No. C383
March 2019

Sustainability assessment of pre-treatment methods for plastic waste from hospitals in Sweden

Commissioned by RE:Source

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Commissioned by: RE:Source
Report number: C383

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This report has been reviewed and approved in accordance with IVL's audited and approved management system.

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Abbreviations

CHP: Combined heat and power plant

GaBi 8: Life Cycle Assessment software used in the study

HDPE: High Density Polyethylene

LCA: Life Cycle Assessment

LDPE: Low Density Polyethylene

NIR sorting: Near infrared technology

PET: Polyethylene terephthalate

PP: Polypropylene

PS: Polystyrene

PVC: Polyvinyl chloride

Thinkstep: Database provider of inventory data for the environmental assessment

Tonne: metric ton

Summary

This study presents results of the sustainability assessment of treatment options for plastic waste from hospitals. The work has been carried out within work package five of the RE:Source project "Sustainable treatment of plastic waste from hospitals". The main research question in the project is whether pre-treatment could remove potential risks and enable more recycling of plastic waste from hospitals. The evaluation is divided into assessment of environmental, economic and social factors. In the environmental assessment, two types of pre-treatment technology and subsequent recycling have been compared with incineration using Life Cycle Assessment (LCA). A qualitative economic assessment investigates cost components connected to different actors in the value chain if pre-treatment were to be introduced. In the qualitative social assessment, interviews have been used to investigate the acceptance, work load and attitudes among staff connected to sorting and pre-treatment of plastic waste.

Results show that pre-treatment and recycling is beneficial from a climate perspective, even with material losses and assumed quality reduction of the recycled material. The pre-treatment solutions are probably too costly to invest in for most hospitals, and the shredding of material in the process presents challenges to subsequent sorting and separation.

There is a delicate balance between work load for employees and separate sorting of different fractions, but there are also success stories where recycling of specific fractions bring revenue to hospitals already today. Key factors for successful sorting include well planned sorting infrastructure, sufficient storage space, good communication and internal quality control.

To facilitate more sustainable procurement of plastics, networking and knowledge sharing between regions would be helpful. Expert support in terms of comparable LCA results and procurement guidelines could also provide support to buyers.

Last, but not least, we found that the motivation of employees is more of a driver than a challenge for increased sorting and recycling: the majority of hospital staff is positive to separate sorting of plastics!

1 Introduction

1.1 Background

This report presents the findings from work package 5 of the project "Sustainable handling of plastic waste from hospitals". The purpose of the work package is to evaluate the environmental, economic and social consequences of the proposed pre-treatment solutions from a system perspective.

The environmental assessment evaluates the new solutions, especially pre-treatment methods and compares with existing waste handling practices using Life cycle assessment (LCA). A qualitative economic assessment investigates aspects associated with the purchase of equipment, costs associated with use of equipment for county councils and alternative costs and revenues connected to waste management and recycling. The work also includes qualitative assessment of what consequences the use of new pre-treatment solutions would bring for the hospital staff in terms of work load, acceptance and attitudes. The economic and social assessments are mainly based on interviews with representatives from three counties/regions participating in the project: Stockholms Läns Landsting (hereinafter SLL), Region Jönköpings län (RJ) and Region Jämtland Härjedalen (RJH).

1.2 Outline of the report

The chapters that this report includes are stated and briefly presented below.

Chapter 1 Introduction
Chapter 2 Scope
Chapter 3 Environmental assessment
Chapter 4 Economic assessment
Chapter 5 Social assessment
Chapter 6 Discussion
Chapter 7 Conclusions

In the next chapter the scope of the study is outlined, identifying for example the study´s purpose and a schematic overview of the studied system. Chapter 3, 4 and 5 presents the environmental, economic and social assessments respectively. Subsequent discussion and conclusions are presented in Chapter 6 and 7.

2 Scope

This chapter describes how the studied system is modelled. It should be emphasized that it is a theoretical system where processes are chosen based on what a system for pre-treatment could look like in the future, where different sorting and treatment processes are available today etc.

2.1 Purpose

The purpose of this study is to:

Describe, assess and communicate differences in treatment options for plastic waste from Swedish hospitals from environmental, economic and social perspectives.

2.2 System overview

Swedish hospitals use large amounts of plastics every year. Most of the material is single use items that are disposed after one use, which enables easy handling and can reduce the risk of contamination and spreading of infection between patients. Due to potential infection risk, regulation and lack of demand for recycled material, the plastic is currently sent to combined heat and power plants (CHP) to be incinerated with energy recovery. Special waste fractions, including blood bags and other plastic products with direct patient and body fluid contact, are destroyed in special facilities. These fractions are not in focus for the current project. Many plastics are however materials that, correctly used, are durable and can be recycled several times. In this study we assess the possibility to pre-treat visibly clean plastic flows to enable increased acceptance and recycling of this material stream. Two different pre-treatment methods are studied, Ozonation and Hydrothermal, illustrated as scenario 1 in below Figure 1. Scenario 2 represents the conventional energy recovery of plastic waste. The processes are described in Table 1 further below.

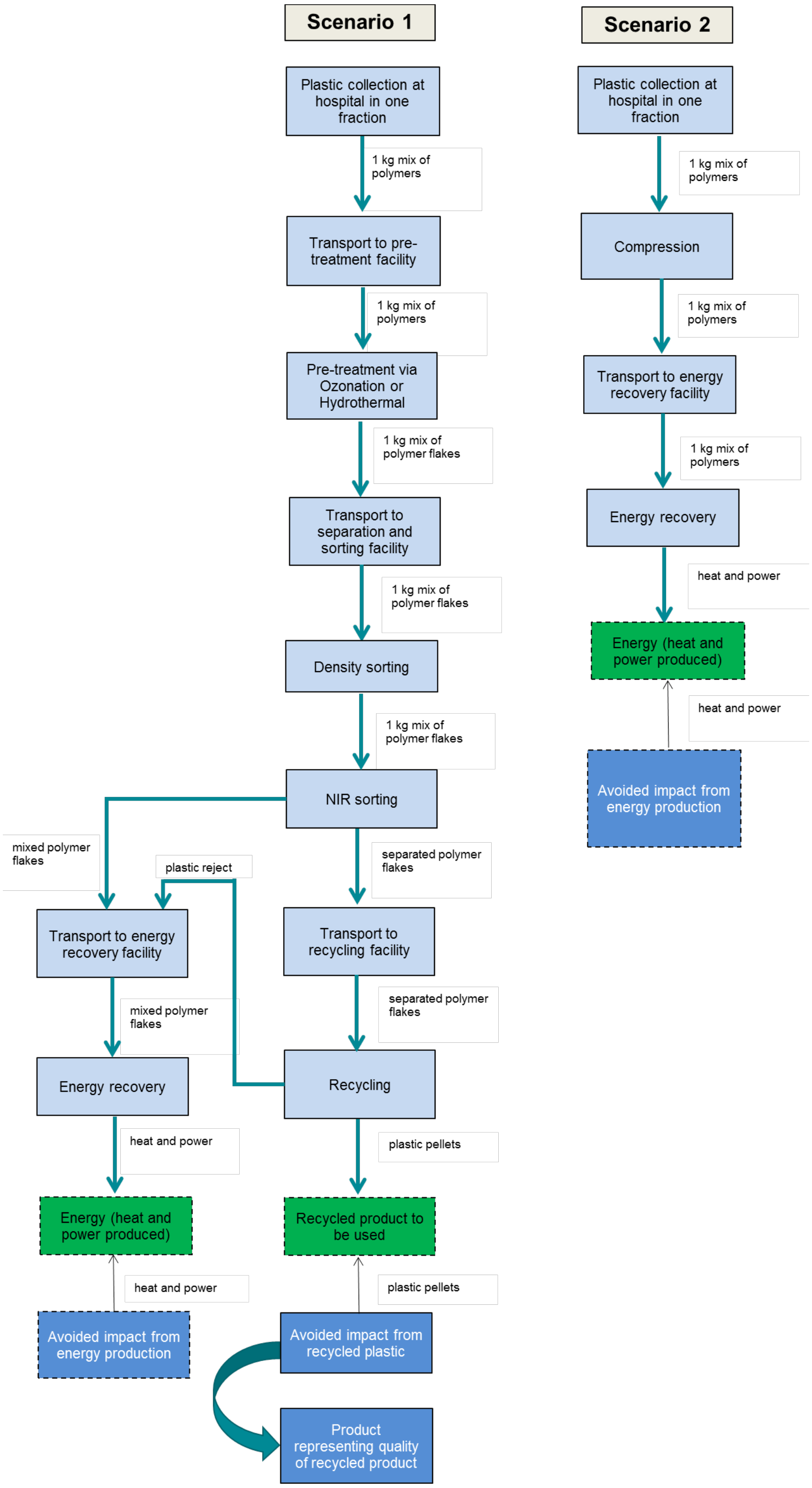

Figure 1 – Overview of the studied system

In the above Figure 1, the scenarios can be seen:

