic model which consists of three base units; in-data, calculation unit and result. The in-data is, for example; generated waste, the waste's composition, the recycling rate and costs connected to the treatment and collection. The calculation unit is the core of the model and consists of six modules; mass flows, waste prevention, collection, economic costs, environmental impact and job opportunities. The mass flow module is based on the waste hierarchy and the waste flows through the module to the different treatment methods in this priority order. The results generated by the model are the social economic benefit, indicators for resource efficiency, the distance to set waste treatment targets and the influence on job opportunities (Gibbs a, et al., 2014).

During spring 2015 the model was handed over from Eunomia Research and Consulting to the EEA and in March a workshop to introduce the model to the MS was held under the name: Expert workshop on the European Reference Model on (Municipal) Waste. The model is continuously (as of today: 2015-22-04) under development and will soon be tested by being introduced to a few interested countries.

The purpose of the model is to give a clear picture of a scenario of the future, where the results are based on complete compliance to the target. The results are mostly shown in relation to other alternative scenarios. The model has for example shown that under the given assumptions a recycling target of 70% will have lower costs than a target of 50%. However, this result is relative to the 50% scenario and the costs will increase compared to a business as usual scenario (Zoboli, 2015).

Dominic Hogg and Timothy Elliott, from Eunomia Research and Consulting, are the model developers and were also present at the Expert workshop on the European Reference Model on (Municipal) Waste. They explained that even though it is a flexible model, there is a range of parameters that will not be possible to change for individual countries or over time. Two examples of parameters which will be constant over time are; collection systems and the specific waste composition. The model is limited by the decision to only include emissions to the air in the environmental impact module. Among other things the importance of being aware of the assumptions and limitations in the model while communicating the generated results, was discussed at the workshop[9].

5.6.3 The Modulations for the IA, Approach and Assumptions

The performance modeling which is done to project 2020 targets is based on each countries current calculation method. However, for the 2025 and 2030 targets it is assumed that method four is used for all member states (Gibbs a, et al., 2014).

In a mail correspondence with Timothy Elliot, from Eunomia Research and Consulting, he was questioned about how data relating to the losses and rejects have been accounted for in the IA. He states that for the modulations the total "loss" rate includes losses at sorting plants and inputs to

[9] Dominic Hogg, Chairman, and Timothy Elliot, Senior Consultant, Eunomia Research and Consulting, personal communication 2015-26-03

reprocessors, but does not include losses during the recycling process itself. He further explains that the loss rate at reprocessors refers to the fact that when bales of recyclables turn up at reprocessors there is almost always some non-target material in the bale as a result of an imperfect sorting process. For metals he says this is just a few percent but for plastics it is quite a bit higher[10]. Elliot admits that the intention of the model was never to include the recycling process losses, for example due to reduction of the material quality. He thinks that the wording in the proposal was too ambiguous in this respect and says that he hopes it will be clearer in any future versions of the legislation.

Elliot was also asked about rejects from the waste-to-energy process. He explained that these are only included in the environmental analysis, where the benefits from recycling metals collected from the bottom ashes are taken into account. However, the bottom ashes are not accounted for nor are the metals calculated for the recycling rate. This is, according to Elliot, because they are classified as industrial waste.

Elliot was also interviewed regarding products from biological treatment, divided into material used for fertilizer and material used as energy (in the form of fuel), such as biogas production and how they are handled in the IA. He simply stated that "Food waste composted or digested in an anaerobic digester is considered 'recycling' for the purposes of calculating the targets"[11].

5.6.4 Rationale for choosing 70% recycling rate for MW

Appendix 6 to the IA states the case l for choosing the recycling rate of 70% (Hogg b, et al., 2014). It argues that although it may be a difficult task, that it is a realistic target in a medium- to longer-term perspective. This appendix is trying to answer the frequently asked question: "what rate of recycling is achievable"

The recycling rate depends on different factors and the report lists a few here:

- The composition of waste
- The infrastructure and information made available to people regarding the recycling service
- Methods of incentives
- Housing stock
- The current state of technology
- The market for materials extracted from the waste stream

To find out what is realistically possible stakeholders were asked, as a part of the Consultation on the European Waste Management Targets, what they felt is the highest recycling rate that could be achieved. The average response for MW was a target of 70%.

The report points out that a vast majority of the MW is recyclable but in some cases it may be a question of cost. This resonates very well with what Anna Fråne from IVL brought up in the interview conducted on 2015-13-03. She pointed out that it is often possible to make better machines and get higher rates, but the limitations is both financial cost and energy costs.

The impact assessment brings up Avfall Sverige as a reference and refers to their survey which shows that 60% of the residual waste stream produced by households in Sweden can be recycled. This is

[10] Timothy Elliot, Senior Consultant, Eunomia Research and Consulting, e-mail 2015-05-05

[11] Timothy Elliot, Senior Consultant, Eunomia Research and Consulting, e-mail 2015-05-05

taken from their report, Avfall Sverige (2012) 2012: Swedish Waste Management, September 2012, where it goes on to state that in households, which today do not separate their food waste for separate collection, about 80% of the residual waste stream could be recycled.

A study made on Wales by Eunomia shows that it is difficult but not unrealistic with a recycling target at 70% for year 2024/25. This could be done with rapid advancement in sorting and reprocessing technologies. As a result of these results the Welsh government introduced a recycling target for all local authorities for waste collection to be at 70% (Hogg b, et al., 2014).

To investigate the possibility of whether MS could reach a recycling target of 70 % by 2030, a list of assumed capture rates for each material in each MS was combined with the waste composition. This combination made it possible to produce a list of estimated recycling rates for each country. From this it could be seen that all MS except for Bulgaria has the possibility to reach 70% recycling. Bulgaria's recycling rate of 68% was due to their poor knowledge of how much of their category "other waste" contains recyclable materials. This was largely affecting the results as one third of Bulgaria's MW was attributed to this category and it was assumed to contain as little as 50% recyclables (Hogg b, et al., 2014).

5.6.5 Assumed waste flows for Sweden when modeling for IA (annex 1 EU waste model)

Data was collected for all member states through a questionnaire. Beyond the normal data collection, investigators came to Sweden additional and held meetings with the Swedish Environmental Protection Agency and the Swedish Environmental Institute (IVL).

The investigation found input data for the IA model where these data included information about collection systems, waste composition, sorting and treatment systems. It was noted that the recycling figures for Sweden are based on the amount of material collected for recycling and therefore exclude the reject losses. The reject losses reported from Sweden for the IA is as presented in Table 6

Table 6. Reject losses reported for Sweden for the IA (Gibbs b, et al., 2014)

Fraction	Estimated reject losses
Newsprint and paper packages	0.5 % at the sorting/control facility.
Paper packages excluding corrugated cardboard	23.5 % wet weight or 14.1% dry weight as reject at the paper mill
Corrugated cardboard	2 % dry weight at paper mill
Newsprint	24 % dry weight of deinking sluge and fibre reject at the paper mill
Metals	0.5 % sorting/control facility (packaging and other metal items)
Plastics	25 % at mechanical processing facility (related to packaging)
Glass	5.7 % at mechanical processing plant

As for organic treatment, incineration, MBT and landfilling no detailed information was provided in the IA. Some explanation for this was given by Timothy Elliot and was presented in the previous chapter 5.6.3.

How the rejects in Table 6 are used in the actual model is not made completely clear in the reporting. From interpreting the report and from personal contact with the model founders, which also ran the IA model, it is understood that the model will account for that the input data from Sweden is data for collected for recycling. Annex 1 in the AI announces that model outputs are accounting for rejects from collected recycling and recycling extracted from residual waste treatments.

Similar investigations and predictions were made for all MS and were compared against the cases of Germany and Croatia, also studied for this paper. The result is presented in appendix 2.

6 The Waste System

6.1 Waste Generation and Management in Sweden

The work in this report is based on waste figures from 2013 when the total amount of collected MW in Sweden was reported to be 4 447 880 ton[12]. This is equivalent to every Swedish person on average having generated 461.2 kilos. The national data is reported for collected waste and for 2013 the distribution of the MW between treatment methods, was as follows; 33% material recycling, 16% biological treatment, 50.3% to energy recovery, and 0.7% to landfill (Avfall Sverige b, 2014).

Since 1994 the material recycling has doubled and the biological treatment nearly quadrupled due to the introduction of food waste source separation in many municipalities. The energy recovery during the same period has made a 70% increase while waste disposed at landfills has decreased by 98% (Avfall Sverige b, 2014). The fast decrease of waste being disposed on landfills has been affected by the ban on landfilling of sorted combustible waste initiated in 2002 (SFS 2001:512) as well as the landfill ban on organic waste from 2005 (SFS 2001:512) (Miljömål, 2015).

6.2 Waste generation and Management in Europe

Conducting a study over Europe as a whole is important as it helps to put the Swedish waste system in perspective.

During the 21st century the MS have been climbing up the waste hierarchy. Between 2001 and 2010 the EU-27’s landfilling rate decreased by 41 million tons, while incineration increased with 15 million tones, and the recycling and composting by 28 million tons during the same period (EEA, 2013). However, there are very large differences between the performances of the different member states. Figure 6 gives an indication of the overall treatment and development in the European countries. One example of the great differences is the amounts of landfilling. In Sweden 0.7 % of the MW was reported to end up in a landfill in 2013, in contrast as for the whole of Europe where it is as high as 34 % (Avfall Sverige b, 2014). Figure 6 (left) shows that between 2001 and 2010 there have been many countries that have climbed up the waste hierarchy. The figure also shows that in 2010, 11 of 32 European countries (EU 27, Croatia, Iceland, Norway, Switzerland and Turkey) sent more than 75% of their waste straight to a landfill. A country may fit in more than one of these categories, as can be seen in the case of Sweden, where the country has both more than 25% recycling and more than 25% incineration. Figure 6 (right) clarifies the treatment distribution in each country in 2009.

[12] In the calculations made for this report, this number is replaced with 4 537 392 ton as grease trap residues, frying grease and cooking oil is included. These fractions are defined as MW but were not included in the statistics provided from SAH 2014.

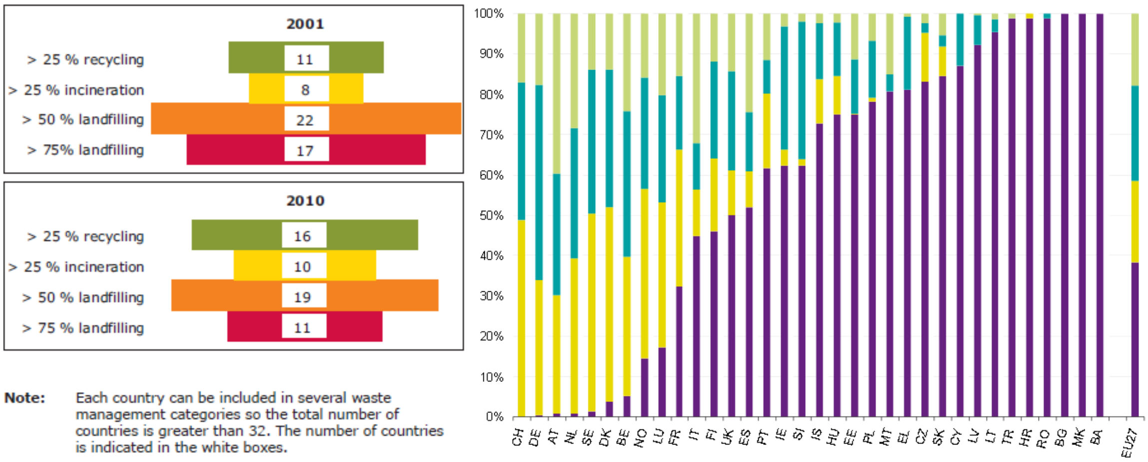


Figure 6. (left) Number of countries at different levels of the MW management hierarchy, 2001 and 2010 (EEA, 2013). (right) Municipal waste treated in 2009 by country and treatment category, sorted by percentage of landfilling (% of municipal waste treated) (Eurostat a, 2015).

When it comes to the collection systems and waste treatment systems, every country has vastly different strategies and it is therefore not possible to say so much about Europe as a whole.

6.3 Administration of the Swedish Waste Management

Sweden has initiated producer responsibility rules, as described in chapter 4.2.3. This means that for materials covered by this legislation, the producers are responsible for the collection and treatment of that specific waste. The MW not covered by the producer responsibility, then falls into the responsibility of the municipalities. However, it is the obligation of each individual household to sort their waste, in order to be in compliance with both, the producers', and the municipalities' available collection systems.

Municipalities are increasingly working with prevention and reuse, to climb the waste hierarchy. They are obliged to have a waste plan and local rules stipulating how to handle the waste treatment. The municipalities may choose themselves to organize the collection of household non packaging waste or they may contract an entrepreneur to do so. Examples of organization strategies which the municipalities may use are; to have self-administration, a municipal enterprise owned independently or jointly with other municipalities, joint boards, or a municipal association (Avfall Sverige b, 2014).

Avfall Sverige reports that 71% of municipalities hired private actors for the collection of waste in bins and bags in 2013. While only 22 % of the municipalities executed the collection themselves and the remaining 7% was in the process of organizing a combination. The treatment of the waste is also either done by the municipality itself or by an external actor which may be either a private actor, or another municipality or municipal enterprise (Avfall Sverige b, 2014).

The waste producer will have to go to a recycling station or to a recycling centre for the collection of waste, which is not collected via door to door collection. A recycling center is a manned station which receives among other things bulky waste, garden waste, waste from electric and electronic equipment, as well as hazardous waste. A recycling station is a smaller facility for packaging and paper, these stations may also be placed in various locations around a city centre (Avfall Sverige b, 2014). The recycling stations are called bring sites. Sweden has set up separate recycling targets for beverage packaging, presented in Table 4. To more easily collect beverage packaging, plastic bottles and metal cans are collected in a separate deposit system. The consumer will be repaid a small amount of capital when the beverage package is returned (Returpack, 2014).

6.4 National Waste Management Actors

Because of the municipal waste collection and disposal obligations, there are a lot of municipally owned waste management companies. Their business is often focused on environment and energy.

The material fractions which are included in the targets for packaging in the directive 94/62/EC are among others; glass, plastic, metal, cardboard and paper. Due to the producer responsibility, some of the packaging producers which manage the same types of material in their packages, have come together and formed collaborative material companies to manage their producer responsibility. In Sweden, these companies are Plastkretsen, Svenska Metallkretsen, Returkartong, Svensk Glasåtervinning and Pressretur. The actors within the market for collecting and recycling of packaging are Förpacknings- och Tidningsinsamlingen, FTI AB, and TMR AB. The two companies both provide services for producers in the packaging market. FTI is owned by the five afore mentioned material companies and is responsible for the operating business for three of the five companies. Svensk Glasåtervinning and Pressretur independently organize the collection of packages (FTI AB b, 2015).

TMR is a private owned company which, similarly to FTI, offers services for producers adhering to the regulations for producer responsibility for packaging. TMR collaborates with municipal waste companies and recycling companies that provide domestic collection of packages for both household and companies. TMR also has a utilization agreement with FTI for handling those customers that does not have access to the domestic collection of packages (TMR AB, 2015).

In 2013, there were 32[13] waste-to-energy plants that treat residual household waste, in accordance to the municipal waste collection and disposal obligation according to SFS 1998:808, chapter 15, 6 §. These are to large extent municipal enterprises[14]. However, there are also some private investors running waste to energy plants, often related to the district heating business.

6.5 Waste Import related to Energy Recovery

Waste treatment is not only a national matter. In 2013 over 301 500 tons of MSW was imported to Sweden (Avfall Sverige, 2014).The national capacity for energy recovery is continuously growing and is already much larger than the nationally available resources. The available capacity for energy recovery enables Swedish plants to import waste from other countries, preventing landfilling (Avfall Sverige, 2014). The possibility for import and thus preventing landfilling in other countries, by lowering the amount of Swedish waste sent to incineration, will according to Profu AB (2013) give a climate benefit. Johan Sundberg at Profu AB also states that if a 70% recycling target would be enforced in combination with landfill bans, the capacity of the European incineration plants would most likely be inadequate to take care of all the rejects from the recycling processes[15].

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[13] At the time of writing this number is 33 (spring 2015).
[14] Jakob Sahlén, Technical Adviser on Energy Recovery, Avfall Sverige, personal communication 2015-22-05
[15] Johan Sundberg, Doctor of Technology, Profu AB, e-mail 2015-11-06

6.6 Rejects in the Waste System

If the recycling system is to be considered in a very general manner, Figure 1 in chapter 2 is a fine starting point. It shows the general steps in a recycling process chain. However, there might be more steps in between, such as second sorting processes. In each step of the recycling process, rejects will arise. Losses will, for example, occur due to misplaced material, dirt and moist or low quality of the material (Hogg a, et al., 2014).

The main rejects in the Waste-to-energy process are either from the flue gas treatment residue or the slag from the furnace, consisting of inert material. The flue gas treatment residue contains toxic substances and it will be stabilized and landfilled or used as a neutralizer during the re-filling of mines (Avfall Sverige b, 2014). Sweden sends fly ash to the Norwegian island Langöya, for instance, where it is used as stabilizer in a limestone quarry (Svenska Energiaskor, 2012).

The slag consists of a course gravel and metal scrap. The metal may be extracted and material recycled (Ragn Sells, 2015). Left in the slag will then be the slag gravel consisting of materials such as; glass, china, sand and other rock like material (Sysav, 2013).

Material which is sent to landfills is material which there is no other treatment option for. This may be porcelain, ceramics or glass but it may also be contaminated substances which there is no other treatment for. There will be no reject from the material that is sent to a landfill. However, there is a collection of gas from the landfill which is created through anaerobic digestion within the landfill (Avfall Sverige a, 2014).

6.7 Swedish Compliance with Directive Targets

Depending on how the calculations are performed and what measuring method is used, material recycling rate in Sweden differ. The numbers used above are the official national count presented by Avfall Sverige, while the recycling rate reported to the EU is different.

The Swedish government specifies that method two is used for the report to EU. In the case of Sweden the numerator is: amount of recycled paper, metal, plastic, glass waste, biological waste, batteries and waste electrical and electronic equipment (WEEE). The denominator is the total amount of generated paper, metal plastic, glass waste, batteries and WEEE. The measuring point is the producer responsibility collection output. The recycling rate was reported to be 62% for 2010. For glass, paper, metal and plastic the separately collected waste is divided with the total amount of waste, while for the waste covered by the producer responsibility is divided with the amount that was set on the market (produced and imported) (Ulvang, 2013). Eq 6.1 shows how the reported recycling rate for Sweden is calculated.

$$\frac{\text{recycling amount of paper,metal,plastic,glass waste,biological waste,batteries and WEEE}}{\text{total generated amount of paper,metal plastic,glass waste,batteries and WEEE}} = \text{reported recycling rate} \qquad \textit{Eq 6.1}$$

6.7.1 The four methods

In a report from SMED the Swedish recycling rate has been calculated for all the four methods allowed for reporting a MS compliance with the WFD. The definition of each method is presented in chapter 4.1.2.1.

Sweden, bases their calculations on method 2, and according to the division presented by Sundqvist (2013) it would be, more specifically 2b, including biological treatment and WEEE (Ulvang, 2013) according to how the calculations are described in Table 7. This means that Sweden reports a material recycling rate of 62% (Ulvang, 2013). These calculations are made for values from 2010 as the sources for data are “Avfall i Sverige 2010” (Naturvårdsverket, 2012) and “Svensk Avfallshantering 2011”.

Table 7 is an extension of Table 3 in chapter 4.1.2.1, including more detailed variations of 2a and 2b and including the calculated recycling rates for Sweden. The values are from 2010 which means that it may have changed now (spring 2015), however the calculations show the recycling rate’s dependence on which is the used calculation method.

Table 7. The recycling rates of Sweden calculated with the four allowed methods, based on (Ulvang, 2013)

Calculation Method	Recycling rate and Preparation for Reuse
Method 1	61%
Method 2a, Only waste from households	45-48% depending on which materials are included
1. Paper, metal, plastic and glass	61.3%
2. Paper, metal, plastic, glass and biodegradables	44.8% (46.1% if including home composting)
3. Paper, metal, plastic, glass, biodegradables, batteries and WEEE	48.3% (49.4% if including home composting)
Method 2b, Waste from households and similar waste streams	60-68% depending on which materials are included
1. Paper, metal, plastic and glass	68.0%
2. Paper, metal, plastic, glass and biodegradables	60.4% (excluding home composting)
3. Paper, metal, plastic, glass, biodegradables, batteries and WEEE	62.0 % (excluding home composing)
Method 3	41%
Method 4	49%

6.7.2 Predictions for the Future

The material recycling is predicted to increase with a total of 25% by 2020 in a report by Profu (Profu AB, 2013). In this study they predict that the total MW will increase while the plastic recycling will increase to achieve a target at 50 %, which until now has not yet been reached. They further predict that there will be a decrease in generated food waste which will increase the percentage of material recycling even further. The increase of material recycling will, according to the report, cause the energy recovery to decrease by 5% during the same period. The amount of waste generated is however predicted to increase. This numbers are calculated using the current calculation system (Profu AB, 2013).

Figure 7 shows the changes in treatment from 1975 to 2010 and how it’s predicted course to the year 2020.

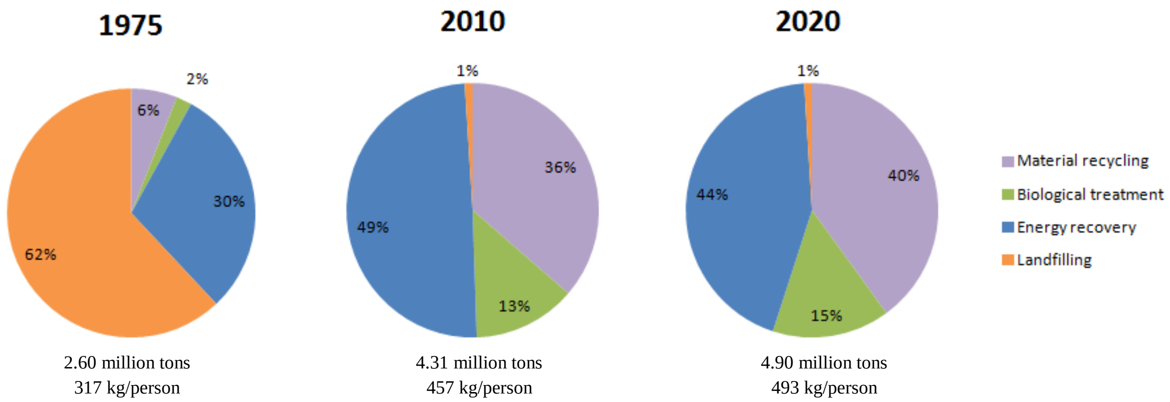


Figure 7. Treated and generated amounts of MSW in Sweden between 1975-2020 (Profu AB, 2013)

A similar study was made for each MS in the impact assessment modeling for the currently withdrawn circular economy proposal. The prediction for Sweden was that the collection for recycling would stay constant at 33% while the percentage of collection for organic treatment will double by 2020, from 15% in 2011 to 30% by the year 2020. The impact assessment predicts an even more drastic reduction of energy recovery from 51% in 2011 to 36% in 2020. For the year 2030 the prediction is that the distribution will remain constant from 2020. However, an increased total amount of MW is predicted. This is expected to be 5 113 000 tons in 2020 and 5 673 000 tons in 2030 (Gibbs b, et al., 2014). This is shown in Table 8.

Table 8. Prediction for 2030 in Sweden made for IA (Gibbs b, et al., 2014)

Total generation	Collection for recycling	Collection for biowaste treatment	Collection for energy recovery	Collection for landfill
5 673 000 tons	33%	30%	36%	1%

Using the aforementioned predictions, the future waste treatment system was modeled for the IA. The result can be seen in Figure 8. It shows the result as measured using method 2, Sweden's current reporting method, and the result using method 4. Sweden generally uses the collected amounts of waste when reporting; this is compensated for by subtracting rejects during the IA calculations for both calculation methods. To what extent or to what precision is not made known in the official documentation. The creator of the model does however point out that there are a lot of rough estimates made[16]. A list of reject streams is included in the annex of the IA and is based on the information collected for the IA. This list is however far from complete. It may be seen in Table 6. Figure 8 shows that based on these predictions, Sweden is on course for full compliance with the current waste framework target for recycling, based on either of the aforementioned measuring methods. The suggested target of 70% will also be reached with measuring method 2 according to these predictions (Gibbs b, et al., 2014).

