Master's Thesis – Master Sustainable Business and Innovation

Scenario-based system assessment for business strategy development in the Circular Economy – A case study of Enviro Waste London Ltd.

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Executive summary

This research explored how waste management companies can create a circular strategy in order to create sustainable value in the Circular Economy (CE). As the CE is defined as a cyclical, closed-loop economic system, as apposed to the linear 'take-make-use-dispose' economy, waste management companies are forced to redefine their role in the economic system. From a waste management business perspective, old-fashioned disposing services, e.g. landfilling, are increasingly questioned, shifting the focus to resource management, in which extending the usability of materials and products is key. This transition is particularly fuelled due to the rising global challenges of increasing waste volumes, resource depletion and climate change. As it might not seem obvious, the latter global challenge is relevant in waste management considerations due to its potential contribution to the avoidance of primary production of materials and products, resulting in net avoided process CO_2 emissions.

In order to anticipate on the transition towards circular resource management, waste management companies are in need of circular strategies, aiming to create sustainable value. For this reason, a case study approach was chosen to enable well-informed decision making in strategy development. This was done for the waste management company Enviro Waste London Ltd. Three different research methods were used for this purpose. The first research approach used was an adapted scenario-based system assessment (*i*Waste model) in order to assess the potential contribution of circular principles in terms of CO_2 emission avoidance, considering different scenarios. The second approach was the identification of barriers for the implementation of a circular strategic initiatives within Enviro Waste, using a questionnaire among employees. The final research approach was a group interview in the form of a semi-structured interactive session with the directors and business operations manager of Enviro Waste, in order to develop a circular strategy based on the outcomes of the two other research methods.

For the scenario-based system assessment, two scenarios were developed and compared to the reference scenario of Enviro Waste. The National Average scenario was used as benchmark to compare the Enviro Waste Management System (EWMS) with the performance on national level for the same materials and products, while the Circular Principle scenario was used to explore how circular principle implementation of one company could influence the performance of their system in terms of avoided CO_2 emissions. Assessing 15 materials and 4 product categories covering collected waste in 12 months, **Figure S – 1** shows the CO_2 emission reduction potentials for both scenarios compared to the reference scenario.

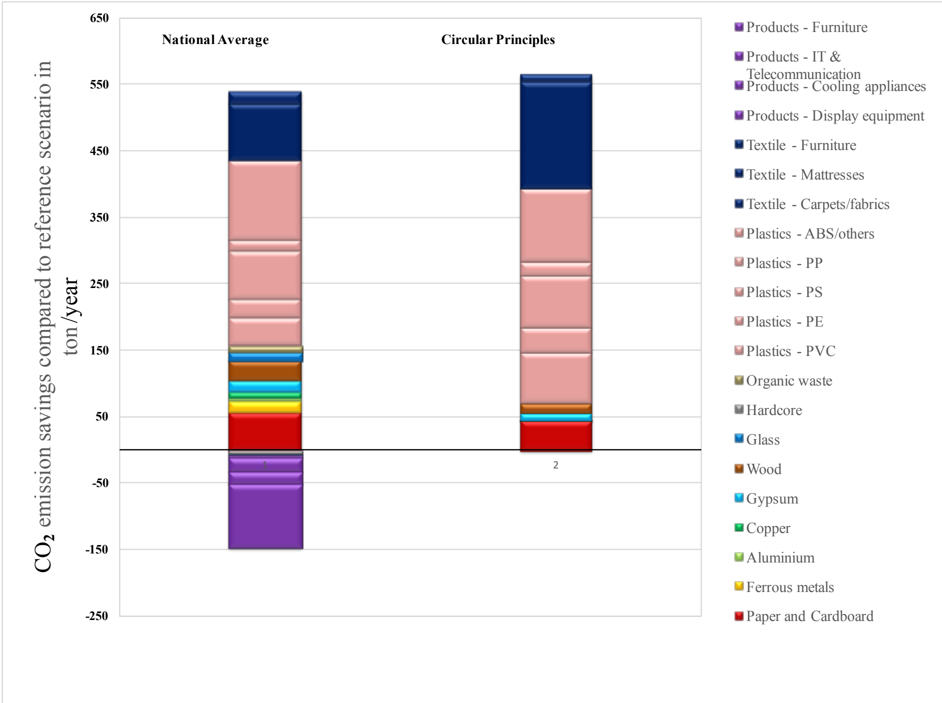

Figure S - 1: CO_2 emission reduction potential for Enviro Waste compared to National Average and Circular Principle scenarios (2015-2016)

Figure S – 1 shows that EWMS avoids in total 0.4 kton less CO_2 emissions compared to the National Average scenario, mainly due to differences in plastics and textiles treatment. However, the EWMS avoids 0.1 kton of CO_2 emission more than national average with the re-use of the product categories. The Circular Principle scenario showed that improved manual separation of paper and cardboard, plasterboard and wood, choosing different waste treatment partners for furniture and general waste, and increasing the energy recovery while diverting waste going to landfill, can result in 0.6 kton more avoided CO_2 emission compared to the reference scenario. Based on these scenarios, **Table S – 1** shows the overall treatment rates for each scenarios.

Table S - 1: Overall treatment rates per treatment process per scenario

Treatment	Enviro Waste	National Average	Circular Principles
Reuse/refurbishment	2.0%	0.3%	2.0%
High value recycling	35.4%	53.3%	40.5%
Downcycling	6.7%	7.9%	8.2%
High efficiency Biomass-to-Energy	7.4%	3.5%	7.6%
Energy recovery/cement kiln	1.9%	2.3%	7.1%
Incineration with Energy recovery	7.3%	6.9%	13.4%
Landfill	39.3%	25.7%	21.3%
	100.0%	100.0%	100.0%

Table S – 1 indicates that EWMS re-uses more products than on national level. However, Enviro Waste recycles 19.1% less, and sent 13.6% more waste to landfill. If Enviro Waste would have implemented the indicated circular principles, the recycling rate would be increased with 6.1%, the energy recovery would be increased with 11.5%, and the landfill rate would decrease with 18%.

The questionnaire among the employees showed no insurmountable barriers for the implementation of circular strategies. However, four barriers were identified as being more prominent than others, namely:

- Economic barriers: financial capabilities, waste partner costs, and return on investment;
- Legal barriers: uncertainty in legislation, and complying with legislation;
- Employee barriers: awareness, attitude and motivation, lack of time/human resources, and REC/IT perception of the company culture and Eli as director;
- Partner barriers: partner formation difficulties.

The interactive session brought the results from the scenario-based system assessment and questionnaire together, in order to develop a circular strategy for Enviro Waste that enables the creation of sustainable value, and contributes to the objectives stated by the directors. The stated objectives for Enviro Waste within five years: (1) Evolve the UK waste management industry; (2) Automated processes; (3) Environmentally friendly focussed employees; (4) Positive leadership from directors; (5) Multiple treatment facilities across the UK; (6) Multiple business units providing professional services.

Based on the interactive session outcomes, the researcher has four business recommendations. This circular strategy is integrated in the company wide strategy, showing its contribution to the overall objectives of Enviro Waste. Firstly, the objectives stated in the interactive session should be specified for Enviro Waste into measurable objectives, in order to better construct related strategies to reach these objectives within five years. Secondly, it is recommended to develop a Circular Economy/CO_2 emissions tool for customers, to contribute to the objective 1 and 3, creating sustainable value with process optimisation and legitimacy building. Thirdly, it is recommended to develop an 'Enviro Way scale' to support the choice for waste partners in the system. The scale should include criteria that partners need to meet in order to be included in the EWMS. The communication of this scale can legitimacy decision making for Enviro Waste, and foster transparency. Fourth, it is recommended to perform company-wide process analyses, in order to spot efficiency opportunities, and include the proposed circular principles from the scenario-based system assessment. This can in turn contribute to the realisation of objective 2, 5 and 6. These four recommendations can simultaneously provide value to realise general strategies identified in the interactive session, e.g. creating a financial plan, attracting investors, attracting appropriate human capital, while growing the business.

An additional remark has to be made on the circular strategy development process for waste management companies in the UK. The role of transparency from waste partners showed to be important in understanding the system performance. However, as the transparency is poor, creating sustainable value in the Circular Economy for a waste management company as ambitious as Enviro Waste showed to be difficult. This is even the case considering the implementation of 'basic' circular principles. Ultimately, the role of transparency from waste partners is impeding the efforts from Enviro Waste to move forward, and potentially other organisations in the UK waste management industry.

Summary

In the current economic system, climate change and material and product durability are considered global challenges in need of different mitigation approaches on different decision levels. As waste volumes are still increasing, and poor management of waste contributes to these global challenges, the importance of efficient, circular waste management systems is evident. Whilst system analysis is a widely used technique to assess the performance of waste management systems, no earlier attempt was identified that includes preparation for re-use as a process. Consequently, this indicates the need for an integrated circular approach to system analysis techniques. Moreover, although system analysis in waste management companies (WMCs) is mainly used for decision making on policy level, little research is performed on its contribution to strategic decision making for individual waste management companies. Therefore, this research was aimed to explore the applicability of preparation for re-use in system analysis for waste management systems, and to explore the contribution of this type of analysis to circular strategy development for individual WMCs. A practice-oriented case study was performed at a WMC operating in London, United Kingdom (UK). The scenario-based system assessment tool *i*Waste was used, as it allows for the adaption of several variables, and provides insight in the environmental performance of a system in terms of global warming potential. Consequently, this model was adapted, including the preparation for re-use process, changing the background data with UK-specific data, and constructing two relevant scenarios. The applicability of preparation for re-use in the scenario-based system assessment was evident in that it allows the comparison of specific materials with product categories, whilst it also allows the assessment of more advanced circular principles. Integrating the outcomes of the scenario-based system assessment in the overall strategy for a individual WMC was done with a strategy development process that uses scenario analysis as input. The scenario-based system assessment contributes to circular strategy development by providing actor structure insight, quantifying specific circular principles performance, legitimising choices for circular strategies, and supporting communication. However, to make informed choices, identification of barriers for the implementation of circular strategic initiatives is important to evaluate the feasibility of its success.

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1. Introduction

The release of the Brundtland report in 1987 accelerated publications in the corporate sustainability literature, feeding into a global debate on Sustainable Development (Murray et al., 2015). Sustainable Development (SD) is defined as "meeting the needs of the present, without compromising the ability of future generations to meet their own needs" (WCED, 1987; p. 43). Product and material discardment, resulting in increasing waste volumes, has gained a prominent position in this global debate, as it potentially jeopardises coming generations to access the materials to meet these needs. Resource stress and price volatility of materials are increasing as a sign of this trend already. Also, material intensity of products and product usage per capita have increased drastically since the Industrial Revolution, changing product durability and complexity, and fuelling an ever-increasing volume of waste (Lieder & Rashid, 2016; Worrell et al., 2016). In turn, these increasing volumes need to be disposed of properly in order to ensure hygiene and reduce the impact on (human) health (Watts et al., 2015; Corvellec, 2012).

In this context, the management of solid waste is seen as a necessity to create sustainable communities. However, waste management accounts for approximately 4-5% of anthropogenic greenhouse gas (GHG) emissions, finding critics of its contribution to global warming (Worrell et al., 2016). To date, materials production accounts for approximately 25% of all GHG emissions (ibid.). Valuating waste as a resource that re-enters the current economy continuously, replacing a 'take-make-use-dispose' or linear approach, positively impacts both materials availability and climate change issues, as GHG emissions are considered the main contributor to climate change (Papageorgiou, Barton & Karagiannidis, 2009; Turner et al., 2015). This revaluation of materials in an economy is referred to as circular thinking, as opposed to linear thinking (EMF, 2012; Geisdoerffer et al., 2017).

As such, there is a common agreement of the waste management industry contribution to sustainable development facing a dual challenge: waste should be treated as a resource, whilst simultaneously maximise CO_2 emission avoidance (EMF, 2012). Overcoming these challenges results in net avoided emissions as actual emissions caused by waste management processes are less compared to emissions caused by the primary production of the same material. Ultimately, this requires best practices from waste management companies operating in waste management systems.

Waste management systems can be defined as all the activities and actors involved in managing waste (Allesch & Brunner, 2014). The activities include collection, transport, separation/sorting, preparation for re-use, recycling, incineration, and/or sending to landfill. Actors can vary in both organisational sizes as well as services they provide in waste management systems. The influence of the global sustainable development debate on the dimensions of these systems is evident when reviewing developments in waste management over the past few decades. These developments have involved complex trade-offs for decision makers from different institutions among technological innovations, economic instruments, and regulatory frameworks (Pires et al., 2011). System analysis has been a commonly used tool to provide the needed interdisciplinary support for decision-making, mainly on a regulatory level (Pires et al., 2011).

Whilst a variety of publications have been devoted to the design of waste management systems, according to a review from Allesh & Bruner (2014), only 2% of the 151 studies they analysed, considered preparing for re-use in their analysis. In contrast, the essence of circular thinking relies on revaluating products to extent their durability, including the preparation of products for re-use. Moreover, in a critical review on the application of system analysis techniques in waste management systems, Pires et al. (2011) stress the importance of site-specific and process-specific system analysis applications to optimize waste management systems. On top of that, relative few studies consider the actual management of individual private waste management enterprises and their strategy development (Corvellec et al., 2012). Nonetheless, a system analysis would enable different types of actors in the system to make well informed decisions to contribute to the improvement of the performance (Xu et al., 2016).

In sum, a research gap is evident in the application of system analysis in waste management considering preparation for re-use, but also the actual usage of these analyses for individual waste management companies. From a business perspective, such analyses would only be of interest when they would create economic value. Value in social and environmental domains has shown to increase economic value for shareholders, referred to as sustainable value creation (Hart & Milstein, 2003; Porter & Kramer, 2011). Hence, waste management companies benefit from a greater understanding of the environmental performance of the system they operate in, in order to increase economic gains and simultaneously create sustainable value (Manda et al., 2016). Consequently, this research aims to addresses the research gap and simultaneously to provide practical implications for waste management companies to use system analysis for strategy development in order to create value with circular thinking, fostering the transition from a linear economy to a Circular Economy (CE).

To reach this objective, a system analysis of waste management systems is performed, considering the dual challenges of these systems. Also, the system analysis is translated into strategies for an individual waste management company. A country that can benefit from this type of research, is the United Kingdom (UK). Waste management in the UK received great attention in the past 10 years, improving waste management systems in accordance with European legislation (EEA, 2016; Nixon et al., 2013). However, in 2014, 21.3% of waste treated in the UK was still sent to landfill (DEFRA, 2016). While investments on infrastructure have been made, the importance of waste management companies to adopt circular strategies in the UK is still considered to be accurate (EEA, 2016). Correspondingly, this research aims to answer the following question*: How does system analysis contribute to circular strategy development for waste management companies in the UK in order to create sustainable value, considering global warming potential and product/material durability?*

Circular strategy development refers to the process of strategy development that can be adopted by organisations, creating sustainable value according to circular principles. In this case organisations refer to waste management companies, considering multiple business perspectives. Sustainable value creation is defined as the creation of an organisations' shareholder value and societal value with a circular thinking mind-set. Global warming issues and product/material durability is aimed to be reflected in the system analysis, identifying both the extension of material and product value, while avoiding CO_2 emissions. The latter involves all the direct and indirect GHG emissions related to the treatment routes of materials and products in waste streams, corrected with production GHG emissions when primary materials production is avoided. This type of system analysis used for an individual waste management company can be considered a novel approach, and therefore is applied in a practice-oriented case study. Moreover, this research was aimed to be exploratory, considering the novelty. Consequently, the case of Enviro Waste London Ltd[1] based in the UK (hereafter Enviro Waste) was selected for this research. Enviro Waste provides a reliable range of waste clearance services in the Greater London area for both homes and businesses, covering the commercial, domestic and construction markets.

In order to answer the main research question, this report is structured in seven sections. The next section discusses the existing literature on how waste management companies can create sustainable value with circular thinking, how CO_2 emission reduction potentials for waste management systems can be assessed with system analysis, and how these type of companies can translate CO_2 emission reduction potential into value creating circular strategies. In section 3, the operationalization of the circular strategy development pathway, defined in section 2, is explained for the case study. In section 4, the results of the case study are discussed, focussing on which products and materials in the waste streams of Enviro Waste have the most potential to avoid CO_2 emissions and maximise material/product value, what the barriers are for Enviro Waste to adopt circular strategies, and what strategies Enviro Waste should adopt in order to utilize the identified opportunities. In section 5, the results are discussed, and circular strategy development with system analysis are reflected on. As a result of the case study, a circular strategy for the business is proposed in section 6. Finally, section 7 provides an answer to the main research question.

[1] http://www.envirowaste.co.uk/

2. Value Creation for Waste Management Companies

First, the concept of sustainable development in relation to waste management companies is discussed. Second, the notion of scenario-based system assessment as a system analysis technique is introduced, showing its use for CO_2 emission reduction potential identifications. Third, the circular economy (CE) as concept is discussed and its meaning for the structure of current waste management systems. Lastly, strategy development as a process for waste management companies is discussed, bringing together the previous sections to derive a stepwise plan for the use of system analysis for circular strategy development in order to create sustainable value with circular thinking.

2.1 Sustainable development for waste management companies

In order to represent sustainable development in businesses, the notion of sustainable or shared value is introduced, tackling global issues by including environmental and social value dimensions alongside economic value creation dimensions (Hart & Milstein, 2003; Porter & Kramer, 2011). Manda et al., (2016) defines sustainable value creation for organisations as "the identification of strategies and practices that contribute to a more sustainable world by viewing global challenges associated with sustainability through an appropriate set of business perspectives, and the utilization of these strategies and practises to drive shareholder value*"*. The relevance of sustainability aspects differs per company, depending on the product systems, geographical scope, and the related social and environmental challenges and drivers involved. Consequently, the sustainability integration in businesses is inherently diverse and complex. In order to ease sustainability integration for businesses, the United Nations presented 17 goals to end poverty, protect the planet and ensure prosperity for all (United Nations, 2017). Based on these goals, global challenges and expected contributions can be defined for specific industries. In the context of resource management, waste management has an important role to fulfil specific goals. Successfully working towards material efficiency contribute directly to goal 12 and 13, and indirectly to goal 6, 11, 14, 15 and 16, see **Figure 1** (UN, 2017).