- Scenario 1a – Recycling, pre-treatment by Ozonation
- Scenario 1b – Recycling, pre-treatment by Hydrothermal
- Scenario 2 – Energy recovery

Scenario 1 is divided based on if the pre-treatment process is carried out by Ozonation or by Hydrothermal. When referring to scenario 1, this includes both a and b.

The processes showed in Figure 1 are briefly described in below Table 1. The transport processes included in Figure 1 are not shown below. More details about the transportation are presented in Chapter 3.3.11.

It is important to emphasize that the system under study does not included any activities before the plastic reaches the hospitals. This is mainly because the results for plastic production are expected to be the same in both scenarios.

Table 1 – Processes included in scenario 1 and 2

Process	**Description**	**Belongs to scenario**
Plastic collection at hospital in one fraction	Used plastic are collected at the hospitals in one fraction.	1 & 2
Compression	The plastics are compressed at or close to the hospitals.	2
Pre-treatment via Ozonation	The plastics are pre-treated by Ozonation at hospitals.	1a
Pre-treatment via Hydrothermal	The plastics are pre-treated by Hydrothermal at hospitals.	1b
Density seperation	The mix of plastics is separted into a 2D (film and foil) and a 3D (rigid) fraction in Germany, using a ballistic separator. This step is designed for separation of larger parts of material, not flakes. The reason for separating in Germany is that the following NIR sorting is not available in Sweden.	1
NIR (Near infrared technology) sorting	The mix of plastics is sorted in Germany with NIR sorting technology, which to our knowledge is not available in Sweden. There are sorting solutions for entire products and flake sorters, which are designed to clean plastic flakes from impurities. Flake sorting is however not designed for separation of different plastic types.	1
Recycling	Plastic is recycled in Germany. The recycled product is plastic pellets.	1
Avoided impact from recycled plastic	As the plastic is recycled, it does not need to be produced somewhere else. An environmental credit is thereby given to the system based on the alternative production of plastics. The quality is however assumed to be lower for recycled than for virgin plastic pellets. The quality factor is further elaborated on in section 3.1.	1

Energy recovery	The plastics are energy recovered at an incineration plant, producing both electricity and heat.	1[1] & 2
Avoided impact from energy production	The energy produced as by-products at the incineration plant does not need to be produced somewhere else. An environmental credit is thereby given to the system based on the alternative energy production.	1[2] & 2

3 Environmental assessment

3.1 Introduction and assumptions

The environmental assessment is carried out using the method Life Cycle Assessment (LCA). Thus, a life cycle perspective is applied aiming to cover the main environmental contributors within the studied system, see Figure 1. Both scenarios start at the collection of plastic at the hospital. One kilogram of collected plastic acts as the functional unit in the comparison i.e. the reference unit for that environmental results are related to. It has been difficult to get detailed information about the composition of the plastics collected by hospitals today. Therefore, it is assumed that the plastic contains 20% of each material LDPE (Low Density Polyethylene), HDPE (High Density Polyethylene), PP (Polypropylene), PVC (Polyvinyl chloride) and others. *Others* are divided in PET (Polyethylene terephthalate) and PS (Polystyrene), in the equal amounts. This assumption is based on the hypothesis that these are commonly used plastic fractions at Swedish hospitals[3].

- No environmental impacts are declared for the raw material extraction and production of the plastic products used at the hospitals, which is excluded in the system boundaries in this study.
- From the NIR sorting, there is a loss of 28% of the material. This rejected plastic fraction is sent to energy recovery. This is both due to limitations in the sorting process and due to that the fraction *others*, representing 20% of the input, is not intended to be recycled.
- In the recycling process, there is a loss of about 16% of the input material which is not recycled. This is sent to energy recovery.
- It is assumed that the four fractions LDPE, HDPE, PP and PVC can be separated, sorted and recycled.
- In the model calculations, PET and PS represent the category *Others*. Fractions other than these two can however be included.
- When materials are energy recovered or recycled, they replace other energy and material production. In the model calculations, this benefit is modeled for:
    - Energy recovery: Credits for the same amount of energy that is generated in the energy recovery process. In scenario 1, the process takes place in Germany and is therefore replacing heat and electricity produced in Germany. Natural gas is used to represent German heat production and the average electricity production mix in

[1] For the plastic that will not be recycled.
[2] For the plastic that will not be recycled.
[3] Fråne och Sundqvist (2014) Återvinning av plast från Stockholms Läns Landstings sjukvårdsverksamhet. Uppdragsrapport.

Germany is used to model the electricity. In scenario 2, the process is located in Sweden and is replacing average Swedish district heat and average Swedish electricity production mix. The sources behind the energy mixes used can be found in Appendix B.

    - Recycling: The quality of the plastic pellet material is assumed to be lower for recycled material compared to virgin material. The benefit of recycling 1 kg material is therefore lower than 1 kg of virgin raw material. This is referred to a material quality factor, which is assumed to be 0.5. This means that when 1 kg is recycled, the credit is 0.5 kg of virgin produced material.

- The plastic waste is assumed to be collected in big bags when transported between the processes. The environmental impact from these containers is however neglected and it is assumed that they are reused several times.
- It is assumed that there is no transport between the NIR sorting and the density separation.

3.2 Environmental indicators

When carrying out an LCA, environmental impact categories need to be selected. In this study, the following categories are used, see Table 2 below.

Table 2 – Environmental impact categories assessed in the study, result is per 1 kg collected plastic.

Impact category	Unit	Method
Global warming potential (Climate change)	kg CO2 equivalents	CML 2001 – Jan. 2016
Eutrophication potential (EP)	g PO4 equivalents	CML 2001 – Jan. 2016
Acidification potential (AP)	g SO2 equivalents	CML 2001 – Jan. 2016
Photochemical ozone creation potential (POCP)	g Ethene equivalents	CML 2001 – Jan. 2016

In addition to the categories above, the energy use is assessed in the study to better understand the use of energy resources, see Table 3.

Table 3 – Energy use assessed in the study result is per 1 kg collected plastic.

Inventory category	Unit	Method
Total energy resources	MJ, lower heating value	Modeled result
Renewable energy resources	MJ, lower heating value	Modeled result
Non-renewable energy resources	MJ, lower heating value	Modeled result

Explanations of the inventory and impact categories are presented in Appendix A.

The processes and data used are described in section 3.3.

The system has been modelled in the LCA software GaBi 8.4. The results, which are presented in section 3.4, have also been extracted from the software.

3.3 Process description and data collection

This section shortly describes the processes included in the overall system, as presented in Figure 1. The collected data for pre-treatment methods, compression and sorting is also presented.

3.3.1 Plastic collected at hospital in one fraction

This process is included in scenario 1 and 2.