[16] Dominic Hogg, Chairman, Eunomia Research and Consulting, personal communication 2015-26-03

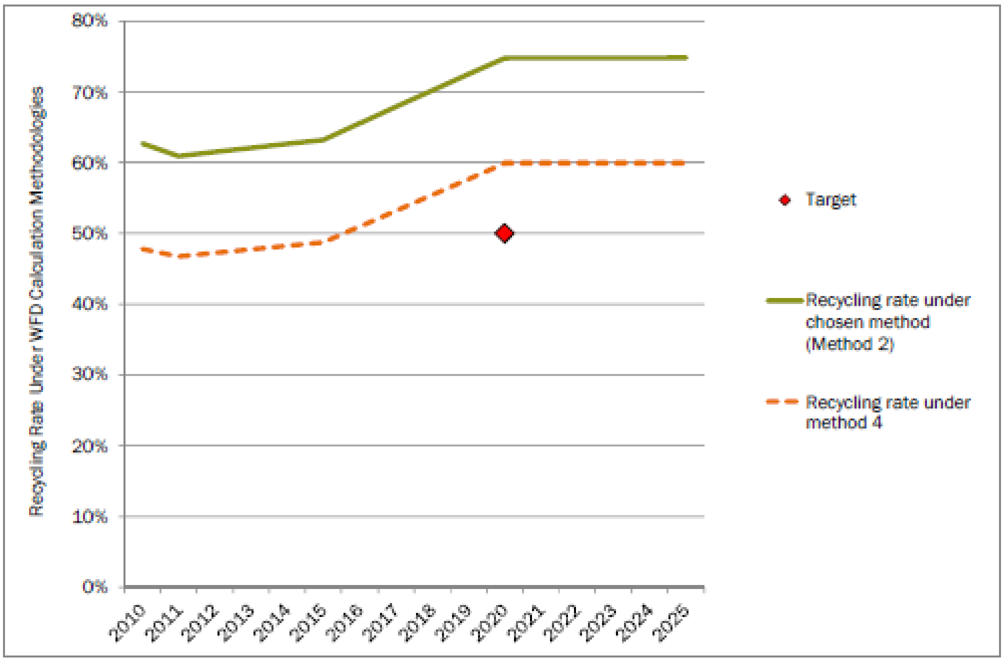


Figure 8. Prediction of the future recycling rate of Sweden with method 2 and 4. The target is the current one set out in the Waste Framework Directive (Gibbs b, et al., 2014)

6.8 Plastic Recycling System

This chapter presents some basic information about plastics and the recycling of plastics.

6.8.1 Different Kinds of Plastic

Plastic consists of organic polymer chains and is often made from crude oil. The crude oil is processed through a distillation process where it is separated into smaller fractions. Plastics are commonly divided into two groups after their characteristics, thermoplastic and thermoset. Thermoplastic can be re-heated and molded several times while thermoset plastic cannot be melted once it has hardened. Depending on the substances the polymer chain is constructed of, it is separated into different subgroups. Examples of thermoplastics are polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC) (Plastics Europe, 2015).

PET plastics are often used to beverage packaging such as PET-bottles or juice packaging. PVC is among other areas commonly used for building products or food and drink packaging. PP is used in a variety of areas where examples are in packaging and textiles. PE is the type of plastics that is produced in the largest volume and is commonly used. It can be produced in a high density form (HDPE) and in a low density form (LDPE) where example of usage areas is kitchen ware, packaging and plastic films (Plastics Europe, 2015). Plastics falling into the limitations outlined in this report are municipal plastic waste, e.g. packaging for consumer goods and wrapping, plastic film, PET-bottles and non packaging plastic. Non plastic packaging is commonly collected at recycling centers or through door-to-door collection. It consists of buckets, plastic outdoor furniture and pots for example. According to Avfall Sverige’s statistical web site, Avfall Web, there were 34 municipalities reporting to collect non packaging plastic as a separate fraction at their recycling center in 2013. However, there may be municipalities who do not report their non packaging plastic collection to Avfall Web.

To provide the plastics with desired characteristics such as softness, elasticity, stability and hardness, additives are added to the polymer chains during the manufacturing process. Many of these additives are seen as pollutants and affect both the environment and the human health. Phthalates are used as softeners while Bisphenol A is used as stabilizers. They could affect the reproduction ability and are hormone disrupting (KEMI, Swedish Chemical Agency, 2014; Klar, et al., 2014). Brominated flame retardants are also a common additive to use and are as well hormone disrupting. There are different amounts of additives depending on the plastic type and the usage area for the plastics. For example are electronic products, commonly produced with PE and PP, and cables of PVC or PE, consisting of a lot of brominated flame retardants. In the opposite, is plastic packaging used for food often thoroughly controlled since the plastic is in direct contact with the food (Bibi, et al., 2012).

Since one of the main components in plastic is crude oil it is beneficial from a climate perspective to recycle plastic. In some cases other fossil fuel based substances are also used when manufacturing plastics. By circulating and using the material again it cuts down on the usage of virgin material (e.g. additional extraction of crude oil) (Plastic Europe d, 2015). Two recycling companies in Sweden, Miljösäck and Swerec, states that recycling one kilo of plastic saves one liter of crude oil and 2 kilos of CO_2 emissions (Miljösäck AB, 2015; Swerec AB a, 2015). Miljösäck base their figures on three LCA studies of plastic recycling (CO2minus, 2015).

However, Dr Costas Velis (2014) presents in his report *Global recycling market – plastic waste: A story for one player- China*, that there are split opinions on whether material recycling of plastics is always the best choice. He presents some research stating that material recycling is preferable over energy recovery, in an environmental perspective, only if the substituting of virgin material is 70-80% due to high contamination levels. He further states that if the environmental benefits should be optimized, the manufacturing conditions should be taken into account before choosing recovery process. He suggests that using closed loop recycling, as the deposit system for PET-bottles, could enhance the pureness of the recycled plastics (Velis, 2014).

6.8.2 Recycling of Plastic Waste

One important component in the recycling process is the collection part. To be able to maximize the recycling of the collected fractions, the fractions are required to be as pure as possible, meaning that they contain only the right type of plastic (Plastic Europe c, 2015).

In Europe the collection of waste and plastic differs. Some countries, e.g. the United Kingdom, mainly collect a mixed waste fraction (recyclables) and a remaining residual waste fraction while others, such as Sweden, Germany and the Netherlands, have collection system based on more separate fractions i.e. separating at source. When collecting the waste in a mixed bulk the waste is sorted into separate fractions at a Material Recycling Facility (MRF), which basically is a central sorting facility. The collection of plastic packaging in Sweden differs between door-to-door collection and collection at bring sites. Plastic packaging in form of drink bottles that is covered by the producer responsibility is collected through a deposit system as explained in section 6.3 (Gibbs b, et al., 2014).

Mixed and polluted (additives as described in 6.8.1. above) ingoing plastic decreases the quality of the recycled material and, hence, could result in an unusable manufactured secondary material in the end (Bibi, et al., 2012). Since the usage and manufacturing of the recycled plastic is dependent on the purity of the ingoing fractions, the sorting and pre-treatment of the collected bulk is essential. There are many different techniques for sorting plastic into separate fractions. Plastic Europe (2015) lists both manual and atomically sorting techniques such as picking, air or liquid density separation, magnetic separation or separation with UV, IR, and laser. At Swerec's recycling facility in Lanna, Sweden, the sorting process is made with air density and IR-technology where three fractions, of hard plastics, at a time can be separated with the IR-technique (Swerec AB b, 2015).

There are different methods available for the recovery of plastic; by energy recovery or feedstock, chemical and mechanical recycling. According to EU's waste hierarchy energy recovery is the third best treatment method. Feedstock recycling is gasifying plastic into synthetic gas for the purpose of replacing fossil fuel as an energy source just as energy recovery (Plastic Europe a, 2015). Generally, in order to maintain the quality of the plastic polymers mechanical or chemical recycling process are the most applicable recovery processes. To ensure the human health and the environmental benefits with plastic recycling there are some factors that should be taken into account, such as the recycling technology, collection, efficiency rate, composition of the waste and products (Plastic Europe d, 2015). The importance of the plastic composition when recycling plastic is further discussed in section 6.8.3.

The recycling facility in Lanna is a mechanical recycling plant where the sorted plastic is washed and grinded into small flakes. Some fractions are not grinded but bundled after the sorting process. The plant can process 10 tons of plastic waste per hour (Swerec AB b, 2015). Plaståtervinning i Wermland, PiW is another plastic recycling company with a very similar recycling process. According to PiW it is, in the sorting process and washing step that rejects arises as dirt and other objects. The dirt and the other objects dissolves, sinks to the bottom or are washed away[17].

The recycling process for PET bottles contains steps as sorting, bundling, grinding and washing. The sorting process is managed by Returpack which is the material company for beverage packaging. Returpack sends the sorted bottles to Cleanaway PET Svenska AB who manages the recycling process with grinding and washing etc. After the grinding and washing, Cleanaway PET Svenska AB sends the material to another company who produces plastic pipes which are transported and delivered to breweries producing new bottles to be filled with their own products (Returpack a, 2015). The PET bottles are managed in a closed deposit system resulting in a straightforward sorting process where Returpack states that about 100%[18] is sent further to the washing and grinding process. As the waste flow is pure, not containing other plastic types or plastic products, a high circulation rate can be achieved (Returpack a, 2015).

As mentioned in chapter 4.1.3 and stated in the packaging and packaging waste directive, the current target for plastic packaging waste is "22.5% should be recovered or incinerated at waste-to-energy plants by the end of 2008" (SFS 2014:1073). Sweden had achieved this target back in 2004. In 2012, Sweden reported a recycling rate of plastic packaging waste of 34. 9 % (the total quantity of recycled plastic packaging waste, divided by the total quantity of generated packaging) and a recovery rate (including both material recovery and incineration at a waste-to-energy plant) of 58.1% for plastic packaging waste (Eurostat b, 2015).

The price of the raw material is an important issue for recycling and manufacturing companies. The plastic fractions chosen to be separated in the recycling process depend on whether it is economically beneficial to recycle that type of plastic at that specific time. It is possible to recycle nearly all types of

[17] Sonja Andersson, Plaståtervinning i Wermland AB, personal communication 2015-11-05
[18] Erik Ebbeson, Customer Manager, Returpack, e-mail 2015-13-04

plastic fractions. The limiting factors are a question of financial profitability[19] and the polluting substances in the plastic

6.8.3 Circulation of Polluting Substances

There is not enough research on the topic on circulation of polluting substances. Information and knowledge about the amount and content of pollutants that is being recycled and returned into products due to recycling could not be found. Literature about the subject is limited and would be needed to be developed.

Given that plastic consists of many polluting substances (some of which are described in 6.8.1), these substances are, as well as the plastic polymers, recycled and returned into the newly produced raw material. When recycling plastic waste, the plastic waste is mixed already at the source, except for PET-bottles. By mixing the plastic waste, waste from different usage areas is also mixed meaning that for example plastic waste from electric products is mixed with packaging waste. The plastic waste is separated into different plastic types before being granulated. As explained in section 6.8.1 there are a lot of additives in e.g. plastic used for electronic products and less additives in plastic packaging. The different plastic waste is mixed during the recycled process hence the recycled raw material will also consist of polluting additives. As there is high demands on many products e.g. plastic packaging used in the consumer goods chain the usage areas for recycled plastic are decreased. There are some techniques for separating plastic fractions that is too contaminated but these are both time consuming and expensive. Thus there are some plastic fractions and products that should not be recycled at the time (Bibi, et al., 2012)

[19] Anna Fråne, Climate and Sustainable Cities, IVL, personal communication 2015-13-03

7 Implementation of Changes in the Waste Directives - Overall MW System in Sweden

The theory presented in previous chapters has shown that new points of measurements for MW statistics are to be expected within the EU. In this chapter the consequences which this would have on reported recycling rates, landfill rates as well as energy recovery rates, from Sweden are investigated.

7.1 The Swedish System in a Flow Chart

The Swedish waste system is in this chapter showed in both a basic and a detailed version. The detailed version is based on the treatment distribution template and the additional information of cans and PET-bottles presented in chapter 2.3.2.

7.1.1 The Basic Version

The Swedish system has been investigated on various levels as a part of this study. The basic version is visualized in Figure 9, where waste streams and direction of the waste through the system is showed.

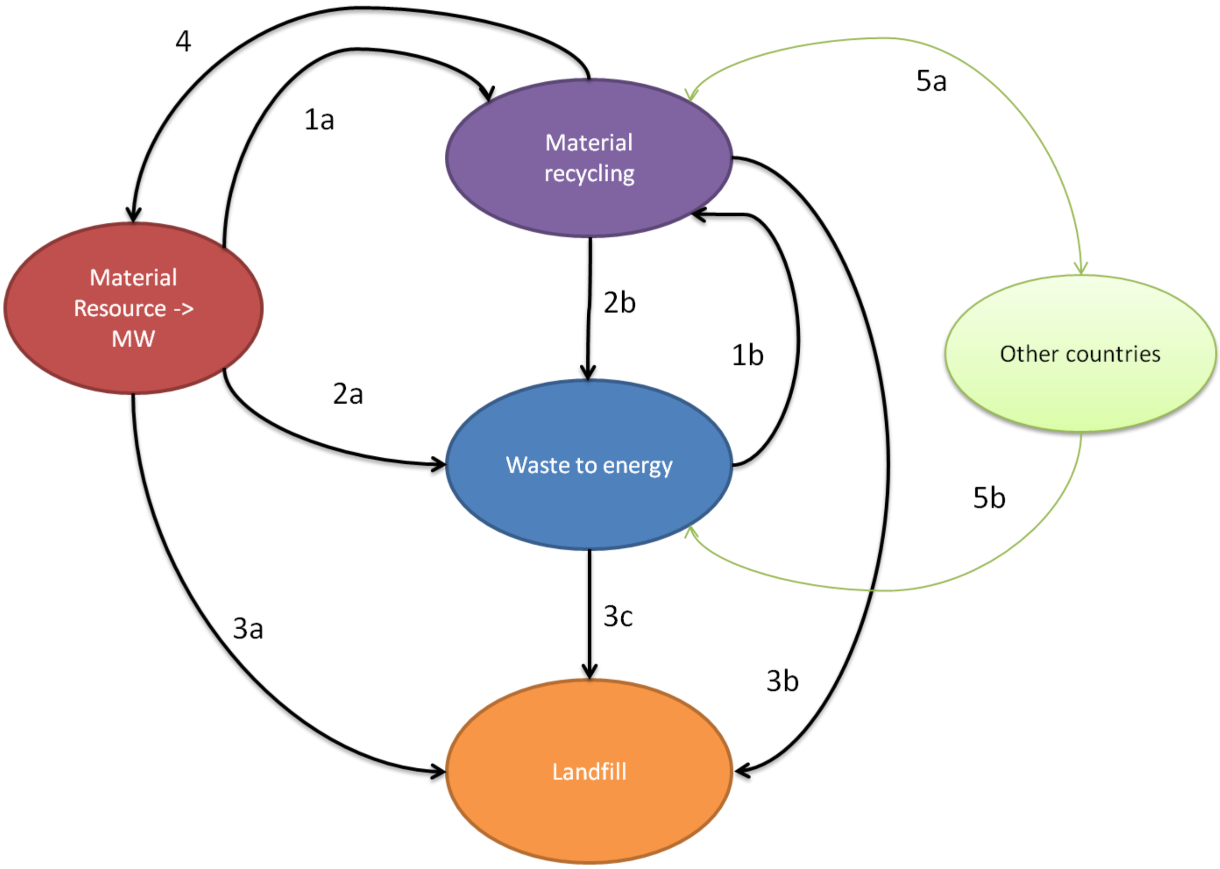


Figure 9. The Swedish waste treatment system

Starting in the material resource box, it is possible to follow the waste streams either to material recycling (1a), waste to energy (2a), or a landfill (3a). The purpose of this figure is to show that the primary treatment methods (1a, 2a or 3a) are not necessarily the last for any given waste stream. From waste primarily collected for material recycling, there will be rejects both in the sorting and the recycling processes. This will in the case of Sweden mostly go to waste to energy plants (2b) and in some cases to landfills (3b). Moreover, there is waste imported to and exported from material recycling plants (5a). The in-streams to the Swedish waste-to-energy plants are, except waste sent directly to incineration (2a) reject from the recycling process (2b) and imported waste from other countries (5b).

To landfilling are so far only in-streams. The streams come from waste-to energy-plants (3c), the recycling process (3b) and straight from the MW collection (3a).

Figure 9 shows the overall picture of how the different waste treatment methods are interconnected and how waste is transported between them. In the next chapter there is a more detailed (but still simplified) chart based on the same principle presented in Figure 9.

According to Jakob Sahlén, Avfall Sverige, the system has traditionally been seen upon in an even more basic manner than in Figure 9. This system approach could be visualized by removing all streams in Figure 9 but leaving only waste stream 1a, 2a, 3a, 4 and 5.

7.1.2 Detailed Flow Chart

In an attempt to visualize a more complete system Figure 10 was produced. It shows the waste fractions in the Swedish MW system and what happens to them. The figure does not indicate the size of the waste streams, instead it shows the paths of the waste through the system. Out from the MW box the fractions are divided after what treatment method they are collected for; material recovery, biological treatment, waste-to-energy and landfill. The collected materials are thereafter divided into different fractions. These fractions are the same fractions as are presented in the treatment distribution template plus cans and bottles collected with the bring system (2.3.2 or appendix 3).

Each of the material recovery fractions has its own individual recycling rate (see Appendix 3) (Sundberg, et al., 2014) and Figure 10 shows to which final treatment method each of the fractions ends up in. The same goes for the fractions sent to waste-to-energy or to biological treatment, the rate of treatment is individual for each fraction.

The final treatment methods material recovery, backfilling, waste-to-energy and biological treatment all have a purpose of utilizing the waste and making it into different kinds of resources again, as a material resource or as an energy resource. Landfilling on the other hand is a final destination and it takes the waste material out of the system. Some of the gas produced form digestion in a landfill may however in some cases be utilized as biogas, in Sweden was a total of 194 GWh extracted for energy use in 2013. The flows visualized in Figure 14 are based on the template distribution estimated for the indicator project (Sundberg, et al., 2014).

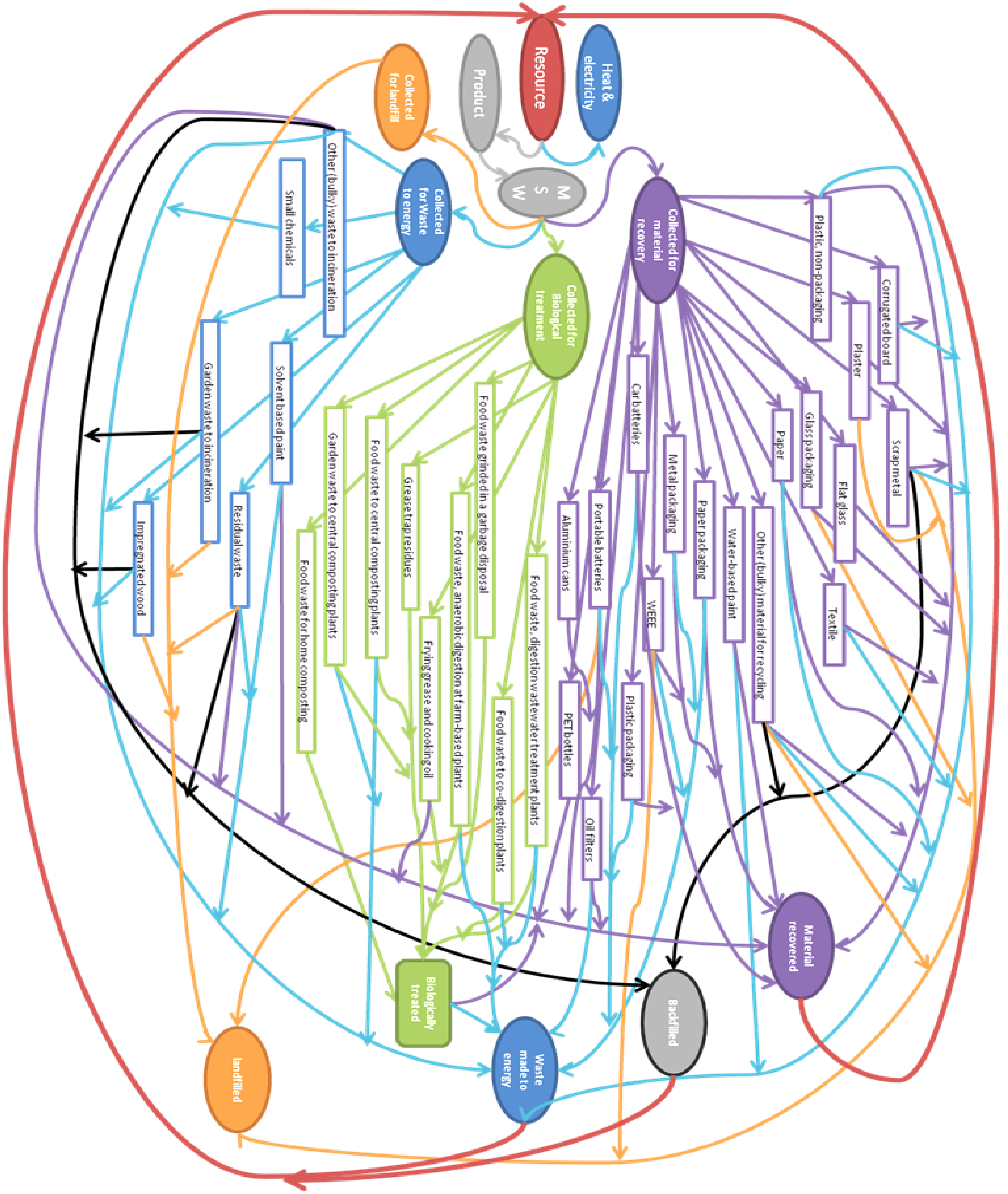


Figure 10. Swedish waste treatment system, overview including all fractions from the model

7.1.3 Collected Waste

The data of collection of MW in Sweden 2013 was retrieved as described in chapter 2. The amounts of waste collected in each fraction based on this are presented in Appendix 3, Table 24. The summarized amounts per collection treatment method, is presented in Table 9.

Table 9. Collected waste in 2013, divided after which treatment it was collected for. Based on (Avfall Sverige b, 2014) and Avfall Web.

Collected for treatment:	Material recycling	Biological treatment	Energy recovery	Landfilling	Total
Collected waste (tons)	1 501 275	766 887	2 235 930	33 300	4 537 392

The distribution of the collected waste is presented in Figure 11 below. It is based on the tonnages for each collected waste stream. This is also close to the distribution of recycling, energy recovery and landfilling that is currently the most commonly reported in Swedish statistics, presented by Avfall Sverige in SAH 2014 and presented in chapter 6.1. The distribution is based on the assumption that all biological treatment fall under material recovery. The distribution does not show the material recycling rate for compliance with the EU Waste Directive targets reported to the European Union. That is measured as described in chapter 6.7 with method 2 and does not take all MW into account.

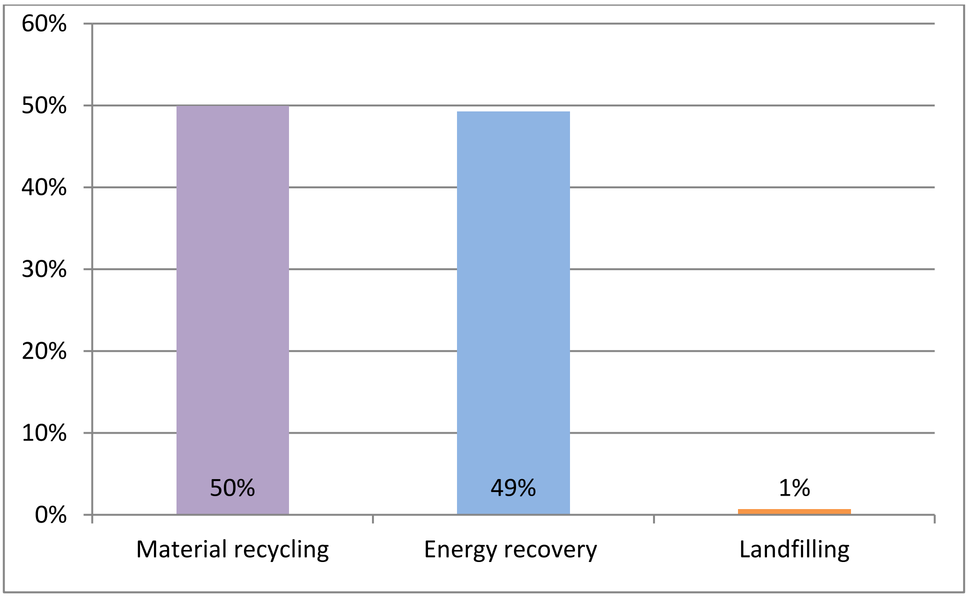


Figure 11. Waste collection distribution in Sweden in 2013. Based on information collected from (Avfall Sverige b, 2014) and Avfall Web.