Figure 1: United Nations Sustainable Development goals relevant for the waste management industry (UN, 2017)

Targets related to the sustainable consumption and production (goal 12) include minimizing waste generation through prevention, reduction, recycling and re-use. Retaining value from resources, in turn, reduces the need for materials production, an industry that requires a large amount of energy, and is a significant source for GHG emissions. As aforementioned, this industry accounts for approximately 25% of all anthropogenic CO_2 emissions (Worrell et al., 2016). Efficient waste management can therefore have a significant effect on the magnitude of CO_2 emissions caused by materials production, resulting in the contribution to goal 13, being climate action.

The global challenges are increasingly reflected in regulatory frameworks for waste management, leading to the implementation of various mechanisms in order to minimize CO_2 emissions and resource drainage (Chaabane et al., 2012). These types of targets are set on international and national level, and sometimes even on regional and sectorial level. The European Union (EU), is committed to reducing GHG emissions by 20% in 2020 and 40% by 2030 in comparison to 1990 (Turner et al., 2015). Member states are developing their own ambitious GHG reduction targets based on these guidelines. Moreover, the waste management sector also has targets related to treatment of waste. The European Commission's approach to waste management is based on the 'waste hierarchy', setting the priority at prevention, (preparing for) re-use, recycling, recovery and, as the least preferred option, disposal (including landfilling and incineration without energy recovery) when shaping waste policy and managing waste at the operational level, see **Figure 2**.

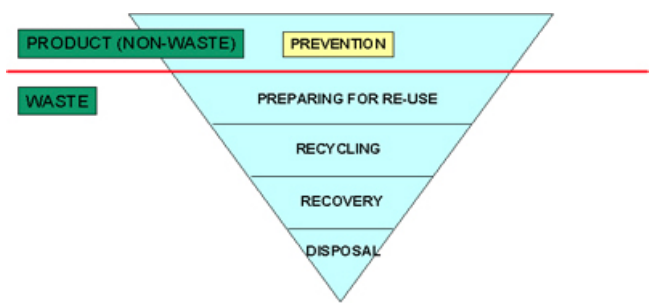

Figure 2: Waste hierarchy (EC, 2016a)

Differences in approaches to comply with these regulatory frameworks have resulted in a great variance of performance among countries in Europe (e.g. Nixon et al., 2013). As a result, different countries are in need of different approaches of waste management companies to fulfil their fundamental and dual role in achieving the sustainable development goals set by the UN. Understanding the national performance and regulatory framework on waste management is therefore important to be reflected in a system analysis, as it enables to link the operation environment with business opportunities.

2.2 Scenario-based system assessment

To identify business opportunities for waste management companies that are both beneficial for the environment and the business, a variety of system analysis techniques can be used (Allesch & Brunner, 2014, Pires et al., 2011). System analysis have shown to be useful for decision-making on several management levels in waste management systems (De la Barrera & Hooda, 2016). More specifically, system assessment tools allow for the evaluation of the performance of a system in order for decision makers to consider how improvements can be made, and these tools can enhance system engineering efforts. Allesch & Brunner (2014) performed a review on assessments methods for solid waste management and stressed three criteria to identify the appropriate evaluation method; goal setting is most important when choosing an assessment method; waste management should be seen from an input-output perspective, not only from an output perspective; and making use of the mass balance principle is key. Reflecting on these criteria, the objective of the assessment in this research is identifying CO_2 reduction potentials in waste management systems. Pires et al. (2011) discusses different system assessment tools applied to solid waste management systems in European countries, and provides an overview of the different techniques. Combining system assessment techniques is not uncommon, fitting into the objective of the assessment (Allesch & Brunner, 2014). Considering the criteria, a combination of life cycle assessment (LCA), material flow analysis (MFA), and scenario development are appropriate to fulfil the objective. The life cycle assessment part can provide insight in the environmental performance of the system, while the material flow analysis differentiate between the input-output of the system. Additionally, scenario development has the ability to explore decisions related to circular thinking. Moreover, scenario-based system assessment is consistently reported as a useful tool for executives to support strategic business development (O'Brien and Meadows, 2013).

A tool covering all three of these techniques is the *i*Waste model, as it is a partial LCA and MFA of a variety of waste streams and its related processes, starting at the generation of waste until the primary production of the same material considered in the waste stream (Corsten et al., 2012; Corsten et al., 2013). This approach allows for different treatment processes of waste streams to be assessed, showing the benefits of different scenarios with CO_2 emission reduction and material durability decisions. Consequently, the treatment processes for specific waste streams can be challenged, which makes it possible to view the potential positive impact on sustainable value creation of circular thinking for waste management companies. Although up until now the model has only been used on national level, it can be adapted for regional systems as well.

Focussing on the LCA part of the assessment, CO_2 emission reduction potentials in waste management systems are considered in this model, as climate action is mainly focussed on minimizing the global warming potential (GWP) through adaptation or mitigation related to GHG emissions. Yet, in the past decades, several (complementary) sets of environmental indicators were developed, assessing different environmental impact categories, including deforestation, acidification, among others (Fang et al., 2014). Accounting solely for energy and GWP can therefore argued to be an insufficient set of indicators to reflect the environmental impact of processes in waste management. In response, Huijbregts et al., (2006) researched the usefulness of cumulative energy demand and GWP as predictor for the environmental impact of products and processes in life cycle based assessments. Huijbregts et al., (2006) were able to suggest that these indicators together provide sufficient indication for several environmental problems. Moreover, including other environmental impact categories only increases the complexity of the system analyses, risking higher uncertainties in the outcomes (ibid.).

Furthermore, conducting environmental system assessments on waste management systems with energy and GWP indicators have shown to be useful in literature, since changing waste management systems can have significant CO_2 emission reduction potentials (Corsten et al., 2013). For example, in the Netherlands, 45% more CO_2 emissions could be avoided, in addition to the overall avoided CO_2 emissions due to waste managamenent, if recycling rates for specific streams would be increased (ibid.).

2.3 Circular strategies for waste management systems

Although varied definitions are given to the CE, it is generally described as a cyclical, closed-loop economic system, as opposed to the linear 'take-make-use-dispose'-economy (Murray et al., 2015; Geissdoerfer et al., 2016). As **Figure 3** illustrates, the CE differentiates between two cycles. First, biological cycles restore non-toxic materials into the biosphere while rebuilding natural capital, after cascading into different applications (EMF and Granta Design, 2015).

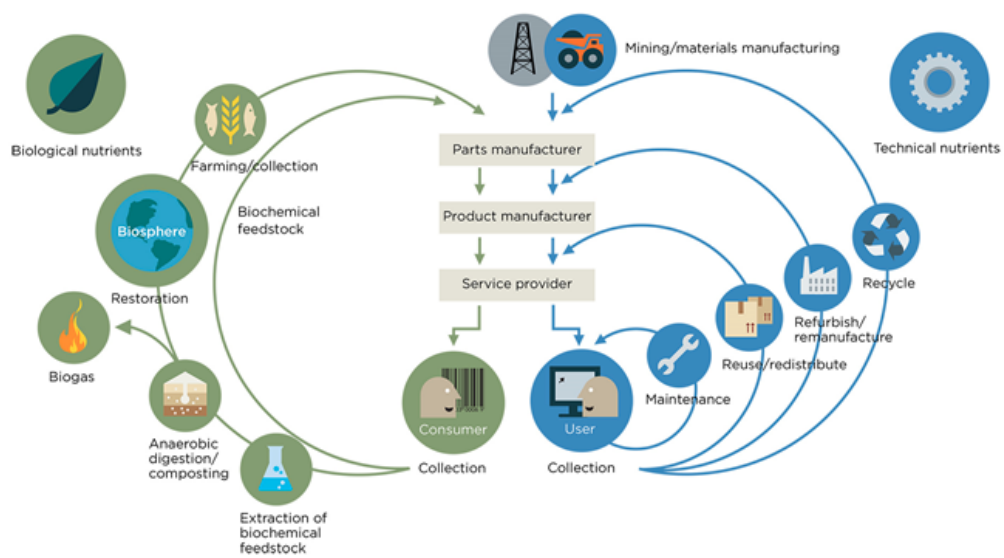

Figure 3: A visual representation of the Circular Economy where materials keep rotating in the economy for as long as possible with the highest possible value (EMF, 2012)

Second, technical cycles restore products, components and materials into the market at the highest possible quality for as long as possible, through maintenance, re-use, refurbishment and recycling (ibid.). Business across all industries can create value in this economy based on the four essential circular principles for value creation (EMF, 2012, p. 30). The *power of the inner circle* refers to the 'treatment' preference of products and materials at its 'end-of-life'. The smallest loop in **Figure 3** (maintenance/repair) has the least impact in material use, labour, energy and externalities; the outer loops have increasingly higher impact (EMF, 2012; Govindan and Soleimani, 2016). This is in line with the waste hierarchy that is into effect in Europe (EC, 2016a). The essence of this value creation principle is that fostering the inner circles presents an opportunity for businesses. The *power of circling longer* refers to keeping products and materials as long as possible, and continuously in the economy. It has been found that, especially for innovation sensitive technologies (e.g. mobile phones), it is an ever-growing challenge to retain value. The *power of cascaded use* across industries refers to the re-use of cascaded materials as a substitute for virgin materials. The last value creation principle is the *power of pure inputs and designs*, in which products should be designed for ease of separation, but also have to be handled with care at the end-of-life to ensure the highest value for as long as possible. The relevance of these value creation principles, however, depends significantly on factors like product and materials that are considered, but also on the (geographical) role of an organisation in a (global) supply chain. The circular principles and related strategies for waste management companies can be seen in **Table 1**.

Table 1: Circular principles translated to opportunities for waste management companies

Circular principles	**Circular strategies for waste management companies**
Power of inner circles	Stimulate refurbishment/re-use Stimulate recycling Divert waste from landfill
Power of circling longer	Educating customers for waste prevention
Power of cascaded use	More disassembly of products Different destinations/usages materials or products
Power of pure inputs	Improve separations (in every process of the system)

From the perspective of waste management companies, their old-fashioned business model of creating shareholder value (e.g. collection, incineration and/or landfill), is challenged in the CE. Although these processes require less energy than for example recycling, the net CO_2 emissions avoided is significantly less. Waste management companies are therefore forced to think differently about their services. Offering innovative services related to redistributing and preparing products and materials for re-use, but also increasing recycling rates in order to avoid materials 'leaving' the economy, offers value creation opportunities for these types of companies.

2.4 Common barriers for circular strategy implementation

Although the circular principles show opportunities for waste management systems to create value in the CE, the actual implementation of these principles in a business context is considered to be a challenging task. To date, in various fields, identifying barriers for the implementation of this type of principles in a business context received increased attention. Shahbazi et al. (2016) conducted research on generic business barriers when material efficiency strategies are implemented in a business context. Generic barriers can be defined in roughly six categories, being technical, economic, organisational, legal, informational and social barriers (Shahbazi et al., 2016). For example, organisational barriers include managers' lack of support for the strategy, or lack of employee motivation to execute it. Identifying the main barriers for businesses enables informed decision making in circular strategies to reach specific company objectives, and deepens the understanding on barriers they are facing in a structured manner (ibid). These barriers impact the feasibility and success rate for the circular strategic initiatives, and in turn, its sustainable value creation.

2.5 Circular strategy development process

Bringing together the perspectives of the section 2.1 to 2.4, the process of circular strategy development for waste management companies using scenario-based system assessment closely fits the process described by O'Brien and Meadows (2013), emphasizing the importance of linking scenario preparation and development with strategy development. In the literature review of O'Brien and Meadows (2013), the support of scenario analysis for strategy development typically consist of three phases, being scenario preparation, scenario development and scenario use. In **Figure 4**, a visual representation of this process is shown, specified for this research in terms of terminology and steps considered, leading towards sustainable value creation.

For the *scenario preparation phase*, the scenario-based system assessment has an LCA and MFA approach, both requiring approaches requiring background information of processes in the system for its use. The novel approach of preparation of re-use as a process in waste management systems is included here.

For the *scenario development phase*, several scenarios are developed in order to spot possible improvements in the system, leading to increased material utilization and CO_2 emission avoidance. As discussed, national performance on waste management can provide guidance to link business responsibility with business opportunity. Additionally, one scenario has to include the adoption of (multiple) circular principles by an individual waste management company.

For the *Circular strategy development phase,* the identified opportunities can be translated to circular strategy initiatives. O'Brien and Meadows (2013), distinguish between three critical phases within this phase. The *orientation phase* is used to familiarise the users of the scenarios with the background and the outcome of the scenario assessment. The users of the scenario analysis are frequently directors or managers determining the course of a company. The *implications phase* aims to discover the scenario implications for the business in order to generate strategic options. These implications can take the form of barriers, as discussed in section 2.4. The identification of these barriers for the implementation of specific circular strategies considered in the scenarios is a useful step for informed decision making for circular strategies. The final phase is *proposing strategic initiatives.* Essentially is this the process of generating circular strategic options for the organisation considering an appropriate set of business dimensions. Hart & Milstein (2003) discussed two important business perspectives to consider when strategies are developed: time and capabilities. The time dimension refers to the firm's need to manage today's business, while keeping in mind the dynamics of the markets and their future positions in this market. The capabilities dimension refers to the firm's need to grow and protect internal organizational skills and capabilities, while simultaneously creating new insights and perspectives from external sources (Hart & Milstein, 2003). While *strategy implementation and the evaluation* is essential to utilize the circular strategy, this research is focussed on the strategy development, excluding the analysis of strategy implementation and evaluation.

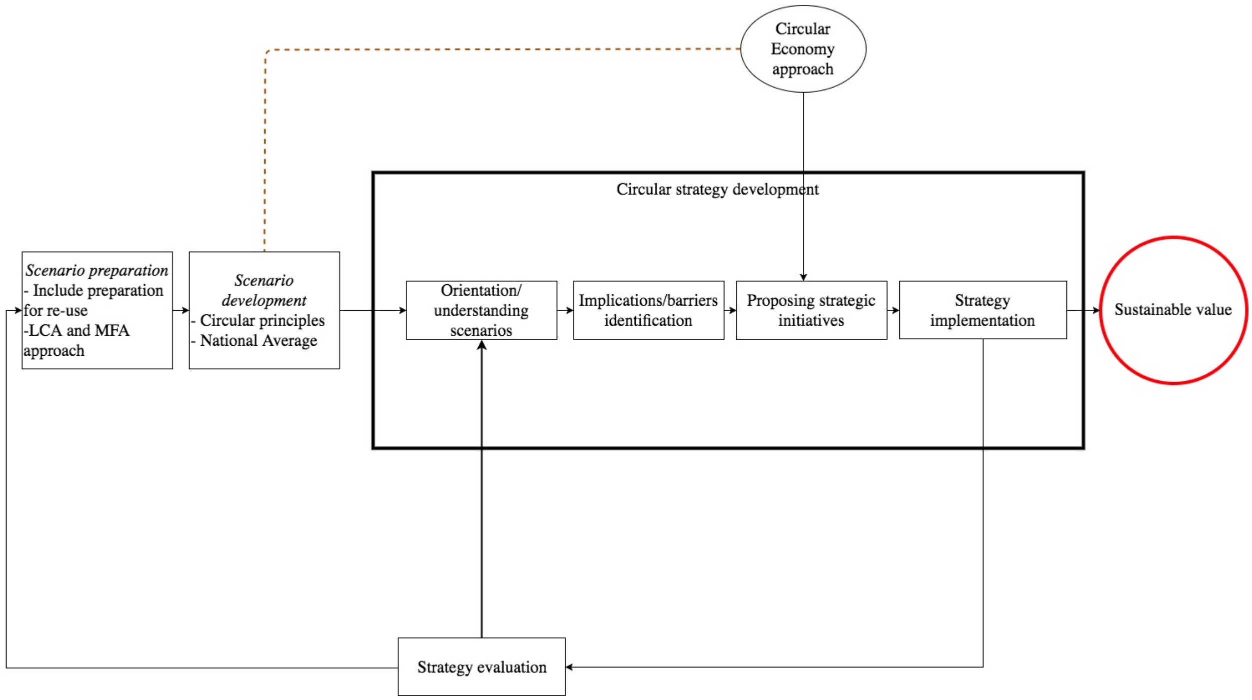

Figure 4: A visual representation of the strategy development process for waste management companies operating in the UK, with scenario analysis as input for strategy development.

3. Case Study: Enviro Waste London Ltd.

A scenario-based system assessment from the perspective of a waste management company was performed in a practice-oriented case study, as Yin (2003) suggests when the phenomenon under research cannot be seen separately from its context. This research was aimed to be exploratory, meaning "to seek what is happening; to seek new insights; to ask questions and to assess phenomena in new light" (Saunders et al., 2003). More specifically, insights were sought in the applicability of material and product durability considerations within the context of scenario-based system assessment, and in the contribution of scenario-based system assessment in the context of circular strategy development. To reach the objective of the research, a mixed-method approach was used, which is defined as "the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches for the broad purpose of breadth and depth of understanding and corroboration" (Johnson et al., 2007). Three distinctive research methods were used and discussed in this section. First, the validity of the case sample is described, followed by the methods used in each of the scenario preparation, scenario development and strategy development phase.

3.1 Case description - Validity

Waste management companies that have focussed their main activities on supporting the linear economy system, are now in need to consider circular strategy opportunities is order to survive the circular focussed transition of the industry. Therefore, in this case study, in-depth knowledge on the strategic logic of waste management companies in the UK was obtained, which in turn can be essential knowledge for decision makers on national level. The case company Enviro Waste was set up in 2011 and thus can be regarded as a start-up, with 51 employees. With their fleet of seven vans, ranging from 3.5 ton to 7.5 ton, they provide wait and load waste clearance services within the area of Greater London. Each vehicle does around 4 to 5 jobs a day, depending on factors, e.g. the type of job, the distance etc. Although Enviro Waste is a minor player in the UK waste management industry (202 mln ton waste treated versus 3 kton waste treated by Enviro Waste), it is important to emphasize that individual strategies can catalyse systematic change (Almeida et al., 2015). Services Enviro Waste fulfils in the waste management system are the collection of waste, manual sorting of the waste, and preparation for re-use of the waste. The data available from Enviro Waste needed interpretation to make them useable for this research. The data files explanation and assumptions made for this purpose can be found in **Appendix A**.