When the plastic products have been used they are collected at the hospital in one fraction. It is assumed that there are no major environmental impacts during this process stage for both scenarios. It is assumed that there are no material losses in the collection at the hospital. For simplicity reasons it is assumed that the fractions only contain the used products.

3.3.2 Compression

This process is included in scenario 2.

After the plastic has been collected it is compressed to reduce its volume. It is assumed that a regular compactor is used and that there are no material losses in the process. The compression is located in Sweden.

Data has been collected from a producer of compactors, Svelog[4]. Data is presented in the below Table 4.

Table 4 – Environmental data for Compression

Inventory	Amount	Unit
Energy use	0.01	MJ electricity /kg plastic

3.3.3 Pre-treatment via Ozonation

This process is included in scenario 1a.

After the plastic waste has been collected, the process ozonation is used to treat the waste. In the process water is infused with ozone for disinfection of the material. The ozonation is located in Sweden and it is assumed that there are no material losses during the process stage.

Environmental data has been collected from the manufacturer of ozonation equipment, Ozonator[5]. Data is presented in the below Table 5.

Table 5 – Environmental data for Pre-treatment via Ozonation

Inventory	Amount	Unit
Energy use	1.0	MJ electricity/kg plastic

[4] https://svelog.com/index.php/produkter/sackkomprimator
[5] Personal communication with Ozonator

3.3.4 Pre-treatment via Hydrothermal

This process is included in scenario 1b.

After the plastic waste is collected, the process hydrothermal is used to treat the waste. In the process, water is heated to disinfect the plastic material. The hydrothermal pre-treatment is located in Sweden and it is assumed that there are no material losses during the process stage.

Environmental data has been collected from the manufacturer of hydrothermal equipment, Red Bag[6]. Data is presented in the below Table 6**.**

Table 6 – Environmental data for Pre-treatment via Hydrothermal

Inventory	Amount	Unit
Energy use	2.1	MJ electricity /kg plastic

3.3.5 Density separation

This process is included in scenario 1.

When the plastic has been pre-treated via ozonation or hydrothermal, it is density separated, using a ballistic separator. The foil and film fractions are separated from the rigid plastics.

The density separation is located in Germany, since the next sorting step in the chain is available in Germany. It is assumed that there are no material losses during the process stage.

Environmental data has been collected from a German manufacturer of sorting solutions. Only energy use has been documented. Data is presented in the below Table 7.

Table 7 – Environmental data for Density separation

Inventory	Amount	Unit
Energy use	0.01	MJ electricity /kg plastic

3.3.6 NIR (Near infrared technology) sorting

This process is included in scenario 1.

The material is sorted by a combination of NIR and VIS sensors, separating the plastics into different material fractions based on polymer types. It is also possible to sort per color, since transparent polymer fractions have a higher value than colored streams. The sorting is however not optimised for shredded plastics, which is an issue that needs to be further investigated. There are flake sorting solutions, but these are designed to remove impurities from separate polymer fractions rather than separating flakes based on polymer type. In scenario 1, we assume that the sorting is adapted so that it works for the shredded plastics, but this is a theoretical case.

[6] Personal communication with Red Bag Solutions.

Environmental data for energy use has been collected from a German manufacturer of sorting solutions. Data is presented in the below Table 8.

Table 8 – Environmental data for Density separation

Inventory	Amount	Unit
Energy use	0.007	MJ electricity /kg plastic

3.3.7 Mechanical recycling

This process is included in scenario 1.

The four plastic materials LDPE, HDPE, PP and PVC are recycled.

The recycling process is assumed to take place in Germany.

No environmental data was collected for the recycling process. Instead generic data set of plastic recycling (Plastic granulate secondary (low metal contamination)) from the database provider ThinkStep was used to reflect the process.

3.3.8 Avoided impact from recycled plastic

In scenario 1 and 2 the plastic material is recycled which implies that the same amount does not need to be produced somewhere else. The quality of recycled plastic pellets is however assumed to be lower than the quality of virgin plastic pellets. An environmental credit is given to the system based on how much that is recycled and the quality factor. For each kg recycled material, 1 kg virgin material is multiplied with the quality factor (0.5). The environmental credit for 1 kg of recycled plastic material is thus 0.5 kg of virgin material.

For the virgin material the data set used are *Polypropylene granulate (PP) mix*, *Polyethylene Low Density Granulate (LDPE/PE-LD)*, *Polyvinyl chloride granulate mix* and *Polyethylene High Density Granulate mix* from Thinkstep´s data base.

3.3.9 Energy recovery

This process is included in scenario 1 and 2.

The energy recovery is located in Germany for scenario 1 and in Sweden for scenario 2.

The datasets used in the energy recovery process are these six Thinkstep datasets: *PVC in waste incineration plant*, *Polyethylene terephthalate (PET) in waste incineration plant*, *Polystyrene (PS) in waste incineration plant*, *Polyethylene (PE) in waste incineration plant*, *Polyethylene (PE) in waste incineration plant* and *Polypropylene (PP) in waste incineration plant*.

3.3.10 Avoided impact from energy production

In the scenarios the plastic material is incinerated with electricity and heat as by-products. This implies that the same amount of energy does not need to be produced from other resources. An environmental credit is given to the system based on how energy that is produced. The energy substituted would have been produced in Germany for scenario 1 and in Sweden for scenario 2 and the average electricity mix and heat production mix for each country are assumed.

The datasets used for the alternative energy production is these Thinkstep datasets: *DE: Electricity grid mix*, *Thermal energy from natural gas* and *SE: Electricity grid mi*x. In addition, the Swedish district heating has been modelled. Background energy sources can be found in Appendix B.

3.3.11 Transport

There are several transports included in the overall system, which can be seen in Figure 1. Each process is described in this section.

In the transport of the plastic products, it is assumed that there are no losses of material. It is assumed that the same transport type is used for all transport: A truck with a total payload of 17 tonne, Euro 5.

Data that is specific for each transport is stated below.

Transport to pre-treatment facility

This transport is carried out in scenario 1.

It is assumed that some of the hospitals have pre-treatment equipment at the hospital and there is no need for transportation. For the other hospitals, there is a need for transport to the pre-treatment facility. The average distance is estimated to 10 km.

Transport to separation and sorting facility

This transport is carried out in scenario 1.

It is assumed that the sorting facility is located 1 350 km from previous process stage. The mixed flakes are sent to sorting, located in Germany.

Transport to recycling facility

This transport is carried out in scenario 1.

It is assumed that the recycling facility is located 100 km from previous process stage.

Transport to energy recovery

This transport is carried out in scenario 2.

It is assumed that the energy recovery facility is located 20 km from the previous process stage.

3.4 Result

The result from the environmental assessment is presented for the parameters listed in Table 2 and Table 3. In section 3.4.1 below, the aggregated result for each parameter is presented for the three scenarios. In section 3.4.2 the result is broken down into the different processes to identify hotspots. The parameter studied in this section is the *Global warming potential*, since that is the most important impact. In section 3.5 a sensitivity analysis is performed. The fraction of plastics sent to energy recovery for scenario 1 is then increased in order to find the break-even between the scenarios.

3.4.1 Aggregated result

The result for the environmental impact categories and energy uses are presented in below Table 9, and displayed per 1 kg collected plastic material. It is important to remember when studying the results in table 3 that the manufacturing of the plastic is excluded from the modelled system. The category global warming potential is presented in a bar chart in Figure 2 below.

Table 9 – Aggregated results for environmental impact categories and energy uses selected in the study, result is per 1 collected plastic.