Figure 11 shows the collection rate for material recycling (50%), energy recovery (49%) and landfilling (1%) in 2013 as calculated for this study.

7.1.4 According to the Circular Economy Proposal

Using the definitions and the measuring method in the LPW, results in a distribution of the final treatment destinations as presented in Table 10 and visualized Figure 12. These definitions are described in chapter 5.5, the method and the assumptions for the implementation are described in chapter 2. The most significant change from what is presented in Figure 11 is that the rejects in the processes are accounted for according to the distribution template. Backfilling is included and described in the definitions but excluded from material recycling and put in its own category. In Figure 12 all biological treatment counts as material recycling.

Table 10. Calculated final treatment distribution, for 2013. Figures based on (Avfall Sverige b, 2014) and Avfall web. Calculated according to the LPW with the distribution based on the final distribution template.

Final treatment	Material recycling	Energy recovery	Landfilling	Backfilling	Total
Treated waste (tons)	1 904 629	2 077 991	1 952 734	36 0962	4 537 392

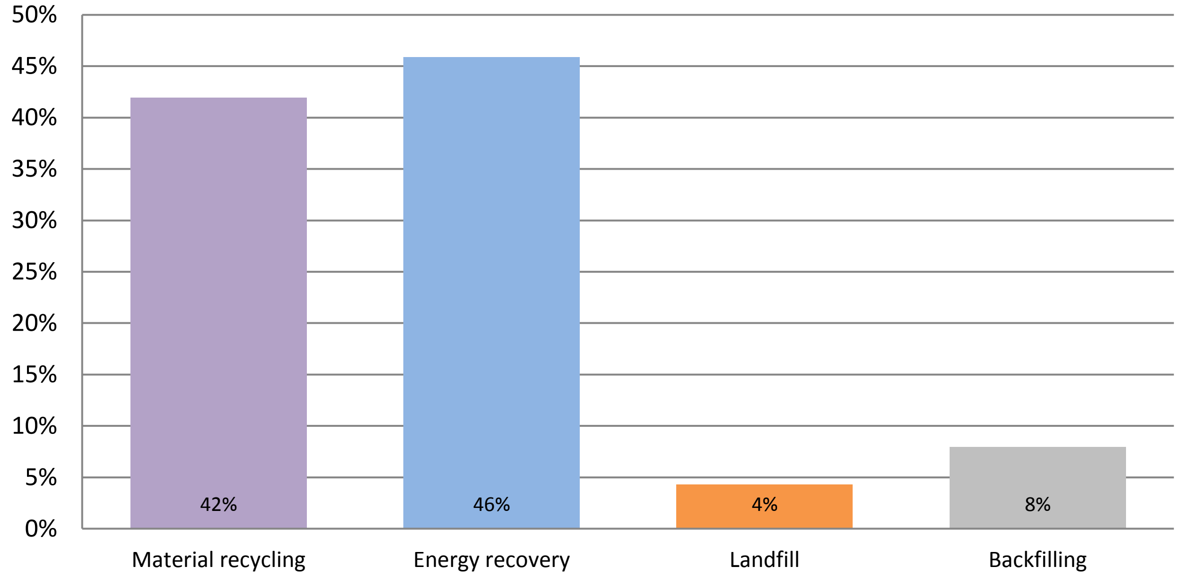


Figure 12. Calculated final treatment distribution of all MW in 2013. Figures based on (Avfall Sverige b, 2014) and Avfall web. Calculated according to the LPW with the distribution based on the final distribution template.

The results from the excel model shows that the material recycling was at 42% in 2013 when counting the final treatment method for each waste steam. The energy recovery was 46% of the MW, 4% ended up on a landfill and 8% ended up as backfilling material.

Table 11 shows the amounts of waste which was collected for a treatment and subsequently what treatment method it finally underwent. A more detailed table showing how each fraction is divided into final treatment methods is to be found in appendix 3 in Table 25.

Table 11. Final treatment in relation to collected waste, using figures from 2013. Figures based on (Avfall Sverige b, 2014) and Avfall web. Calculated according to the LPW with the distribution based on the final distribution template.

	Material recycled (tons)	Energy recovered (tons)	Landfilled (tons)	Backfilled (tons)
Collected for material recycling (tons)	1 204 181	239 490	46 458	12 609
Collected for biological treatment (tons)	676 386	90 502	0	0
Collected for energy recovery (tons)	24 062	1 747 999	115 515	348 353
Collected for landfilling (tons)	0	0	33 300	0
Total (tons)	1 904 629	2 077 991	195 274	360 962

From the results shown in Table 11 was Figure 13 made. It shows what happens to the waste collected for each treatment method. For instance is 80% of the total MW which was collected for material recycling finally material recycled while 16% was energy recovered, 3% was landfilled and 1% was used as backfilling material. The middle column is the result if counting the collection for both material recycling and for biological treatment the same.

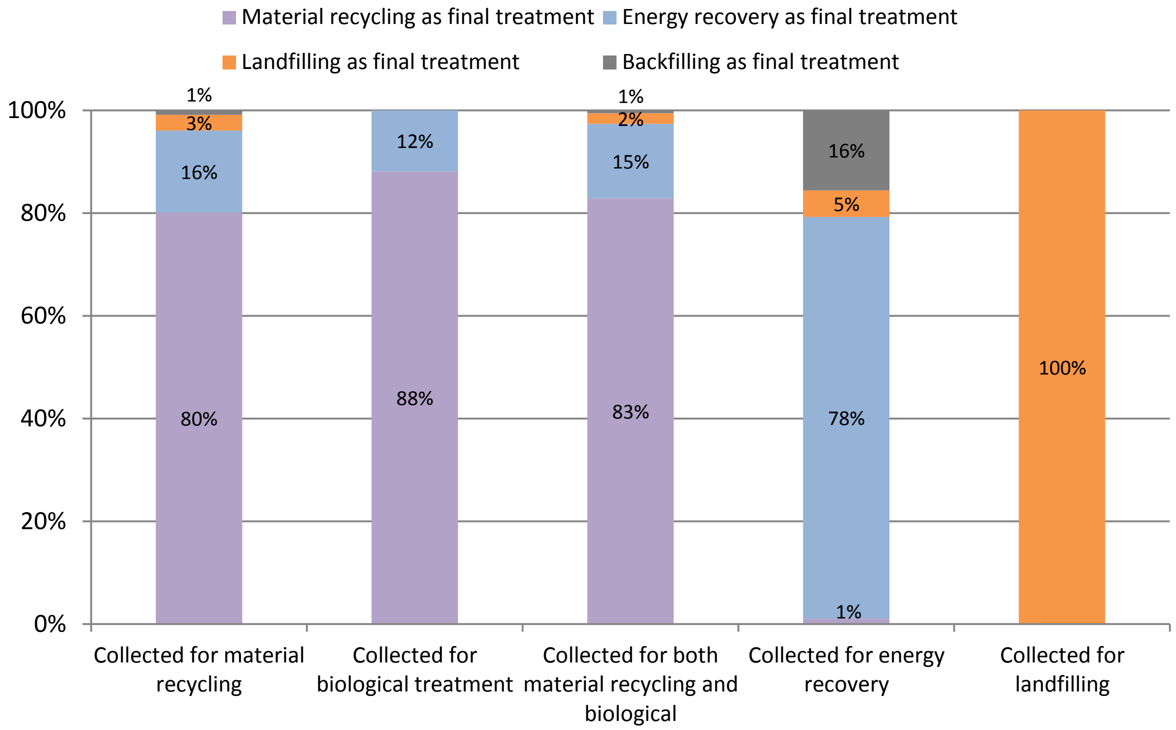
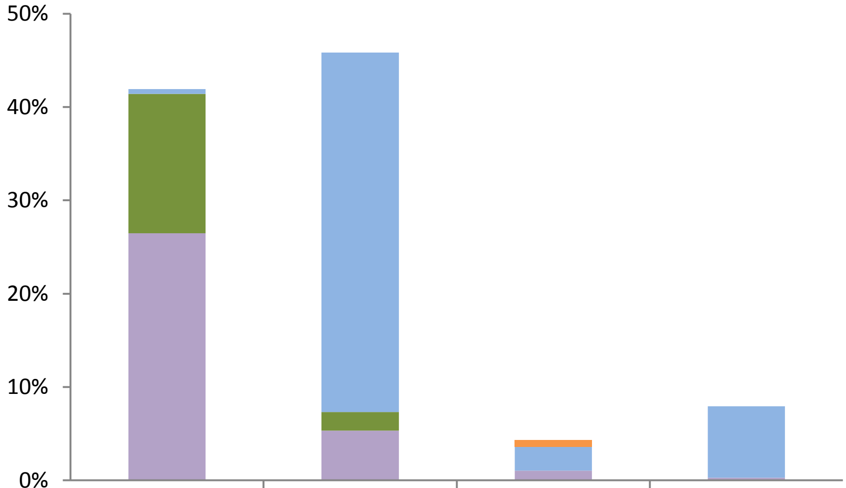


Figure 13. The diagram shows at which treatment method the waste collected for a treatment method will end up in 2013. The middle column is the two left columns emerged. Figures based on (Avfall Sverige b, 2014) and Avfall web. Calculated according to the LPW with the distribution based on the final distribution template.

Figure 14 shows how much of the total waste has undergone a specific treatment as a final step. However, the columns are divided into colors after which treatment method the waste was collected for. For example; everything in the column marked material recycling is the waste actually material recycled. The green part is representing the waste which originally was collected for biological treatment. The total height of each column is equivalent to the height of the corresponding column in Figure 12.

The table underneath the diagram in Figure 14 shows the percentage of the total MW that was collected for the treatment method represented by the row and ended up in the treatment represented in the column. Examples of this are that 15% of all MW was collected for biological treatment but ended up as being material recovered, and that 3% of all MW was collected for energy recovery but ended up on a landfill.



	Material recycling	Energy recovery	Landfill	Backfilling
Collected for landfilling	0%	0%	1%	0%
Collected for energy recovery	1%	39%	3%	8%
Collected for biological treatment	15%	2%	0%	0%
Collected for material recycling	26%	5%	1%	0%

Figure 14. Final distribution of waste treatment. The color in the figure indicates the treatment method the waste stream was collected for (in 2013) and the column in which it is placed indicates the final treatment of that waste stream. Figures based on (Avfall Sverige b, 2014) and Avfall web. Calculated according to the LPW with the distribution based on the final distribution template.

Figure 14 may be studied together with Figure 15, which clarifies which treatment method the waste in each column originally was collected for. It shows the distribution of the treatment methods the waste in each final treatment method originally was collected for.

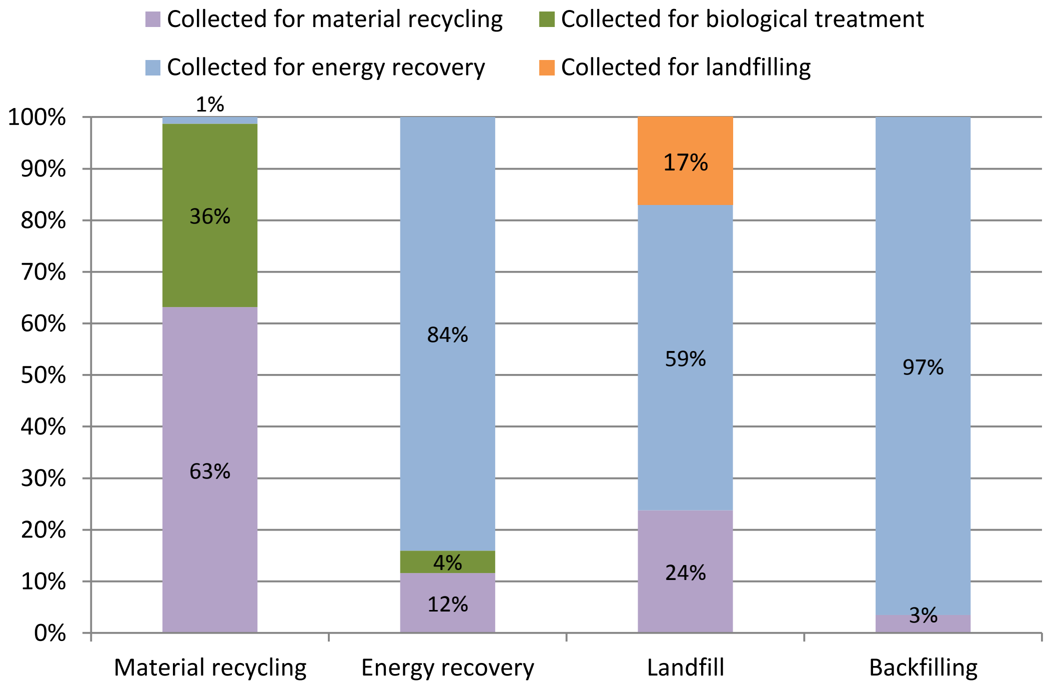


Figure 15. Each column represents 100% of the waste finally treated with each method. The colors show the distribution of the treatment methods for which the waste was collected for in 2013. Figures based on (Avfall Sverige b, 2014) and Avfall web. Calculated according to the LPW with the distribution based on the final distribution template.

Figure 14 and Figure 15 how that material recycling is dominated by waste which also was collected for the purpose of being material recycled. A 36 % part was collected for biological treatment but as this chart count all biological treatment as material recycling this was also collected in the purpose of ending up in this column. There is 1% of the material recycled waste which was sent to energy recovery and later ended up as material recycled this is as described earlier (chapter 6.6) mainly scrap metals.

The origin of the waste which is recovered as energy is to 84 % waste which was collected for energy recovery. However, 16% (4% and 12%) of the waste which was energy recovered was collected for material recycling. This is for example rejects from the recycling process.

Of the material being landfilled is 17% collected for landfilling. The more dominating source of material for the landfill is the reject from energy recovery processes which constitutes 59% of all MW which is landfilled in Sweden. The rejects from material recycling is making up 24%.

As the statistics are organized today, nothing is collected for the purpose of backfilling. The backfilling column is instead composed by 97 % of rest products from the waste-to-energy process and 4% from the material recycling process.

7.1.5 Special Case Biological Treatment

In the previous calculations all organic treatments have been counted as recycling. However, there are reasons to interpret the directive and the proposal in a way that imposes a separation between the products from the anaerobic digestion. The bio-fertilizer goes in this case to recycling and the biogas to energy recovery. The reasoning behind this separation and how it was done is available in appendix 5. The food waste from anaerobic treatments is estimated to be 76 % recycling and 24 % energy recovery by weight based on these calculations.

How a change of counting the biological treatment affects the full system is seen in Figure 16. The red and green fields show together all waste collected for biological treatment. The red fields are the waste (food waste, grease trap residues, and frying grease and cooking oil) which actually undergoes an anaerobic treatment process. The green fields are the rest of the waste collected for organic treatment (the rejects from anaerobic digestion process and waste collected for composting). The grey parts of the columns are MW collected for other treatments than biological treatment.

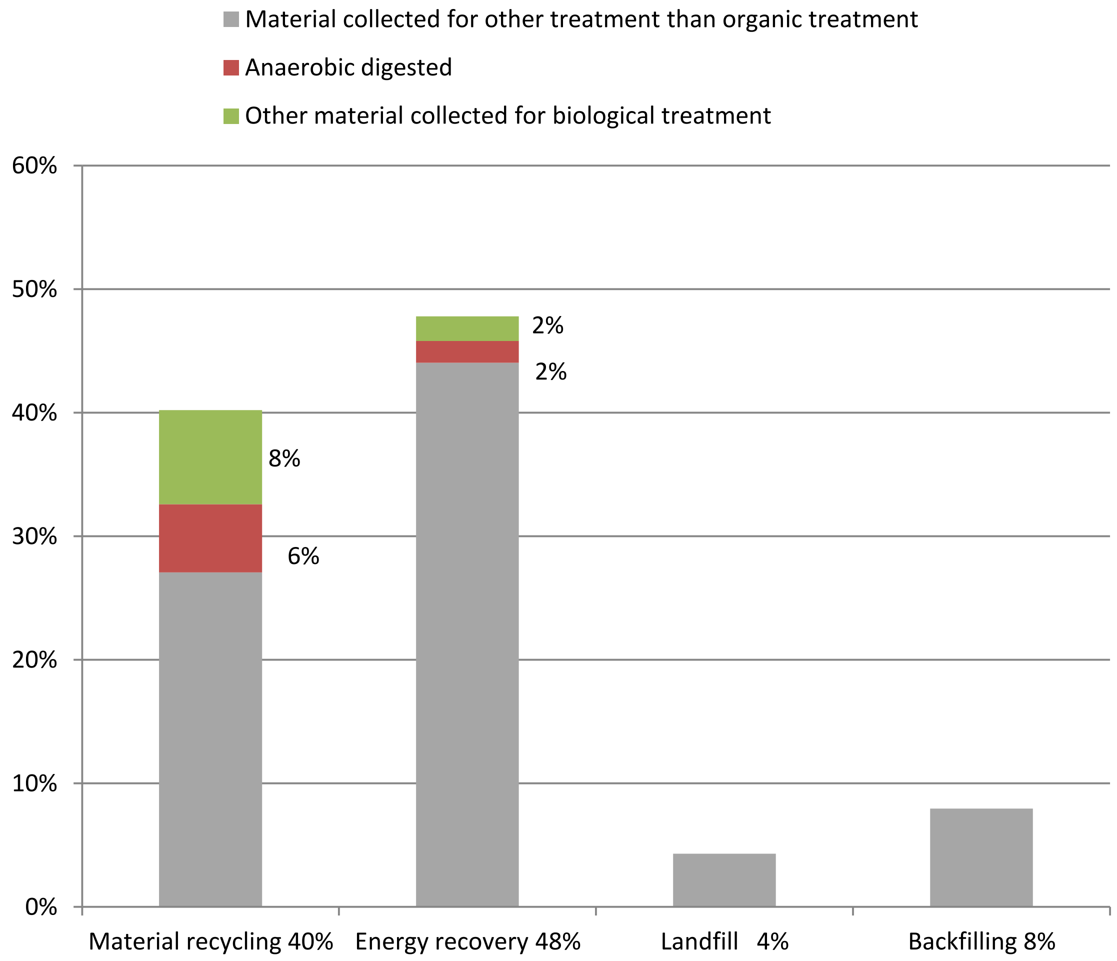


Figure 16. Final treatment method of MW in Sweden if biological treatment is separated between energy recovery and material recycling. Figure based on 2013 values, (Avfall Sverige b, 2014), (Avfall Sverige , 2009) and Avfall web.

The change in biological treatment brings the material recycling rate down to 40% with 2013 years value for Sweden. The energy recovery then stands for 48%. Landfilling and backfilling will not be affected by the change and stays at 4% respectively 8%. Changing the way of counting the products from the anaerobic digestion process moves 2% of all MW from recycling to energy recovery, as can be seen in Figure 16.

7.2 Overview Targets and Current Position

To give an overview of the recycling and landfilling targets both in the EU and nationally in Sweden compared to the current levels, Table 12 has been created. From the left, it shows the current national targets in Sweden, followed by the current EU directive targets for waste treatment which are in force. These targets can be compared to the current state of Swedish waste treatment which is shown in the following column. The last two columns shows the targets which was proposed in the LPW and the current state in Sweden measured in the way stated in the proposal, also shown in 6.3.3 above.

Table 12. Targets and proposed targets, EU and Sweden, compared to waste management performance.

	Current Swedish law/targets	Current EU directive targets (2008/98/EC and 1999/31/EC)	Current Swedish MW recycling rates with current measuring methods	Proposed Target (COM(2014) 397 final, 2014)	Current rate with new measuring, According to this study
Material recycling, MW	- The recycling rate for packaging waste shall be 55% by 2017 and 65% by 2020[20] -The material recycling from households shall increase and at least 90% of the households shall be satisfied with the collection[21] -50 % of the food waste by 2018 shall be collected and at least 40% of this shall be treated in a manner that also recovers the energy [22]	-50 % by 2020	-Reporting to EU (method 2): 62% -Avfall Sverige national count: 49%	-50% by 2020 -70% by 2030	41.5%
Landfilling	landfill ban on collected & sorted combustible waste, & on organic waste	A list of wastes which are not accepted on a landfill reduce the amount of biodegradable MW going to landfills to 75 % by 16 July 2006, to 50 % by 16 July 2009 and to 35 % by 16 July 2016	-Avfall Sverige, national count: 0.7 %	Phasing out landfilling for recyclables by 2025	4.3%

7.3 Future Projection

In order to give a possible picture of a future waste treatment system in Sweden a basic projection was made for this study. The projection is made from the standpoint that the 70% recycling target is reached in 2030 and aims to give a picture of the amounts of waste which will have to be collected for the purpose of material recycling for this to be possible. It also aims to give a picture of how the distribution of waste treatment will be between the other treatment methods as a consequence of the material recycling at 70%.

For these calculations to be carried out, series of rough estimates had to be done, which means that the results also have to be seen as such. In this whole paragraph is biological treatment included in material recycling and the rate between these two is assumed to stay the same as today.

[20] SFS (2014:1073)
[21] (Naturvårdsverket, 2012)
[22] (Naturvårdsverket, 2012)

For the calculations was the prediction of the total amount of MW in 2030 from the IA in Sweden used. This was 5 673 000 tons. The material recycling rate was set to 70% and from this could the amount of waste which would have to be recycled be calculated to 3 971 100 tons. With the knowledge of the distribution of the final treatment method of the waste collected for material recycling (middle column Figure 13) could the collected amount be calculated to 4 792 656 tons. The calculation is shown in Eq 7.1. This was done with the estimation that all the waste finally treated for material recycling was also collected for this purpose.

$$\frac{5\ 673\ 000\ \text{tons} * 0.7}{0.829} = 4\ 792\ 625\ \text{tons} \qquad\qquad \textit{Eq 7.1}$$

The waste to the other treatment methods which comes from the material recycling, as rejects, was also calculated using the rates in Figure 13.

To calculate how much was collected for landfilling was the rate set to 0.7 percent. This is the same rate as it is today and was chosen because neither of the predictions from chapter 6.7.2 saw a change in the landfilling rate. This was also seen as a reasonable estimation as the waste which is landfilled in Sweden today generally is waste which there is no better treatment for, see section 6.6.

The waste which neither was collected for landfilling nor for recycling was counted as collected for energy recovery.

The rejects from each treatment method was assumed to be equal to what they are today and the rejects could also be divided on the basis of the rates given in Figure 13. This means that the projection is based on an assumption that the processes will not be more efficient than today in 2030.

The rejects from the energy recovery process which can be material recycled as a final treatment method was in this way found to be 9 071 tons. This low number shows that the estimation to neglect this in the material recycling calculations earlier was okay. It will not change the 70% material recycling as the total amount of final material recycling now will be 3 980 171 tons.

Table 13 shows the results for which amounts which will have to be collected for each treatment method in 2030, and it also shows the amounts finally treated with each method.

Table 13. The 2030 projected amounts of waste collected for treatment and in final treatment method. Result calculated for this study according to given assumptions.

	Collected (tons):	Final treatment (tons)
Material recycling	4 792 656	3 980 171
Energy recovery	840 633	1 353 525
Landfilling	39 711	181 360
Backfilling presented	0	157 944
Total:	5 673 000	5 673 000

The results in Table 13 were used to make Figure 17, showing the collection rates and the rate of each final treatment method.