3.2 Scenario preparation

In this research, a clear distinction was made between scenario preparation and development, as the approach for the system analysis was LCA- and MFA- based. Both approaches require background information in order to calculate the magnitude of CO_2 emission reduction potentials for the Enviro Waste management system (EWMS). Hence, first the reference scenario and related background information were prepared. The *i*Waste model of Corsten et al. (2013) is built in Excel and allows for the calculation of energy consumption and CO_2 emissions for a waste management system. This model considers specific waste streams and its related materials, and all the activities involved in the system. In order to construct the reference scenario, observation of the company's operations and informal interviews took place with employees from Enviro Waste. This also involved contacting partners of Enviro Waste who are responsible for other services provided in the EWMS.

3.2.1 System boundaries for LCA calculations

The model of Corsten et al. (2013) builds on the partial life cycle of materials, and in this research also the partial life cycle of products, starting at waste generation and ending at the stage of production of secondary material or product that is comparable with a primary material/product or its function. Enviro Waste distinguishes three types of waste based on their generation site: municipal solid domestic waste, municipal solid commercial waste, and construction waste. In **Figure 5,** a visualisation of the system boundary of this research is shown. All the main activities of a waste management system were considered, including collection, sorting/separation, transport, preparation for re-use, recycling, energy recovery and/or landfilling. As aforementioned, the model focuses solely on energy consumption and CO_2 emissions. The *functional unit* is the treatment of one ton of wet material or product collected and sent for treatment as waste. The next section will go into more depth about the treatment routes for the waste streams of Enviro Waste.

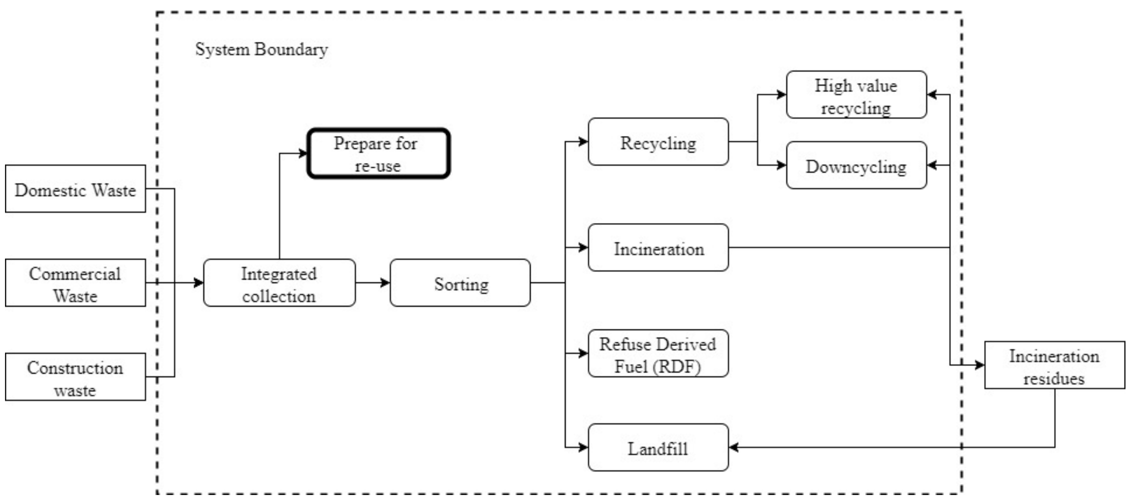

Figure 5: System boundary and treatment routes of the waste streams collected by Enviro Waste

The scenarios are based on the waste collected by Enviro Waste from December 2015 to November 2016, as this period covers their financial year. The preparation for re-use is a new process considered in the *i*Waste model, and therefore also products are assessed. In **Table 2** and **Table 3,** the 15 materials and 4 product categories that cover most of these waste generation sources are shown. The choices for the product categories were based on the data from REC Products, which is a subsidiary of Enviro Waste. Most of the products prepared for re-use could be classified as 'Waste of Electrical and Electronic Equipments' (WEEE) or furniture. Data on the treatment rates of the products from **Table 3** were available, and are therefore considered in this analysis. All these products were considered to be reusable, and all the materials were considered to be useable as secondary material, or for energy recovery.

Table 2: Main materials representing the composition of all three waste generation sources

General	Metals	Plastics
Paper & Cardboard Gypsum Wood Hardcore waste Glass Textile *From carpets & fabrics* *From mattresses* *From furniture*	Ferrous metals Aluminium Copper	Polyvinyl Chloride (PVC) Polyethylene (PE) Polystyrene (PS) Polypropylene (PP) ABS/other plastics

Table 3: Main products representing the composition of all three waste generation sources

WEEE	Other
Cooling appliances Display equipment IT & Telecommunication	Furniture

3.2.2 Waste treatment processes

The collected waste by Enviro Waste went through several stages, as already shown in **Figure 5**. The general stages are described below. For more detail on the treatment for each specific stream discussed in **Table 2** and **Table 3**, see **Appendix B**.

At Enviro Waste, the collected waste is tipped in the *manual separation* yard, in which reusable products, metals, wood, bulky items, hazardous items and general waste are separated. *Mechanical separation* is usually applied for paper, plastic and metal (Corsten et al., 2013), however, this is service is not provided by Enviro Waste. *Preparation for re-use* is a new treatment process considered in the *i*Waste model, taking into account the re-use of products to be introduced in the market as a whole again. The previously mentioned subsidiary of Enviro Waste named REC Products sells prepared items on eBay to be re-used. When the products were regarded not suitable, its disposal was considered as well in the analysis. Therefore, assumptions were made on the composition and its treatment process in recycling, incineration and/or landfill. *Recycling* is defined as materials extracted from waste streams being used as resource for the production of new goods with similar function, excluding electricity production in this definition (Corsten et al., 2013). Two kinds of recycling were considered. First, *high quality recycling* refers to the recycling of materials that can replace primary resources. However, for some of the materials, the quality will not be the same as the primary material after recycling. This is referred to as *down cycling*. **Appendix C** provides an overview of the considered replaced materials in each of these processes, and additionally the replaced products considered for the products stream.

The uptake of *Energy from Waste (EfW)* has increased rapidly in the past few years (Nixon et al., 2013). Energy recovery takes up a variety of forms. Waste with high caloric content can be used as secondary fuel, also referred to as Refused Derived Fuel (RDF), in for example cement kilns, electricity generation facilities, or special biomass plants (Corsten et al., 2013). From this perspective, waste can replace fossil fuels in the generation of electricity and heat.

However, also lower calorific waste is used in specially designed *waste incinerators* in order to produce electricity and heat. After incineration of this general waste type, metals are extracted from the bottom ash, and consequently can be recycled as well (Corsten et al., 2013; Cory Environmental, 2014).

When re-use, recycling or energy recovery are no option for the collect waste, either due to capacity shortage, high contamination rates, or economic incentives, the final treatment option for waste is disposing it in *landfill* sites. In some landfill sites, methane capture installation extract methane from the waste in order to produce electricity and heat. In that case, landfills can also be assumed to be an energy recovery operation. The Landfill Allowance Trading Scheme (LATS) requires landfill sites to have advanced methane capture technologies in place (Frank et al., 2016). Therefore, it is assumed that the waste from Enviro Waste ending up in landfill will be used to generate electricity and heat.

3.2.3 Energy carriers for the UK

The energy consumption of the processes in the EWMS can be either from the energy carrier electricity, heat or a fuel type, e.g. diesel. In order to calculate the amount of the energy required and related CO_2 emitted for these processes, data were collected from e.g. the International Energy Agency (IEA) (2008), the European Commission (2016b) and other national and international statistics providers. For electricity and heat, the UK fuel mix and its related conversion efficiency were used. In order to calculate the total amount of electricity needed, the conversion from primary energy to consumed electricity and heat needed to be considered as well. Therefore, the Well-to-Tank energy was also considered. The most accurate data was available for 2015, in which the energy needed to generate 332.9 TWh equalled 802 TWh (DECC, 2016, p. 116). The electricity consumption of one kWhelec therefore requires 2.4 kWh of primary energy. See **Table 4** with an overview of the energy carriers used in this research.

Table 4: Information on energy and CO_2 emission factors for electricity, heat and steam

National data	Value	Representing year	Source
Electricity - Primary Energy	2.4 kWhprim/kWhelec	2015	DECC (2016)
Electricity - Emission Factor	0.45 $kgCO_2$/ kWhelec	2016	DECC & DEFRA (2016)
Steam/Heat - Primary Energy	1.06 GJprim/GJ	2016	DECC & DEFRA (2016)
Steam/Heat - Emission Factor	59.7 $kgCO_2$/GJ	2016	DECC & DEFRA (2016)

The conversion efficiencies for incinerators and cement kilns are assumed to be the same for the UK as for the Netherlands. UK-specific data on the conversion efficiency of biomass-to-energy plants was used for high-calorific wood waste, being 28.3% (AEBIOM, 2015). Energy consumption due to transport is dependend on the type of transport, the weight of the load, speed and distance (RIVM & Novem, 1992). A widely used unit for transport energy consumption is therefore MJ/ton.km. In all three scenarios, the energy consumption for collection of construction and demolition waste was used, being 1.5 MJ/ton.km for smaller transport distances with skip vehicles and Enviro Waste trucks, and 0.65 MJ/ton.km for long distances with large volume and weight transport (RIVM & Novem, 1992).

The avoided energy consumption and CO_2 emissions can be calculated using the 'Gross Energy Requirement (GER)' value for materials and products (Worrell et al., 1994). This value represents the energy content of a material or end product, considering all the technologies and circumstances that involve the production (ibid.). The GER of materials was derived from the data provided by Worrell et al. (1994). Ultimately, as this research also takes into consideration product recovery, scientific literature sources were used to provide data for the GER of products. For further details on the assumptions made for the products, see **Appendix B.**

In sum, the production of basic resources, semi-finished products and fully finished products are considered. The basic assumption made in this research is that re-used and/or recycled materials *replace* primary products or materials (Corsten et al., 2013). With these processes, energy consumption and related CO_2 emissions are avoided that would otherwise be consumed and produced for the production of the replaced primary product or material. The avoided energy and CO_2 emissions are allocated to how the material/product was treated. Only one life cycle is considered. The only exception in this allocation method is with the recovery of energy from waste, where it is argued that the production of electricity in a conventional electricity centre is avoided.

3.3 Scenario development

The treatment processes performed in the EWMS were used to calculate the CO_2 emissions and energy consumption per material/products stream. Two scenarios were considered in order to identify reduction potentials for Enviro Waste, referred to as the *National Average* and *Circular Principles* scenarios. The data sources used per stream for the 15 materials and 4 products are shown in **Appendix D**, and the treatment rates considered for each stream for all three scenarios are shown in **Appendix E**.

3.3.1 Scenario - National Average

For comparison reasons, the status quo of Enviro Waste was compared with the national average treatment of the same materials and products. In this scenario, it is assumed that the same amount of waste with the same composition was collected, but that every stream was treated as if all the waste management systems operating on national level would perform as a collective. To illustrate, if 'x' amount of wood was collected by Enviro Waste, b % was recycled, c % used for energy recovery and d % went to landfill. For the same amount 'x' wood, the treatment rates on national level in the same year were considered, in which e % was recycled, f % was used for energy recovery and g % went to landfill. This approach was used for the materials, but also for the product groups. According to these treatment rates, the CO_2 emission avoidance was calculated. This type of secondary data was collected from scientific literature and documentation provided by national reporting sources, e.g. the Waste and Resource Action Plan (WRAP), an organisation that provides national documentation on waste management systems, and the Department for Environment, Food and Rural Affairs (DEFRA), a ministerial department from the UK which has also done extensive research on the national waste management systems.

3.3.2 Scenario - Circular Principles

This scenario introduced several circular principle practices that have the possibility to be implemented by Enviro Waste. This scenario was developed after the National Average scenario was finished. The circular principles included in this scenario were based on **Table 5**.

Table 5: Circular principles related to opportunities for waste management companies considered in the Circular Principles scenario

Circular principles	Opportunities for waste management companies	Used in the Circular Principles scenario
Power of inner circles	Stimulate refurbishment/re-use	-
	Stimulate recycling	Sending general waste to separator to increase recycling rates
	Divert waste from landfill	Sending more waste for RDF or incineration
Power of circling longer	Educating customers for waste prevention	-
Cascaded use	More disassembly of products	Possibility to disassemble furniture
	Different destinations/usages materials or products	-
Pure inputs	Improve separations (in every process of the system)	Improve separation at the yard

With the development of this scenario, assumptions were made that are representable for a real life scenario. The circular principles not considered in this scenario were discussed in the scenario assessment use phase, as they involve customer behaviour changes or increased focus on the collection of specific products or materials, and were therefore not related to changes in the process of waste treatment.

3.4 Circular strategy development process

In this phase, the scenario-based system assessment was considered in a wider context, being the circular strategy development process for Enviro Waste. When companies wish to accomplish environmental, social and economic responsibility, a well-defined corporate (circular) strategy is needed (Engert & Baumgartner, 2016). However, there is not a one-single-fit strategy, as circumstances vary considerably, depending on factors such as sector, products, stakeholders, policies, and internal processes, among others, which poses a relatively challenging task for companies (ibid.). Consequently, implementing circular principles related to CO_2 emission reduction potentials within Enviro Waste have the possibility to face significant barriers in order to succeed. Hence, in this phase, two research methods were used to assess the feasibility of the identified reduction improvements from the scenario-based system assessment. Referring to the circular strategy development pathway discussed in section 2, these phases consists of scenario orientation for users, followed by the assessment of the implications of the scenarios with a questionnaire among employees, and the development of circular strategic initiatives in an interactive session/group interview with the directors of the company.

3.4.1 Orientation phase

The orientation phase is a phase which is meant to to familiarise the users of the scenarios-based system assessment outcomes, to enable them to make informed decisions. The decision makers in strategy for Enviro Waste are the directors, as they determine the vision and strategy of the company, but also the employees, executing the possible changes in strategy that might impact their day-to-day work. Therefore, two different approached were used to familiarise these two target groups: a questionnaire stating possible circular principles to be implemented by Enviro Waste for the employees (see **Appendix F**), and an infographic providing insights in the scenario-based system assessment as input for the group interview with the directors (**Appendix G**). As the target groups required different insights from the scenarios, different approaches were chosen to display the outcomes from the scenario-based system assessment. Both familiarisation approaches were immediately followed up by the next phase, being the assessment of the implications of scenarios.

3.4.2 Implications phase- Questionnaire

The main objective of this questionnaire was to explore the opinion from employees on circular principles barriers and if there is a different perception in different departments, being the office, REC/IT and operations, as these departments operate in different locations. The barriers were grouped in six categories: technological barriers; economic barriers; organisational barriers; legal barriers; informational barriers; and social barriers (Shahbazi et al., 2016).

This research approach was chosen, as many of the staff are poor in English, which hinders the communication in interviews. Moreover, due to time and money restrains, it was not possible to have a translator assisting the researcher in interviews. The questionnaire was sent out to the employees for the first time on the 19th of July 2017 and closed on the 22th of August 2017. The layout of the questionnaire can be found in **Appendix F.** The entire population was aimed to contribute to the questionnaire (census), as otherwise a single extreme case can have a skewing influence on the overall (statistical) sample (Henry, 2009; p. 214). The following criteria had to be met by the employees to allow them to participate in the questionnaire: working for longer than one month at Enviro Waste; not on maternity leave for more than one month; directly involved in the waste management processes performed by Enviro Waste (excluding cleaners). Almost the entire population, 42 out of 43 employees, filled in the questionnaire. However, two questionnaires were excluded as they showed to be falsely filled in (multiple answers were given while one answer was required). The overall response rate was therefore 93%.

In order to avoid the risk of uninformed response due to socially desirable answers, the researcher made clear that it was anonymous and stressed the importance of answering as honest as possible. The analysis of the questionnaire was conducted with SPSS, where six variables were computed, according to the barrier categories. The reliability of the questions in each computed variable was analysed with Cronbach's alpha (Fielding, 2009). In order to analyse if the difference between the departments was significant, the one-way ANOVA was used, as it allows the comparison of the means among three or more groups (Fielding, 2009). Values less than 0.05 in this analysis indicated a significant difference between the opinions of the groups (Fielding, 2009). The next step was comparing the barrier categories among the three departments, but also comparing the environmental focus and awareness of the employees per department (first three questions). From the outcomes of the questionnaire, the employees' opinion on the biggest barriers for Enviro Waste were identified. The outcomes of this analysis was used in the interactive session.

3.4.3 Developing strategic options – Interactive session

The aim of the interactive session was developing a circular strategic initiative portfolio, considering time and capability dimensions, and sustainable value creation linked to the initiatives. The interactive session started with an explanation on the infographic, to make the users familiar with the outcomes of the scenario-based system assessment (Shahbazi et al., 2016). Back casting was used to determine the (long-term) objectives of the company. The three directors and the business operations manager were asked to write down their answers on post-it to the following questions: How do you see Enviro Waste in three to five years if there were no barriers?; What are the biggest barriers for Enviro Waste to reach these objectives within five years? The post-its were used to ensure everyone's full participation. After they were given the time to answer these questions on post-its, they were asked to pitch to each other. After the pitches, the researcher categorised the barriers in the six barrier clusters that were also considered in the questionnaire. The identified barriers by the employees and the directors were compared, in order to spot any discrepancies. This was done using a second infographic, covering the results from the employee questionnaire.

As the barriers where identified and the goals and objectives were made clear for Enviro Waste within five years, the following question was asked: What are possible circular strategic initiatives to overcome the barriers and reach the long-term goals for Enviro Waste, considering time and capabilities dimensions? The outcomes of the interactive was used to construct an integrated circular strategy for Enviro Waste, which supports the objectives for Enviro Waste within five years, and considering the main identified barriers.