Impact category	Scenario 1a – Recycling (Ozonation)	Scenario 1b – Recycling (Hydrothermal)	Scenario 2 – Energy recovery	Unit
Global warming potential (Climate change)	0.53	0.55	2.8	kg CO2 equivalents
Eutrophication potential (EP)	-0.07	-0.06	-0.19	g PO4 equivalents
Acidification potential (AP)	-0.52	-0.48	-0.54	g SO2 equivalents
Photochemical ozone creation potential (POCP)	-0.23	-0.22	-0.17	g Ethene equivalents
Total energy resources	-23	-20	-17	MJ, lower heating value
Renewable energy resources	-0.74	0.27	-11	MJ, lower heating value
Non-renewable energy resources	-22	-21	-6.3	MJ, lower heating value

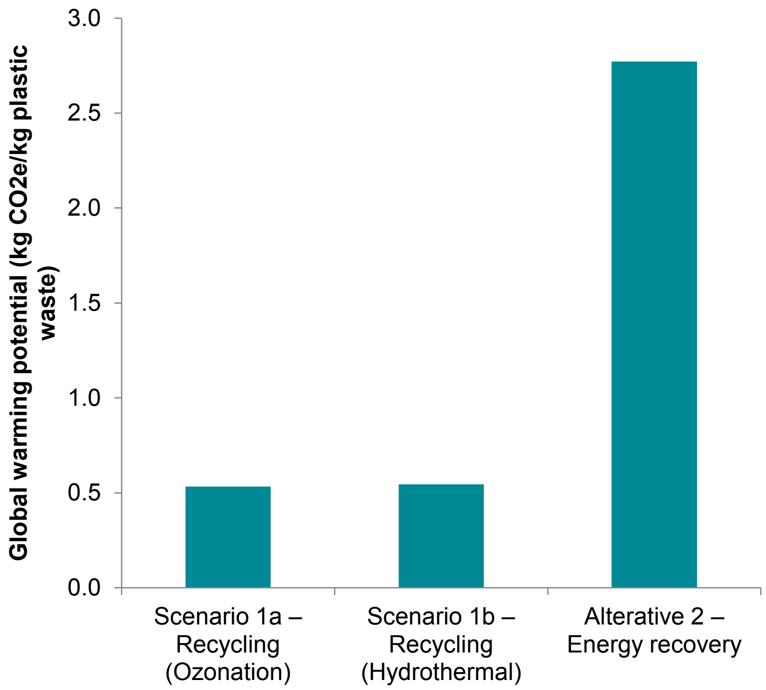

Figure 2 – Global warming potential for the different scenarios.

It is important to remember when studying the results above that the manufacturing of the plastic are excluded from the modelled system. Plastic production is mainly fossil based and has a large environmental impact that is not included in the results of this study. This is the reason why results have negative numbers for most of the impact categories, indicating a net benefit rather than an impact. For the three categories *Acidification potential*, *Photochemical ozone creation potential* and *Total energy resources* similar results can be seen for the scenarios. The last one is however the sum of the two bottom categories *Renewable energy resources*, *Non-renewable energy resources*. The negative figure is larger for scenario 1a and 1b for the category *Non-renewable energy resources*. This is due to that fossil energy is replaced for the avoided production of energy and plastic material. In scenario 2, the energy produced is instead replaced with more renewable energy. The two remaining categories are *Global warming potential* and *Eutrophication potential*. The difference for the *Global warming* category is thoroughly described in the next section. The *Eutrophication potential* gives a larger environmental benefit for scenario 2. In this case it is due to the benefit of replacing Swedish district heat, which is produced partly from biomass as energy source giving a major contribution to the *Eutrophication potential*. In summary, the system expansion has a large impact on the results in terms of which processes for energy and heat production that are used for modelling replaced production.

3.4.2 Result per process

This section is analyzing the *Global warming potential* regarding the differences between the scenarios and the contributions from the different processes. In the below tables Table 10 the result for the *Global warming* category is presented.

Table 10 – Results per process, Global warming potential (kg CO2 equivalents)

Process	Scenario 1a – Recycling (Ozonation)	Scenario 1b – Recycling (Hydrothermal)	Scenario 2 – Energy recovery
Transport to pre-treatment facility	<0.01	<0.01	-
Compression	-	-	<0.01
Pre-treatment via Ozonation	<0.01	-	-
Pre-treatment via Hydrothermal	-	0.02	-
Transport to separation and sorting facility	0.08	0.08	-
Density separation	<0.01	<0.01	-
NIR sorting	<0.01	<0.01	-
Transport to recycling facility	<0.01	<0.01	-
Transport to energy recovery facility	<0.01	<0.01	<0.01
Recycling	0.40	0.40	-
Energy recovery	1.16	1.16	3.0
Avoided impact from recycled plastic	-0.54	-0.54	-
Avoided impact from energy production	-0.58	-0.58	-0.21
Total	0.53	0.55	2.8

It can be seen in the table above that the *Global warming* impact is negligible for several processes, including the transport categories (except the transport to the separation and sorting facility, Sweden to Germany), compression, the separation and sorting processes. The impact from the ozonation process is also negligible in this context and the other pre-treatment method, hydrothermal gives only a slight contribution.

The impacts from recycling are identical for scenario 1a and 1b but are zero for scenario 2 as no plastic is recycled in that scenario. The same goes with the avoided impact for the recycled plastic. It seems that the credit (-0.54) of recycling the material is not so much bigger than the impact (0.40) it comes with. This is due to the quality factor of the plastic that is assumed to be 50% (see section 3.1), not giving the full benefit of replacing virgin plastic. Setting a different quality factor would change the results; the higher the quality of the recycled plastics, the more benefit is gained in terms of replaced production of virgin material. The energy recovery impact for scenario 1 is about 40% of the impact for scenario 2. This is because 40% of the plastic is energy recovered in scenario 1 and 100% is energy recovered in scenario 2. For the avoided energy production, credit is given to 40% of the material in scenario 1 and 100% of the material in scenario 2. The result is however -0.58 for scenario 1 and -0.21 for scenario 2. The reason for this is that the climate credit per MJ is bigger for energy avoided with German energy production mix than for Swedish energy production mix.

This sums up to 0.53 and 0.55 kg CO_{2e}/kg plastic for scenario 1a and 1 b respectively and 2.8 CO_{2e}/kg plastic for scenario 2. The major reason for the difference is the impact from the energy recovery process where the difference is about 1.8 between the scenarios. Given this, it would be interesting to visualize how an increased ratio of plastic going to energy recovery for scenario 1 would affect the result for the *Global warming* category.

3.5 Sensitivity analysis

Currently, about 40% of the plastic is sent to energy recovery in scenario 1. 20% is due to the fraction *others* is not intended to be recycled. 8% is due to limitations in the NIR sorting. The remainder of 12% is due to that the recycling process is limited in its ability to recycle all input material.

In this sensitivity analysis, the scenarios are assessed regarding the fraction of plastic waste that needs to be sent to energy recovery, for scenario 1, to reach break-even for the *global warming potential*. This is shown in the below Figure 3.