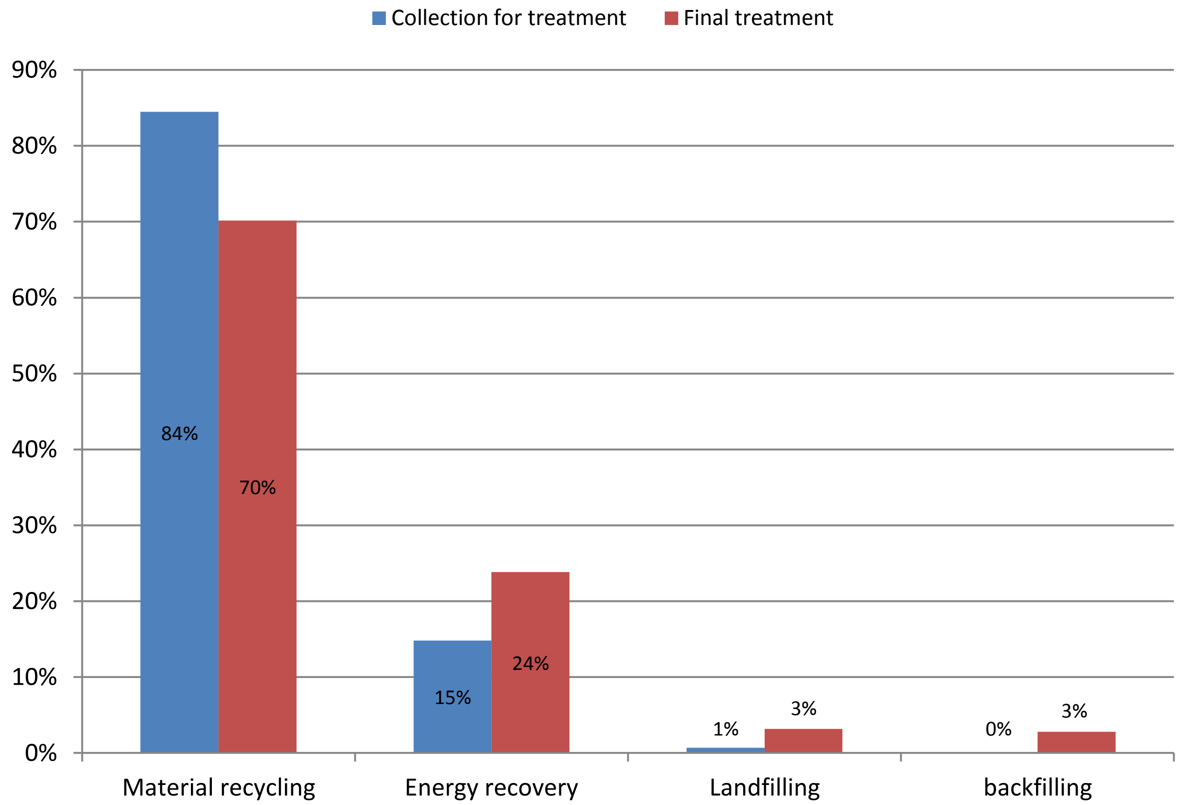


Figure 17. The result for the distribution of the waste for both collection and final treatment method, calculated in this study

Figure 17 shows that under the given assumptions of a 70% recycling rate, the collection rate would have to be 84%. Energy recovery as final treatment could be down to 24% while the collection for it would have to be at a mere 15%. It was set in the calculation that the collection for landfilling would be 0.7% which in Figure 17 is rounded to 1%. 3% of the MW would be treated in a landfill as a final treatment. There is nothing that is collected for backfilling but about 3% would end up as backfilling material in this scenario.

The distributions of the treatment methods which the waste was collected for are shown in Figure 18. It shows each final treatment method in one column and the colors indicate the treatment method the waste was collected for. The percentage is of the waste treated with that treatment method.

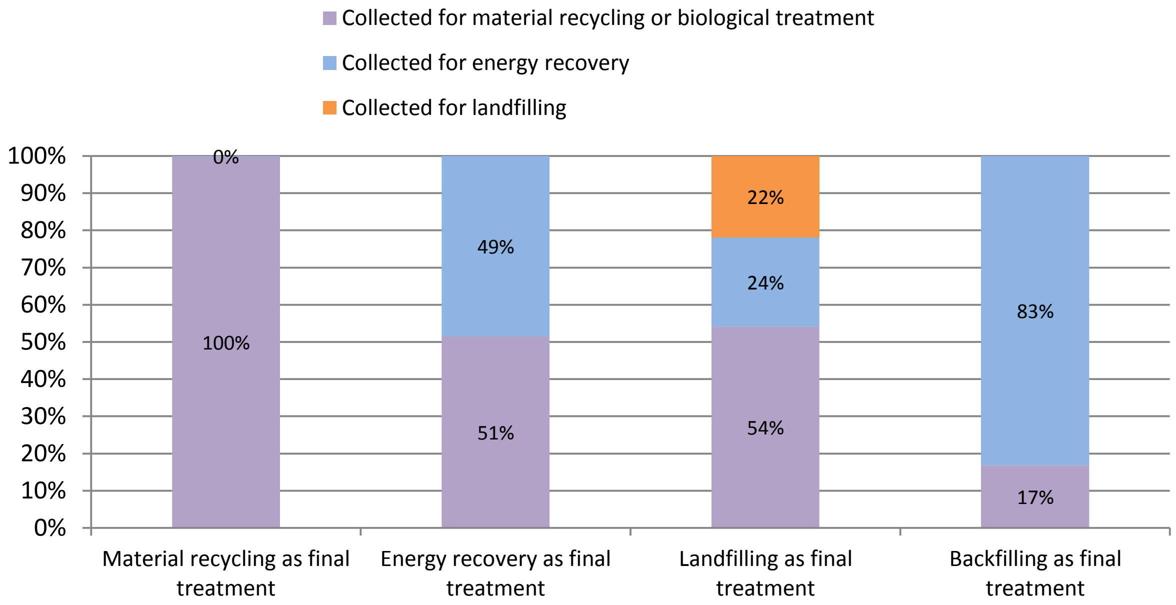


Figure 18. The distribution of which treatment method the waste within each final treatment method will have been collected for in 2030 according to the calculations made for this study

Figure 18 shows that the waste which originally was collected for energy recovery but ended up as material recycled is negligible at near 0%. The energy recovery treatment method is dominated with rejects from the material recycling process with 51%. The scenario also makes the rejects from material recycling the dominating part of the waste which finally gets landfilled. The backfilling material is however still 83% rejects from the energy recovery process.

8 Implementation of Changes in the Waste Directives – Case Study of Plastic Recycling System in Sweden

Waste systems are by nature very complex systems; this is illustrated in Figure 10, where 34 fractions for waste treatment are included. This report seeks to answer which data is missing for Sweden to be able to show compliance to the suggested recycling targets. To be able to answer that question, the recycling market requires further investigation. Due to the complexity of the overall waste system the study focus on the plastic fraction to be investigated in greater detail. The purpose of the detailed study is to survey the plastic recycling market to understand how the different flows of respective waste fractions affect each treatment method, and the system as a whole. In order to describe the market, a detailed visualization is required. In addition, the aim of the study is also to confirm the accuracy of the recycling efficiency rate for plastics from the treatment distribution template. This is relevant since the proposed LPW measuring method (described in chapter 5.5.1 above) includes subtracting the reject.

8.1 Survey of Actors in the Plastic Recycling Market

This chapter presents the actors which were contacted for this survey and the information retrieved from them.

8.1.1 Companies Providing Services for Producer Responsibility

8.1.1.1 FTI AB

As mentioned in section 6.3, FTI has the main responsibility for collecting and managing plastic packaging. According to FTI, "FTI's role is to provide all companies with access to the nationwide recycling system, which is designed to simply and efficiently meet producer obligations." (FTI AB a, 2015). FTI provides and manages the bring system in Sweden. In the first stage of the system, containers are emptied and the collected material is brought to pre-sorting facilities where the plastic packaging waste is bundled. FTI also provides door-to-door collection, where entrepreneurs are conducting the collection and bringing it to pre-sorting facilities. At these facilities pre-sorting is done where misplaced material, as bicycles or other miscellaneous objects are separated[23]. FTI cooperates with entrepreneurs managing the overall process of emptying of the bring containers, transporting the packaging waste to pre-sorting facilities and thereafter to recycling facilities. FTI has about 40 pre-sorting facilities scattered around Sweden. They also have contracts with three recycling facilities in Germany, Umweltdienste-Kedenburg, Relux Recycling GmbH and Hubert Eing Kunststoffverwertung GmbH, and Swerec in Sweden. When responding to questions in the survey FTI used the word *sorting facilities* instead of recycling facilities. FTI also has requirements for the recycling rate of the plastic packaging waste going into the recycling process, at the recycling facilities, that at least 80% should be recycled[24]. The recycling rates are followed up every month and the requirements of the recycling rates are equal for all recycling facilities[25].

In 2013, a total of 186 344 tons of plastic packaging was put on the market by FTI's members and 48 986 tons was collected from Swedish households. The amounts of packaging plastic collected from companies and businesses i.e. comparable household waste, were not retrieved since FTI reports only the total amounts of recycled plastic packaging material and not the collected amounts. These numbers

[23] Carolina Landerdahl, Operating Analyzer, FTI AB, e-mail 2015-14-05
[24] Peter Svärd, Manager for Transport/Facilities FTI AB, e-mail 2015-19-05
[25] Peter Svärd, Manager for Transport/Facilities, FTI AB, e-mail 2015-18-05

are received by the Swedish EPA who is responsible for the national waste statistics. When reporting the amounts that were material recycled, FTI subtracts the rejects from the collected amounts. The rejects contain moisture, misplaced waste, items and plastic and also plastic packaging that were not possible to recycle[26].

Tests are made on the collected material to see how much moisture and misplaced material the waste contains. The rate of moisture is calculated based on core samples and was measured to be 12% in 2013[27]. The rate of misplaced plastic, i.e. non packaging plastic, and other material, is determined with random samples. The producer responsibility only applies to plastic packaging and not other plastic products such as non package plastic. It is therefore necessary to find out the rate of misplaced items and plastic. In 2013 the rate was determined to 17.5%[10]. The rate of misplaced items and moisture differ between plastic packaging collected from households and plastic packaging collected from companies and businesses. Therefore the overall rectified rate was determined to 73%[28] i.e. the amount of collected material that is plastic packaging. The rate of moisture and misplaced items (27% of the total collected) are subtracted from the collected packaging waste when calculating the recycling rate[29]. FTI presents the number 68 419 tones of material that have been recovered in 2013[30]. The recycling rate of plastic packages put on the market by FTI's clients in 2013 was 36.7%[31].

8.1.1.2 TMR AB

TMR is, like FTI, a supplier of producer responsibility services. TMR offers assistance with collection and recycling of packaging waste to their members, the producers of packaging material. The collection is carried out via agreements with waste management entrepreneurs, who collect the packaging waste through the bring system, door- to-door collection or from recycling centers. The collected plastic packaging is sent to recycling but occasionally it is managed at pre-sorting facilities before it is sent onward to recycling. During the survey, TMR was asked where, meaning to which facilities, the plastic waste is sent to be recycled. However TMR replied that they do not share information about their partners, although they did state that there are other recycling facilities than Swerec in Sweden and surrounding countries. TMR defines recycling of plastic packaging according to the praxis used since the implementation of the producer responsibility. The plastic packaging is recycled when delivered to a recycling facility, while the moisture and misplaced material are subtracted. To eliminate misunderstandings, TMR also explains that a recycling facility, which manages plastic waste, is equivalent to what is sometimes referred to as a sorting facility. This means that the recycling of plastic waste is in fact the sorting according to its associated plastic fraction, including granulating when the fractions are separated. The sorted and recycled plastic is then sent onward to the plastic industry (as granulate) to be manufactured into new products[32].

8.1.1.3 Returpack

Returpack is responsible for the deposit system in Sweden for metal and plastic beverage packaging (metal cans and PET-bottles). The company is owned by Sveriges Bryggerier AB, Svensk Dagligvaruhandel and Livsmedelshandlarna. It is commissioned by its owners to manage the collection and recycling of beverage packages to fulfill the producer responsibility obligation

[26] Henrik Nilsson, Head of Department, FTI AB, personal communication 2015-03-06
[27] Carolina Landerdahl, Operating Analyzer, FTI AB, e-mail 2015-21-05
[28] Carolina Landerdahl, Operating Analyzer, FTI AB, e-mail 2015-14-05
[29] Carolina Landerdahl, Operating Analyzer, FTI AB, e-mail 2015-21-05
[30] Henrik Nilsson, Head of Department, FTI AB, personal communication 2015-03-06
[31] Carolina Landerdahl, Operating Analyzer, FTI AB, e-mail 2015-14-05
[32] Carl Lundqvist, TMR AB, e-mail 2015-09-04

(Returpack b, 2015). The PET-bottles collected in the deposit system are sent to Returpack's sorting plant where the bottles are sorted and bundled (Returpack a, 2015). Since the bottles are managed in a deposit system the fraction of disposed bottles collected in the system is uncontaminated with other objects i.e. a loss rate of 0%[33]. After that the bottles are transitioned to the recycling facility located in the near surroundings of the sorting plant. The recycling facility is owned and managed by the company Cleanaway PET Svenska AB as explained in section 6.8.2. According to Returpack, the only fractions not being recycled are the refuse from recycling and production processes[34]. In 2013, Returpack reported a recovery rate of 82.9% (Returpack, 2014).

8.1.2 Recycling Companies

Contacted recycling companies are presented below. The type of MW managed during the recycling process as well as the recycling efficiency rates is explained.

8.1.2.1 Swerec

Swerec is a plastic recycling company. They manage the complete recycling process from sorting to new raw material. The plastic waste is provided by municipalities, industries and waste management companies. Swerec receives the main part of the producer responsibility collected plastic packaging that is collected and handled by FTI. In addition about 25 municipalities send their collected non packaging plastic to Swerec to manage and recycle[35].

The recycling process contains a separation step where the mixed plastic is separated into different plastic fractions such as PP, HDPE and LDPE (described in section 6.8.1), a washing step where the plastic waste is washed and finally a grinding step where the fractions are made into granulate. The different plastic granulates are then sold back to the plastic industry as new raw material (Swerec AB a, 2015). The separation process begins with separating light weight plastics, such as bags and plastic film, with a large industrial fan. The lighter plastics are blown off into a separate fraction while the heavier plastics remain. The plastic fractions with higher density such as HDPE and PP are separated with IR-technology. The IR-technology can separate three fractions a time. The plastic with lower density commonly LDPE is baled and sold to the industry. The fractions that are left after the separation with the IR-technology and other light weight plastics such as fruit or cheese packaging are sorted as reject and are sent to energy recovery (Miljönytta, 2013).

According to an interview with Jörgen Sabel, CEO at Swerec, made by Miljönytta (2013), Sabel explains that about 15-20% of the plastic waste received at their facilities is sorted to energy recovery. The content of this fraction differ widely, it could be dirt, snow, as well as other waste or material. Since these materials are included in the waste received at the facility it is also counted as plastic waste at collection sites. This may result in misleading recycling statistics (Miljönytta, 2013). During the work with this report, attempts were made to contact Swerec to confirm information about the recycling process and the amount of disposed fractions. Swerec chose not to provide answers to the questions asked nor comment regarding the numbers found in the literature.

8.1.2.2 Plaståtervinning i Wermland

Plaståtervinning i Wermland, PiW, is also a plastic recycling company. They recycle LDPE and HDPE and to some extent PET. Their raw material is provided by entrepreneurs such as Sita, Ragnsells and Stena Recyling which do the collection and provide high quality plastics. PiW also has

[33] Erik Ebbeson, Customer Manager, Returpack, e-mail 2015-13-04
[34] Erik Ebbeson, Customer Manager, Returpack, e-mail 2015-13-04
[35] Jörgen Sabel, CEO, Swerec AB, personal communication 2015-13-04

some suppliers from Norway. The origin of the raw material is plastic from the consumer market such as wrapping and packaging. Since the material is provided by delivery companies there is no knowledge of the share of MW being recycled at PiW. The plastic arrives either bundled up or loose in transportation containers. Before entering the recycling process, pre-sorting is conducted by an employee where the incorrect plastic type is sorted out from the manufacturing process and sent to energy recovery. As is inherent in the recycling process, the plastic may contain dirt, soil, ice and snow that must be separated from the material.

The recycling process at PiW includes grinding, washing, melting and finally the production of granulates. PiW estimates that after the recycling process about 10-20% is lost as reject. Generally all recycled LDPE is delivered to PiW's sister company in Estonia, but in some cases it is also delivered to customers in Sweden. The recycled HDPE is sold to customers in Estonia[36].

8.1.2.3 Cleanaway PET Svenska AB

Cleanaway PET Svenska AB is responsible for the recycling of plastic beverage packaging, PET-bottles. They receive the collected PET- bottles from Returpack. The recycling process consists of 13 steps starting with a pre-sorting of misplaced objects and a separation according to color. The bottles are grinded into flakes and washed where labels and food residue are separated and disposed to energy recovery. The next step includes a separation of plastic fractions where plastic of either HDPE or PP are separated to be recycled into new caps for the bottles. The recycling process continues with a further sorting process where small particles such as labels or multilayer films, are separated. Thereafter the material is once again washed, sterilized and finally undergoes a final separation process, where foreign particles can be disposed to energy recovery. After the final separation bags are filled with granulate and transported to the plastic industry to be manufactured into new bottles (Veolia Umweltservice PET Recycling GmbH, 2015). The recycling process results in key products, by-products and reject. The key products is granulate, the by-products are caps from the bottles and the reject is comprised of misplaced aluminum cans, steel wire used for baling, glue and labels. Cleanaway PET Svenska AB recycles about 26 000 tones of PET-bottles/ year. About 19 000 tones is collected in Sweden and the rest, about 7 000 tones is bought from the Nordic market. The recycling efficiency rate is 88% where 11% is sorted as reject. The reject is sent to a heating pan where it is energy recovered as district heating[37].

8.1.3 Entrepreneurs

The answers and information retrieved by the entrepreneurs contacted during the survey is presented below. The business of the company is presented as well as how they manage MW.

8.1.3.1 Sita

Sita is a recycling and waste management company. Some of their services are; decontamination of soil, different collection services, transport services, and waste treatment services. They have customers in the building and construction sectors, industry and in the office and real estate markets. They are often contracted by real estate owners and housing societies to collect and manage their waste (Sita , 2015). The waste collected often consists of residual waste which is separated by fractions at source, such as paper and plastic packaging. Regarding the packaging waste, Sita collaborates with FTI and is in some cases hired to manage the waste.

[36] Sonja Andersson, Plaståtervinning i Wermland AB, personal communication 2015-11-05

[37] Thomas Ottosson, Local manager, Cleanaway PET Svenska AB, e-mail 2015-21-05

Sita is also hired by some municipalities for the collection of their MW and to manage their recycling centers. When managing the recycling centers, Sita is responsible for collecting and treating the waste. Sita also has their own recycling centers that are available for both companies and for private citizens. The customers using these recycling centers pay for entree and not for the amount of disposed waste. Sita do not differ between businesses and private citizens, hence Sita does not have any knowledge about the origin of the waste or amounts collected from each customer. Since Sita does not have any responsibility to the municipals to report the figures of collected MW, the data is not figured into the national waste statistic[38].

Sita does not recycle plastics nor do they conduct any pre-sorting. They assure the quality by sorting the collected plastics into different fractions depending on their type. For example, they separate PPE, PP and by color and transparency. When the plastic is sorted into the different fractions, Sita does a quality check to assure the purity of the fractions and thereafter they bale the plastic and sell it to recycling companies. In Sweden they send it to e.g. Swerec or Miljösäck. They also send the plastic to their own recycling plants in Europe (e.g. Holland) as well as to buyers from China. When they sell the waste to other countries they assume that the recycling process and grade is similar to those in Sweden, since the materials they send have the same purity and the buyers have quality demands[39].

8.1.3.2 Stena Recycling

Stena Recycling manages packaging waste from bring sites and door-to-door collection, on behalf of FTI. The plastic waste is bundled at storage facilities where it is thereafter sent to Swerec or similar companies in Germany as determined by FTI. Collaboration with municipalities in terms of collection or transporting packaging waste occurs in those cases where municipalities have engaged liabilities of managing the packaging waste. When receiving the plastic waste at the storage facilities some sorting of larger objects such as plastic suitcases or bicycles is done. As for the municipal plastics, i.e. non packaging plastics, tests have been made in collaboration with some municipalities but the results have not been very positive since the process of separating different plastic types is challenging[40].

8.1.3.3 IL Recycling

IL Recycling offers door-to-door collection as one of their services to property owners and housing societies. Plastic packaging waste is one of the fractions collected and the statistics of the collected packaging waste is reported to FTI.

IL Recycling also manages recycling centers for municipalities where the service are procured. It is up to each municipality to decide how and where the collected waste should be treated. Besides managing recycling centers, IL Recycling also receives non packaging plastics from municipalities and recycling centers. IL Recycling is paid to receive and handle the plastics. The plastics are then sorted and quality checked and then sent to recycling facilities, such as Swerec in Sweden or other facilities abroad[41].

8.1.3.4 Ragnsells

Ragnsells collaborates with FTI and receives plastic packaging waste from FTI, which is baled and then sent forward to recycling facilities determined by FTI, either to Swerec in Sweden or to facilities in Germany. In addition, Ragnsells manages recycling centers for municipalities. The aim differs slightly, in some cases they are commissioned to manage the whole waste chain from collection to

[38] Mats Lundsgård, Regional Head, Sita, personal communication 2015-10-04
[39] Mats Lundsgård, Regional Head, Sita, personal communication 2015-10-04
[40] Anders Lindqvist, Product Manager, Stena Recycling, personal communication 2015-11-05
[41] Elisabeth Lindh, Sustainability Manager, IL Recycling, personal communication 2015-29-05

treatment at their own treatment facilities and in other cases they send the collected waste through to the different treatment methods determined by the municipality (Ragnsells, 2015). Ragnsells does not have a recycling facility, i.e. they do not recycle plastics in the context of sorting plastic waste into different plastic fractions such as PP and PE. However, when managing plastic waste it is baled and quality checked before sent forward to recycling facilities or manufacturing industries[42].

An attempt was made to gain information about Ragnsells regarding collection of non packaging plastics in the municipal recycling centers which they are commissioned to manage. Three different employees were contacted about the non packaging plastics but no information was retrieved. However the last contacted employee in an attempt to gain information from colleagues eventually reported that no information about whether or not Ragnsells collects non packaging plastics from the recycling centers, commissioned to them by municipalities, was retrieved. The contacted employee explained that they might receive non packaging plastics which they are commissioned to bale and send forward to recycling but this information could not be verified[43].

8.1.4 Producer

8.1.4.1 Miljösäck

As explained above, Miljösäck is both a manufacturing and a recycling company. Miljösäck produces different type of products, mainly bags from different plastic materials but also granulate made of recycled plastics. The raw material used for their products is primarily taken from plastic packaging film residues and LDPE collected from industrial businesses as waste companies, as well as wholesaler merchants and retailers (Miljösäck AB, 2015). A small amount of the raw material originates as packaging waste, which is therefore counted as MW. The packaging waste is collected by FTI or TMR and bought from Swerec as granulate, old plastic bags or bundles of plastic films.

Before producing granulate or new plastic bags, the raw material goes through a sorting process where the main objective is to separate it into different fractions to make sure that the material going into the production is of proper quality. Dirt and other misplaced items are also sorted out from the raw material. There is roughly 10-15% of the incoming raw material that is separated as reject from the sorting process[44].

Miljösäck explained that the provided raw material is of better quality now compared to a few years ago. They continuously have discussions with waste management companies about how and what should be put in the recycling bins. This has resulted in a higher level of purity in the fractions collected for recycling[45].

8.1.5 Municipalities collecting non packaging plastics

Some municipalities collect non packaging plastics as a separate fraction at their recycling centers. According to Avfall Sverige’s statistical website, Avfall Web, there were as many as 34 municipalities which reported collecting of non packaging plastic in 2013. There was no attempt to confirm the waste flows and the collected amounts of non-packaging plastic due to the limited time frame of the report. This would have been a very time consuming task, as there is no complete compilation available. Instead information about collection of non packaging plastics on recycling center was retrieved by

[42] Patrik Isaksson, Ragnsells, personal communication 2015-29-05
[43] Patrik Isaksson, Ragnsells, personal communication 2015-02-06
[44] Jimmy Steen, Purchasing Manager, Miljösäck, personal communication 2015-04-05
[45] Jimmy Steen, Purchasing Manager, Miljösäck, personal communication 2015-04-05

Avfall Sverige. In addition when contacting entrepreneurs who are stating on their website that they handle recycling centers, they were asked if and how they manage non packaging plastics.