3.5 Reliability

To assure reliability of the research, triangulation of data collection was needed to eliminate chance (Jick, 1979; Verschuren & Doorewaard, 2010). As aforementioned, the use of a mixed-method approach allows for qualitative and quantitative methods to complement each other, and providing data from different sources (Jick, 1979). Empirical data collection was triangulated with a questionnaire, a group interview in the form of an interactive session, and observations. The different sources considered were primary data from Enviro Waste, secondary data from (national) statistics and scientific literature, the questionnaire responses and the interactive session.

Regarding the scenario-based system assessment, it is not uncommon to make assumptions and use data that might influence the outcomes significantly (Turner et al., 2015). Ultimately, the scenario assessment is meant to be exploratory, meaning that performing the assessment should give new insights for further research in this field. This also means that caution is needed with hard statements and generalisation of results and conclusions. Hence, to increase the reliability of the assessment, all the assumptions made and argumentation used are discussed to make the assessment as transparent as possible.

To ensure reliability of the questionnaire, standard statistical methods were used. In this case, Cronbach's alpha was needed to analyse the internal correlation between the questions within the categories (Saunders, 2003, p. 374). An additional reliability check was used in the form of a check question. The question 27 was included to assess if the answers to questions 4 to 26 represented the same outcome as in question 27. Additional reliability tests were performed when needed. Lastly, to ensure the reliability of the interactive session, it was recorded to enable back checking in the analysis phase.

4. Results

In section 4.1, the results from the reference scenario will be discussed. Hereafter, the analysis of the National Average and Circular Principles scenarios are discussed in section 4.2. In section 4.3, the analysis of the questionnaire is discussed and the identified barriers for Enviro Waste to adopt circular principles are discussed. The combination of the findings from these sections was used for the interactive session. The result of this session are discussed in section 4.4.

4.1 Reference scenario

In **Figure 6**, the overall composition of the waste collected by Enviro Waste and handled by the Enviro Waste Management System (EWMS) from November 2015 until December 2016 is shown. In total, 3.1 kton of waste was collected, of which 10.4% was not considered in the analysis, referred to as 'Other'.

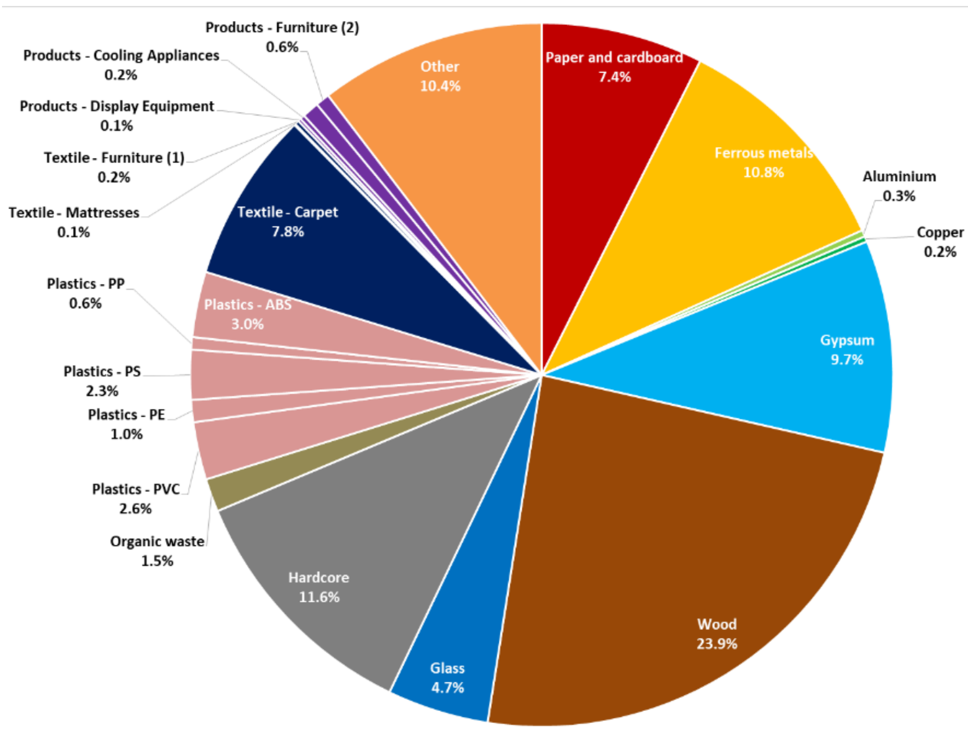

Figure 6: Overall composition waste collected and handled by the Enviro Waste Management system between November 2015 and December 2016

In **Table 5**, the avoided energy consumption and CO_2 emissions are shown per stream, and in **Figure 7**, the relative contribution per stream to the total avoided energy and CO_2 emissions are shown in percentages.

Table 6: Avoided and consumed energy and CO2 emissions per stream for the Enviro Waste management system in 2015-2016

	Energy (GJ primary)	CO_2 emissions (ton)
Paper and Cardboard	-2361	-105
Ferrous metals	-5954	-590
Aluminium	-1588	-91
Copper	-607	-38
Gypsum	-377	-27
Wood	-7107	-338
Glass	20	1
Hardcore	4	-49
Organic waste	-83	23
PVC	-47	-3
PE	4	0
PS	9	1
PP	2	-3
ABS	-135	-8
Carpets/fabrics	-676	-40
Mattresses	-12	-2
Furniture (1)	-12	2
Display equipment	-262	-4
Cooling appliances	-466	-24
IT & Telecommunication	-337	-21
Furniture (2)	-668	-138
TOTAL	**-20652**	**-1455**

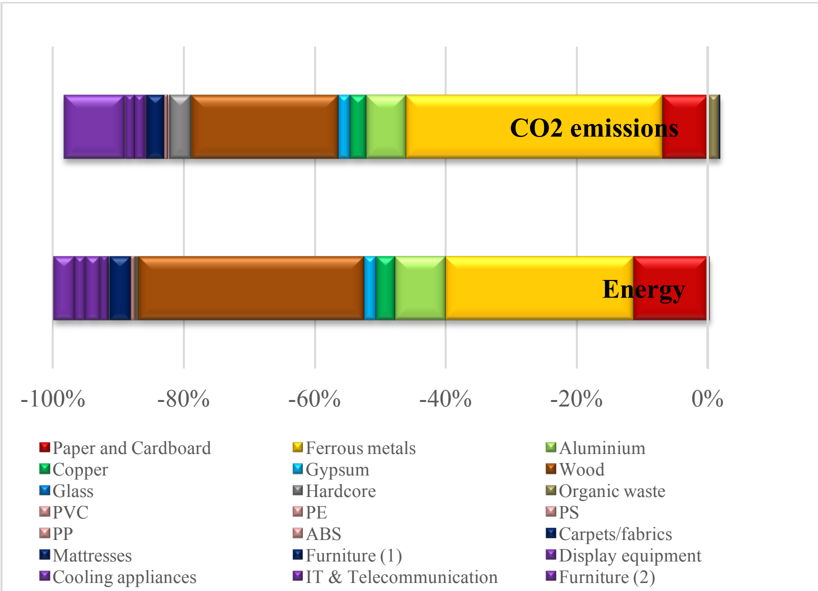

Figure 7: Contribution per stream to the total energy consumption and CO_2 emissions of the Enviro Waste Management System in 2015-2016, in percentages

Analysing the results from **Table 6** and **Figure 7**, the following can be stated:

- Overall, the EWMS contributed to the avoidance of 20.7 TJ of primary energy and 1.5 kton of CO_2 emissions in 2015-2016;
- The treatment of ferrous metals and wood together contributed for 64% to the total avoided energy consumption and 65% to the total avoided CO_2 emissions;
- Paper & cardboard (11% and 7%), aluminium (8% and 6%) and the refurbished products (8% and 13%) contribute significantly as well;

Combining the results of the total weight per stream collected, and the avoided energy and CO_2 emissions of that stream, the *avoidance intensity* for each stream can be calculated in GJ/ton treated stream and kg CO_2 emissions/ton treated stream. A positive avoidance intensity indicates that the waste that is treated results in more energy consumption and/or CO_2 emissions, while a negative avoidance intensity shows that the treated waste results in avoided energy and/or CO_2 emissions. Ranking the avoidance intensity of each stream gives a pattern shown in **Figure 8**, which indicates that five streams have the highest avoidance intensity per ton treated waste. The five streams that follow have a medium avoidance intensity, but not as significant as the first five. The other streams have a low avoidance intensity, and two streams even contribute negatively to the overall avoided energy and CO_2 emissions.

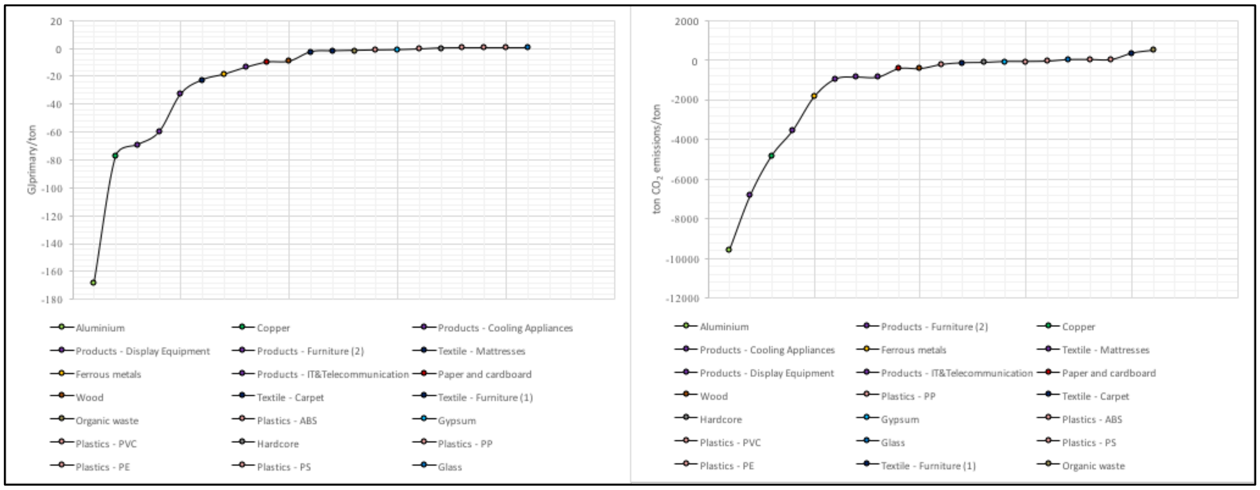

Figure 8: Energy (left) and CO_2 emissions (right) avoidance intensities per stream, ranking from high to low

In sum, the EWMS performs relatively well on the following materials:

Table 7: CO_2 emission avoidance intensity of streams Enviro Waste performs good at

1. Aluminium	(9.6 ton CO_2/ton)	6. Textile - Mattresses	(1.4 ton CO_2/ton)
2. Products - Furniture	(6.8 ton CO_2/ton)	7. Products - Display Equipment	(0.9 ton CO_2/ton)
3. Copper	(4.8 ton CO_2/ton)	8. Products - IT and Telecommunication	(0.9 ton CO_2/ton)
4. Products - Cooling appliances	(3.5 ton CO_2/ton)	9. Paper and Cardboard	(0.5 ton CO_2/ton)
5. Ferrous metals	(1.7 ton CO_2/ton)	10. Wood	(0.4 ton CO_2/ton)

Except for two, all these streams contain a type of metal. The streams that are close to zero in **Figure 8**, meaning they have a low avoidance intensity, can be argued to have a sufficient reduction opportunity. The magnitude of this opportunity depends on how the streams can, and should, be handled differently.

4.2 Scenario comparison

The treatment rates per stream from the reference scenario, the National Average and Circular Principles scenarios can be found in **Appendix E.** The difference in treatment rates determined the total avoided energy and CO_2 emissions in each scenario**.** In **Figure 9** and **10**, the difference in energy and CO_2 emissions avoidance in the National Average and Circular Principles scenarios per stream compared to the reference scenario are shown.

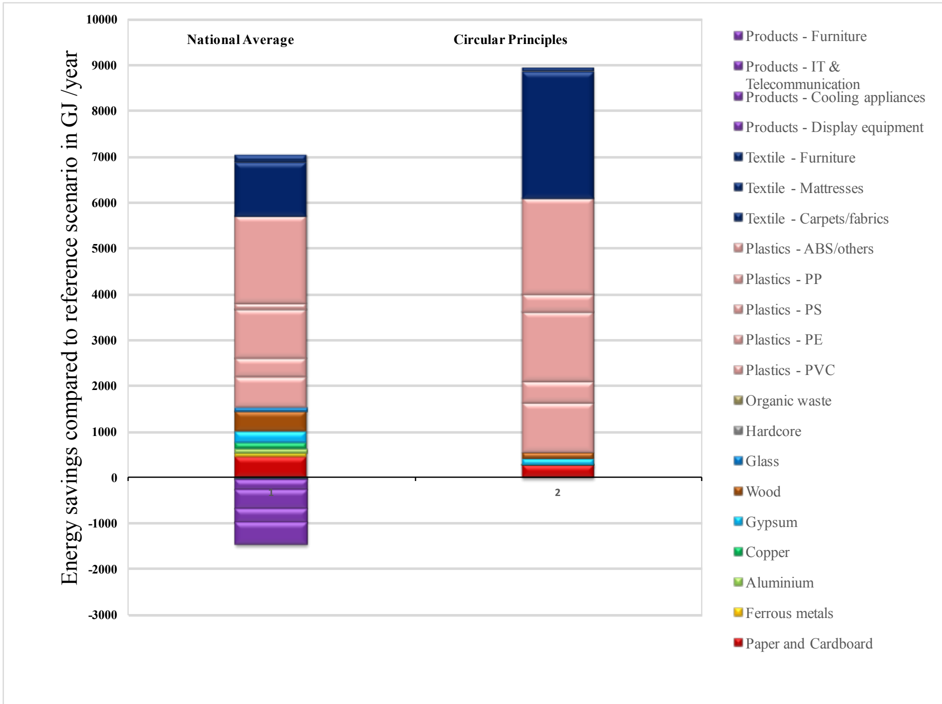

Figure 9: Energy reduction potential for Enviro Waste compared to National Average and Circular Principle scenarios (2015-2016)

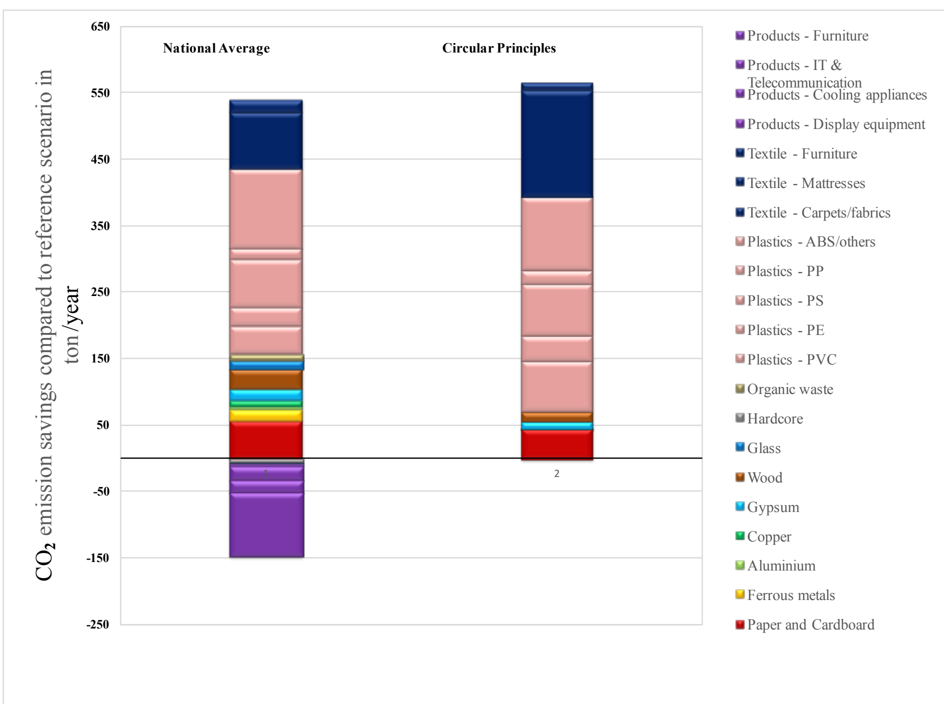

Figure 10: CO_2 emission reduction potential for Enviro Waste compared to National Average and Circular Principle scenarios (2015-2016)

Based on the result from **Figures 9** and **10**, it can be seen that the EWMS performs better compared to national average with the re-use of products, especially with furniture. However, except for textile from mattresses and ferrous metals, all the other materials have significant improvement potentials, both in energy and CO_2 emissions. More specifically, although the streams of wood, and paper & cardboard perform relatively well in the reference scenario, compared to National Average, there are still improvement potentials for these streams. The streams that have high improvement potentials in the National Average scenario correspond with the results from the reference scenario, in which all the product streams and the metals perform relatively well. Meanwhile, the materials with low avoidance intensity were argued to have significant improvement potentials, showing significant reduction potentials in the National Average scenario.

Looking at the Circular Principles scenario, several strategic initiatives could result in outperforming the national average in terms of avoided energy and CO_2 emissions. Especially the plastics (63% energy and 58% CO_2 emissions avoidance potential) and textiles (31% energy and 29% CO_2 emissions avoidance potential) are major potential contributors to these improvements. The main circular principles considered here are better separation, (as a result) more recycling and increased energy recovery rates, in turn, to reduce waste going to landfill. This predominantly results in the consideration of other partners in the EWMS for Enviro Waste. In **Table 8**, the overall treatment rates for all the streams combined are shown per scenario.