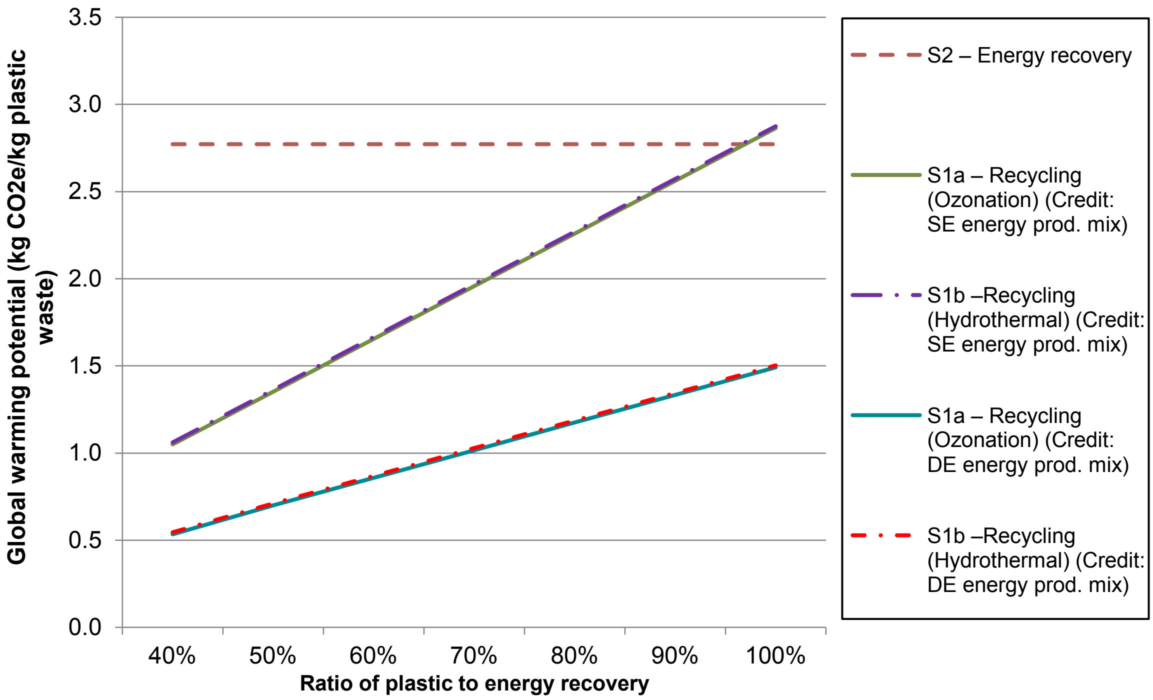

Figure 3 – Sensitivity analysis of recycled plastic with different proportions to energy recovery.

The graph above illustrates the effect of changing the portion of plastic waste sent to energy recovery for scenario 1a and 1 b (i.e. the recycling scenarios). These two are starting at 40% plastic waste to energy recovery. The portion is increased up to 100% to identify the break-even between scenario 1a and 2 and between scenario 1b and 2. Two different approaches are used. In the baseline method, German energy production mix is the basis for the avoided energy production. This is illustrated in the above figure as *Credit: DE energy prod. mix* for Scenario 1a and 1b. This is changed to Swedish energy production mix which is illustrated above as *Credit: SE energy prod. mix* for scenario 1a and 1b.

No parameter is changed for the second scenario (energy recovery), and 100% of the plastic waste is sent to energy recovery. This is illustrated a horizontal dotted red line above. It could be noticed that the Swedish energy production mix is applied in this scenario to compute the environmental credit.

It can be seen in the above figure that by increasing the ratio of plastic to energy recovery for scenario 1, the climate impact increases. The impact for scenario 1a and 1b are similar, which is why the lines are next to each other. When applying the German energy production mix to scenario 1, the impact is still lower compared to scenario 2 for all ratios of plastic to energy recovery. If the Swedish energy production mix is used instead, the break-even is at about 95% of the plastic going to energy recovery for scenario 1. It is however not reasonable that only 5% of the material is recycled in a system created for recycling the plastic. The conclusion is therefore that both scenario 1a and 1b give lower climate impact than scenario 2.

4 Economic assessment

The economic assessment focuses on the Swedish hospitals' perspectives. It is a qualitative assessment based on interviews with the three of the five hospitals represented in the study[7] and cost data from different actors in the value chain. Each region has their specific arrangement for waste handling for hospitals and other facilities with service providers, sometimes through the facility owner/landlord. The terms and costs for the services are set through public procurement contracts and renegotiated regularly. In some cases, the hospitals have different service providers for different fractions, and the total number of waste fractions can be up to 40. Costs for waste handling therefor vary between regions and hospitals, depending on the design and volume of their contracts, the transport distances in the area, the local fee for incineration of waste and other factors such as current material prices.

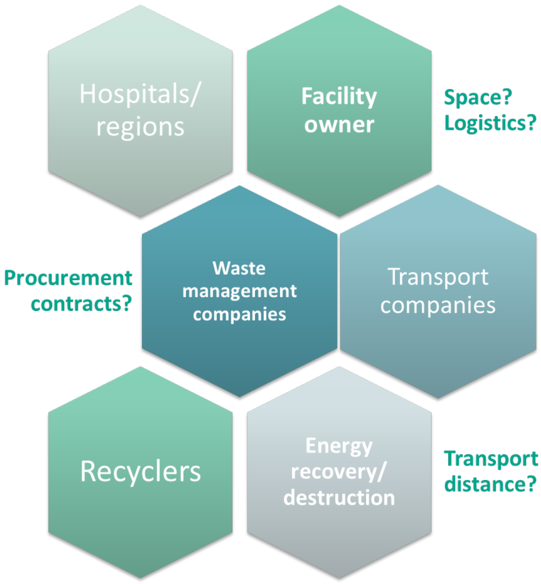

Figure 4: Illustration of actors in the plastic management value chain (in hexagons), and some factors influencing the cost structure (green text).

Some Swedish counties/regions do not sort plastics separately, while others sort up to three different fractions of plastics; see appendix C for examples. All three hospitals participating in this study have some kind of separate sorting of plastics. Two of them also have compression of soft plastics on site to save space and facilitate transportation. Today, a large amount of used plastics are not sorted separately but sent to energy recovery with other combustible waste. As presented in the previous chapters, this study investigates if a larger amount of plastics could be sorted and sent for recycling using a pre-treatment step. This alternative comes with several costs of investments and usage costs. Table 11 below presents the different types of costs related to energy recovery, pre-treatment and recycling. It also gives examples of known costs, and shows which costs have not been available to the research team in the study.

[7] Stockholms Läns Landsting (hereinafter SLL), Region Jönköpings län (RJ) and Region Jämtland Härjedalen (RJH).

4.1 Cost components

The different costs related to pre-treatment, recycling and energy recovery are borne by different actors in the value chain. One of the largest costs in the pre-treatment and recycling scenarios is the investment in the different pre-treatment machines for ozonation or hydrothermal treatment. The investment could either be taken by the hospitals themselves or by a recycling company. The cost of investment has not been shared by the pre-treatment representatives in the project, but interviews point to that it would be a substantial cost even for a large hospital. For smaller hospitals, it would not be a feasible investment. If a hospital would invest in pre-treatment, an additional employee might also be required to operate the machine, which would mean additional staff cost.

Other costs include transportation of the material to Germany or to energy recovery, sorting and recycling costs and fees for energy recovery. These costs would likely be borne by the waste management companies, and reflected in the costs for waste handling of the plastic fractions. The ownership of the material normally shifts to the waste management company at the pickup from the hospital[8].

Table 11 – Costs components and example revenues for handling of plastic waste

Cost component	Actor bearing the direct cost	Cost (SEK)
Compression of soft plastics (film/foil)	Hospitals/Region	Not known
Investment in pre-treatment machine Ozonation	Hospital/Region	Not known
Investment in pre-treatment machine Hydrothermal	Hospital/Region	Not known
Extra staff to operate the pre-treatment machine	Hospital/Region	Ca. 800 000 - 1 000 000 per year
Transport to Germany (1350 km)	Waste management company (possibly through subcontractor)	Depends on setup and material quality
Separation, sorting and recycling Reception fee	Waste management company	Not known.
Transport to energy recovery (20 km)	Waste management company	Depends on contract
Reception fee for energy recovery	Waste management company	Example: ca 600/ton (varies per region)
Revenues for clean plastic fractions (based on data from one Swedish recycler)	Waste management company/Hospital/Region (how revenues are distributed depends on contract setup)	2500 – 5000 per ton for clean and well separated PE and PP fractions

[8] Personal communication with Stena Recycling

The main conclusion when discussing costs is that it is impossible to present a cost structure that applies to the generic scenarios studied in the project. Most costs depend on the local conditions and setups between actors in the value chain. The actors contacted are cautious to give examples even of transport costs without knowing more about the exact quality and amount of material[9]. Costs for sorting and recycling have been equally difficult to find for a theoretic case like the one in the study. It is in fact highly uncertain if the pretreated material can actually be separated into different plastic types after being shredded and mixed in the pre-treatment machine. German sorting company Tomra offers test sorting of plastics in its demonstration facility. The first day is then free of charge, second day is 7500 Euro and third day 1500 Euro, and this could be a possible test to determine if it is possible to separate mixed shredded fractions with NIR/VIS technology[10].