It was found out that there are several municipalities that are having problems with the financial profits of sending the collected fraction of non packaging plastic to recycling. Given that the fraction is not homogenous and contains different amount of plastic types the sorting becomes more expensive. In addition, the transport is also expensive due to the fact that non packaging plastic often has a large volume but a low weight. By crushing and compression the plastic before transporting it to recycling facilities, the cost could be significantly reduced[46].

Another problem is the narrow supply of recycling facilities in Sweden. Swerec which is located in southern Sweden makes it difficult for municipalities in northern Sweden to make it profitable to collect and recycle non packaging plastics. Therefore there are some municipalities collecting non packaging plastic that send the fraction to energy recovery instead[47].

8.1.5.1 Sysav

Sysav is a waste treatment company owned by 14 municipalities located in the southern Sweden. According to Sysav, they collect, recycles and treats waste from households and industries in southern Skåne“(Sysav, 2015). Sysav was contacted in order to retrieve information about whether they collect non packaging plastics and how they are treated. They report collecting non packaging plastic from one of their recycling centers and explain that one common problem for not collecting non packaging plastics is the lack of space in the recycling centers. The collected non packaging plastic is sent straight to recycling facilities without any intermediary steps. Since December 2014 the collected fraction has been sent to Swerec but during previous years the there has been some variation between different recycling facilities in Sweden, Denmark and China. A new project to decrease the loss rate has been initiated by Sysav where plastic bags are separated at their recycling centers. Tests have also been made to sort out PP but the cost is too high to make it profitable. The price of sending the non packaging plastic to recycling is high resulting in a difficulty to increase the collection. Sysav state that the value of a mixed fraction of non packaging plastic is low and has decreased even more the last few months due to decreasing oil prices. They explain that it is too inexpensive to produce virgin plastic[48].

8.2 Visualizing Plastic Waste System through Flow Chart

As in section 7.1 an attempt was made to map out part of the plastic recycling market and is shown in figure 19. The arrows are drawn between the actors based on the information retrieved during the survey and presented in chapter 8.1 above. The entrepreneurs are either collaborating with FTI or municipalities. It is not confirmed that PiW receive plastic from MW since they do not know the origin of their raw material (it may be industrial plastic). Therefore the arrows not confirmed as MW are dashed in the flow charts. As TMR declined to answer the questions about their clients, the waste flows related to their collection and recycling is unknown.

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[46] Britta Moutakis, Technical Adviser on Hazardous Waste, Recycling Centers and Collection of Food Waste, Avfall Sverige, personal communication 2015-07-04

[47] Jon Nilsson-Derf, Technical Adviser on Material Recycling, Recycling Centers, Collection and Transporting of Waste, Avfall Sverige, e-mail 2015-13-04

[48] Ellen Lindblad, Project Manager, Sysav Utveckling AB, E-mail 2015-25-03

It was not possible to retrieve the quantities in every step of the chain for the overall system, therefore the overall flow chart lacks quantities.

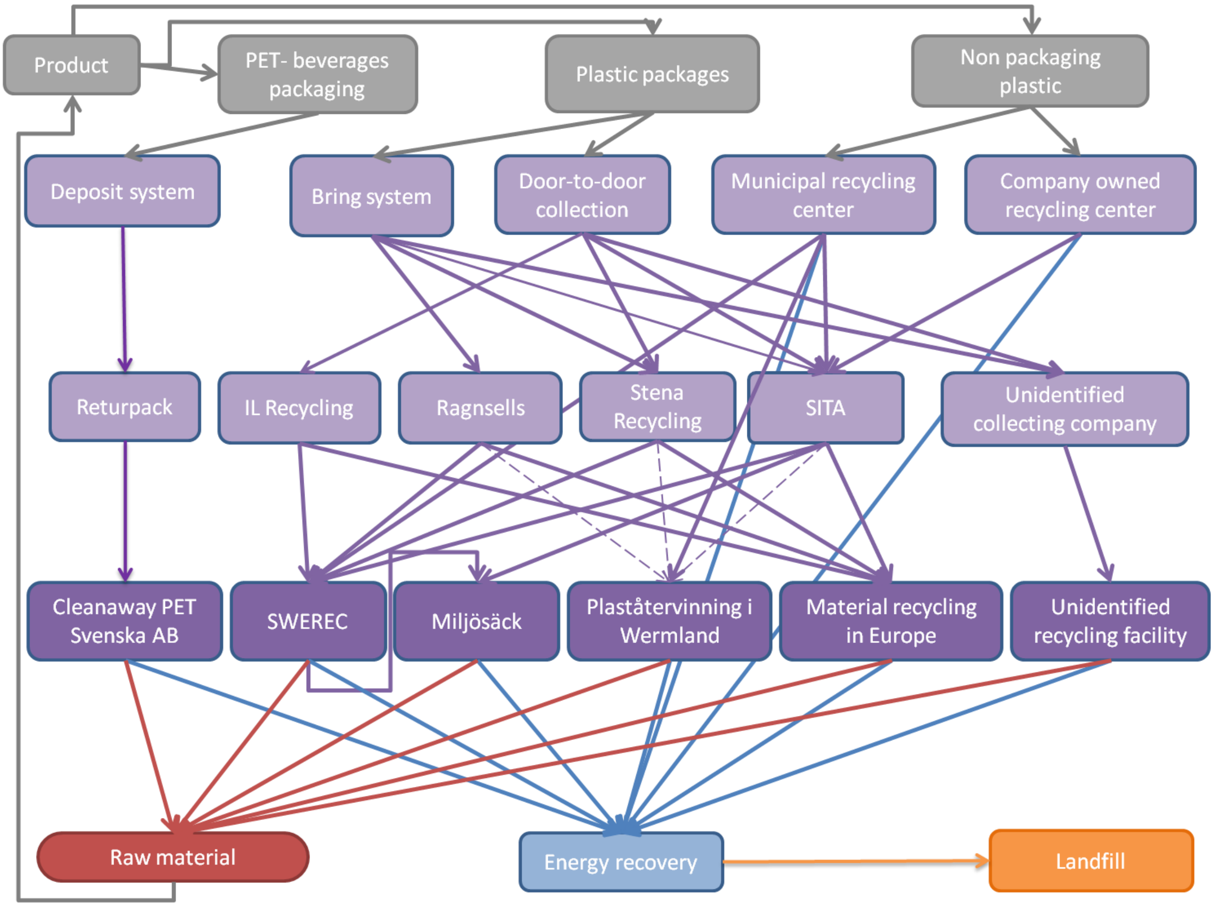

Figure 19. Flow chart showing the overall plastic waste flows from collection to treatment. IL recycling, Ragnsells, Stena Recycling and SITA are cooperating with FTI while the partners to TMR are unidentified in this survey. Gray boxes are different kinds of plastics and plastic waste, light purple boxes are collection methods and actors, dark purple boxes are recycling facilities. Figure is based on the survey made for this study.

8.3 Implementation of the Legislative Proposal in the Swedish Plastic Waste System

In this chapter the changed perception of the waste system is visualized and calculations of recycling rates according to the LPW measuring method are made in those cases where quantities of the plastic waste are available.

Separate flow charts are made for the collection of plastic packaging waste, non packaging plastic waste and plastic beverage packaging waste. In addition, a general flow chart showing the process from plastic waste to a new product is also included. The quantities which were retrieved are instead included in the corresponding flow chart.

8.3.1 Plastic Packaging Waste

TMR and FTI are responsible for collecting and recycling the plastic packaging waste. Each of their plastic packaging waste managing chains is presented below.

8.3.1.1 FTI

The plastic package waste flow for which FTI is responsible is presented in the flow chart below, Figure 21. The figure is based on responses from FTI, Sita, Ragnsells, IL Recycling and Stena.

Recycling and were retrieved during the various surveys (see section 8.1). FTI reported the recycling facilities which the collected plastic packages are sent to, but not the entrepreneurs used for collecting and sending plastic packaging waste to recycling. The contacted entrepreneurs reported having collaborations with FTI. The system in the dotted box is how the current waste system is viewed according to current measuring method when calculating recycling rates i.e. regarded as recycled when sent to a recycling facility.

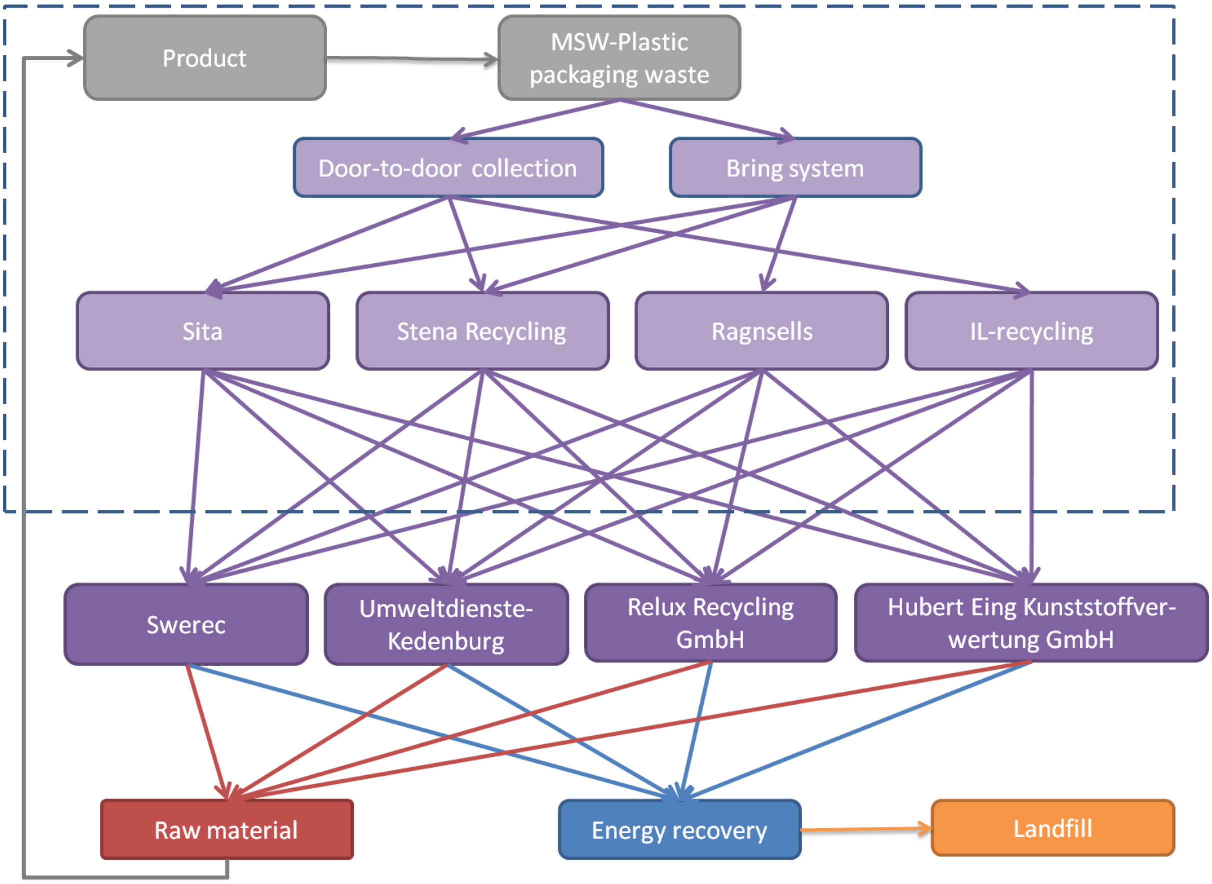

Figure 20. Flow chart showing the plastic packaging waste flow from collection to treatment managed by FTI. Figure is based on the survey made for this study.

As mentioned above, in section 8.1.1.1, FTI reports the amount of material that is recycled with a recovery rate of 36. 7%. The rejects are subtracted in this recovery rate. It was also presented that, 73% of the collected material consists of plastic packaging waste. FTI also stated having a demand on recycling facilities to have a recycling efficiency rate of 80%, the lowest recycling efficiency rate permissible. The recycling efficiency rate however, probably varies somewhat.

Table 14. A summary of FTI's handled amounts of waste 2013

Process step	Amount (tones)
Put on market	186344
Collected household waste	48986
Recycled	68419

Assuming that the recycling efficiency rate is 80% and that 73% of the collected material is plastic packaging waste, the recycling rate is assumed to be calculated as presented in the equation 8.1.

$$Recovery\ rate = \frac{(48\,986+X)*0{,}73*0{,}8}{186\,344} = \frac{68\,419}{186\,344} = 37\% \qquad \text{Eq 8.1}$$

When assuming the above calculation, equation 8.1, collected amounts of plastic packaging waste can in turn be calculated, see equation 8.1, to 117 156 tones.

$$Collected\ amount\ of\ plastic\ packaging\ waste = \frac{68\,419}{0{,}73*0{,}8} = 117\,156\ tones \qquad \text{Eq 8.2}$$

This figure is assumed as the collected amount of plastic packaging waste from FTI and is used in further calculations.

The recovery rate is calculated to 63% according to equation 8.3.

$$Recycling\ rate = \frac{117\,156}{186\,344} = 63\% \qquad Eq\ 8.3$$

The loss rate was given by FTI as 73%. A summary of the calculated rates can be seen in Table 15.

Table 15. Summary of FTI's rates in 2013

Recycling rate	63%
Recovery rate	37%
Loss rate	73%
Recycling efficiency rate	80%

8.3.1.2 TMR

The plastic packaging waste which TMR is responsible for is managed according to the flow chart presented in Figure 21. The flow chart is based on information retrieved by TMR, see chapter 9.2.1.2. No information about collected or recycled quantities was retrieved by TMR. Nor was information received about how entrepreneurs use their recycling facilities in collaboration with TMR. Therefore, entrepreneurs and recycling facilities are still unknown, as shown in the flow chart. Since amounts and recovery rates also unknown, no calculation of the recycling rates is made.

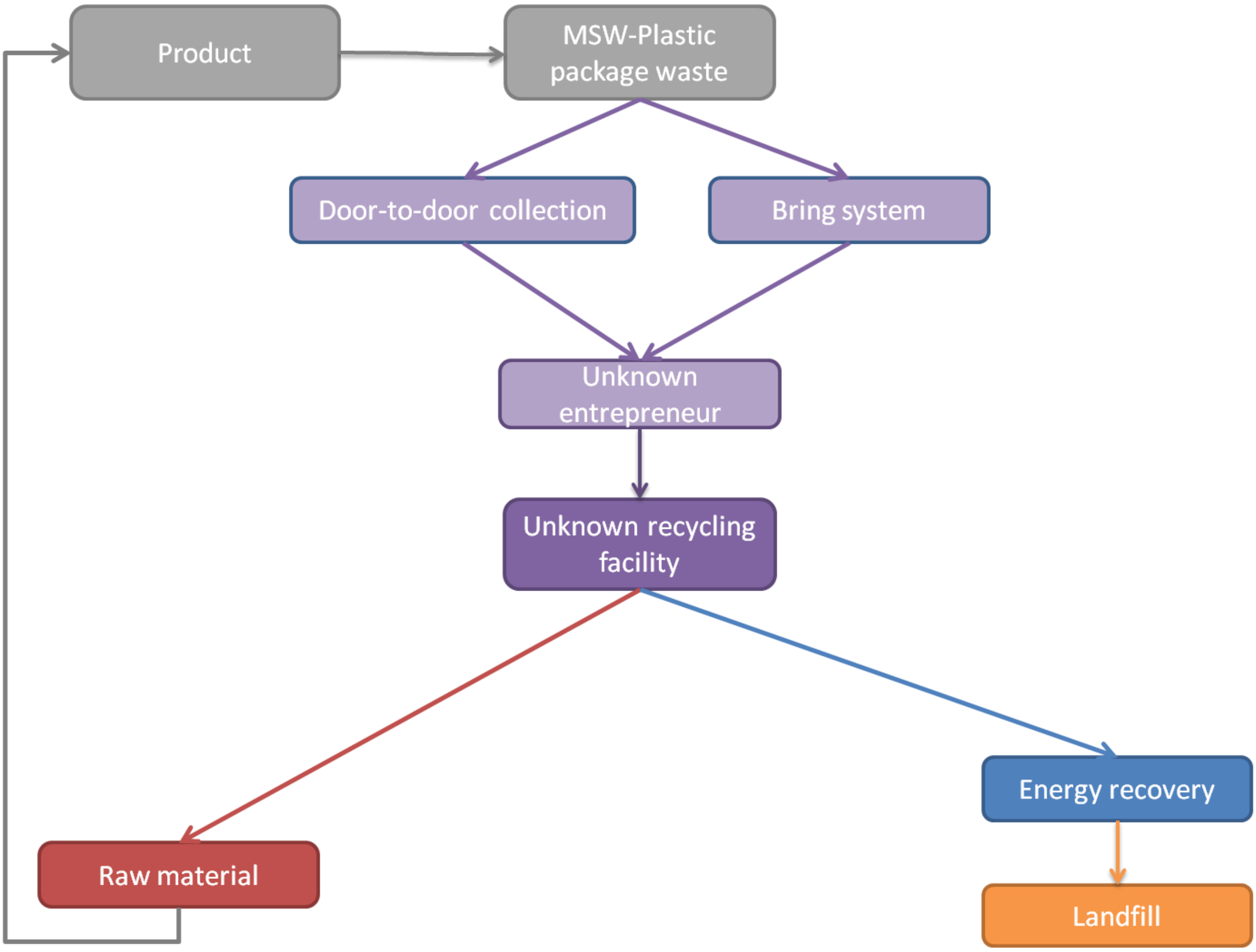

Figure 21 Flow chart showing the plastic packaging waste flow from collection to treatment managed by TMR

8.3.1.3 Returpack

In order to understand the changes that the implementation of the LPW will have on the recycling rates, the recycling rates have been calculated according to the LPW measuring method i.e. subtracting the rejects from the collected amounts of plastic beverage packaging waste. In addition, the plastic beverage packaging waste system is visualized in a flow chart in order to show how the plastic waste system is changed according to the implementation of the legislative proposal.

The given amounts of collected, sorted and recycled PET-bottles are presented in Table 16 and is retrieved by Returpack and Cleanaway PET Svenska AB (see chapter 8.1.1.3 and 8.1.2.3 above).

Table 16. Reported amounts of plastic beverage packaging waste from Returpack and Cleanaway PET Svenska AB.

Process step	Amount (tones)
Put on market	23 319
Collected	19 326
Presorting	0
Recycled	17 007
Reject	2 126

The flow chart showing the plastic beverage packaging, PET-bottles, is based on information retrieved by Returpack and Cleanaway PET Svenska AB and can be seen in Figure 22. The figure shows the plastic beverage packaging waste system according to the legislative proposal. The system in the dotted box is how the current waste system is viewed according to current measuring method when calculating recycling rates i.e. regarded as recycled when sent to a recycling facility. The quantities are shown in figure 22.

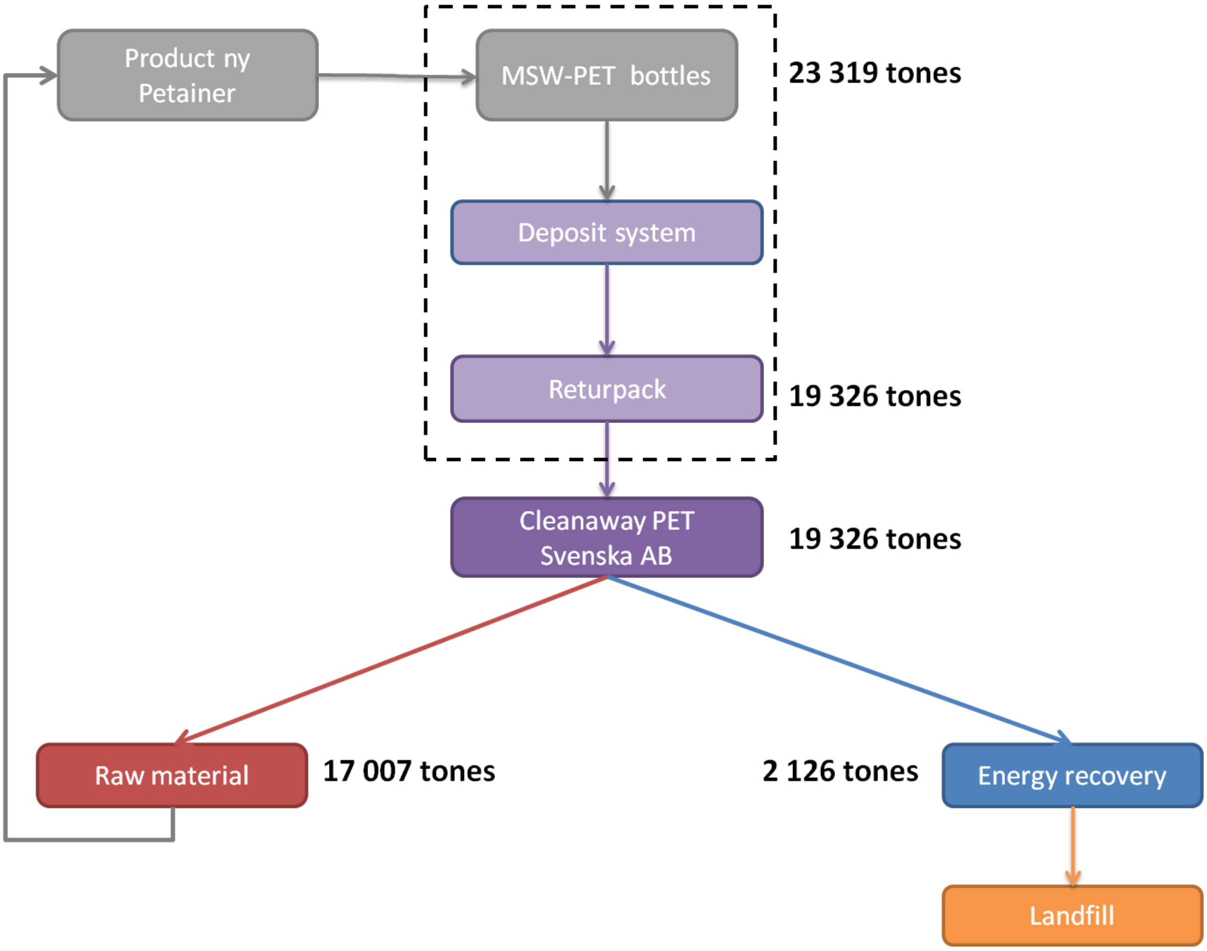

Figure 22. Flow chart showing the plastic beverage packaging waste flow from collection to treatment. Figure is based on the survey made for this study.

The calculations of the rates related to recycling are made by using the equations presented in chapter 2.2 and shown in Eq 8.5- 8.9.The results are presented in Table 17.

$$Recycling\ rate\ packaging = \frac{19\,326-0-2\,126}{23\,319} = \frac{17\,007}{23\,319} = 0.73 \qquad Eq\ 8.5$$

$$Recovery\ rate = \frac{19\,326}{23\,319} = 0.83 \qquad Eq\ 8.6$$

$$Loss\ rate = \frac{0}{19\,326} = 0 \qquad Eq\ 8.7$$

$$Efficiency\ rate = \frac{19\,326-2\,126}{19\,326} = \frac{17\,007}{19\,326} = 0.88 \qquad \text{Eq 8.9}$$

Table 17. Calculated recycling, recovery, loss and recycling efficiency rates for plastic beverage packaging waste

Recycling rate	73%
Recovery rate	83%
Loss rate	0%
Recycling efficiency rate	88%

The recycling efficiency rate of Cleanaway PET Svenska AB recycling process is 88% and Returpack's loss rate is 0%, hence the result is a recycling rate of 88% for PET-bottles.

When calculating according to the LPW measuring method the recycling rate is 73% in comparison to the current measuring method where the current reported recycling rate (.i.e. recovery rate in this report) is 83%.