Table 8: Overall treatment rates per treatment option for each scenario

Treatment	Enviro Waste	National Average	Circular Principles
Reuse/refurbishment	2.0%	0.3%	2.0%
High value recycling	35.4%	53.3%	40.5%
Downcycling	6.7%	7.9%	8.2%
High efficiency Biomass-to-Energy	7.4%	3.5%	7.6%
Energy recovery/cement kiln	1.9%	2.3%	7.1%
Incineration with Energy recovery	7.3%	6.9%	13.4%
Landfill	39.3%	25.7%	21.3%
	100.0%	100.0%	100.0%

Table 8 shows that Enviro Waste re-uses more products than on national level. On national level, more high value recycling takes place rather than down cycling compared to Enviro Waste, and overall, 19.1% more recycling takes place on national level. Moreover, in the reference scenario, 13.6% more waste was send to landfill compared to national average. More importantly, the Circular Principle scenario shows a significant improvement of diverting waste from landfill (18%), but also an increase of the recycling rates. The recycling rates in the Circular Principles scenario, however, can not be exceeded with the implemented changes yet.

The combination of the reference scenario results, and the comparison of the reference scenario with the National Average and Circular Principles scenario, point to the same focus streams to improve the environmental performance of the EWMS. Considering the streams with low avoidance intensities from the reference scenario, the highest potential streams from National Average, and the nine highest potential streams from the Circular Principles scenario, the focus streams and related reduction potentials for Enviro Waste can be found in **Table 9**.

Table 9: Focus streams for Enviro Waste with reduction potential when circular principles are implemented

Reduction potential	Energy (TJ)	CO_2 emissions (ton)
Stream		
1. Plastics - ABS/other plastics	2.1	111
2. Textile - Carpets & fabrics	2.8	160
3. Plastics - PS	1.5	79
4. Plastics - PVC	1.1	76
5. Wood	0.1	15
6. Plastics - PE	0.8	38
7. Paper & Cardboard	0.3	45
8. Gypsum	0.1	10
9. Textile - Furniture	0.1	11

In **Figure 11**, the sources of the focus streams are shown, except for PE, gypsum and textile from furniture, as no distinctive sources could be identified.

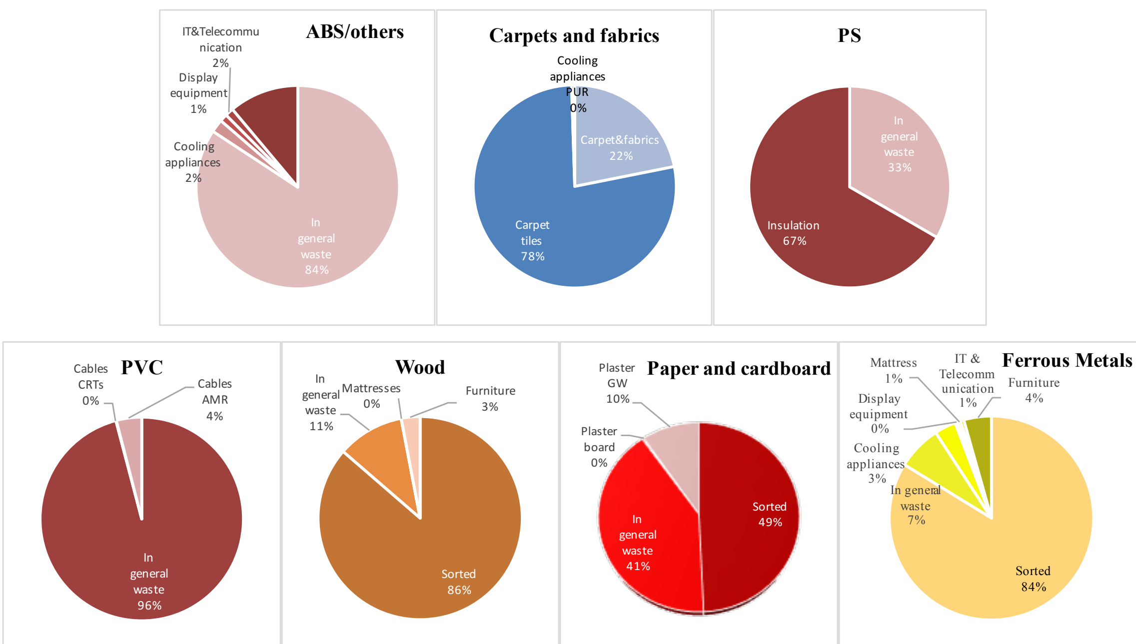

Figure 11: Sources of the focus streams for energy and CO_2 emission reduction for Enviro Waste

From another perspective, the increase of collection of good performing streams can a positive impact on the avoidance of energy and CO_2 emissions as well. Therefore, increasing the collection of cooling appliances, display equipment and IT & Telecommunication is also considered as important circular strategic initiative.

4.3 Implications scenarios - Questionnaire

The mean of the questions was considered to represent the level of the barrier. The the level of barrier could be determined using the calculated mean range as can be seen in **Table 10** (Shamsuddin et al., 2017). Question 27, which was included as a check question, could not be used for the analysis as almost 50% of the participants answered the questions falsely or not at all.

Table 10: Level of mean measurement

Central Tendency level	Mean range
1.00-2.33	Low barrier
2.34-3.67	Medium barrier
3.68-5.00	High barrier

First, the three questions displayed in **Table 11** were used to assess the employees' opinion on their personal environmental awareness and their opinion on Enviro Waste as a company. In these questions, question 2 was reverse phrased, and therefore the response scale was reversed. There is a statistically significant difference between the departments in two out of three these questions, as can be seen from the significance being less than 0.05 (Fielding, 2009). Being environmentally friendly is equally important to operatives and office workers, and for REC/IT workers medium important. Moreover, while REC/IT workers consider the environmental performance of Enviro Waste to be medium, operatives, and especially office workers, belief that Enviro Waste has a high environmental performance. On top of that, REC/IT workers and the operatives believe that Enviro Waste can do a lot more to become environmentally friendly, while the office workers have a weaker opinion on this matter.

Table 11: Questionnaire results on environmental awareness and performance Enviro Waste

		How important is being environmentally friendly for you?	What do you think of the environmental performance of Enviro Waste?	Do you think Enviro Waste can do more to become environmentally friendly?
REC/IT	Mean	Medium	Medium	High
Office	Mean	High	High	Medium
Operations	Mean	High	High	High
Total	**Mean**	**High**	**High**	**High**
	Sig.	0,070	0,013	0,047

The reliability of six computed variables representing the six barrier categories was tested using the Cronbach's alpha, as can be seen in **Table 12**.

Table 12: Cronbach's alpha for the six variables representing six barrier categories

Variable	Cronbach's alpha	N of items
Social	0.799	3
Organisational	0.861	11
Informational	0.113	2
Legal	0.386	2
Technical	0.159	4
Economic	0.506	3

While the social and organisational categories showed a high internal consistency, and therefore a high reliability, the rest of the questions showed a low reliability, showing a value lower than 0.6 (Shamsuddin et al., 2017). A possible explanation is that the questions were based on categories that also consisted of subcategories (ibid.). Hence, all barrier categories, also with high Cronbach's alpha values, were analysed based on the single questions representing different subcategory barriers (Fielding, 2009). The means and barrier level per subcategory are shown in **Table 13**. There were four reversed phrased questions, of which the outcomes were reversed in order to make them comparable with the other outcomes.

Table 13: The barrier levels per subcategory barrier according to Enviro Waste employees

Barrier category	Sub-category	Level of barrier
Social barriers	Low public pressure	Low barrier
	Lack of awareness	Low barrier
	Lack of market preference and demand	Low barrier
Organisational barriers	Limited environmental awareness directors - James	Low barrier
	Limited environmental awareness directors - Eli*	Low barrier
	Limited environmental awareness directors - Marc	Low barrier
	Limited top management commitment and support for sustainability initiatives	Low barrier
	Poor partnership formation and management	Medium barrier
	Limited development of the environmental supply sector	Low barrier
	Lack of focus on corporate image and social responsibility*	Low barrier
	Unclear/weak strategic and business goals, lack of environmental goals in company vision and corporate values, and misalignment of short- and long-term strategic goals*	Low barrier
	Negative employee attitudes	Medium barrier
	Limited environmental motivation and awareness among employees	Medium barrier
	Lack of human resources and time	Medium barrier
Informational barriers	Lack of information, e.g., regarding environmental legislation or collection and disposal options	Low barrier
	Insufficient technical and environmental training, education and reward systems	Low barrier
Legal barriers	Uncertainty regarding future legislation, e.g. Brexit	Medium barrier

	Difficulties associated with the process of applying/complying with legislation*	Medium barrier
Technical barriers	Trade-offs and difficulties in balancing	Medium barrier
	Lack or scarcity of advanced technology and equipment with lower-environmental impacts	Low barrier
	Technical and detailed knowledge from employees, e.g., waste material awareness	Medium barrier
	Aversion to innovation and technological change	Low barrier
Economic barriers	Limited financial capability for environmental investments*	Medium barrier
	High costs of environmentally friendly waste handlers	Medium barrier
	High short-term costs and low short-term economic benefits	Medium barrier

Based on **Table 13**, it can be stated that there are no insurmountable barriers for the implementation of circular principles within Enviro Waste according to the employees, as no barrier is categorised as being high. From the main categories, economic and legal barriers are consistently reported as medium level barriers, and social and informational barriers are consistently categorized as low level barriers. Within the organisational barrier category, a distinction can be made between top management, partnerships, corporate focus and employees barriers. While the top management and corporate focus are considered to be low barriers, partner formation and employee attitudes were seen as medium barriers. Within the technical barriers, difficulties in trade-offs and technical knowledge from employees are considered medium barriers.

As this questionnaire was also aimed to spot differences in opinions among departments as well, the significant differences between the departments for each question was generated. There were five questions in which significant differences were detected, which are marked with * in **Table 13.** In **Table 14**, the differences can be seen for these questions.

Table 14: Subcategory barriers that received significant different opinions among the departments of Enviro Waste

	Limited environmental awereness directors - Eli	Lack of focus on corporate image and social responsibility	Unclear/weak strategic and business goals, lack of environmental goals in company vision and corporate values, and misalignment of short- and long-term strategic goals	Difficulties associated with the process of applying/complying with legislation	Limited financial capability for environmental investments
REC/IT	Medium barrier	Medium barrier	Medium barrier	Medium barrier	Medium barrier
Office	Low barrier	Low barrier	Low barrier	Medium barrier	Medium barrier
Operations	Low barrier	Low barrier	Low barrier	Medium barrier	Low barrier

REC/IT sees specifically one of the directors as a medium barrier, and also considers the lack of corporate focus and strategy as a bigger barrier, compared to the other departments. An explanation can be that the REC/IT workers mainly deal with this specific director, and his way of working is also reflected in the other two sub barriers. Difficulties with legislation are al categorized as medium barrier, however, the difference between the departments is predominantly based on the average mean, in which the office has a lower barrier than the other departments. An explanation can be that the compliance manager is present in the office most of the time. Finally, the difference in opinion considering financial capabilities between the operatives and the other departments might be due to difficulties in the question, as the other economic sub barriers were considered to be high. In sum, the only difference in barrier perception has to do with one department, related to one director. Ultimately, a number of barriers need to be considered when developing a circular strategy for Enviro Waste, summarised in **Table 15**.

Table 15: Enviro Waste specific barriers for the implementation of circular strategic initiatives

Barrier type	**Specific for Enviro Waste**
Economic barrier	Financial capabilities Waste partner costs Return on investments
Legal barriers	Uncertainties in legislation Complying with legislation
Employee barriers	Awareness, attitude and motivation of employees Lack of time and human resources REC/IT perception of the company culture and Eli as director
Partner barriers	Partner formation difficulties

4.4 Developing strategic initiatives – interactive session

This section provides an overview of the five-year objectives for Enviro Waste, related general strategic initiatives and relevant circular strategic initiatives as proposed by the directors and business operations manager. In this session, the identified barriers derived from the questionnaire were also taken into consideration. Consequently, five-year goals for Enviro Waste and related general strategic initiatives are shown in **Figures 13 to 18**. The colours of the strategic initiatives indicate the type of sustainable value that can be created with that specific strategy, according to Hart & Milstein (2003), see **Figure 12**. The researcher categorized the initiatives according to their contribution to the goals, and initiated circular strategic initiatives related to the general strategic initiatives, stemming from the scenario-based system assessment outcome. Each objective and strategic initiative is discussed in light of its created value in the Circular Economy.

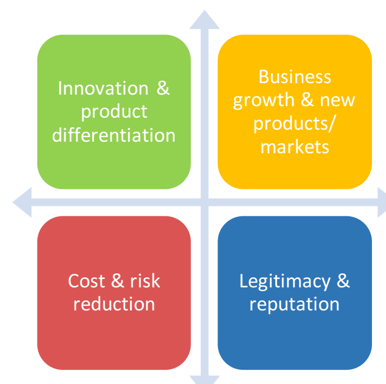

Figure 12: The sustainable value created derived from Hart & Milstein (2003).

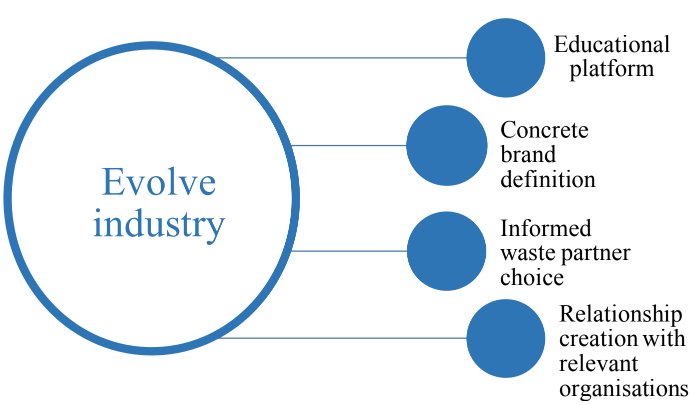

Figure 13: Objective 1

The first objective is evolving the industry, in which Enviro Waste aims to contribute to the transition of the waste management industry towards increased circular principles. Four related strategic initiatives were linked to this objective, as can be seen in **Figure 13**. The educational platform could be launched using a CE/CO_2 emission tool, using the data generated with the scenario-based system assessment. Brand definitions is aimed to be in line with CE values. Also, making informed waste partner choices can be ensured by creating an 'Enviro Way scale', in which organisations need to fulfil specific criteria in order to handle the waste collected by Enviro Waste. The scenario-based system assessment showed that different partners need to be chosen for the treatment of carpets and fabrics, furniture, IT shredding, and general waste. Additionally, creating relationships with organisations active in the waste management industry is relevant, but also with organisations that share the same objective as Enviro Waste, e.g. the Ellen Macarthur Foundation. These four strategic initiatives, integrating a circular perspective, can lead to sustainable value in the form of legitimacy and reputation.

The second objective is creating automated processes within Enviro Waste. In order to reduce the human capital needed for processes that can also be executed by machinery, Enviro Waste aims to automate their current and future processes. In order to reach this goal, performing process optimisation analyses across the company is needed, in order to spot improvement and automation opportunities. Including a circular strategy perspective to this analysis can help spotting opportunities for circular principles. The inclusion of increased manual separation in the yard of paper & cardboard, plasterboard, wood and plastics, as was identified in the scenario based system assessment is an example for the inclusion of a circular strategy perspective. The evaluation of the specific role of each job function in these processes can simultaneously increase the efficiency of processes. Therefore, the sustainable value created with these two strategies are cost and risk reduction, while implementing more circular principle processes, including automated separation, can also create business growth.

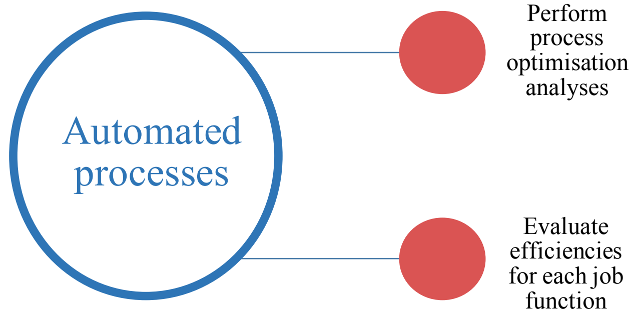

Figure 14: Objective 2

The third objective for Enviro Waste is having environmentally friendly focussed employees, willing to contribute to the stated objectives. Therefore, developing internal communication procedures on circular strategy implementation within Enviro Waste and industry transition trends can contribute to more involvement of employees. From this perspective, creating a hiring process that attracts the 'right' people has the potential to reduce risk and costs. Especially as high human resource turnover can lead to reduced interest and effort for the company, which was shown in the barrier identification from employees, sufficient and skilled human capital is needed to reach the objectives.

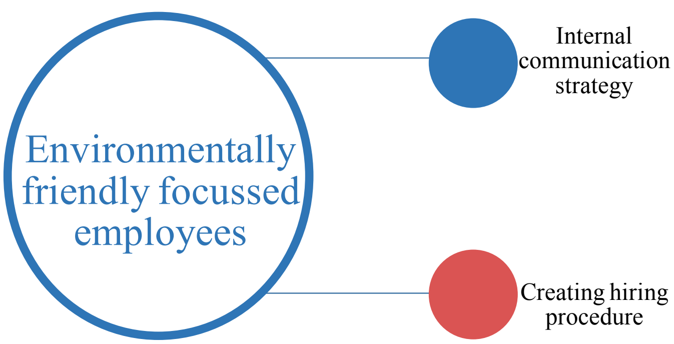

Figure 15: Objective 3

The fourth objective for Enviro Waste is strongly connected with the third objective, being positive leadership from directors, in the form of an employee protection scheme and training program. The directors strive to provide jobs that include personal and professional development, and excellent labour conditions. This, in turn, can benefit the hiring procedure. As a result, hiring the 'right' people will benefit the realisation of the other objectives, too. The training program is recommended to be based on circular economy principles, preparing the employees on future transitions in the industry and the company. Moreover, including employees in circular principle ideas generation for Enviro Waste is beneficial for the success of a company, e.g. an Enviro Waste idea generation box, in which each department manager has to check the ideas from their employees on a weekly basis. The value created with these strategies are reducing risk through optimization of human resources, and including stakeholders/employees in the business processes, creating legitimacy.