The examples of revenues from recycling companies are also not applicable to the case of mixed fractions, since they represent clean and fully separated flows of specific polymer types, like pure transparent LDPE or shredded rigid PP. Another important factor for recycling companies is the access to sufficiently large volumes that are stable over time[11].

Fees for energy recovery vary by region, and are normally included in the price that hospitals/regions pay for waste collection. However, the fee for destructing contagious wastes is sometimes borne directly by hospitals[12]. This cost can be between 2 900 – 15 000 SEK per ton, compared to other fractions that can cost 600 SEK per ton (combustible waste from industry[13]) and yet others that are cost neutral[14]. One possible option from an economic perspective could therefore be that the hospitals pretreat contagious waste streams so they can be sent to energy recovery rather than destruction. This would drastically lower the costs for the hospitals in the cases where they pay for destruction themselves.

Many waste management companies are also skeptical regarding if plastic streams from hospitals should be recycled at all, due to the potential contamination and infection risk.

4.2 Possible setups

There are basically two setups for the pre-treatment case; one where the investment in machinery is taken by hospitals and one where a waste management company buys the machine and offers pre-treatment as part of their service. If the waste is classified as contagious, the second option may involve more expensive storage and transport. Below is a table outlining the cost components for hospitals in the two options, where red cells are costs, yellow cells are potential or uncertain costs and green cells represent reduced cost components.

A third setup is, as discussed above, to pretreat contagious waste at the hospitals and send it for regular energy recovery. This would not replace any primary plastic material through recycling, but could reduce the need for other energy sources and reduce cost for the hospitals.

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[9] Personal communication with Stena Recycling
[10] Personal communication with Tomra, Germany.
[11] Personal communication with AXJO Plastics.
[12] Personal communication with Ewa Frank, SLL.
[13] Example from waste management company SYSAV: https://www.sysav.se/foretag/Priser/
[14] Personal communicaiton with Catarina Standroth, RJ.

Table 12: Cost components borne by hospitals for two possible setups, presented as increased costs (red), uncertain cost (yellow) and cost reductions (green).

Pre-treatment in hospitals	Pre-treatment at waste management company
Investment in pre-treatment machine (Ozonator or Red Bag hydrothermal)	NA
Possible extra employee for pre-treatment operation	Possible extra service cost for pre-treatment.
Extra cost for sorting and recycling (included in waste management fee)	Extra cost for sorting and recycling (included in waste management fee)
Possible revenue from recycling (included in waste management fee)	Possible revenue from recycling (included in waste management fee)
Lower cost for incineration (included in waste management fee)	Lower cost for incineration (included in waste management fee)

The option where the investment is taken by waste management companies is more attractive and feasible for smaller hospitals that do not have sufficient volumes of plastic waste and smaller budgets. Even if some large hospital would in theory be able to take the investment, they would need to first make sure that the business case is positive. To evaluate the business case requires investigations along the entire value chain, and it is doubtful if hospitals would see this as a key priority. As one of the interviewed representatives put it: “Waste management is not our core business”.

5 Social assessment

The assessment of social factors is a qualitative analysis based on interviews with three project partners representing regional hospitals and healthcare in the project. The interviews were focused around the work environment, staff attitudes and practical handling of plastic waste in the hospitals and other healthcare institutions. The interview questions can be found in appendix C. The aim of the interviews was to identify challenges and key factors for successful sorting in hospitals, and to investigate the attitudes towards implementation of new pre-treatment methods.

5.1 Current success factors and challenges

As described shortly in section 4, the regions have different prerequisites for plastic sorting, like the size of the region and hospitals, transport distances, storage space and budgets. Each region also has separate contract setup for waste handling, and a different level of dialogue with the local waste management companies. These are some of the reasons why sorting and handling of plastic waste is done in different ways today.

One key aspect to increase sorting of plastics for recycling is how the regions interpret what is contaminated plastic waste. The central regional support function called "vårdhygien" (healthcare hygene) plays an important role in this interpretation, guiding the hospitals in their county/region on what is contaminated and how to handle different products in different situations. Some of the region representatives feel that the advice from vårdhygien differs depending on which person you ask. This makes it difficult to implement stringent and clear instructions to the staff on how to handle plastic waste. Clear and continuous information is a key factor to implement successful sorting. Below figure shows two examples of current instructions to staff regarding plastic sorting. These and additional examples can be found in appendix D.

Figure 5: Examples of instructions for sorting rigid and coloured soft plastics in Region Jönköpings län[15]

[15] Personal communication with Catarina Strandroth, Region Jönköpings län.

It is important to inform and educate the staff on a regular basis, to refresh the knowledge and provide feedback on why sorting is performed and how the material is treated. This is a challenge in large hospitals, with thousands of employees and sometimes high staff turnover. The hospitals have similar setups for staff education with selected representatives being responsible for information and communication to all employees. The information is shared through regular meetings, letters and signs in the work place. The performance improves when representatives have chosen the task to inform colleagues themselves rather than having been assigned the task by management[16].

The infrastructure for sorting, such as well-designed sorting furniture, also improves sorting performance and increases collected volumes. It is helpful if the facility owner provides good furniture as part of the service, so that hospital staff doesn't have to organise this. When new hospitals are designed it is important to provide adequate space for sorting in many areas of the departments. In SLL, the new hospital was designed with only one sorting room per department, and additional sorting infrastructure had to be set up, requiring large efforts and resources[17].

The level of transparency and the procurement contract setup between regions and waste management companies also plays an important role in how plastic sorting is carried out. With close cooperation, solutions can be found for specific fractions or products based on local conditions. In Jönköping, the separation of clear soft plastics provides an extra income for the region. They have also identified clean aprons as a separate fraction that is now sent to recycling. Having one waste management company for all fractions enables a deeper cooperation and a better dialogue, as opposed to having several different companies. This was expressed both by Jönköping and SLL, who have switched from 5 and 3 companies in the past to one service provider for all fractions.

The hospital in Östersund has different colors of collection bags for different waste fractions. This simplifies sorting for the staff and increases the quality of collected fractions[18]. Internal quality checks are also important to have good sorting results. In both Östersund and SLL, the caretakers inspect the bags before pickup, and remove bags which contain the wrong type of materials.

There is a limit to how many fractions the staff is willing and able to sort. In SLL, the staff is very content with sorting all plastics in one fraction. The other two regions sort up to 3 fractions, but the number also differs between hospitals in each region. All three regions state very clearly that sorting per plastic type is not a viable option, since there are too many material types and it would be too time consuming and complicated for the staff.

Reducing the amount of different materials that are sourced, and using criteria to enable recycling are two possible goals for procurement in hospitals, but knowledge and resources are often lacking. There is a lack of guidance on these subjects, for example from the procurement agency. A procurement network between regions could also help to transfer knowledge, exchange success stories and produce standardised guidelines for the benefit of both hospitals and product manufacturers.[19]

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[16] Personal communication with Ewa Frank, SLL.
[17] Personal communication with Ewa Frank, SLL.
[18] Personal communication with Åsa Paletun, RJH.
[19] As discussed in the final seminar of the project, Stockholm 20181120.

Introduction of a new waste system in one of SLLs hospitals has proven to be a challenge. Both sorting volumes and quality have decreased when a waste suction system was introduced[20]. This highlights the importance of routines and continuous information, and the fact that it takes time to implement a stable and successful practice. Table 13 below summarises the identified success factors and challenges in hospitals relating to plastic waste sorting.

Table 13: Summary of current success factors and challenges related to plastic sorting.