8.3.2 Non Packaging Plastic Waste

The non packaging plastic waste is collected by municipalities or entrepreneurs. The flow chart for non packaging plastic, see Figure 23 is like the other flow charts, based on information retrieved during the survey. Since the entrepreneurs, Sita and Ragnsells mention managing non packaging plastic waste on their web sites, but when contacted, the management could not confirm this. Therefore the arrows representing these waste flows are dashed in the figure. As mentioned in chapter 8.1.5 there are 34 municipalities reporting collection of non packaging plastics. Swerec declared receiving non packaging plastic waste from about 25 municipalities and one municipality sending the collected waste to PiW. It is not known where the collected non packaging plastic waste, from the remaining 8 municipalities is treated. It could either be sent to recycling facilities abroad or for energy recovery.

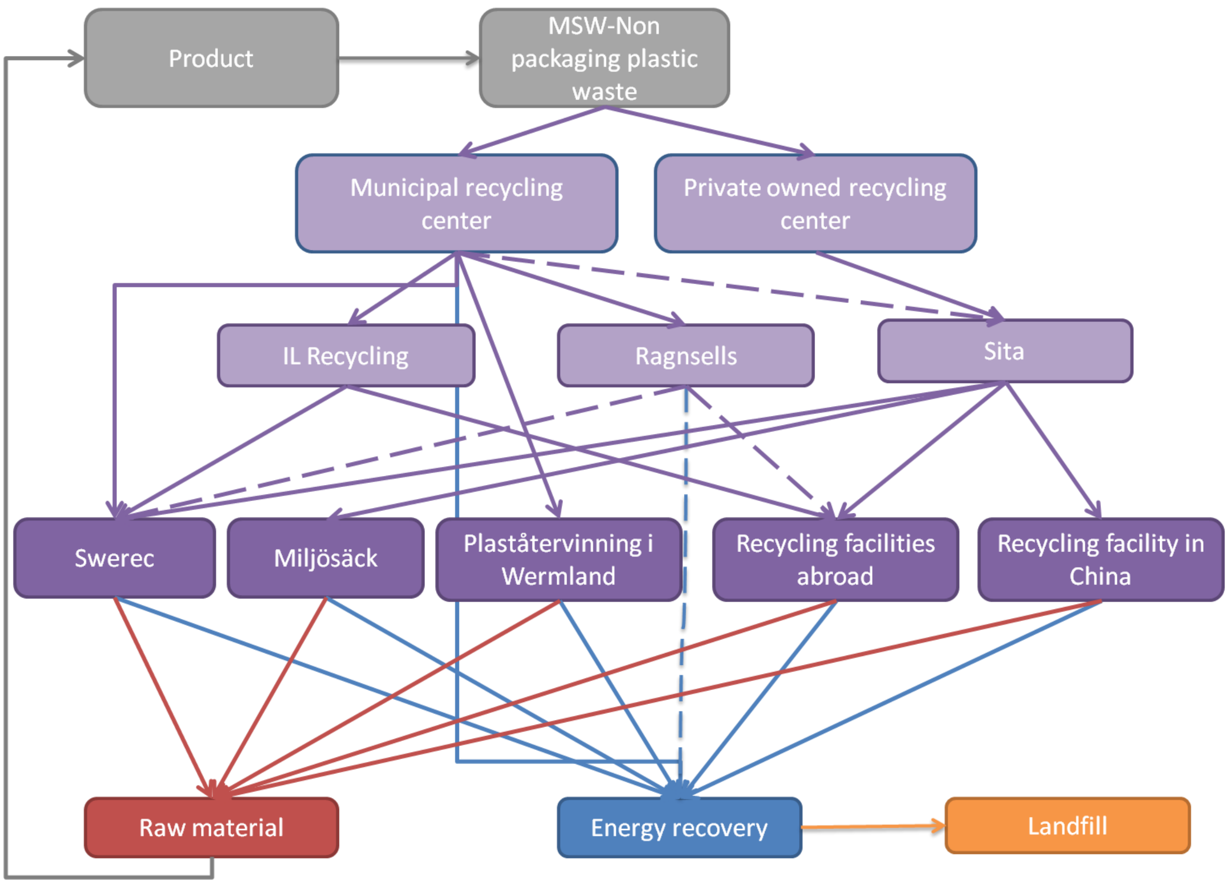

Figure 23. Flow chart showing the non packaging plastic waste flow from collection to treatment. Figure is based on the survey made for this study.

8.3.3 Example of the Process from Plastic Waste to a New Product

This chapter is included in the report to show the full recycling chain from waste to a new product. This example shows that there are several losses along the way. Miljösäck was contacted, as they recycle plastic, but also manufacture newly recycled plastics into plastics bags. A flow chart of the process is presented in Figure 24.

As mentioned in chapter 8.1.4.1, Miljösäck buys both the recycled plastics from Swerec as well as directly from consumer goods industries. The recycled plastics from Swerec consists of loose plastics i.e. not granulates. As can be seen in the flow chart in Figure 24 and mentioned above, when receiving both recycled plastics and plastic waste, a sorting is made where 10-15% is separated and sent to energy recovery. Before the sorting at the manufacturing factory, the raw material has gone through a recycling process at Swerec's recycling facility where about 25% was separated from the collected plastic waste meaning that only 65% of the collected plastic waste is manufactured into new products. The residual from the recycling and manufacturing processes i.e. 35% of the collected plastic waste is sent to energy recovery.

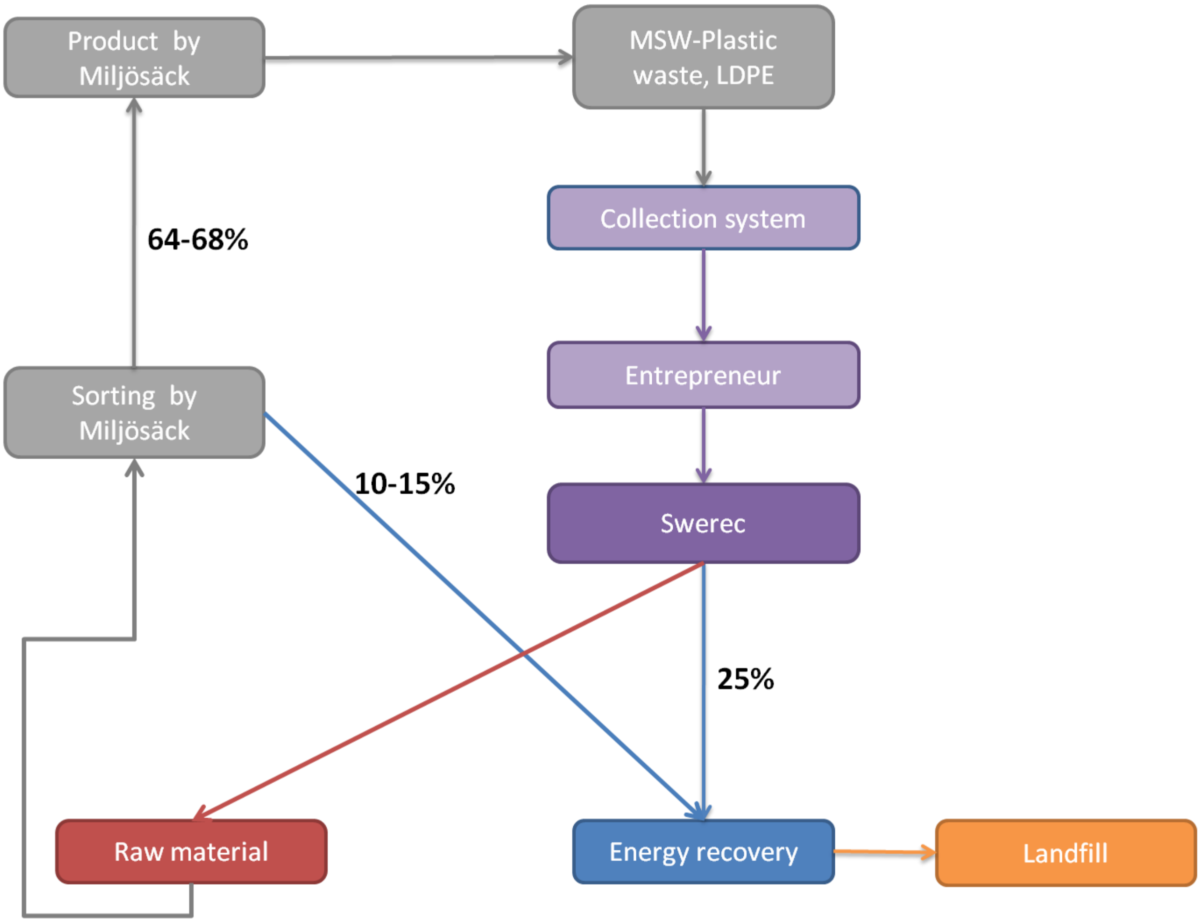

Figure 24. The example of the process from plastic waste to new product. Figure is based on the survey made for this study.

8.3.4 Recycling Efficiency Rate of Plastic Recycling

As explained in section 2.3.4, a survey was made to confirm recycling efficiency rates when recycling plastics. As presented in Table 6 and according to the treatment distribution template provided by IVL (see section 2.3.2), 25% is separated as losses in the recycling process. These figures are both provided by IVL, which in turn refers to Swerec as the source. Miljönytta, PiW and Cleanaway PET Svenska AB reports different recycling efficiency rates. Table 18 shows a summary of reported recycling efficiency rates of plastic recycling. It can be seen that 10 -25 % is screened out as reject in a recycling process.

Table 18. Summary of reported recycling efficiency rates of plastic recycling based on information from IVL, Miljönytta, PiW and Cleanaway PET Svenska AB.

Source	Reject (%)
Impact Assessment	25
Distribution template for plastics	25
Miljönytta	15-20
Plaståtervinning i Wermland	10-20
Cleanaway PET Svenska AB	11

A calculation of how the recycling rate would change if the LPW would be implemented was made for this study. Since FTI already reports the amounts that are material recycled, it is only the amounts from the plastic beverage packaging waste that has to be changed.

To show the size of the recycling efficiency rate a calculation has been made. Since the amounts for total collected plastic packaging waste is unknown, the targets have been calculated with the amounts reported by FTI and the amounts for collected plastic packaging used in the above calculations in chapter 7. The recovery rate uses the collected amounts of plastic beverage packaging waste and the amounts of plastic packaging waste which is material recycled.

$$Recovery\ rate = \frac{19\,326+117\,165}{23\,319+186\,344} = 0.65 \qquad \text{Eq 8.10}$$

The recovery rate was calculated to 65%. This calculation includes the calculated amount for FTI's collected material, meaning that the rejects is not subtracted from this figure.

The recycling rate when implementing the LPW in Sweden is calculated below. The amounts reported by FTI as material recovered and the amounts of collected plastic beverage packaging waste are used. The rejects are subtracted from the of collected plastic beverage packaging waste.

$$Recycling\ rate = \frac{19\,326-19\,326*0{,}11+68\,419}{23\,319+186\,344} = 0.41 \qquad \text{Eq 8.11}$$

The recycling rate was calculated to 41%

The recycling rate was calculated with the figure for collected amount of plastic packaging, used in the calculations for the overall recycling rates for Sweden made in chapter 7, instead of the figure reported by FTI.

$$Recycling\ rate = \frac{19\,326-19\,326*0{,}11+90\,055-90\,055*0{,}25}{23\,319+186\,344} = 0.41 \qquad \text{Eq 8.12}$$

The recycling rate was also calculated to 41%. This indicates that the amounts used for plastic packaging in chapter 7 are a good assumption.

To see the how the recycling rate depends on the recycling efficiency rate, the recycling rate was also calculated using an efficiency rate of 10 % since it could differ between 10-25%, see Table 18.

$$Recycling\ rate = \frac{19\,326-19\,326*0{,}11+90\,055-90\,055*0{,}1}{23\,319+186\,344} = 0.47 \qquad \text{Eq 8.13}$$

To give an overview of the recycling target in the EU compared to the calculated levels, Table 19 has been created. From the left, it shows the current EU directive target for plastic packaging waste which is in force. It is followed by the target which was proposed in the LPW. These targets can be compared to the calculated rates which are shown in the following columns. When changing the recycling efficiency rate for the plastic packaging waste to 10% the recycling rate increases to 47%. Table 19 shows that depending on the calculation method the share an interval

Table 19. Shows the current EU target, the proposed LPW target and calculated rates for plastic packaging waste.

	Current EU directive target (94/62&EG)	**Proposed target (COM(2014) 397 final, 2014)**	**Recovery rate- using current measuring method**	**Recycling rate according to LPW measuring method with an efficiency rate of 10 %**	**Recycling rate according to LPW measuring method with an efficiency rate of 25 %**
Material recycling, Plastic packaging	-22,5 % by 2020	-45% by 2020 -60% by 2025	65 %	47%	41%

9 Analysis

9.1 Structure of the Overall MW System in Sweden

The visual figure over the entire Swedish treatment system shows that even the basic structure (Figure 9) shows a more complex system than could be understood from the reported statistics alone. In this structure of the overall MW system rejects, otherwise omitted from the data, are shown being sent between treatment methods, giving a more accurate picture of the system. These waste streams are also part of connecting the system back to the idea of a circular economy, by showing the ways in which the waste resource could be brought back into the system. This is also the case in the detailed flowchart (Figure 10) which shows how each fraction will end up in different treatment methods, aiding the effort to achieve higher rates of recirculation of resources.

9.2 Structure of Plastic Recycling System in Sweden

The survey of the plastic recycling market showed that it is a highly complex system with many different actors. The actors contacted in the survey are only a small selection of the entire range interactions between the various companies involved. There are larger organizations, such as FTI, TMR and the municipalities, responsible for the collection and recycling of the plastic waste. In reality the actual execution of the collection and delivery of recyclables is made by different entrepreneurs.

The system, however, is not very straightforward. As explained in section 4.2, there are both obligations associated with the municipalities to collect and manage MW as well as producer responsibility. The plastic waste is sent between large number of actors making it complicated to map out and have control over the various waste streams. All waste flows have not necessarily been confirmed exactly which has been represented in the flowcharts of the visualized system in Figure 19, Figure 21 and Figure 23.

9.2.1 Non-packaging Plastics

Regarding non-packaging plastics, the collection and management of the MW is in some cases, outsourced to entrepreneurs, as expressed by Sita and IL Recycling in section 8.1.3 and shown in Figure 23**.** As presented in chapter 8.1.5, there are 34 municipalities reporting collection of non-packaging plastic. However, about 25 non-packaging plastic flows are sent to recycling at Swerec and 1 flow is sent to recycling by PiW. The treatment method for the rest of the non packaging plastic waste flows which then should be about 8 flows is not confirmed. There are also municipalities who did not report whether they collected plastics or not. This indicates that there is a knowledge gap concerning the overall picture, about what happens with the non-packaging plastics.

Sita has recycling centers where citizens can turn in and sort their waste. They have no responsibility to report to municipalities how much of their waste which is MW, and do therefore not differentiate MW from industrial waste, as described in chapter 8.1.3.1. A quantity of the waste turned in by private citizens is most likely MW and should therefore be accounted for in the national statistic.

The knowledge among the entrepreneurs beyond their own part of the recycling chain is meager, this was further verified from the contact with Ragnsells. During the survey a number of employees from Ragnsells were involved but no one could give an answer to the question if they handle non-packaging MW plastics and if they did how much. This was the case even though the information on the homepage said that they are responsible for some municipal recycling centers, which implies working with MW.

The poor knowledge of the plastics heritage and destination handled by the entrepreneurs is remarkable but not very surprising. As the statistics for the recycling rates do not ask for this information there are no incentives for the actors to track these flows.

9.2.2 Plastic Packaging Waste

PiW explained that they receive plastic waste from entrepreneurs like Sita and Ragnsells, in which they could identify a portion of packaging waste in its contents. They do not keep protocols of the origin of the provided waste. Since it is uncertain where the flows originate from, the mapping of the flows is also uncertain and the flows of MW are lost in the complexity of the system.

Swerec on the other hand chose not to provide information for this study and even though it seems like they keep track of the plastic streams within the process the information from their facility was gathered from external sources.

FTI and TMR together provide the services for the producer responsibility of packaging. The study has shown that FTI collaborates with other entrepreneurs that collect plastic packaging waste and send it to be recycled. There may be additional intermediary step and actors which, for example, only pack it into bales before sending the plastic packaging material forward in the recycling chain.

TMR is assumed to work in similar collaborations but they do not share information on their partners. This lack of transparency results in further unidentified plastic packaging waste flows.

The overall analysis of the gathered information about the actors concerning the recycling of plastics is that the information is not shared along the process. There are many actors and collaborations where the overall picture is difficult to gather. Hence the non-existing transparency of the companies and the difficulty to compile and gather information it is hard to compile a correct picture of the efficiency of the recycling process, as can be seen in the calculations made in section 8.3.4.

9.2.3 Depositing System

Due to the deposit system constituted according to the producer responsibility, explained in section 4.2.3, the waste flows of plastic beverage packaging is identified through the whole waste treatment chain, from collection to new product. Since the waste flows are identified and very straightforward, the quantity of the waste flows was also identified, making it less problematic to calculate recycling rates according to the implementation of LPW.

9.2.4 Structure of the Plastic System with Different Measuring Methods

As can be seen in the flowcharts presented in sections 8.2 and 8.3, there is a difference between the perception of the plastic waste system according to the current measuring method, and the LPW measuring method. Visualizing the plastic recycling system with the current measuring method, includes the flows of plastic packaging from the point where they are put on the market, to the point which they are collected as plastic packaging waste, and sent to recycling. In the visualization according to the LPW measuring method the flows are additionally followed through the entire recycling process. Meaning all the way to the point where the plastics leave the recycling process as new raw material. This means that the reject from the recycling process is also taken into account. To execute this has, as described above, proven to be very complicated as there is a lack of provided information between the actors along the recycling chain.

9.3 Recycling Rates in the Overall MW System in Sweden

9.3.1 Collection Distribution and Final Treatment Distribution

After studying the diagrams presented in chapter 7, there are a few things that are worth commenting on after comparing the diagrams. Figure 11 visualizes how the system is currently seen in Sweden, with only a small difference caused by the two additional fractions (grease trap residues, and frying grease and cooking oil) added in this study. Figure 12 visualizes how it could be seen if a change similar to the one in the LPW was passed. One of the more significant differences between them is in the material recycling column, where large portions of the waste sent to recycling were lost as reject, mainly to energy recovery. This changes the recycling rate by as much as 8 %-units. In addition, the energy recovery has a lower rate, about 5 %-units, when factoring in the final treatment, as it is distributed between remaining treatment methods. The rejects from energy recovery are dominated by the waste stream going to backfilling, followed in size by the stream to landfilling. The proposed method shown in Figure 12 is more accurate when it comes to the amount of the Swedish MW that ends up at a landfill. This shows that in the end, 4% is disposed of in a landfill instead of the mere 0.7% which is sent directly there. While a further 8 % is used for backfilling.

9.3.2 Backfilling as Material Recycling or not

It would be interesting to imagine a case where the LPW measuring method is implemented but backfilling was still included in material recycling, as it is included today. This could be visualized by simply moving the column representing backfilling to the material recycling column in Figure 12, which would in effect make the total material recycling rate 50%. In this case the recycling rate would be even higher than the collection rate is today (Figure 11). This is a consequence of the rejects from the incineration process, which make up a very dominant portion of the backfilling material. This is verified by Figure 15 showing the final treatment distribution in relation to the collected material. It is further confirmed in literature, showing that the bottom ashes from the waste-to-energy process are often used as backfilling material (chapter 6.6). The fraction gained from counting backfilling as recycled material in the calculation of rates, is similar in size to the rejected fraction lost from the material recycling process. The backfilling amounts are not representing nor related in a significant way to the recycling rejects which are lost in the process. It is however an interesting coincidence that the end results for recycling is so close when comparing the scenario with the collection rate in Figure 11.

9.3.3 Separation of the Products from Anaerobic Digestion

In Figure 16, the final treatment methods include a separation for anaerobic digestion, in which the natural consequence is that the energy recovery increases and has an inverse relationship with the amount of material recycling. The analysis of this result is however, that a change in the approach to the statistics for organic treatment would have a noticeable effect on the final statistics for the distribution of waste between the treatment methods. This would technically, put the production of biogas further down in the waste hierarchy making it a lower priority, as described in chapter 4.1.2. There is a big difference in the current recycling rate in Sweden depending on how it is calculated, as can be seen in Figure 11 and Figure 12. Table 12 aims to give a clearer picture of the current and possible future targets compared to the current recycling and landfilling rates.

9.3.4 Landfilling

Sweden is already fulfilling both current and future EU directive targets by having a landfill ban on collected combustible waste and on organic waste. However, there is a big difference when comparing the landfilling rate for the two measuring points. In the case of the measuring method in the proposal, the landfilling rate increases more than 6 times. The amounts considered 'landfilled' then changes from the collected 33 300 tons to 1 952 734 tons of material which actually ends up on a landfill.

9.3.5 The Impact of Measuring Methods

In contrast to landfilling rates, the recycling rate will decline with the LPW measuring method. From the 62% reported to the EU in 2010, using method 2, to a mere 42% in 2013, a difference of 19 %-units when the rates should have increased due to more collection of recyclables. Compared to Avfall Sverige’s national statistics the rates are also lower with the LPW measuring method. When these numbers are compared to the targets in Table 12, it can be seen from following the proposal, that Sweden is 30%-units away from fulfilling the 70% target for recycling 2030.

After comparing the 42% recycling rate results (Figure 12) with the current reporting system it has been found that there is a difference in the results. Method 4 may be seen as the most similar calculation method, of the current alternatives, to the method suggested in the LPW. However, the calculations made using method 4 was described in chapter 6.7 as being 49% (Sundqvist, 2013). These calculations were still based on the collected amounts for recycling. The LPW measuring method is a completely new version of calculating the recycling rate.

The results in chapter 7 compared to the theory put forward here, shows a strong dependence on where along the recycling chain the measurements are made and what measuring method is used for the calculation. The definitions have also proven to have an impact of the results. This has been shown for example as the definition of material recycling excludes backfilling and when investigating the separation of biological treatment.

9.3.6 The Future of the Treatment System in Sweden

The projection for how the system would look in 2030, under the given assumptions, is presented in chapter 7.3. It foresees a scenario where material recycling is the dominating treatment method and the rejects from this process makeup a large part of the material treated in the remaining treatment methods.

As the material recycling increases to 70%, the amount sent directly to energy recovery will decrease in Sweden, as we already have a very low rate of landfilling. This has the effect that the percentage of material recycling originating from the energy recovery process will decrease, as there is less energy recovery compared to material recycling. Therefore, this fraction in the final material recovery will be even smaller than it is today, from 1% now (Figure 14) to about 0% (Figure 18). The calculations show that the fraction is negligible, but the decision was taken to represent it in Figure 18 to indicate its presence.

The energy recovery of the MW produced in Sweden will, as mentioned, decrease and a larger part of the energy recovery will then consist of the rejects from the material recycling process. This would be as much as 51% of the MW compared to the 16% (Figure 15) of today. This would be a result of collecting less waste for the purpose of sending it straight to energy recovery. The same trend is seen in the landfilling column in Figure 18, as the material recycling takes a larger part in the system the landfilling material will also be dominated by rejects from this process.

The assumption that the collection for landfilling will not decrease is reasonable. It is based on the current practice of sending materials with no other treatment options straight here (chapter 6.6). This goes along the same lines as the future predictions of both the IA, for 2020 and 2030, and the prediction for 2020 by Profu (chapter 6.7.2).

When comparing the results of this study to the predictions of Profu (Profu AB, 2013) and IA (Gibbs b, et al., 2014) in chapter 6.7.2, it is the first and most important factor to keep in mind that none of these predict a 70 % recycling rate for Sweden. The starting point for this study was 70 % recycling rate and the chance for this to actually happen was not calculated. The two predictions from the literature were instead based on the trends and current targets in the Swedish waste system. Neither of the two predictions includes backfilling as an independent treatment method, meaning that the backfilled amounts might be included in their results for material recycling resulting in a higher material recycling rate than using the LPW measuring method.

9.4 Plastic Recycling Rates

9.4.1 Efficiency Rates

An attempt was made to confirm the recycling efficiency rate for plastics presented in the treatment distribution template (see section 8.3.4). There are four different sources reporting recycling efficiency rates for the recycling of plastic packaging waste as presented in Table 18. Three of the recycling efficiency rates apply to Swerec's facility while the last one applies to the recycling facility owned by PiW. Overall, the recycling efficiency rate of plastic packaging waste recycling, as understood for the context of this study, varies between 10-25%, meaning that this amount is separated as reject and sent to energy recovery. The three different recycling facilities studied have different incoming plastic waste and recycling processes. Cleanaway PET Svenska AB is for example only equipped to recycle PET-bottles while Swerec and PiW recycle a larger spectrum of plastic fractions. This includes plastic packaging waste, non packaging waste and industrial residual plastic waste.