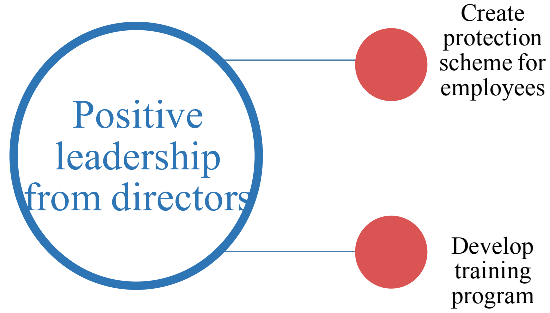

Figure 16: Objective 4

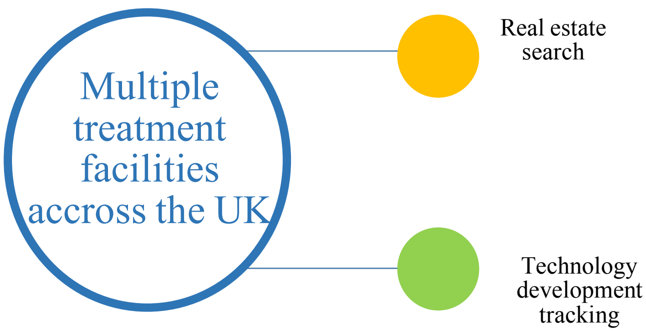

Figure 17: Objective 5

The fifth objective is related to the services Enviro Waste aims to provide in the Enviro Waste Management System (EWMS). As they currently only separate the waste manually, they aim to separate the waste with separation machinery at different locations in the UK. In order to reach this objective, it is therefore necessary to start searching for real estate to enable the execution of business growth, but also to grow the infrastructure for preparation for re-use. Additionally, spotting technological developments in the fields that Enviro Waste, creating business growth. From a circular strategy perspective, considering real estate and circular principle technology solutions has the potential to create sustainable value with innovation and service differentiation. Additionally, having automated processes defined in the objective 2, Enviro Waste can grow its business, using the standard procedures based on the process optimisation analyses. Additionally, the procedures create the opportunity to franchise the business.

The last objective is related to professional service provision from multiple business units, operating under the Enviro Waste 'umbrella'. Four general strategic initiatives were proposed related to financial risk

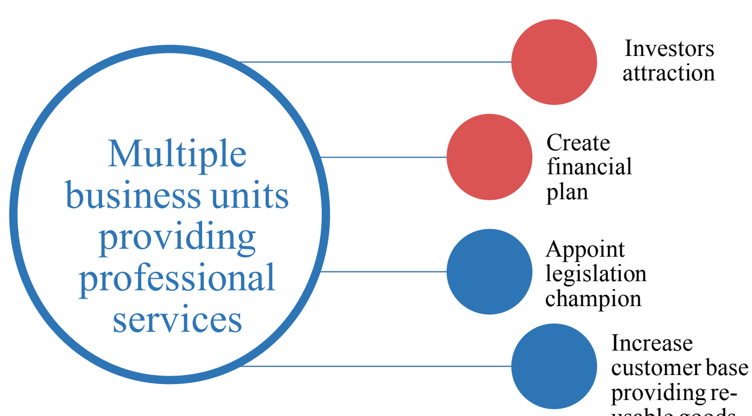

Figure 18: Objective 6

reduction, legislation risk reduction, and customer focus. From a circular strategy point of view, attracting investors and creating a financial plan should be in line with all the other objectives. Ensuring income streams while simultaneously creating societal value in this financial picture is crucial. As the waste management industry is in a transition phase, investors will likely be more interested in future oriented organisations like Enviro Waste, creating value with circular principles. Consequently, creating legitimacy and building a reputation is important. Therefore, increase the preparation for re-use infrastructure of Enviro Waste, as this is one of the most important circular principle adopted by Enviro Waste, can provide an opportunity. Striving to receive more goods that have the potential to be re-used is therefore recommended, e.g. airport lost&found departments. On top of that, a legislation champion should be appointed to understand regulatory changes applicable for Enviro Waste, reducing risks.

Considering these five-year objectives and related strategic initiatives, creating sustainable value is in all instances related to creating business value. While twelve from the overall sixteen strategic initiatives are in need of immediate actions (red and blue), future strategic initiatives are also considered, in order for the organisation to create value with business growth and innovation.

5. Discussion

In this section, the aim is to reflect on the most important factors influencing the results of the scenario-based system assessment and the strategy development process. Moreover, the aim is to identify opportunities for improvement in both research method and strategy development process, in order to contribute to the body of literature on scenario-based system assessment for circular strategy development for waste management companies.

The scenario-based system assessment used in this research can be considered as a first attempt to explore more circular principles in a waste management context, and its contribution to CO_2 emission avoidance. However, conducting the analysis revealed four major factors in the research method and data collection affecting the results. Firstly, *data accuracy and consistency* in general was poor. For the reference scenario, detailed and consistent data records were unavailable, leaving the researcher with data gaps. The main data gaps included the missing weights from re-used products, missing weights from jobs, and the overall composition of the collected waste. A database on the weights for the re-used products was created using a list with average weights for a wide variety of products (FRN, 2009), in consultation with experts from REC. The missing job weights were estimated using interpolation, resulting in a 0.1% difference between waste collection and yard output. The composition of the collected waste was estimated using an elaborate identification of materials in general construction waste, in consult with five experts of Enviro Waste dealing with waste separation on a daily basis. However, as Enviro Waste is in a growing phase, the composition of the waste can differ each year, indicating that the avoidance intensity per stream gives a better indication on Enviro Waste performance rather than the actual avoided emission per waste stream. An overview on how data gaps of Enviro Waste were dealt with is given in **Appendix A** for transparency reasons.

Secondly, the *lack of transparency of waste handler partners* resulted in a lack of specific data for the reference scenario, which made it necessary to make assumptions on the treatments per stream. From the seven direct partners, four allowed the researcher to do informal interviews and observations on site. From the other three partners, two were paid an unannounced visit to enable at least observation, while many of the questions were answered unsatisfactory. From the second tier partners, none of five approached organisations allowed the researcher to visit, and only insufficient responses were given via e-mail on the researcher's questions. An explanation of this lack of transparency can be the limited impact of one individual waste management company on the entire system. Since Enviro Waste is a relative small actor, the data might not be available for them, while for other (bigger) actors, this data might be easier to obtain because of its power within the system. Alternatively, the lack of transparency could be a sign of bad performance from the partner's side. Indeed, the involved organisations not open for visits received fines from the Environmental Agency for non-compliance.

As discussed in the section 3, overcoming a lack of transparency and therefore data gaps, triangulation of data sources was aimed to ensure accurate outcomes, using informal interviews with waste handlers, observation at their site and registered data from the Environmental Agency (EA, 2015). Unfortunately, comparing the outcomes of these data sources often showed *contradictions in data*. The lack of transparency and mismatch of triangulation outcomes was covered using consultation with expert from Enviro Waste and choosing worst case scenario where necessary.

Emphasizing the research method, the *scope of the system for the analysis* could be an influential factor, especially the variety and complexity of the processes considered, and variables impacting these processes. Examples of these variables are the energy mix within a country, which changes each year, technical developments in the industry, and processes performed in other countries not accounted for, for example in waste export to the Netherlands and China. This requires an in-depth understanding of the entire system, which often cannot be acquired from the perspective of a single actor in the system, as was clarified with the lack of transparency of partners in this research. However, this is a common occurring problem in LCA research approaches related to background information (Allesch & Bruner, 2014; Corsten et al., 2013). Also, the accuracy of the *i*Waste model method fits the purpose of this research (Allesch & Bruner, 2014), which is aimed to be exploratory.

Finally, the *inclusion of preparation for re-use* in the scenario-based system assessment influences the outcomes of the assessment in several ways. As this process was considered an addition, the comparison with the National Average scenario might be skewing. The results indicated that with some streams, Enviro Waste performed worse, while this was mainly due to the amount of that specific stream being treated, for example with ferrous metals. A difference in stream weights was, although normalized, impacted by the products being re-used versus disposed of. As Enviro Waste re-used more products, less weight was treated in the other processes, while on National Average, more of the streams was disposed of. The avoidance intensity can provide a better indication of performance. However, due to the small volumes of the collected stream, this is more appropriate in the larger waste management systems. In addition, the assumed composition of the re-used products can differ from the actual composition of these products in the waste. Difficulties were also found in keeping the same system boundary approach, as all the materials in a products were considered in the preparation for re-use process, while when products were not fit for re-use, only the material that are considered in the analysis were accounted for. An example is the consideration of lead in products, while this stream is not considered in the material streams. Not to forget, easiness of separation and materials contamination with other materials all influence the recyclability of streams. Based on this research method reflection, in order to further develop the use of circular principles in system assessment for waste management, further research should first of all focus on the inclusion of more streams in the analysis, or the exclusion of materials within products that are not considered in the rest of the streams. Also, research on the suitability of discarded products for re-use on a national level could assist in spotting opportunities for large re-use infrastructures.

Factors influencing the result from the circular strategy development phase are the quality of input for the questionnaire and interactive session, and the ethnical background of the participants in both steps. With the questionnaire, the positive way of questioning might have triggered the respondents to fill in answers that they think are desirable. Moreover, the translation of the questionnaire might have influenced the results as well. These considerations might be an explanation that the barriers identified with the questionnaire were mostly considered to be low. Moreover, the differences between the departments in opinion on barriers could be explained by the variety of national backgrounds working at Enviro Waste. In general, the department consisting of mainly East-European employees considered most barriers as low. For these reasons, together with a better understanding on the nature of the barriers, a group interview in the form of an interactive session took place with the directors and business operations manager.

The input for the interactive session was the infographics displayed in **Appendix G**. These infographics were aimed to be easily understandable and questions were answered to the participants' satisfaction. Although the outcomes of the scenario-based system assessment were understood by the participants, the results of the interactive session mainly shows general strategic initiatives, focussed on the present rather than the future. An explanation can be the lack of specified objectives and strategies for Enviro Waste. Moreover, in the interactive session, the participants did not show a shared understanding of where they want Enviro Waste to be in five years. Nonetheless, based on the identification of the factors influencing the results, the next section provides recommendations for Enviro Waste on a circular strategy.

6. Business Recommendations

This section provides relevant business recommendation for the case study organisation Enviro Waste. The circular strategic initiatives were embedded in the overall strategy of Enviro Waste, in order to link the circular strategies with the overall objectives of the company and the the sustainable value creation. In should be noted, however, that no attempt was made to evaluate the monetary value of the strategic initiatives.

Based on the results and discussion, four recommendations are considered for Enviro Waste. The first and foremost recommendation is related to the current stated objectives for Enviro Waste. The researcher identified discrepancies among the directors on the focus of the organisation and the objectives within five years. It is therefore recommended to specify the objectives stated in the interactive session to make them measurable. For example, an important step is defining the recycling and re-use rate to be reached within three years, and within five years, in order to define specified strategic steps towards these objectives, assisted with the scenario-based system assessment outcomes.

The three other recommendations can be considered an integrated circular strategy proposal for Enviro Waste for the short term. This circular strategy can be integrated in the company wide strategy, showing its contribution to the overall objectives of Enviro Waste. First of all, it is recommended to develop a Circular Economy/CO_2 emissions tool for customers, creating sustainable value with process optimisation and legitimacy building. Moreover, it is recommended to develop an 'Enviro Way scale' to support the choice for waste partners in the system. The scale should include criteria that partners need to meet in order to be included in the EWMS. The communication of this scale can legitimacy the decision making for Enviro Waste, and fosters transparency. On top of that, it is recommended to perform company-wide process analyses, in order to spot efficiency opportunities, and include the proposed circular principles from the scenario-based system assessment.

These four recommendations can simultaneously provide value to realise general strategies identified in the interactive session, e.g. creating a financial plan, attracting investors, attracting appropriate human capital, while growing the business.

7. Academic Implications

In this section, an answer to the research question is given. However, considering the discussion points in this research and the exploratory nature of the research, the results were not aimed to be generalized. This research aimed to explore the circular strategy development process using system analysis, with a focus on the sustainability challenges the waste management industry is facing.

The system analysis used for this case contributed to strategy development in four distinctive ways. First, the scenario-based system assessment of the EWMS gives insight in the actor structure of the system, including actors beyond the direct partners from Enviro Waste. Although the actors in the system were limitedly transparent, these insights provide the strategy decision makers with accurate knowledge on the (environmental) performance of their partners. Second, the analysis pointed out specific improvement opportunities in the waste management system related to circular principles. The assessment especially pointed out specific streams that have the potential to be returned to the economy with more value than they are doing now, providing detailed improvement opportunities. Third, the thoroughness of the assessment legitimises choices for specific circular strategic initiatives. Fourth, it is a useful communication method, both internally as externally, to show the performance of an actor specific system.

Based on these contributions, it can be argued that the development of the ***i*Resource model**, as opposed to the *i*Waste model, is essential to foster the CE for the waste management industry. The use of preparation for re-use in this model showed its applicability in system analysis in two ways. It not only allows comparison of a materials and products, it also allows to show the environmental benefit of circular efforts from waste management companies in more depth. This research provided a starting point for an integrated circular economy waste management system assessment, including preparation for re-use of products. However, more case study research is required to make this novel method applicable for more waste management systems.

However, in order to create value, the appropriate use of the outcomes of the scenario-based system assessment is crucial, including the orientation of the outcome, assessing the implications of the implementation of circular principles, and linking them to the overall objectives and strategy of the organisation, in order to create sustainable value. Using the questionnaire and interactive session to identify barriers for the implementation of circular strategic initiatives was therefore needed to enable informed decision making. Nevertheless, it is important to point out that, for the considered waste management system, the integration of straightforward circular principles is lacking, e.g. separation of streams and high value recycling. This indicates how much efficiency opportunities still exists that should be implemented prior to fostering other circular principles, e.g. preparation for re-use. A main barrier evident in this research was the role of partner transparency in this system for an ambitious organisation like Enviro Waste. Ultimately, a lack of transparency impedes organisations to bring their circular approach to the next level.

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Appendix A: Adjustments and assumptions data Enviro Waste

The data needed for the scenario analysis was based on the following organisational documents:

- Yard & Operations Report 2016 v6, backed up with waste transfer notes;
- Service CEO Special items charged (dec 2015- nov 2016);
- REC products listed items (dec 2015- nov 2016);
- Furniture Reuse Network (FRN) average weights (FRN, 2009);
- Secure destruction and wiping jobs (dec 2015- nov 2016).

Combining the data from these documents enabled the formation of a representative material flow chart from collection up unto the output of the yard and further. **Table 17** represents the fields covered in the 'Yard & Operations Report 2016 v6' document, and the adjustments made.

Table 16: Relevant fields covered in the 'Yard & Operations Report 2016 v6' document, and the adjustments made.

Relevant Fields	**Units and assumptions**
Vehicle mileage	Mileages driven per vehicle. Used to calculate the energy consumption and CO_2 emissions for the transport of Enviro Waste
Vehicle registration	Used to ascertain which jobs went to transfer stations and which jobs went to the Enviro Waste yard.
(Full) Postcode	
Start time	
Completion Time	
Job Type	The EWC code for the job. Differentiate between 20 03 01D (domestic waste), 20 03 01C (commercial waste) and 170904 (construction waste).
Actual load size and cubic yards 150%=16 cy, 100%=14 cy, 75%=10, 50%=7, 33%=5, 25%=3, 15%=1 cy.	During the considered 12 months, the standard registration of cubic yards changed due to price changes to the customers. For the analysis, the actual load size in percentages was used to get consistency in the cubic yards per job. As 18% of jobs had missing weights, the allocation method for these missing jobs were calculated using these three fields. In each EWC field, the heavy duty and light duty jobs were determined. After that, the average weight per cy job was calculated. With these calculations, the missing jobs were interpolated with these values. This resulted in a difference of 0.1% underestimation of the Enviro Waste yard input compared to the output.
Light duty or heavy duty	
Total weight	
Supplier weight	Supplier weights were often higher than what the Enviro Waste trucks

	showed on their calibrated scales. The difference can be clearly seen when comparing the waste that goes directly to other transfer stations, compared to the related job weights. A difference of 2.8% was found. The impact of this weight difference on the outcome of this analysis is unknown.
Furniture (yes or no)	This fields is tracked since August only. Based on all these YES/NO registered jobs for furniture, 41.3% of the domestic jobs, 26.9% of the commercial jobs and 3% of the construction jobs contain furniture. However, as furniture is also assumed to be tables, steel cabinets etc., this data cannot provide any indication for the total collected furniture and is therefore not used.
Composition job load - Mixed waste, Hardcore, Plasterboard, Metal, Wood, Paper & cardboard, Fabric & carpet, Green, White goods, WEEE, Secure Paper, Secure Electronics.	Registered in volume percentages. After a job, the drivers filled in a form about the composition of the waste collected. Sometimes it did not add up to 100%, and it is not clear if the drivers understood that it has to be volume or weight. Nonetheless, it used for comparison reasons for the assumed composition of the waste.
Hazardous wastes - Fluorescent tubes, Lead Acid Batteries, Paint, Monitors/TV, Fridge/Freezers	When hazardous waste is collected, a consignment note has to be filled in and signed by both the disposing and receiving party. Most items are charged extra, but because of client benefits Enviro Waste offers, this registration does not always correlate with the charged items. A combination of these two fields was used to determine the number of collected items.
Additional items charge	

Appendix B: Background information *i*Waste model

Transport

Energy consumption due to transport is dependend on the type of transport, the weight of the load, speed and distance (RIVM & Novem, 1992). A widely used unit for transport energy consumption is therefore MJ/ton.km. In all three scenarios, the energy consumption for collection of construction and demolition waste was used, being 1.5 MJ/ton.km for smaller transport distances with skip vehicles and Enviro Waste trucks, and 0.65 MJ/ton.km for long distances with large volume and weight transport (RIVM & Novem, 1992). The distances were determined based on the distance between the treatments facilities derived from Google Maps in June 2017. For unknown treatment plants, the standardized distances provided by RIVM & Novem (1992) were considered. In **Table 19,** the transport assumptions are shown.