Success factors
Good dialogue with waste management company
One waste management company for all fractions
Clear and continuous information and feedback
Dedicated staff representatives
Internal quality control
Different colors of collection bags for different fractions
Good sorting infrastructure provided and designed in dialogue with the staff to fulfill needs
Few plastic fractions (maximum 2-3)
Challenges
Limited space for sorting and storage in existing buildings
Unclear advise from vårdhygien regarding contaminated plastics
Introductions of new systems and practices
Large amount of employees and staff turnover
Inadequate space designed for sorting in new hospitals
High stress levels makes it difficult to prioritise sorting
Lack of criteria for procurement

[20] Personal communication with Ewa Frank, SLL.

5.2 Attitudes to pre-treatment

The staff in the three interviewed regions has an overall positive attitude to sorting plastics, and sorting practice has been implemented for a long time in all three regions. The staff is very engaged and often eager to sort out more plastics to recycling within their current system setup.

The attitudes to pre-treatment differ between the three interviewed representatives, where SLL has a slightly more positive view. The main reason for this is that a pre-treatment system would work well together with the new suction system at the hospital Nya Karolinska, at least in theory. However, initial dialogue with the manufacturer suggests that the investment cost would be too high. For the older hospital in Huddinge, pre-treatment would not fit well with the current sorting practice.[21]

For Jönköping and Jämtland/Härjedalen, it is not feasible to invest in pre-treatment due to smaller volumes and constrained budgets. Depending on what fractions would be collected, the handling would be more or less complicated. There seems to be consensus that contaminated waste should be handled as today, to limit infection risks. Then the need for pre-treatment is limited, since the collected fractions are already "clean". The acceptance from waste collectors is instead solved through dialogue and cooperation.

Two of three regions, SLL and Jämtland/Härjedalen, foresee additional staff needs in connection to pre-treatment, while Jönköping believes that tasks could be shifted among existing staff since pre-treatment could replace current baling practice.

A short list of the different opinions from hospital representatives in the project regarding pre-treatment is presented below:

- Investment in machinery is too expensive!
- Extra staff could be required for operation, extra information and new work tasks.
- Sorting would be too complicated if more fractions were introduced, but...
- ... if all plastics were collected in one fraction it would instead mean a simplification.
- re-treatment could potentially replace current baling practice, which takes a lot of time.
- There is really no need for pre-treatment if only clean fractions are collected.

[21] Personal communication with Ewa Frank, SLL.

6 Discussion

6.1 LCA results and methodology

The overall result from the LCA is that plastic recycling is positive from a climate perspective. This is true even with the large losses of material assumed for the case. In LCA studies, the system boundaries and dataset selection are important factors influencing the results. In this study the system boundary has been drawn at the hospitals collection, which means that the environmental impact from primary plastic production is not included. This should be kept in mind when interpreting the results. System expansion has been used to illustrate the gains of replacing material production and energy production by recycling and energy recovery. A dominance analysis shows that the datasets dominating the results are the energy mixes in Sweden and Germany. When calculating replaced energy production, average or marginal data can be chosen.

In the calculations the average energy mixes for the two countries, Sweden and Germany, are used. There are different energy mixes in the countries which have different environmental impacts, where the spread can be large e.g. between different regions or between different companies. The scope of this study is to provide an overview that corresponds to the energy conditions in the countries and not to demonstrate the environmental performance of different companies. As an example, it has not been investigated what energy mix a certain region has used, but average conditions for Swedish energy production have been adopted.

In cases where plastic is used in Sweden and then transported to Germany for recycling and energy recovery of rejected fractions, environmental impact becomes less than if the plastic is energy recovered or recycled in Sweden. This is because the energy being replaced (no need to be produced) has a greater environmental impact in Germany than in Sweden. This aspect should be taken into account when comparing the different scenarios as the average environmental performance of several of the included environmental impact categories are lower for Swedish energy production than for German energy production. Therefore, the chart in the sensitivity analysis should also be studied to get a complementary image.

6.2 System setup to enable recycling

At the core of this study is the conflict between quality of pre-treated plastic fractions and the need to make sorting sufficiently simple for staff. The suggested setup to collect only one mixed plastic fraction is not optimal from a quality perspective, since the pre-treatment includes shredding of the material. The mixed shredded fraction will then be difficult to separate without putting in a lot of effort and cost. The separation technology investigated in this study is designed for larger sizes, such as complete products, or for removing impurities from clean and already separated fractions. Recyclers need clean fractions in their processes, and traceability through the value chain is important in order to resolve potential quality issues. This would be difficult for a mixed and shredded fraction. On the other hand, hospitals have limited capacity to sort out specific products or product types, due to time constraints and lack of physical space. Separate sorting and recycling of film fractions is however performed successfully in some hospitals today, providing revenue to the hospitals. Especially clear film and foil fractions have a good market. There are Swedish actors who recycle these fractions today, reducing the need for costly transports. The reason we have chosen Germany for recycling is that the NIR sorting is not available in Sweden. This could change in the future. The German actors that we contacted in the study were very skeptical to handle any fractions from health care. The stigma around hospital waste is still strong, which indicates that recycling and sorting abroad could be difficult.

In terms of cost, the cost components for waste separation, recycling and energy recovery are usually not visible to the hospitals. There is maybe no need for complete transparency, but trust and dialogue within the value chain can enable solutions that minimises cost and increases recycling. Pre-treatment is probably too costly for most regions today, but may have potential for large regions in the future. This is however only true if it enables contaminated fractions to be recycled. In that case, pre-treatment would also mean substantial cost reductions for hospitals in terms of avoided destruction. As long as only "clean" fractions are sorted, the acceptance could instead be built on communication and trust in the value chain.

7 Conclusions

The conclusions that can be drawn from this study are:

- The LCA shows that plastic recycling makes sense from a climate impact perspective.
- Pre-treatment of mixed plastics is no optimal solution, since the shredding of material puts high requirements on sub-sequent sorting and separation. It is uncertain if separation of a shredded, mixed fraction is even possible with currently available technologies.
- There is a delicate balance between work load for employees and separate sorting of different fractions, but there are also success stories where recycling of specific fractions bring revenue to hospitals.
- Source separation into plastic types is not possible, since it is too difficult to see the difference between plastic types and the staff work load would be too high.
- Investment in pre-treatment is too costly for most hospitals, and the benefit could be questioned as long as only "clean" fractions, that would not really need pre-treatment, are collected. The pre-treatment is then just a costly way to increase acceptance of the fractions.
- Increased recycling of specific fractions could be achieved through local agreements with waste management companies and recyclers.
- The size and quality of collected volumes are limiting factors to enable more recycling, since many recyclers need continuous access to stable material flows of homogenous quality.
- The determination of quality of the material after these pre- treatments methods was one of the questions that were worked in work packages 3 and 4 and the results were promising. The quality of recycled material were better than average because of the high quality of medical plastics. This good enough quality of both examined materials gave potential to manufacturing durable products such as two type of flooring products (for more information see the RE:source report of the project)
- A strategic network for procurement between regions would have potential to reduce the amount of plastic types and harmonise sustainability criteria for procurement between hospitals and regions.

- Polymer experts and experts in LCA could be a fundamental help in terms of comparable material and LCA results, and procurement guidelines is also needed to support buyers.
- Key factors for successful sorting include well planned sorting infrastructure, sufficient storage space, good communication and internal quality control.
- The motivation of employees is more of a driver than a challenge: the majority of hospital staff is positive to separate sorting of plastics!

References

Personal communication with Ozonator

Personal communication with Red Bag Solutions

Personal communication with Stena Recycling

Personal communication with Tomra, Germany

Personal communication with AXJO Plastics

Personal communication with Ewa Frank, SLL

SYSAV waste reception fees: https://www.sysav.se/foretag/Priser/

Svelog compressor data: https://svelog.com/index.php/produkter/sackkomprimator

Personal communicaiton with Catarina Standroth, Region Jönköpings län

Personal communication with Åsa Paletun, Region Jämtland Härjedalen

Final project seminar, Stockholm 20181120

Fråne och Sundqvist (2014) Återvinning av plast från Stockholms Läns Landstings sjukvårdsverksamhet. Uppdragsrapport.