FTI reports that the collected amount of plastic packaging waste had a moisture rate of 12% and a rate of misplaced waste and plastics of 17.5% i.e. 73 % of the collected waste was plastic packaging waste. In contradiction, FTI does not share the collected amounts but only the amounts of plastic packaging waste that is recovered material. FTI states that this factor of 27% is subtracted when reporting the national waste targets see chapter 8.1.1.1. It is unclear though what amount they report to the national statistics, hence it is also uncertain which recycling efficiency rate that is used. The collected amount, including moisture and misplaced waste and plastics is sent to recycling. When received at the recycling facility, the moisture, misplaced waste and plastics not possible to recycle that had been included in the collected material, are separated. However the moisture, misplaced waste and plastic not possible to recycle are included in the recycling efficiency rate. As described in chapter 8.3.4 above, the recycling efficiency rate differs between 10-25% depending on incoming material. Depending on how much moisture and misplaced items the collected amount contains, the recycling efficiency rate varies. The recycling efficiency rate could also depend on how much of the chosen plastic fraction is later recycled from the incoming material.

9.4.2 Plastic Recovery Rate

As explained in chapter 4, the targets for recycling rates (or recovery rates as used in this report) differ between the European legislation and the legislation in Sweden, since Sweden has set up more ambitious targets for collecting plastics. By calculating the plastic recovery rate, according to the current measuring method, the result in equation 8.10 is a rate of 65%, in comparison to calculating the recycling rate according to the LPW measuring method where the result of the rate is 41 %, see equation 8.11. When transitioning the calculation of the recycling rate into using the LPW measuring method the rate decreases. This can be seen in the calculations of the recycling rates for both plastic packaging waste collected by FTI and plastic beverage packaging waste collected by Returpack. More importantly is seen in the recycling rate for the overall plastic packaging waste i.e. by including the plastic packaging waste from both FTI and Returpack. As the recycling rate decreased from 65% using the current measuring method to 41% using the LPW measuring method, the result is a decrease by 24% units, consisting of the rejects from the recycling processes. Instead of already having reached the recycling target of 65%, proposed in the LPW, Sweden would need to make up and additional 24% to reach the target. This 24% can be attributed to the rejects from the recycling processes. The recycling rate is thus dependent on the recycling efficiency rate. By changing the recycling efficiency rate the recycling rate also varies.

9.4.3 Example from Miljösäck

The example of the process from plastic waste to new product, described in 8.1.9.3, shows that an additional sorting process is needed, in Miljösäck's manufacturing process, where 10-15 % is disposed and sent to energy recovery. This means that about 63-68% of the collected plastic waste actually becomes a new product. Looking at the whole system is important in the context of transitioning into a circular economy (CE). If resources are used more efficiently, the whole system would need to be more efficient. As Ellen Macarthur and Braungart mention, see chapter 3, it is necessary to make developments addressing the whole product chain, from manufacturing to recycling, into new products.

10 Discussion

10.1 Structure of the Overall MW System in Sweden

In the investigation it was discovered how the waste system is put together and how the perception of the system changes depending on the calculation method used for the various recycling rates. It is important to understand that it is only the manner in which the system is understood that changes and not the way the system actually is built up.

Figure 9 and Figure 10 shows in what ways the system is complex and how most of the collected waste fractions are divided between more than one final treatment method. A process will always have losses and this divides each fraction into several streams. It is meaningful to track these waste streams in order to ensure recirculation of the highest possible amount of resources. This would likely become easier if the systems and targets were better adapted to the actual structure of the system. There should also be high levels of transparency in the recycling rates and openness about how actors collaborate.

10.2 Structure of the Plastic Recycling System in Sweden

In the analysis the many problems with non-transparency between the many actors in the plastic recycling system were brought forward. The investigation made for this report has led to an impression of a complex system where no one really has the overall picture. It may seem strange that no one knows how everything is connected. It is very likely that the actors only know the information relevant to them and their business. The current measuring methods and systems approach does not require some of the facts and figures which were asked for in this investigation e.g. rejects, the previous and following process step in the recycling chain. These figures are important for the system approach described here and asked for in the legislative proposal on waste targets (LPW). Some of the information could also be valuable in order to improve the system. This could for example ensure that the plastic is sent to the recycling facility where that specific kind of plastic is treated as efficiently as possible which complies with Velis (2014) thoughts on using closed loops systems, see section 6.8.1. Using closed loops systems and separate technical cycles (explained in section 3.3) is a way to achieve a transition to a circular economy.

As it is now, the MW and the industrial plastics are combined together early in the recycling chain and this leads for example to that the rejects specifically for MW will be very hard to distinguish. The complexity of the system and the overall picture of how the different parts in the MW plastic recycling system are connected make it very difficult to find reliable data of the total recycling rate.

10.3 Recycling and Treatment Rates in the Overall MWS System in Sweden

10.3.1 Collection Distribution and Final Treatment Distribution

The fact that the Figure 11 and Figure 12 are so different is a natural consequence of rejects being versus not being accounted for. However, that these differences are significant is still remarkable and it shows yet again that it is inappropriate to report the collection for each treatment instead of what actually happens to each waste stream. This reporting system gives an incomplete picture of how the Swedish waste system currently works.

10.3.2 Backfilling

There is a large amount of waste that is used for backfilling which now is counted as material recovery. Material used for backfilling is generally not MW, the backfilling-related MW in Figure 14 is instead the reject from the energy recovery process, and to a lesser extent, small scrap metal and other bulky materials from the material recycling process.

10.3.3 Separation of the Products from Anaerobic Digestion

The separation between energy recovery and recycling from the anaerobic digestion would be complicated to implement in reality. This is especially described in appendix 5, where plenty of assumptions had to be made in order to calculate a theoretical division between biogas and biofertilizer. This would also be a peculiar way of measuring the result from the anaerobic digestion, as the waste hierarchy prefers material recycling before energy recovery. At the same time, biogas has often been the preferred product over bio-fertilizer, from anaerobic digestion. It is significant that this way of counting moves 2 % units from recycling to energy recovery. Two percent may seem low, but this is remarkable considering that landfilling today is reported as 0.7%. This is a relatively large impact of change in the statistics reporting system. It indicates yet again the necessity of clear and unified waste management reporting methods. The biogas rate from the anaerobic digestion is also very ambiguous as the rates used in these calculations are both theoretical and contains rough estimates for certain values. This is further explained in appendix 5.

10.3.4 The Impact of Measuring Methods

Another clear sign of the need of LPW measuring methods within the EU are the different results for the recycling rate in Sweden calculated by Sundqvist (2013). He shows the four methods currently allowed according to 2008/98/EC and calculates nine different rates for Sweden (chapter 6.7). This study calculates a further two (excluding the collection rate calculations); one overall rate if the LPW would have been interpreted and another with the separation of anaerobic digestion, which also could be a possible interpretation. This gives a total of 11 possible calculation methods presented which creates a confusing and untenable situation.

With this background, it becomes apparent that MS using different calculation methods prevents the ability to make accurate comparisons between different countries' waste treatment practices. It also results in that a country's compliance with the targets may be dependent on which method they choose to use when they report their result to the EU.

One may argue that the measuring method in the proposal makes more sense than the one in the current 2008/98/EC directive. This statement is based on the fact that only collecting the waste fractions are no guarantee for the intended treatment to be executed and it could therefore be claimed to be irrelevant how much is collected if there is no further information after that. Reporting the actual recycling rate will also foster openness in the entire recycling chain, for example making control of the efficiency in the process easier.

As of now, (2015-20-04) the proposal has been withdrawn but this does not lessen the need for a harmonized measuring system smaller. The fact that the system in place now makes it impossible to compare waste treatment performance between the member states is just one of the arguments to why a harmonized calculation method should be kept for the next proposal.

10.3.5 The Future of the Treatment System in Sweden

The assumption of no increase in efficiency in any of the treatment processes is very unlikely. This is a fault in the calculation but as the increase is very difficult to predict this was still the most accurate way to do the calculation at the level attempted in this study.

Another very rough estimate is the ratio between the material recycling and the biological treatment being the same in 2030. This is not very likely as Sweden is working very actively with decreasing the food waste and with increasing the collection. However, as one of these factors will raise the organic waste ratio in the recycling collection pile and one of the factors will lower it, the decision was to leave it at the same ratio. This is not the same assumption made in the predictions made by Profu or in the IA shown in 6.7.2**.** They also did not put biological treatment and material recycling as the same treatment method. However, they both predicted that material recycling and biological treatment methods will increase. This is also the case in the calculations made for this study.

As mentioned the future scenario from this study is built on a large amount of assumptions and it should be pointed out that the result is very hypothetical. However, it might still give a picture of a possible development in the waste management system. The system setup may be seen as a mix of a future scenario and an application for how today’s system would behave if the recycling rate was brought up to 70%. This is said in the sense that the circumstances in the projection in many ways are assumed to be unchanged which is not very likely. One adaption to a future scenario is however that the total amount of waste is assumed to increase. This will make it possible to use the projection to assume future treatment amounts but it will not change the rates compared to a scenario where the 70% target was implemented on the current system.

Comparing the future projection of this study with the predictions found in the literature (Profu AB, 2013; Gibbs b, et al., 2014) in 6.7.2 shows that the projection and the predictions were made under completely different assumptions. However the assumption that the landfilling stays at the level of today is likely and made in all the studied predictions. Both of the predictions found in the literature predict more energy recovery in the future than this study does; this is natural since they do not predict as much material recycling.

This study's projection and the predictions in the literature are made under different presumptions and should therefore be used for different purposes. The literature studies are indicators of where Sweden is heading whereas this study may be used for the purpose of showing how likely Sweden is to reach a recycling rate of 70%. It should be kept in mind that they are developed after the current goals and targets which mean that they could change if for example new and tougher targets were set.

The projection made for this study is in contradiction to the studies found in the literature made with the condition of Sweden reaching a 70% recycling rate. The projection may therefore be useful to study the effects of this change if it were to happen. This is a reasonable starting point for this kind of reasoning even under the very rough estimates discussed above.

In the IA it is reported that theoretically a 70% recycling rate would be possible in Sweden as of now (chapter 5.6.4). This study is looking at the waste composition and from what can be read in the IA it is not based on the countries’ possible waste treatment development. A more credible investigation would have to take into account a country's economic conditions and access to technology and knowledge. If these things are not considered the investigation is only giving a theoretical result.

There is a large gap from the targeted 70% recycling rate and this study's calculated 42% recycling rate. According to the prediction in the IA this gap is still large in 2030, with current development, even also while looking at the collection rate.

10.3.6 Outlook

To put the possibility of reaching the proposed targets in perspective Sweden is much above average compared to the development of the waste management in the EU. In 2010, only 16 out of 32 countries had recycling rates above 25% (chapter 6.2 (EEA, 2013)**).** This is relevant to point out as the projections indicate that it would not be insignificant for Sweden to reach the 70% target and the fact that many countries are far behind in this development indicates even greater difficulties for them. As mentioned in chapter 5.2 a number of countries have already expressed the opinion that the targets were set too high when the circular economy agenda was put forward in 2014.

When studying the results of the composition of the waste in each final waste treatment method, it is relevant to discuss the role of energy recovery. The rejects from the material recovery process, in Sweden, will mainly go to energy recovery and to a smaller extent to landfilling. In the scenario where 70% recycling is implemented, the energy recovered material will to an even larger extent consist of these rejects (Figure 18).

This leads to the question how the implementation of the LPW would affect other countries in the EU. The landfill ban would not affect Sweden; as such practices are already banned. Considering the countries that now have more than 75 % landfilling, would probably give a completely different projection. In many countries the rejects from the material recycling process would raise the energy recovery rates, compared to today. As can be seen in appendix 1**,** the LPW is suggesting a maximum landfilling rate of 5 % of all MW and a landfill ban on recyclables. This would probably mean a greater increase for the need for waste-to-energy possibilities in many MS, which (as mentioned in chapter 6.5) may become problematic considering low incineration capacity in Europe. Increased energy recovery would ensure that also the rejects from the recycling process in these MS would be used as an energy resource and in that way contribute to the circulation of resources.

10.4 Quality Recycling

Something that cannot be seen in the flow chart and the movement of reject through the system is the importance of designing materials in a matter which enables recycling of them. This would probably decrease the rejects in the recycling process all together. As mentioned before, this was not a scenario included in the calculations of this study. The importance of extraction of toxic substances from the system (described in chapter 6.8.2) should also not be neglected. This would be done by energy recycle material which risk putting unwanted substances back into the system if material recycled. By improving the quality of the material recycled and minimizing the toxicity, the circular economy would become more sustainable.

10.5 Recycling Rates for the Plastic Recycling System in Sweden

If the plastic waste flows i.e. MW plastic packaging, MW non packaging plastic and industrial residual would be completely pure, without contamination of other plastic fractions, when entering the recycling process and processed separately at the facilities it would have been more easily to calculate each of the plastic fractions recycling rates. However since the separation at source is not 100% perfect the problem of misplaced plastic fractions in the collected plastic packaging waste still remains. The waste generators disposing their packaging waste at the separating source i.e. the bring system or in domestic containers, are not the perfect user, meaning that some of the waste will be misplaced.

Some amounts of MW- plastics will always be lost in the statistics since it is difficult to know the rate of misplaced plastic fractions i.e. non packaging plastics in the plastic packaging waste and the other way around accordingly.

The recycling efficiency rate depends on the contamination of the incoming waste in the context of dirt, moisture, and wrongly sorted plastic fractions. It also depends on the chosen plastic fractions to be recycled in that specific bulk. For example, if the rate of PE in the incoming bulk is low, the outgoing amount of recycled PE is low i.e. the resulting recycling efficiency rate is also low. As put forward in the former discussion it is difficult to calculate a resulting recycling rate with a 100 % significance since the recycling rate is depending on several factors. But to get an overall correct picture of the recycling rate and accordingly amount of recycled plastics, it is important to include separated fractions that are sent to energy recovery.

10.5.1 Energy Recovery

It could be argued that it is important to shine a light on the amount of waste separated to energy recovery during a recycling process in the context of transitioning into a circular economy. As stated in chapter 3, the purpose of a circular economy is to utilize as much of the resources as possible. If for example it is reported that 65% of the plastic packaging put on the market is material recycled an incorrect picture of the resources used is presented. It also gives an incorrect picture of the ease to which a circular economy is achievable. If it is actually only 41% that is recycled, both due to the recovery rate and to the contamination of the plastic waste, it is complicated and impossible to make a change. If it is known that 24% is separated as reject, investigations on increasing the pureness of the collected waste, developing the recycling process or the contamination of the plastics could be made.

10.5.2 Calculation Methods Applied on Plastic Packaging Waste

The calculation of recycling rates in chapter 8.3.4 is based on several assumptions since there were a lot of confusing and contradictory figures. Amounts collected and recycled by TMR are also missing. Since TMR also recycles plastic packaging the figures collected by them should be included in the calculation of recycling rates. As it is unknown what is included in FTI's reported amounts of recovered plastic material, it is difficult to be precise in the calculation of the collected amounts of plastic packaging waste and the calculation is also based on different assumptions. It was chosen to use a recycling efficiency of 80% in the calculations but as seen in the study this figure varies between 10-25%.

Both calculations of recycling rates, of plastic packaging waste and plastic beverage packaging waste, show that an implementation applying the LPW measuring method would increase the distance to the recycling targets for plastic packaging. The calculations also show that it is a large amount of the collected packaging waste that is sent to energy recovery. Applying this calculation and the implementation of the legislative proposal on a large scale and in the European Union, would require a large amount of energy recovery. This can also be seen for the full system in Figure 18 showing the collection rate needed for the recycling rate to be 70%.

10.6 Toxic Substances in Plastic

To be able to decrease the rejects due to contaminated plastics from the recycling process, development in the production chain would be needed. Polluting subjects, such as bisphenol A, Phthalates and brominated flame retardants, need to be eliminated from the plastics. This is also important to transition to a circular economy where resources could be more efficiently used by re-using and recycling products several times before being disposed.

Concerning polluted substances included in plastics and a transition to a circular economy, could energy recovery become a solution while the process of eliminating the subjects in the producing chain is developing. By combusting the material that is polluted the polluting subjects is also eliminated from the society. When recycling material that is polluted, the polluting subjects remains in the society and is circulating in the products.

10.7 Plastic Beverage Packaging

As mentioned in the analysis, the recycling chain of plastic beverage packaging is straightforward. This is preferable in the sense of switching to use the LPW measuring method, fulfilling the recycling targets and in turn of transitioning into a circular economy.

10.8 Importance of Knowing the Waste Treatment System

It is relevant to bring up the reason in what way the knowledge of the outlay of the waste treatment system. One of these is; that the knowledge of how something is makes it possible to change. More transparency and a better overview of the system would enable identification of the week parts in the treatment chain and this would make it possible to improve the overall system more effectively. It would also benefit the cooperation between waste treatment actors. If the full system was possible to overview it would be easier to find the best possible treatment for each waste stream. The waste could be sent to where it would be taken care of in the most resource efficient manner.

11 Conclusion

This paper seeks to answer how the Swedish waste treatment system would be affected by the measuring method and the higher recycling targets from the Legislative Proposal to review recycling and other Waste-related targets in the EU from 2014 (LPW). This may be concluded by answering the following research questions:

How does the perception of the overall system change when applying the proposed LPW measuring method?
The overall system approach will change significantly when applying the measuring method proposed in the LPW. This does not mean that anything in the way the actual system functions will change, but by recognizing that there is reject stream between the treatment methods, will build a more complete systematic understanding. By including the rejects the actual circulation of resources will become more apparent. Applying the proposed LPW measuring method would make it easier to follow the collected waste fractions through the system by, for example, finding out where there is room for improvement.

How does the recycling rate change with the proposed measurement method compare to the current measurement methods?
The recycling rate will be reported as lower, as compared to the measuring methods currently used by Sweden. The recycling rate would be 42% with the LPW measuring method compared to the 50% collection rate calculated in this study or the recycling rate of 49% reported by Avfall Sverige as national data. The difference is even more significant compared to the 62% recycling rate calculated with method 2. The projection showed that to be able to accomplish the 70% target with the LPW measuring method, a collection rate of 84% to material recycling is required. In the current measuring methods the rejects are not included in the calculations. The case study of plastics showed that the reject rates are hard to verify and this leads to the conclusion that the actual recycling rate according to the LPW measuring method also is impossible to verify with the statistics available.

What data is missing for Sweden to be able to show compliance to the suggested targets concerning recycling, in the plastic recycling system and in the system as a whole?
For Sweden to be able to show compliance to the suggested targets concerning recycling, important statistical information is needed. To have knowledge of the efficiency rates of the recycling processes is essential in order to calculate recycling rates for the suggested targets. Today, there is very little knowledge of the system as a whole and about the recycling rates. Since actors are only involved in managing their own businesses, actors have little knowledge of how the system is connected, or which fractions that is MW. One way of solving this reporting issue would be that the recycling companies report the waste which has been recycled instead of the company reporting what they collect. This would however not be possible as much of the waste is exported to be recycled and mixed with international waste fractions.

What is the consequence of the lack of reliable data?
There is sensitivity in the system because of the lack of reliable data. This has been difficult to investigate due to the complicated nature of the whole system, as only the plastic fraction has been possible to further investigate due to the time frame of the study. However it can be seen that the rates of recycling for plastic packaging will differ depending on which data is relied upon. It is further concluded that it is likely that there are similar cases in the fractions which have not been investigated closer in this study. This means that the issue of not knowing which data is reliable makes the recycling rates themselves unreliable.

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Appendix

1 Appendix – Table of Directive Changes

Table 20. Relevant changes in the Waste Framework Directive and comments

Article	Parag	Current waste framework directive	Proposal to change	Comments
3 Definitions	1	1.'waste' means any substance or object which the holder discards or intends or is required to discard.	(1a). "municipal waste" means waste as set out in Annex VI*.	Annex VI: Municipal waste includes household waste and waste from e.g. retail trade and small businesses similar in nature and composition to household waste, collected by or on behalf of municipalities.
3 Definitions	15	15. 'recovery' means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations.	15(a). "material recovery" means any recovery operation, excluding energy recovery and the reprocessing into materials which are to be used as fuel*.	The list of recovery operation in Annex II includes e.g. energy recovery and composting.
3 Definitions	17	17.'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.	(17a). "backfilling" means any of the following types of recovery: (i) recovery where waste is used in excavated areas such as underground mines or gravel pits for the purpose of e.g. slope reclamation, (ii) recovery where waste is used for the purpose of e.g. construction, land reclamation or landscaping and where the waste is substituting other non-waste materials which would otherwise have been used for that purpose*.	The inserted defintion could be interpreted as ashes used for backfilling in mines can be counted as a recycling operation meaning that it also could be included in the calculation of the recycling target stated in article 11, paragraph 2 (a). Or that backfilling is a new defined recovery method.
11 Re-use and recycling	2	(a) 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.	(a) by 1 st January 2020 at the latest, recycling and preparing for re-use of municipal waste shall be increased to a minimum of 50% by weight**. (c) by 1st January 2030 at the latest, recycling and preparing for re-use of municipal waste shall be increased to a minimum of 70% by weight***.	The change of paragraph 2 (a) is in line with the harmonisation of the defintions. The target is changed from adressing "waste materials such as at least paper, metal, plastic and glass from households.." to adressing municipal waste.
11 Re-use and rec	4	4. By 31 December 2014 at the latest, the Commission shall examine the measures and the targets referred to in paragraph 2 with a view to, if necessary, reinforcing the targets and considering the setting of targets for other waste streams. The report of the Commission, accompanied by a proposal if appropriate, shall be sent to the European Parliament and the Council. In its report, the Commission shall take into account the relevant environmental, economic and social impacts of setting the targets.	4. For the purpose of calculating whether the targets laid down in paragraph 2(a) and (c) have been achieved, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process less the weight of any materials which were discarded in the course of that process due to presence of impurities and which need to be disposed of or undergo other recovery operations. However, where the discarded materials constitute 2% or less of the weight of the waste put into that process, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process**.	
11 Re-use and rec	5	5. Every three years, in accordance with Article 37, Member States shall report to the Commission on their record with regard to meeting the targets. If targets are not met, this report shall include the reasons for failure and the actions the Member State intends to take to meet those targets.	5. For the purpose of calculating whether the targets laid down in paragraph 2(b) has been achieved, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process less the weight of any materials which were discarded in the course of that process due to presence of impurities and which need to be disposed of or undergo other recovery operations. be understood as the weight of the waste which was put into a final preparing for re-use or recycling process**.	
37 Reporting	4		4. For the purpose of verifying compliance with Article 11(2)(b), the amount of waste used for backfilling operations shall be reported separately from the amount of waste prepared	The replacement of paragraph 4 together with the new definition of backfilling as recovery method means that