Table 17: Energy consumption transport per treatment partner of Enviro Waste and other actors in the system

Transport		km	MJ/ton.km	MJ/ton
Collection	Enviro Waste	13.5	0.0018	0.024
First tier				
To seperation station - General Waste	Manns Waste Management	21.9	1.5	32.85
To shredding company - Paper+IT	Pulse environmental	2	1.5	3.00
To shredding company - Wood	Connect Waste Management	21.6	0.65	14.04
To MRF - Special items	Environcom	185	0.65	120.25
To MRF - Hardcore	Sharp Skips	24.1	1.5	36.15
To RDF producing facility - Bulky Waste	Hinkcroft/HTL	15.8	5.2	82.16
To scrap metal facility	AMR	0.5	1.5	0.75
Second and third tier				
To paper mill	Kemsley Mill	75.3	0.65	48.95
To metal melting facility	Undefined	200	0.65	130.00
To gypsum recycling facility	Plasterboard Recycling.co.uk (NG32 3EW)	209	0.65	135.85
To chipboard recycling facility	Undefined	200	0.65	130
To biomass plant - Wood	Norford (FK7 7BQ)	677	0.65	440.05
To glass recycling facility	Berymann Glass recycling (Tilbury)	24.1	0.65	15.67
To harcore treatment facility	Recycled in Orsett (RIO) (RM16 3BB)	21.6	0.65	14.04
To composting facility - Organic	Undefined	50	0.65	32.50
To anaerobic digestion facility - Organic	Undefined	50	0.65	32.50
To plastic baling facility	Hearnes recycling (RM4 1ER)	18.3	0.65	11.90
To plastic recycling facility	Hearnes recycling (ME2 4ED)	56.4	0.65	36.66
To plastic recycling B facility				
To mattress recycling facility	Matt UK Ltd. (ME4 4SR)	48.9	0.65	31.79
To textile recycling facility	Undefined	50	0.65	32.50
To CRT recycling facility (Wales)	Environcom Wales	209	0.65	135.85
To cement plant	*Roadtransport within UK*	200	0.65	130.00
To incinerator	Cory Riverside Energy	23	0.65	14.95
To landfill - monocell	Undefined	200	0.65	130.00
To landfill - non-hazardous	Undefined	200	0.65	130.00

1. Paper and Cardboard

For the *i*Waste model, four different ways of paper and cardboard collection were considered: separate collection (for secure destruction), integrated collection, which is partly separated at the yard, integrated collection not separated in the yard and included in the general waste stream, and lining paper from plasterboard. The separately collected paper and the sorted paper from the yard, together responsible for 55% of this stream in the reference and National Average scenario, was considered to be recycled in all scenarios. The sorted paper and cardboard was transported in the Enviro Waste trucks to three different processors, being Viridor, Datashred or Pulse Environmental. Datashred is not used anymore, as Enviro Waste found out that their business is not reliable for secure destruction, and *Viridor* sent part of this stream to Pulse Environmental, among others. Therefore, the treatment conditions from Pulse Environmental were considered for paper and cardboard. As most of it is office paper, it can be contaminated with o.a. folders. This contamination rate differs per batch, and is assumed to be 3.6% (Corsten et al., 2013). A great portion of the paper and cardboard collected by Enviro Waste is non-secure data and is baled according to its grade by partners. As no distinction could be made in the specifications of Enviro Waste and the grades, it is assumed that everything was baled and sold as mixed paper and cardboard (25119: Waste and scrap of paper or paperboard, nes, (inc unsorted waste and scrap) – also known as 'Class I Mixed Grades') (CEPI, 2014). According to the Environmental Manager of Pulse, the market dynamics, and especially the prices, determine greatly to which paper mill the baled paper and cardboard are being sold. Due to business protection, he could only share one of the mills they do business with, being the Kemsley Mill in Kent. Their main produce is de-inked paper (DS Smith, 2017). Therefore, only high value recycling is considered in this analysis. In the Circular Principle scenario, an increase in paper and cardboard sorting in the Enviro Waste yard results in higher recycling rates.

The third and fourth option differ on national level compared to the Enviro Waste situation. The paper in general waste is considered to have the same treatment percentages as household and other wastes, see **Table 19** (DECC & DEFRA, 2016). These treatment rates we considered, as no data is available on how much paper is extracted from general waste in the UK. However, as Manns Waste Management did not send waste for energy recovery, in the reference scenario this fraction is sent to landfill (EA, 2015).

Table 18: Treatment rates for paper and cardboard in general waste (derived from DECC & DEFRA (2016))

	Enviro Waste	**UK**
Recycling	6.64%	6.64%
Energy recovery	0%	46.83%
Landfill	93.37%	46.54%

Lining paper from plasterboard is assumed to be recycled when the plasterboard is recycled, and otherwise it is assumed to be landfilled (Turner et al., 2015). For further information, see section 3. Gypsum.

2. Metals

Metal is used in a wide variety of products and has a high monetary value. It is therefore understandable that in several stages of waste treatment processes, machinery is installed in order to extract metals from other waste streams. An electromagnet can be used to separate ferrous metal, while an eddy-current machine separates non-ferrous metals, e.g. copper and aluminium. Different streams collected by Enviro Waste contain metals. First of all, construction and demolition waste contain metals, e.g. steel beams, metal pipe, window frames, nails, mattresses etc. Moreover, cooling appliances, IT and telecommunication, display equipment, and even furniture, all can contain both ferrous and non-ferrous metals.

The treatment for each metal-containing product differs. As Enviro Waste is specialised in WEEE handling, the products are either (1) data wiped, followed by preparation for re-use or recycled (depending on market value), (2) send for secure destruction with an UNTHA shredding machine (UNTHA, 2017) at Pulse Environmental, (3) send for metal recovery to the scrap metal organisation Argall Metal Recycling (AMR), or (4) mixed with other general wastes. (1) Data-wiped items were aimed to be resold through the REC Products network on eBay as much as possible. (2) The WEEE sent for secure destruction is incinerated after shredding, with metals being recovered after the energy recovery process at Cory Environmental. (3) Metals treated by AMR were separated further in different grades of metals, and sent to other organisations for recycling. According to the scrap metal organisation Argall Metal Recycling (AMR), depending on the type of metal and the market dynamics, the recycling process takes place in either the Middle East and Asia, or in Europe. However, as no specific data could be provided for treatment processes outside Europe, it is assumed that metals were recycled in the UK. (4) WEEE ending up in general waste were mostly small appliances. Their main components were metals and plastics which are difficult to separate, and were therefore assumed to be landfilled by Manns Waste Management. The author assumed that from all the small electronics in general waste, 25% was ferrous metal and 75% was ABS/other plastics. The high plastic content is the reason it was not sent to AMR.

Ferrous metals

Ferrous metals are metals containing iron. This type of metal is incorporated in several products, and is the third biggest stream collected by Enviro Waste. For the sorted ferrous metals, the national average treatment rates are assumed for Enviro Waste, due to confidentiality reasons from AMR. These treatment rates are 99.7% recycling, and 0.3% landfill (DECC & DEFRA, 2016). As the metal in general waste is incorporated in complex products containing several metals, it is assumed it is landfilled in both the reference scenario as the National Average scenario. The ferrous metals recovered from incineration are considered to be down cycled, as the quick heating and cooling down cause cracks, resulting in a 16% material loss (Corsten et al., 2013).

Non-ferrous metals

Non ferrous metals are metals that do not contain iron. The main non-ferrous streams collected by Enviro Waste were copper, bronze and brass, and aluminium. Other streams, including printed circuit board, lead, zinc, were not considered in this analysis, as they represent a small fraction of the total waste collected, and sufficient data was unavailable on their treatment routes.

Aluminium

On national level, 99.92% of collected aluminium was recycled, of which 0.08% was send to landfill (DECC&DEFRA, 2016). These treatment rates were also used for the reference scenario. As Pulse Environmental sent secure destructed products for energy recovery, Cory Environmental recovers metals after this process. This is also assumed for national average. When aluminium is incinerated, a separation efficiency of 20% is considered (Corsten et al., 2013).

Copper

It is assumed that all the cables collected by Enviro Waste comprise of 66% copper in terms of weight (Turner et al., 2015). The separate collected copper is assumed to have the same treatment rates as on national level, being 99.92% recycling and 0.08% send to landfill (DECC&DEFRA, 2016). When copper is incinerated, a separation efficiency of 20% is considered (Corsten et al., 2013).

3. Gypsum

Gypsum is an addition to the *i*Waste model, and the stream is fourth biggest stream collected by Enviro Waste. Moreover, gypsum is a widely used material in construction, especially in the United Kingdom, (Rivero et al., 2016; GPDA, 2015). To include this stream, data on energy consumption and CO_2 emissions for the treatment processes were required, but also data on the avoided energy and CO_2 emissions. Data on the avoided energy and CO_2 emissions were derived from the supplementary data of Rivero's publication (2016). The energy consumption and CO_2 emissions for recycling plasterboard was derived from Turner et al. (2015). In this process, the paper wrapped around the gypsum is assumed to be recycled when sent to a plasterboard recycling facility (Rivero et al., 2016). Consequently, the treatment of plasterboard impacts the paper and cardboard avoided energy and CO_2 emissions.

In 2003, Council Decision decided that 'non-hazardous gypsum based materials should be disposed of only in landfills for non-hazardous waste, in cells where no biodegradable waste is accepted'. This is due to potential hydrogen sulphide (H_2S) formation, which is an extremely hazardous gas (EA, 2011). Therefore, gypsum based materials received to be disposed of in mono-cell landfills, but this is only done to a limited extent. First of all, manual sorting lacks the thoroughness to separate 100% of plasterboard from general waste. Second of all, plasterboard is sometimes seen as wood, therefore wood processing facilities receive plasterboard as well, as confirmed by Connect Waste management and the EA (2015). Consequently, it is unknown how much gypsum waste is treated within general waste on national level. This is also the case for Envrio Waste.

Considering Enviro Waste, plasterboard is mixed with general waste. Due to a lack of transparency from Manns Waste Management, educated guesses were made about the treatment of plasterboard. It is assumed that plasterboard is manually sorted from the general waste with a sorting efficiency of 60%. This is assumed, as relative big pieces can be extracted from the general waste in the same way as with wood. It is assumed that only manual sorting of plasterboard takes places and that the plasterboard that is not separated, is being landfilled (40%). Part of the collected plasterboard was directly sent to a transfer station after separate collection. For this fraction, it is assumed that 100% of the plasterboard is recycled.

As no specific information is available on the overall treatment rates of plasterboard in the UK, the rates for mineral waste from construction and demolition are used (DECC & DEFRA, 2016). This waste stream also includes concrete, bricks etc., as they also contain minerals, however, this is the best available data. The treatment rates are 95.2% recycling and 4.8% landfill (DECC & DEFRA, 2016).

4. Wood

From all the waste collected by Enviro Waste in one year, wood was the biggest stream, covering 24% of the total collected waste. All the wood was stacked in a roll-on-roll-off and sent to Connect Waste Management for treatment. Connect Waste Management categorized everything as C-grade waste, as different grades are not separated at the yard due to space limitations. According to Connect Waste Management, the load is separated according to grades. For th enalaysis, the overall composition of the wood collected by Connect Waste management is assumed, being 40% of A grade waste, and 60% B/C grade wood, as confirmed over the phone. The treatment of wood depends greatly on its grade, however, for this analysis, it is assumed that the grade mix from Enviro Waste is representative for the national wood grade mix. For Enviro Waste, the wood that is still in the general waste is assumed to be sent to landfill.

It should be noted, however, that wood is also treated outside the UK, and the wood mix on national level can differ from the wood composition of Connect Waste Management. For example, in 2015, Connect Waste Management sent 84.6% of the treated wood waste outside the UK (Environmental Agency, 2015). Due to limited data availability on these matters, this approach is chosen.

5. Glass

Glass collected by Enviro Waste is mixed with general waste, or comes from display equipment. For glass in general waste, it is assumed that glass is not separated by Manns Waste Management[2] (EA, 2015), and therefore ends up in landfill. The glass in general waste is assumed to be recycled for 36.4% on national level, and the rest was being landfilled (FEVE, 2010, derived from Lets Recycle, 2012). This rate was the best available data, as only recycling rates of separate collected glass is provided on a yearly basis (DEFRA, 2016b). Moreover, in this analysis, down cycling of glass is not considered, while 24.3% of glass is used as aggregate in the UK.

Glass from CRTSs as display equipment contain lead, and therefore has to be dealt with in a special manner. Enviro Waste sent their display equipment for recycling to Environcom[3] in Grantham, where after it is sent to their CRT recycling facility in Wales. In the recycling process, attempts are made to separate the lead from the glass, where the CRT glass contains on average 20% lead and 80% glass. As lead is not taken into consideration in this analysis, it will

[2] http://www.mannswaste.co.uk/
[3] http://www.environcom.co.uk/

not be accounted for. CRTs are considered hazardous waste, the disposal of it is strictly coordinated by the Environmental Agency. It is therefore assumed that all the glass from CRTs is recycled in the UK.

6. Hardcore

The hardcore waste considered in this analysis included dirt, sand and soil, concrete, bricks, ceramics, rock and gravel, other aggregates. Enviro Waste seperates part of this stream, especially the bulky heavy hardcore. On the other hand, soil and sand was mainly mixed in the general waste. It is assumed that the hardcore treated by Sharp Skips[4] was partly crushed and recycled, while the soil in the general waste was separated with machinery and partly recycled by Manns Waste Management. On national level, the soil treatment rates were considered (DECC & DEFRA, 2016).

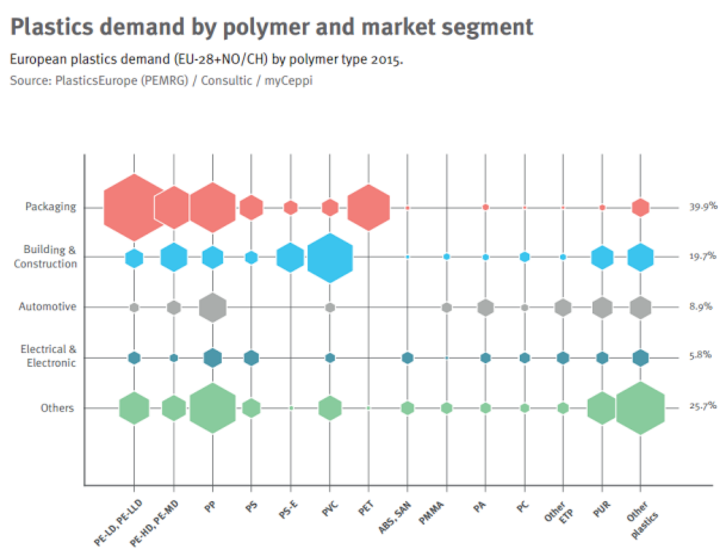
7. Organic waste

All organic waste is all disposed of in the general waste skipwas mixed in the general waste, and is assumed to have been sent to landfill by Manns Waste Management. On national level, the composting and anaerobic digestion industries are increasingly providing solutions for green waste management (WRAP, 2015). In 2014, 5.9 Mton of waste was composted, while 5.3 Mton was used in AD facilities (WRAP, 2015). Therefore, it is assumed that approximately 25% of organic waste is composted, 25% is digested, and the rest is tipped in landfill.

8. Plastics

The variation in types of plastic and its application in multiple products makes it difficult to be separated and treated. According to Plastics Europe (2016), the building and construction industry covers 19.7% of plastic demand in Europe, with PVC being the largest type of plastic used, see **Figure 12** (Plastics Europe, 2016). Based on the plastic demand in the building and construction industry, the composition of the type of plastics in the general waste stream of Enviro waste, see **Table 21**.

Figure 19: Plastics demand by polymer and market segment (Plastics Europe, 2016)



[4] http://www.sharpskips.co.uk/

Table 19: Composition of plastics in general waste based on the applications percentages in the construction industry (derived from PlasticEurope (2016))

Type of plastic	**Application in construction industry/ composition in general waste of Enviro Waste**
PVC	50%
PE	20%
PS	15%
PP	10%
PET	0%
ABS	5%

It should be noted that in the plastic stream of this research, only thermoplastics were considered (Plastics Europe, 2016). The thermosets, e.g. polyurethane and polyester, are considered within the textiles stream. For all plastics mixed in the general waste, the treatment rates on national level were derived from PlasticEurope (2016), being 28% recycling, 31% energy recovery, and 41% going to landfill. As data was not found on what type of recycling takes place, it is assumed that 50% was high value recycling, while the other 50% was down cycling. For the plastics in the Circular Principles scenario, it is assumed that it is not possible to separate the plastics from the yard in the near future. This is mainly due to the variety of plastic types collected, the difficulty to collect large volumes of one specific type of plastic, and the time it will take to physically separate it. Moreover, from this model, down cycling requires more energy than the production of wooden poles, resulting in net emitted CO_2 instead of avoidance. Hence, this scenario stimulates the use energy recovery from plastics with incineration. The only streams that has the potential to be recycled are PVC and PE, as the technology exists to separate these streams.

More specific assumptions were made related plastics in cables and WEEE. Cables were considered to consist of 66% copper, and 34% PVC (Turner et al., 2015; BPF, 2017). The PVC from cables were considered to be recycled by AMR and Environcom. The plastics from cooling appliances were assumed to be 50% ABS and 50% PP (Wäger, 2009), while the small electronic devices mixed in general wastealso tipped was assumed to comprise of 75% ABS and 25% ferrous metals (Wäger, 2009). For display equipment, the plastics were considered to be ABS too (Wäger, 2009). Lastly, snsulation material was considered to comprise of EPS and was taken into account in the PS stream (Turner et al., 2015).

9. Textiles

In this scenario analysis, textiles are considered coming from three different sources: carpet (tiles) and fabrics, mattresses and furniture. These streams are mainly treated by Hinkcroft[5].

9.1 Carpet (tiles) & fabrics

The carpet and fabric waste stream is a difficult stream to recycle, due to its contamination rate with direct and chemicals of 30% in terms of weight (Turner et al., 2015). Since 2007, the NGO Carpet Recycling UK was created to stimulate the recycling of carpets in the UK (Goulding, 2016). Ever since, they managed to realize a carpet recycling rate of 10.9%, while 20.1% was used as Carpet Derived Fuel (CDF) in cement kilns, while the rest was sent to landfill (69%). Nowadays, Carpet Recycling UK distinguishes 20 facilities that contribute to the treatment of carpets. Based on the database provided by the Environmental Agency, it is assumed that 18% is used in the production of RDF, while the rest was sent to landfill.