Appendix A. – Description of inventory/impact categories

The environmental inventory/impact categories included in the study are presented and briefly explained below.

Inventory/Impact category	Description
Climate change/Global warming potentials	A global climate change is a problem for many reasons. One is that a higher average temperature in the seawater results in flooding of low-lying, often densely populated coastal areas. This effect is aggravated if part of the glacial ice cap in the Antarctic melts. Global warming is caused by increases in the atmospheric concentration of chemical substances that absorb infrared radiation. These substances reduce the energy flow from Earth in a way that is similar to the radiative functions of a glass greenhouse. The characterisation factor is measured *in kg CO_2 equivalents per kg of the emitted substance*, and thus, the unit of the category indicator is kg *CO_2 equivalents (kg CO_2 eq.)*. The method used in this is CML 2001 – Jan. 2016
Eutrophication potential (EP)	When the nutritional balance in the soil and waters is increased, it is called eutrophication. For example, in aquatic systems, this leads to increased production of biomass, which may lead to oxygen deficiency when it is subsequently decomposed. The oxygen deficiency, in turn, kills organisms that live in or near the bottom of the lakes or coastal waters. It also makes the reproduction of fish more difficult. The category indicator is the potential of the emissions from the system investigated to deplete oxygen in aquatic systems, e.g. through increased biomass production. The potential contribution to eutrophication is in this study expressed as phosphate-equivalents, i.e., the capacity of 1 mg of a substance to favour biomass formation compared to that of 1 mg of phosphate (PO_4^{3-}). The characterisation factors used for eutrophication are measured in *g PO_4^{3-}-equivalents per g of the emitted substance*. Thus, the unit of the category indicator is *mg PO_4^{3-}-equivalents*. The method used in this is CML 2001 – Jan. 2016
Acidification potential (AP)	Acidification stands for the decrease of the pH value in terrestrial and water systems. This is a problem, e.g., because it causes substances in the soil to dissolve and leak into the water systems. These substances include nutrients, which are needed by plants, as well as metals such as aluminium and mercury, which can have toxic effects in the aquatic ecosystems. Reduced pH in the water system also has direct, ecotoxic effects, reducing the number of species that can live in lakes, etc. Emission of acidifying substances also causes damage on human health, and on buildings, statues and other constructions. The characterisation factors are measured in *mg SO_2-equivalents per g of the emitted substance*, and thus, the category indicator is measured in *mg SO_2-equivalents*.

	The method used in this is CML 2001 – Jan. 2016
Photochemical ozone creation potential	This environmental impact category describes the problem of oxidant formation in the tropic sphere. An oxidant is a substance that can oxidize a substance (e.g. I- (iodide) to I2 (iodine). In this context, the main oxidant is ozone. Ground-level ozone is formed by a chemical reaction between air containing high levels NOX with volatile organic compounds in the presence of sunlight. The most effective ozone producers are propane and ethylene. Smog is a consequence of this reaction. Ground-level ozone is harmful to humans and the environment. To quantify ground level oxidant formation, measure the amount in *mg ethylene equivalents*. The method used in this is CML 2001 – Jan. 2016**.**
Renewable energy resources	This category represents the use of primary renewable energy resources such as biomass fuels, wind power, solar power, and hydro power. A primary energy resource is an energy resource in the form it exists on earth before it is processed i.e. the original resource. For biomass fuels it can be e.g. the forest resource for wood pellets. For wind, solar and hydro power the original resource is not so obvious. Instead, the produced or used amount of energy is used as a base to calculate the primary resource using some kind of efficiency for the energy production. This resource category is given in MJ used renewable primary energy. For fuels, the energy content has been calculated using the lower heating value (LHV).
Non-renewable energy resources	This category represents the use of primary non-renewable energy resources such as crude oil, coal, natural gas, and uranium. A primary energy resource is an energy resource in the form it exists on earth before it is processed i.e. the original resource. The non-renewable energy is energy sources that is not renewed and thus exist in a limited amount on earth. The resources of fossil fuels (coal. oil, and gas) are good example but uranium for nuclear power production is also a non-renewable energy resource. This resource category is given in MJ used non-renewable primary energy. For fuels, the energy content has mainly[22] been calculated using the lower heating value (LHV).

[22] The uranium energy has been calculated separately for a nuclear reactor.

Appendix B. – Energy sources in the model calculations

Energy sources	Swedish electricity mix (%)	Swedish district heating (%)	German electricity mix (%)
Brown coal	-	-	26.4
Hard coal	1.6	2.3	23.4
Heavy fuel oil	2.0	1.6	0.8
Natural gas	0.4	1.9	9.5
Peat	0.1	2.4	
Nuclear	46.3	-	28.8
Waste (incl. gas and heat)	-	42.4	1.6
Blast furnace gas	0.9	-	1.2
Other fossil fuels	-	0.1	-
Solid biomass	2.5	40.5	0.1
Hydro	45.6		4.9
Power for heat pumps, boilers etc	-	6.1	-
Gaseous biomass	0.2	-	0.6
Wind	0.4	-	2.8
Bio oil	-	1.5	-
Tall oil	-	0.9	-
Primary bio fuels	-	0.2	-
Total	**100**	**100**	**100**

Appendix C. Interview questions

- How many fractions are sorted today (plastic and others)?
- How does sorting and volumes differ between departments?
- What types of extra work would increased sorting bring?
- What are the employee's attitudes to sorting? To more sorting?
- Is there a limit in terms of number of fractions?
- What factors influence the staff attitudes in positive vs negative direction?
- Are there any work environment risks related to more sorting?
- What preparations would be needed to introduce pre-treatment?
- What types of information is needed?
- Would additional staff be required?
- What prerequisites would have to be fulfilled for you to consider introducing pre-treatment?
  _ with regards to costs
  _ with regards to work load
- Would you consider investing in a pre-treatment machine?
  _why/why not?
  _what would it cost?
- How should a pre-treatment system be designed in terms of actors, responsibilities and costs?

Appendix C.
Sorting instruction examples

Sorting instructions from SLL, where all plastics are sorted in one fraction:

Sorting instruction for transparent film and foil, Jönköping:

Mjukplast ofärgad

EXEMPEL: Plastförkläden, påsar, bubbelplast, krympfilm, pallhuvar, pallomslag. Utsorterad mjukplast ger en intäkt.
OBS samlas i plastsäck märkt returplast.

INTE: All färgad och synligt oren plast/plastartiklar, färgad emballageplast, slangar & "droppåsar", frigolit, engångshandskar.

Vid frågor, kontakta respektive avfallsterminal på sjukhusen.

JRAB

Region Jönköpings län

Sorting instruction for coloured film and foil, Jönköping:

Mjukplast färgad

EXEMPEL: Färgad mjukplast som brödpåsar, bärkassar, färgade plastförkläden (synligt rena), packskynken till sterilgods, annan färgad mjukplast.
Utsorterad mjukplast ger en intäkt.

INTE: Ofärgad och synligt oren plast/plastartiklar, engångshandskar.

OBS samlas i plastsäck märkt returplast.
Vid frågor kontakta respektive avfallsterminal på sjukhusen.

JRAB

Region Jönköpings län

Sorting instruction for rigid plastics, Jönköping:

Hårdplast

EXEMPEL: Burkar, dunkar, flaskor, hinkar, förpackningar, plastbestick, engångsartiklar i plast, kontorsartiklar i plast

INTE: Förpackningar som är orena eller ej tömda, handskar, slangar och sugsystem, infusionsaggregat, provtagningsrör, andningsmasker, sprutor/förpackningar.
Förpackningar med symbol.

Vid frågor, kontakta respektive avfallsterminal på sjukhusen.

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