Table 21.Relevant changes of packaging and packaging waste directive 94/62/EC

Article	Paragra	Current packaging and packaging waste	Proposal to change	Comment
6 Recovery and recycling	1	1. In order to comply with the objectives of this Directive, Member States shall take the necessary measures to attain the following targets covering the whole of their territory: (a) no later than 30 June 2001 between 50 % as a minimum and 65 % as a maximum by weight of packaging waste will be recovered or incinerated at waste incineration plants with energy recovery; (b) no later than 31 December 2008 60 % as a minimum by weight of packaging waste will be recovered or incinerated at waste incineration plants with energy recovery; (c) no later than 30 June 2001 between 25 % as a minimum and 45 % as a maximum by weight of the totality of packaging materials contained in packaging waste will be recycled with a minimum of 15 % by weight for each packaging material; (d) no later than 31 December 2008 between 55 % as a minimum and 80 % as a maximum by weight of packaging aste will be recycled; (e) no later than 31 December 2008 the following minimum recycling targets for materials contained in packaging waste will be attained: (i) 60 % by weight for glass; (ii) 60 % by weight for paper and board; (iii) 50 % by weight for	(f) by the end of 2020, a minimum of 60% by weight of all packaging waste will be prepared for re-use and recycled; (g) by the end of 2020, the following minimum targets for preparing for re-use and recycling will be met regarding the following specific materials contained in packaging waste: (i) 45% of plastic; (ii) 50% of wood; (iii) 70% of ferrous metal; (iv) 70% of aluminium; (v) 70% of glass; (vi) 85% of paper and cardboard; (h) by the end of 2025, minimum of 70% by weight of all packaging waste will be prepared for re-use and recycled; (i) by the end of 2025, the following minimum targets for preparing for re-use and recycling will be met regarding the following specific materials contained in packaging waste: (i) 60% of plastic; (ii) 65% of wood; (iii) 80% of ferrous metal; (iv) 80% of uminium; (v) 80% of glass; (vi) 90% of paper and cardboard; (j) by the end of 2030, a minimum of 80% by weight of all packaging waste will be prepared for re-use and recycled; (k) by the end of 2030, the following minimum targets for preparing for re-use and recycling will be met regarding the following specific materials contained in packaging waste: (i) 80% of wood; (ii) 90% of ferrous metal; (iii) 90% of aluminium; (iv) 90% of glass.***	New recycling targets for each material is being suggested.
6 Recovery and recycling	1	- II -	1a. For the purpose of calculating whether the targets laid down in Article 6(1)(a) to (k) have been achieved, the weight of waste prepared for re-use and recycled shall be understood as the weight of the waste put into a final preparing for re-use or recycling process less the weight of any materials which were discarded in the course of that process due to presence which need to be disposed of or undergo other recovery operations. However, where the discarded materials constitute 2% or less of the weight of the waste put into that process, the weight of the waste prepared for re-use and recycled shall be understood as the weight of the waste which was put into a final preparing for re-use or recycling process. *	The new harmonised calcuation method is also included in the packaging and packaging waste directive
6 Recovery and recycling	3		3. Member States shall, where appropriate, encourage energy recovery, where it is preferable to material-recycling for environmental and cost-benefit reasons. This could be done by considering a sufficient margin between national recycling and recovery targets.****	Paragraph 3, that is now proposed to be deleted, is taking into consideration that products might need to be destroyed /managed with incineration in those cases where it is better for the environment.
6 Recovery and recycling	12		12. Member States shall take appropriate measures to encourage the design of packaging in order to reduce its environmental impact and the generation of waste in the course of the production and subsequent use, provided that such measures avoid distortions of the internal market and do not hinder compliance with this Directive by other Member States. Those measures shall include measures to encourage the development, production and marketing of packaging that is suitable for multiple use, that is technically durable and that is, after having become waste, suitable for re-use and recycling in order to facilitate proper implementation of the waste hierarchy. The measures shall take into account the full life cycle impacts of packaging.***	The new paragraph encourage the member states to think about the product design that occurs upstream from the waste management

Table 22. Relevant changes of Landfill directive 1999/31/EC

Article	Paragraph	Current Landfill Directive	Proposal to change	Comme
2 Definitions	(a)		(aa) "residual waste" means waste resulting from a recovery, including recycling, operation which cannot be further recovered and as a result has to be disposed*.	
5 Waste and treatment not acceptable in landfills	2		2a. Member States shall not accept the following waste in landfills for non-hazardous waste by 1 January 2025, recyclable waste including plastics, metals, glass, paper and cardboard, and other biodegradable waste*.	
5 Waste and treatment not acceptable in landfills	2		2b. Member States shall not accept a quantity of waste in landfills for non-hazardous waste in a given year exceeding 25% of the total amount of MW generated in the previous year, from 1 January 2025*.	
5 Waste and treatment not acceptable in landfills	2		2c. Member States shall endeavour to accept only residual waste in landfills for non-hazardous waste by 1 January 2030, with the result that the total amount going to such landfills does not exceed 5% of the total amount of MW generated in the previous year. The Commission shall review this objective by 2025 and, if appropriate, submit a legislative proposal for a legally-binding 2030 landfill reduction target*.	

2 Appendix - Impact Assessment

Alternative scenarios

The alternative courses of action investigated in the IA were (SWD(2014) 208 final , 2014):

Option 1: Ensure complete compliance with current targets but without further EU-measures.

Option 2: To simplify, improve monitoring and diffuse the best practices. This would be done by aligning central concepts like; recycling and reuse, by simplifying measuring methods and reporting obligations, and by removing obsolete requirements. It would further require the creation of national registries on waste collection and management, establish minimum conditions for the operation of EPR schemes and the introduction of an early warning system to monitor member states performance.

Option 3: Increase the EU targets. While incorporate the main objectives of the 7th EAP, upgrading and clarifying targets and also removing obsolete existing targets. To find realistic targets and deadlines to be achieved by all member states, the performance of the most advanced member states was taken into account.

Option 3.1: Increase the recycling/reuse target for MW:
Low: 60% reuse/recycling target by 2030; 50% by 2025
High: 70% reuse/recycling target by 2030; 60% by 2025

Option 3.2: Increase the re-use/recycling targets for packaging waste:
Increased material based targets between 2020 and 2030 (80% overall reuse/recycling)
Variant: specific separate target for nonferrous metals (‘metal split’)

Option 3.3: Phasing out landfilling of recoverable MW:
Ban on plastic/paper/glass/metals by 2025 (max 25% landfilling), global ban by 2030 (max 5%)

Option 3.4: Combination of options 3.1, 3.2 and 3.3:
Option 3.5: Same as option 3.4 but with different deadlines for different groups of MS
Option 3.6: Same as option 3.4 but with shortened deadlines for all MS and with the possibility for expansion for some of them
Option 3.7: Same as option 3.4 but with an increase of the landfilling ban to include all waste similar to MW
(SWD(2014) 208 final , 2014)

Result of IA

Option	Financial costs (NPV 2014-2030), € billion (1)	External costs (NPV 2014-2030) € billion (2)	Net social costs (1+2)	Jobs (FTEs in 2030)	GHG million tonnes $CO2_{eq}$ (2030)	GHG million tonnes $CO2_{eq}$ (2014-2030)
Option 3.1- low	-3.73	-3.96	-7.69	78,519	-23	-107
Option 3.1- high	-8.41	-8.49	-16.91	137,585	-39	-214
Option 3.2	-11.2	-8.45	-19.66	107,725	-20	-183
Option 3.2 – metal split	-13.48	-10.05	-23.53	107,643	-24	-250
Option 3.3	5.64	-0.65	4.99	46,165	-13	-49
Option 3.4	-12.65	-13	-25.65	177,637	-44	-308
(1) Option 3.5 and 3.6	-13.62	-13.58	-27.2	177,628	-44	-320
(2) Option 3.7	-10.7	-18.3	-29		-62	-443

Note, negative costs represent a benefit

Figure 25. The figure shows the table which in the final impact assessment presented the results.

The table is showing the most central effects from the different alternatives. From this the IA contributes to the conclusion that the alternatives 3.4-3.7, which in turn are combinations of alternative 3.1, 3.2 and 3.3, will be the most cost effective and create the most job opportunities. These options will also contribute to the largest reduction of GHG emissions.

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Scenario Number	Scenario Details	Target Year			Assumptions
		2020	2025	2030	
Business As Usual	Steady State Waste Management.	-	-	-	This assumes that the levels of recycling and the share of waste treatment systems remain constant after the last reported year. This provides a base case against which to compare the more dynamic future projection baselines (and scenarios in the further analysis).
Baseline 1	Baseline 1 scenario.	-	-	-	This Baseline presents an objective view of likely future waste management based upon realistic expectations for the performance and delivery of future waste management systems (see Section 4.0).
Baseline 2	Baseline 2 scenario.	-	-	-	This Baseline reflects MSs' stated intentions which are taken 'at face value'. Where MS plans or intentions have not yet been published or made available, it has also been necessary to project conservatively (see Section 4.0).
Scenario 1	Full implementation of existing targets	50% any method	-	-	This scenario assumes full implementation of the existing targets. This includes the current 50% recycling/preparation for reuse target in the Waste Framework Directive. This scenario forms the basis against which Scenarios 2 to 4 are compared.
Scenario 2.1	60% MSW recycling target by 2030	50% any method	50% method 4 only	60% method 4 only	Commission Decision 2011/753/EU allows MSs to report on their recycling rates using one of four different calculation methods (see Appendix 7). These scenarios assumed that MSs will use their chosen method for the existing 2020 target. For the 2025 and 2030 targets these scenarios assume that calculation Method 4 is used by all MSs (i.e. % MSW recycled)
Scenario 2.2	70% MSW recycling target by 2030	50% any method	60% method 4 only	70% method 4 only	
Scenario 3	Limiting the landfilling of MSW residual waste to 5% (in addition to scenario 1.0)	-	-	5% of MSW to landfill	This scenario assumes that landfilling is restricted to 5% of MSW generated in 2030.
Scenario 4	Limiting the landfilling of MSW residual waste to 5% with 70% recycling target in 2030 (i.e. Scenario 3 + scenario 2.2)	As for scenario 2.2 above	As for scenario 2.2 above	As for Scenario 3 and 2.2 above	This scenario investigates the combined costs and benefits of introducing a landfill ban together with a recycling target of 70% in 2030.

Figure 26. The table in the figure visualizes the scenario details from the modeling for the IA, the target year and the assumptions made for the modeled scenario

Other countries waste flows in the IA (with focus on Germany)

To put the assumed waste flows for Sweden in a perspective it is relevant to study how the IA handled other countries data and waste streams. The first example is Germany. Germany is interesting from the point of view that in the "10 countries calculation method report" it is the only country of the ten which is using method 4 to report their compliance to the waste framework directive 2008/98/EC. As mentioned before method 4 is the method used in the IA for future projections (further than 2020) of countries recycling rates.

As described in the "10 countries calculation method report" Germany calculate their compliance with the targets using "the total amount of MW delivered to recycling facilities" in the numerator and the "total MW collected (from households and similar waste, both separated and non-separated collection), measured as waste amount delivered to waste treatment facilities" in the denominator.

In Appendix 1 for the EU waste Model the same statement is given for Germany as for the Swedish calculations:

> The data in the tables above show the rates of material collected or sent for treatment and disposal; this is the data used as the primary inputs to the model to control the mass flows. The model outputs shown in the charts that follow include the percentage final management destinations (accounting rejects from collected recycling and recycling extracted from residual waste treatments), as well as a tonnage representation of the change in the management of waste for each of the modeled baselines.

This is yet another point of uncertainty of how the model is built as there are no reject percentages given for any fractions in Germany's case. However, the graph in figure 27 which is one of the results given in appendix 1, gives the impression that the method Germany is using today is the same as the method 4 used in the IA. This may be due to recalculations for the IA accounting for rejects even if that is not really how Germany reports today.

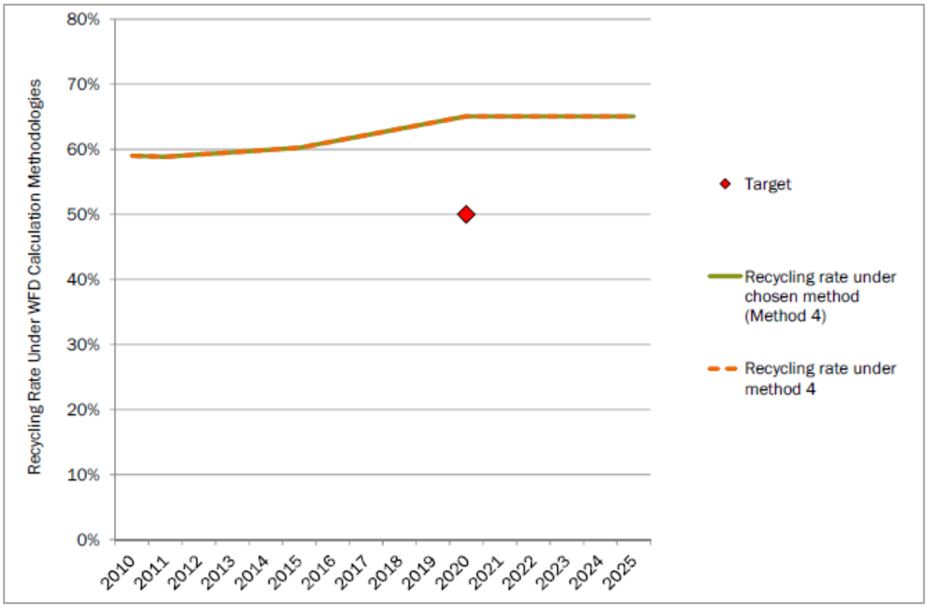

Figure 27. results for Germany in IA

In "Targets Review Project appendix 9 definitions, data and statistics" Germany's losses, during the recycling process for packaging fractions, has been estimated Figure 28. These may or may not have been used for the modeling task. It is also pointed out that the data is from 2010 and available for limited geographical areas.

Material	Loss Rate
Glass	10%
Plastic	15%-30%
Paper and Card	15-30%
Aluminium	60-70%
Tin plate	5-8%
Drinks cartons	Circa 25%

Source: GVM

Figure 28. The figure shows a table presenting Germanys loss rates in the IA

As can be seen from this, the losses are very uncertain and are given in big ranges. It is also very unsure if this report is made after the model report just reviewing the targets or if these numbers are used in the model. If that is the case both appendix 1 EU waste model and appendix 9 target review fail to say so.

Another example is Croatia which also does not include rejects in their data reported to Eurostat. The data refers to amounts collected and therefore there is no data on rejection rate. However also Croatia has the standardized text

> “The model outputs shown in the charts that follow include the percentage final management destinations (accounting rejects from collected recycling and recycling extracted from residual waste treatments), as well as a tonnage representation of the change in the management of waste for each of the modeled baselines.”

It is not shown how this will be done as no data for this exists. However in Croatia’s case this may have less importance as of when the report was written the collected amount of recyclables was solely 7% and this is where they have a lot of developing potential.

3 Appendix- input data excel model

The table bellow shows the sources on which the distribution template was based for the waste indicator project by Sundberg (2014). The table was handed over by Carl Jensen from IVL via e-mail.

Table 23. The Sources of the recycling rate information, used for developing the distribution template.

Recycling fraction	Source of information given to IVL
WEEE	Elkretsen
Portable batteries	Elkretsen
car batteries	Boliden Bergsoe
Corrugated board	Miljörapporter (Fiskeby Board)
Metal bulky waste	Miljörapporter från fragmenteringsanläggningar som gås igenom inom SMED vid framtagning av den nationella avfallsstatistiken. Siffrorna är delvis uppskattade eftersom ”kommunskrotet” innehåller en mindre andel icke metaller jämfört med bilar som också hanteras på en fragmenteringsanläggning.
Plaster	Gips Recycling
Flat glass	Svensk Glasåtervinning
Plastics	Swerec
Glass packages	Svensk Glasåtervinning
Newsprint	Miljörapporter (Fiskeby Board)
Paper packaging	Miljörapporter (Fiskeby Board)
Plastic packaging	Swerec
Metal plastics	David Palm: Carbon footprint of recycling systems A comparative assessment of bring- and co-mingled curbside collection and sorting of household recyclable materials

Table 24. Collected waste divided into fraction and intended treatment method

Collected for	Waste fraction	Collected waste (ton)
Material recycling	Corrugated board (ton)	43420
	Scrap metal (ton)	153030
	Plaster (ton)	22410
	Flat glass (ton)	1400
	Plastic, non-packaging (ton)	4170
	Textile (ton)	0
	Other (bulky) material for recycling (ton)	99150
	Glass packaging (ton)	315376
	Paper (ton)	332780
	Paper packaging (ton)	215570
	Plastic packaging (ton)	90055
	Metal packaging (ton)	27649
	WEEE (kg)	146270
	Car batteries (kg)	6850
	Portable batteries (kg)	3120
	Oil filters (kg)	1740
	Water-based paint (kg)	4210
	PET bottles	19326
	Aluminum cans	14749
Biological Treatment	Food waste to co-digestion plants (ton)	225320
	Food waste that undergoes anaerobic digestion at wastewater treatment plants (ton)	79320
	Food waste grinded in a garbage disposal unit (ton)	2032
	Food waste that undergoes anaerobic digestion at farm-based plants	2400
	Grease trap residues (ton)	99994
	Frying grease and cooking oil (ton)	2111
	Food waste to central composting plants (ton)	63030
	Garden waste to central composting plants (ton)	292680
	Food waste for home composting, one family homes (ton)	48700
	Food waste, home composting, multiple family homes (ton)	0
Energy Recovery	Small chemicals (kg)	1926
	Solvent based paint (kg)	5604
	Impregnated wood (kg)	35443
	Residual waste (ton)	1540719

	Garden waste to incineration (ton)	66944
	Other (bulky) waste to incineration. (ton)	585292
Landfill	Straight to Landfill	33300
	Total amount of MW:	4537392

4 Appendix – Output-data excel model

Table 25. The table shows what amount of each fraction which will be treated with which treatment method

Collected waste fraction	Material recovery	Energy recovery	Landfilling	Backfilling
Corrugated board (ton)	30394	13026	0	0
Scrap metal (ton)	140788	3061	1530	7652
Plaster (ton)	20169	0	2241	0
Flat glass (ton)	1400	0	0	0
Plastic, non-packaging (ton)	3128	1043	0	0
Textile (ton)	0	0	0	0
Other (bulky) material for recycling (ton)	91218	1983	992	4958
Glass packaging (ton)	299608	0	15769	0
Paper (ton)	232946	99834	0	0
Paper packaging (ton)	150899	64671	0	0
Plastic packaging (ton)	67541	22514	0	0
Metal packaging (ton)	23501	4147	0	0
WEEE (kg)	98001	24866	24866	0
Car batteries (kg)	5823	1028	0	0
Portable batteries (kg)	1716	343	1061	0
Oil filters (kg)	870	870	0	0
Water-based paint (kg)	2105	2105	0	0
PET bottles	19326	0	0	0
Aluminum cans	14749	0	0	0
Food waste to co-digestion plants (ton)	166737	58583	0	0
Food waste that undergoes anaerobic digestion at wastewater treatment plants (ton)	58697	20623	0	0
Food waste grinded in a garbage disposal unit (ton)	2032	0	0	0
Food waste that undergoes anaerobic digestion at farm-based plants	1776	624	0	0
Grease trap residues (ton)	99994	0	0	0
Frying grease and cooking oil (ton)	2111	0	0	0
Food waste to central composting plants (ton)	61139	1891	0	0
Garden waste to central composting plants (ton)	283900	8780	0	0
Food waste for home composting, one family homes (ton)	0	0	0	0
Food waste, home composting, multiple family homes (ton)	0	0	0	0
Small chemicals (kg)	0	1926	0	0
Solvent based paint (kg)	2802	2802	0	0
Impregnated wood (kg)	0	29418	3190	2835
Residual waste (ton)	15407	1201761	77036	246515
Garden waste to incineration (ton)	0	55564	6025	5356
Other (bulky) waste to incineration. (ton)	5853	456528	29265	93647

Straight to Landfill (ton)	0	0	33300	0
Total (ton)	1904629	2077991	195274	360962

5 Appendix- Biological treatment

In the withdrawn proposal, as it was put forward, the measuring points will be defined for the waste's final treatment. This may complicate the measurements and reporting related to the biological treatment, especially from the anaerobic digestion. The final product from this process is both biogas and bio-fertilizer.

Biogas is used as a source for energy and does therefore not fall under the current waste framework's definition of recycling: "recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;" from the 2008/98/ec
However, the product bio-fertilizer which comes from the same anaerobic digestion process may be counted for as recycled.

An interpretation of the withdrawn proposal's measuring points combined with the definition of recycling and material recovery may lead to that the part of the food waste that ends up as energy will have to be reported as such and the part that is recycled will be reported as such. That this is a possible interpretation was confirmed by the juridical consultant Sven Lundgren at Avfall Sverige[49]. As of now, Sweden counts all food waste that undergoes the anaerobic digestion process as material recycled for compliance with the waste directive targets.

According to Katarina Hansson, quality responsible for bio-fertilizer at SYSAV, most co-digestion plants today built for digestion at 10-12%. However, the development is toward anaerobic digestion at dryer conditions. There is no general answer to what normally is added during the process. This will differ between different preparation- and digestion plants depending on the preparation technique and depending on the substrate which is treated and so on[50].

Sysav states that they treated 35 333 tons of food waste in 2014 in their pre-treatment plant and to this they added 4897 m^3 water. This slurry was delivered to the digestion plant in Kristianstad where it was further mixed with other types of food waste before the production of biogas and bio-fertilizer.

After consolidating with Lovisa Björnesson[51] at LTH the theoretical exchange of biogas from anaerobic digestion of organic waste could be calculated. However this is dependent on the components of the waste. A table of the methane content was found in Avfall Sverige (2009) and the quote for food waste could be calculated. However as the methane content in all fractions could not be found the same value as for food waste was applied for all fractions undergoing anaerobic digestion. This is not a completely correct assumption but the results will still indicate a possible division. The calculations are shown in Table 26. TS stand for dry substance and VS is the organic material.

[49] Sven Lundgren, Avfall Sverige, Juridical Consultant, personal communication 2015-07-05
[50] Ellen Lindblad, Sysav, Project Manager, e-mail 2015-18-04
[51] Lovisa Björnesson, Lunds Tekniska Högskola, Professor, personal communication, 2015-22-04

Table 26. Table showing results in each calculation step values are based on: (Avfall Sverige , 2009)

	TS (kg)	VS/TS*TS (kg)	m3 CH3/ ton VS	Methane ratio	methane m3
Values for food waste/calculation:	33%	85%	461	63%	
For 1 kg food waste:	0.00033	0.0002805	-	-	461*0.0002805= 0.1293105
methane kg	**total bio-gas m3**	**co2**	**co2 kg**	**Bio-gas kg**	**Bio-fertilizer kg**
(m=pVM/RT)	0.1293105/0.63	0.2052548-0.1293105	(m=pVM/RT)	(CH3+CO2)kg	Food waste-biogas
0.0925574	0.2052548	0.0759443	0.149125434	0.2416829	0.7583171

The table shows that from one kilo food waste the theoretical exchange will result in 0.24kg biogas and 0.75kg bio-fertilizer.

As the ratio between gas and fertilizer is so varying and since it may be a question of how to interpret the directive all the bio-treatment has been counted as recycled in the rest of the calculations of this report. However this is showing some of the definition issues that still will have to be met. It also shows the complexity of the waste system and it indicates that this is a reporting issue that could have to be tackled in a near future, if a similar proposal will pass.

6 Appendix - Interview questionnaires

Interview Questions- to recycling companies and alleged* recycling businesses

1. Does your business include recycling of plastic? I.e. do you have recycling facilities where plastic waste is processed from waste to raw material, i.e. granulate?
   a. If your business do include recycling of plastic, how is that process constructed, i.e. what does it conclude?
   b. Do you have any presorting before the plastic waste is entering the process?
   c. Do you receive any rejects from the process? How much do you assume or appreciate is separated as reject in you process?
   d. Who deliver the plastic you recycle?
   e. Where do you send the recycled plastic?

2. How do you define recycling?

3. The investigation is limited to MW, Are you managing municipal plastic waste, that is plastic packaging or "municipal plastic" such as plastic furniture, buckets toys etc. ?
   a. Do you collaborate with FTI?
   b. Are you employed by municipals to manage their "municipal plastic"? How many municipals do you collaborate with?
   c. Do you know the share of plastic packaging, municipal plastic and industrial plastic managed in your process?

4. Do you import or export plastic waste or raw material? To or from where?

* alleged businesses meaning businesses that does not possess recycling facilities but is managing plastic waste, as in separating, quality checking ,bundle it and making sure that the plastic waste is recycled.

Interview Questions- to businesses using recycled plastics as raw material

1. What is your business relation to recycled plastics? In what way are you using it?
    a. What kind of resource do you use as raw material in your process? In what appearance does it arrive i.e. granulate, bags, plastic film etc?

2. How are you managing the provided raw material? Do you have to do some presorting of the plastic before it is sent to production?
    a. What is separated or disposed? Is it wrong type of plastic or other objects?
    b. How much is separated as reject? Figures?

3. What kind of businesses do you have as suppliers?
    a. Do you have municipals, FTI, TMR or other waste management companies as providers of your raw material?
    b. Do you know the share of recycled plastic that origin as MW, going into your processes?

4. Does your business also include recycling of plastics? Are you managing municipal plastic waste as resource, that is plastic packaging or “municipal plastic” such as plastic furniture, buckets toys etc.?