9.2 Mattresses

Enviro Waste sent their mattresses to Hinkcroft, who in turn sent them to the recycling facility Matt UK[6]. From e-mail conversations, it was stated that 7% is sent for RDF, and the rest is dismantled and separated in the different materials. No information was provided about contamination rates of these materials and possible rejects. Therefore, the data from Turner et al. (2015) is used, assuming material loss of 20% for the textiles, which are assumed to be landfilled. This results in a recycling rate of 74.4% and landfill rate of 18.6% of all the mattresses collected by Enviro Waste. On a national level, mattresses are still being sent to landfill in most cases, especially because of a lack of mattress recycling facilities (Oakdene Hollins, 2016). Based on a research conducted on mattress recycling in the UK, data of 2014 shows a recycling rate of 16%, 11% energy recovery, and a landfill rate of 73% (ibid.).

Wiping cloth production is 40% cotton and 60% artificial textile. It is assumed that they substitute for paper wipers and primary PP respectively. The mattress filling fibre substitute primary PUR foam, with a substitution factor of 1 to 67.

9.3 Furniture

Several types of furniture are collected by Enviro Waste, of which as much as possible is being refurbished and resold through the REC Products network. For the explanation on the refurbishment of furniture, see section 13. This choice is based on the contamination rate and the expected remaining economic value of the furniture.

Furniture can contain different materials. Steel cabinets were send to AMR after dismantling, and are not included in this stream. This also counts for solely wooden furniture that goes directly to Connect Waste Management. The rest of the items were sent to Hinkcroft. For the recycling of furniture, a combination of the composition of a sofa and an

[5] http://www.hinkcroft.co.uk/
[6] http://www.matt-uk.co.uk/

office chair is considered in this analysis, see **Table 22** (Oakdene Hollins, 2013). For the recycling of furniture, four types of materials were considered: steel, wood, plastics and textiles. While the textiles are considered in the textile sheets, the wood, plastics and steel are considered respectively in the like-named stream (for plastics ABS). It is assumed that 18% is used for RDF (EA, 2015), and the rest is landfilled. This is also the case for wood and plastics, however, the steel is considered to be fully recycled due to its monetary value.

Table 20: Weight percentages furniture (derived from Oakdene Hollins, 2013)

Composition furniture	Weight(%)
Steel	28%
Wood	42%
PUR foam	7%
Textile	5%
Plastics	20%
	100%
Source: Oakdene Hollins (2013) p. 138, based on office chairs and sofas	

10. Products - WEEE

Waste of Electronic and Electric Equipment (WEEE) is defined as "an electrically powered appliance that no longer satisfies the current owner for its original purpose" (Buekens & Yang, 2014). The first four WEEE categories set up in the EU directive account for almost 95% in terms of weight of the overall WEEE (Buekens & Yang, 2014, p. 416). Eurostat provides data on the re-use, recycling and other treatment rates of WEEE products for coutnries in Europe, distinguishing ten separate categories, see **Table 23**. The recovery rate includes both energy recovery and recycling. It is therefore assumed that from the overall recovery 70% is energy recovery and 30% recycling of separate materials, except for display equipment (100% aimed to be recycled due to its status as hazardous waste).

These data suggest that on national level, more is being recycled rather than refurbished, which results in higher avoided emissions for specific waste streams, but this is straightened in the product streams. In the WEEE categories, the energy and emissions from products that are landfilled as a whole are considered in this part, not under the several other materials.

Table 21: Waste electrical and electronic equipment (WEEE) by waste operations in 2014 (derived from Eurostat (2015))

WEEE categories	Reuse	Recovery	Landfill
Large household appliances	3.8%	88.3%	7.9%
Small household appliances	0.7%	88.3%	11.0%
IT & Telecommunication	7.9%	85.8%	6.3%
Consumer equipment	7.0%	86.9%	6.2%
Lighting equipment	0.0%	78.5%	21.4%
Gas discharge lamps	0.0%	0.0%	100.0%
Electrical and electronic goods	0.7%	88.0%	11.3%
Toys	2.0%	85.6%	12.4%
Medical devices	1.6%	85.2%	13.2%
Monitoring and control instruments	0.0%	84.2%	15.8%
Automatic dispensers	0.0%	89.7%	10.3%

10.1 Display Equipment

The display equipment considered in this analysis are (computer) monitors, CRTs and flat screens. CRTs and some flat screens are sent for recycling to Environcom. The treatment rates from *large household appliances* from Eurostat were considered, see **Table 23**. The overall composition of display equipment can be found in **Table 24.** The components marked in pink are not considered in the analysis, as they are not covered in the other analysed streams.

Table 22: Display equipment composition (derived from Turner et al. (2015))

Composition CRT	Weight (%)
Steel	18.8%
Aluminium	2.0%
Copper	0.3%
Other metals	0.9%
Plastics (ABS)	16.4%
Cable	2.3%
PWB (printed wiring board)	4.7%
CRT glass	53.4%
Other	1.3%
	100%

10.2 Cooling appliances

At Enviro Waste, cooling appliances were either prepared for re-use, or sent to Environcom for recycling, respectively for 27% and 73%. On national level, the treatment rates from *large household appliances* from Eurostat were considered, see **Table 23.** The overall composition of cooling appliances with weight percentages are given in **Table 25**. (Eco3e, 2016; Horie, 2004). The energy consumption for the manufacturing process of cooling appliances are came down to 5940 MJ for an 80.85 kg-fridge (Horie, 2004, p. 20; p.45), resulting in an energy consumption of 73.5 GJ/ton cooling appliances. However, no details were provided on the actual CO_2 emissions related to this specific energy consumption. This is also highly dependent on factors, e.g. production country, type of fridge etc. Therefore, the avoided CO_2 emissions from cooling appliances were derived from the UK Government Conversion Factors for

Company Reporting (DECC & DEFRA, 2016). The energy consumption for refurbishment of cooling appliances were based on data from Environcom.

Table 23: Weight percentages of cooling appliances (derived from Horie (2004))

Composition cooling appliances	Weights
Steel	62%
Copper	3%
Aluminum	3%
Glass	4%
Plastics	21%
ABS	11%
PP	11%
PUR foam	7%
Others	1%
	100%

10.3 IT & Telecommunication

In total, 24 ton of this category was prepared for re-use. Another 4 ton was shredded for secure destruction. This comes down to a total collection of 28 ton of this stream. On national level, the treatment rates from *IT and Telecommunication* from Eurostat were considered, see **Table 23.** The avoided energy and emissions are first of all derived from UK Government Conversion Factors for Company Reporting (2016). The average weight of the IT products can be seen in **Table 26**.

Table 24: Weight percentages IT & Telecommunication

Composition IT &Telecommunication	Percentage
Steel	50%
Plastic	34%
Aluminium	8%
Copper	8%

11. Products – Furniture

In total, 20.4 ton of furniture was resold in 2015/2016 by Enviro Waste. Various types of furniture were re-used, e.g. office chairs, tables, desks, couches, containing several different materials. For this analysis, the re-use of furniture avoids the production of new furniture. Consequently, a mix of different items were considered in the avoided energy and CO_2 emissions. The substituted furniture was for 33% based on a chair, for 33% based on two types of tables, and for 33% based on a steel frame cabinet, See **Table 27**.

Table 25: Substituted furniture (derived from Spitzley et al. (2006); Dhingra and Gavrish (2016))

Siento Chair		
Weight (ton)	0.03	
	46.0	GJ/ton furniture
	114	kgCO2/ton furniture
Substitution	33%	
AirTouch table		
Weight (ton)	0.05	
	62.5	GJ/ton furniture
	220	kgCO2/ton furniture
Substitution	17%	
Garland desk		
Weight (ton)	0.12	
	28.3	GJ/ton furniture
	218	kgCO2/ton furniture
Substitution	17%	
Sofa		
Weight (ton)	0.06	
	7.0	GJ/ton furniture
	1651	kgCO2/ton furniture
Substitution	33%	

Appendix C: Definitions high value recycling and down cycling per stream

Table 26: Definitions high value recycling and down cycling per stream

Material	Substituted product	High value recycling	Substituted material	Downcycling	Substituted material
Paper&Cardboard		De-inked paper	*Paper from wood*	Inked paper	*Paper from wood*
Wood		Chipboard	*Primary chipboard production*	High efficiency energy recovery	*Conventional electricity production*
Plastic - PE		PE	*1 on 1 primary PE*	Production marker post	*Wooden pole*
Plastic - PP		PP	*1 on 1 primary PP*	Production marker post	*Wooden pole*
Plastic - PS		PS	*1 on 1 primary PS*	Production marker post	*Wooden pole*
Plastic - PVC		PVC	*1 on 1 primary PVC*	Production marker post	*Wooden pole*
Plastic - other		ABS	*1 on 1 primary ABS*	Production marker post	*Wooden pole*
Hardcore		Production recycled sand	*Shingle/sand and cement in concrete*	Production recycled sand	*Shingle/sand*
Glass		Use glass shard for glassproduction	*Primary glass*	-	-
Aluminium		Aluminium	*Primary aluminium*	-	-
Ferrous metals		Steel	*Primary steel*	Steel manufacturing with 16% loss	*Primary steel*
Copper		Copper	*Primary copper*	-	-
Gypsum		Gypsum	*Primary gypsum*	-	-
Textile					
Carpet and fabrics		Equestrian surfacing	*Primary PE*	-	-
Mattress		Wiping cloths	*40% paper wiping cloth, 60% artificial wiping cloth*	Mattress filling fibre	*Primary production PUR foam (substitution factor 1/67)*
Furniture		Wiping cloths	*40% paper wiping cloth, 60% artificial wiping cloth*	Mattress filling fibre	*Primary production PUR foam (substitution factor 1/67)*
Display equipment	*Flatscreen*		*Plastics, metals, glass*		
Cooling appliances	*Domestic fridge*		*Plastics, metals, PUR foam, glass*		
IT & telecommunication	*Small WEEE*		*Platsics, metals*		
Furniture	*33% chair, 33% wooden and metal table, 33% sofa*		*Metals, wood, PUR foam, plastics, textile*		

Appendix D: References per scenario per stream

Table 27: Sources used for treatment rates determination per scenario

Material/ product	Specification	Source for Enviro Waste	Source for National Average
Paper & Cardboard	In general waste	Same as national average (household rates)	DEFRA (2016). UK statistics on Waste[7]. Household treatment rates.
Ferrous metals	Sorted and in general waste	Authors' assumptions based on contact with AMR	DEFRA (2016). UK statistics on Waste. Ferrous metals waste treatment rates
Aluminium	Sorted	Authors' assumptions based on contact with AMR	DEFRA (2016). UK statistics on Waste. Aluminium waste treatment rates.
Copper	Sorted	Authors' assumptions based on contact with AMR	DEFRA (2016). UK statistics on Waste. Copper waste treatment rates.
Gypsum	Sorted and in general waste	Authors' assumptions based on contact with Manns Waste Management	DEFRA (2016). UK statistics on Waste. Mineral waste treatment rates.
Wood	Sorted and in general waste	Authors' assumptions based on contact with Connect Waste Management	DEFRA (2016). UK statistics on Waste. Wood waste treatment rates.
Glass	General waste	EA (2015) Waste Data Interrogator[8] - Manns Waste Management	FEVE (2010) derived from Lets Recycle (2012)
Hardcore	General and sorted	Sharp Skips information on website	DEFRA (2016). UK statistics on Waste. Soil waste treatment rates.
Organic waste	General waste	EA (2015) Waste Data Interrogator - Manns Waste	WRAP (2015). Organic recycling industry status

[7] https://www.gov.uk/government/statistical-data-sets/env23-uk-waste-data-and-management
[8] https://data.gov.uk/dataset/waste-data-interrogator-2015

		Management	
Plastics	General waste	EA (2015) Waste Data Interrogator - Manns Waste Management	PlasticEurope (2016). An analysis of European plastics production, demand and waste data
Textile – carpet&fabrics	General waste	EA (2015) Waste Data Interrogator - Hinkcroft	http://www.letsrecycle.com/news/latest-news/carpet-and-mattress-recycling-poses-significant-challenge/
Textile - mattresses	General waste	Matt Recycling UK	Oakdene Hollins (2016) End of Life Mattress report 2016.
Textile - furniture	General waste	EA (2015) Waste Data Interrogator - Hinkcroft	See furniture
Display Equipment		Enviro Waste data	Eurostat (2015). Represents 2014, Large Household appliances
Cooling appliances		Enviro Waste data	Eurostat (2015). Represents 2014, Large Household appliances
IT & Telecommunication		Enviro Waste data	Eurostat (2015). Represents 2014, IT & Telecommunication
Furniture		Enviro Waste data	Oakdene Hollins (2013). Furniture mass and product flow data to inform re-use market development in the UK.

Appendix E: Treatment rates per stream per scenario[9]

Paper and cardboard	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 45% send with general waste, of which 6.6% is recycled A, and the rest going to landfill. • 55% sorted and sent for recycling A • Rejects 11.9% go to cement plant	• 45% send with general waste, of which 6.6% is recycled A, 47% going to incineration, and 47% going to landfill. • 55% sorted and sent for recycling A. • Rejects 11.9% go to cement plant	• 25% send with general waste, of which 6.6% is recycled A, and the rest going to landfill. • 75% sorted and send for recycling A • Rejects 11.9% go to cement plant
Plasterboard	• 97% in general waste, of which 60% is sorted and recycled • 3% separate collected, 100% recycled	• 97% in general waste, of which 95% is recycled. • 3% separate collected, 100% recycled	• 50% of plasterboard in general waste, of which 60% is sorted and recycled • 50% separated, 100% recycled
Ferrous metals	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 100% to landfill	• 100% to landfill	
Sorted	• 99.7% recycled, rest goes to landfill	• 99.7% recycled, rest goes to landfill	
IT& Telecommunication	• 100% recycling B after incineration	• 93% recycling A, 7% going to landfill	
Furniture	• 100% separation to recycling A	• 49% recycling A, 26% recycling B after incineration, 25% to landfill	• 50% recycling A, 25% recycling B after incineration, 25% to landfill
Mattresses	• 74.4% to recycling A, 7% recycling B after incineration, 18.6% landfill	• 16% recycling A, 11% recycling B after incineration, 73% to landfill	
Display Equipment	• 99.7% recycled, rest goes to landfill	• 28% recycling A, 64% recycling B after incineration, 8% to landfill	
Cooling appliances	• 99.7% recycled, rest goes to landfill	• 28% recycling A, 64% recycling B after incineration, 8% to landfill	
Aluminium	**Enviro Waste**	**National Average**	**Circular Principles**
Sorted	• 99.9% recycled, rest goes to landfill	• 99.9% recycled, rest goes to landfill	
IT& Telecommunication	• 20% separation efficiency after incineration going to recycling A, rest to landfill	• 20% separation efficiency after incineration going to recycling A, rest to landfill	• 100% separation to recycling A, no incineration
Display Equipment	• 99.7% recycled, rest goes to landfill	• 28% recycling A, 64% also recycling A after incineration, with 20% separation efficiency, rest goes to landfill	
Cooling appliances	• 99.7% recycled, rest goes to landfill	• 28% recycling A, 64% also recycling A after incineration, with 20% separation efficiency, rest goes to landfill	

[9] Note: Recycling A is high value recycling, and recycling B is down cycling.

Copper	Enviro Waste	National Average	Circular Principles
Sorted	• 99.9% recycled, rest goes to landfill	• 99.9% recycled, rest goes to landfill	
IT& Telecommunication	• 20% separation efficiency after incineration going to recycling A, rest to landfill	• 20% separation efficiency after incineration going to recycling A, rest to landfill	• 100% separation to recycling A, no incineration
Cables	• 100% separation to recycling A	• 49% recycling A, 26% also recycling A after incineration, with 20% separation efficiency, rest goes to landfill	
Display Equipment	• 99.7% recycled, rest goes to landfill	• 28% recycling A, 64% also recycling A after incineration, with 20% separation efficiency, rest goes to landfill	
Cooling appliances	• 99.7% recycled, rest goes to landfill	• 28% recycling A, 64% also recycling A after incineration, with 20% separation efficiency, rest goes to landfill	
Gypsum	**Enviro Waste**	**National Average**	**Circular Principles**
Plasterboard general	• 100% to sorting company, 60% sorted and recycled, rest to landfill	• 95.24% recycled, rest to landfill	• 50% to sorting company, 60% sorted and recycled, rest to landfill
Plasterboard sorted	• 100% recycled	• 100% recycled	• 50% of plasterboard sorted at Enviro Waste 50% separated, 100% recycled
Wood	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 60% sorting efficiency, of which 40% will be send for recycling A, 30% to recycling B, 29% to incineration and the rest to landfill. The other 40% that is not sorted will be send to landfill.	• 60% sorting efficiency, of which 80% will be send for recycling A, 12% to recycling B, 6% to incineration and the rest to landfill. The other 40% that is not sorted will be send to landfill.	• 80% sorting efficiency, of which 40% will be send for recycling A, 30% to recycling B, 29% to incineration and the rest to landfill.
Sorted	• 40% will be send for recycling A, 30% to recycling B, 29% to incineration and the rest to landfill.	• 80% will be send for recycling A, 12% to recycling B, 6% to incineration and the rest to landfill. The other 40% that is not sorted will be send to landfill.	
Mattresses	• 74.4% was send for recycling A, and the rest is sent to landfill	• 16% will be send for recycling B, 11% for incineration, rest goes to landfill	
Furniture	• 18% used for RDF in cement kiln, the rest is sent to landfill	• 49% recycling B, 26% cement plant, 25% to landfill	50% recycling A, 25% incineration, 25% to landfill

Glass	Enviro Waste	National Average	Circular Principles
General	• Everything is crushed and sent to landfill	• 36.4% recycling A, rest send to landfill	
Cooling appliances	• 100% recycled	• 28% recycling A, 64% ends up in incineration, rest goes to landfill	
Display Equipment	• 100% recycled	• 28% recycling A, 64% ends up in incineration, rest goes to landfill	
Hardcore	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 49.9% recycling A, 20.5% recycling B, rest to landfill	• 18% recycling A, 39% recycling B, rest to landfill	
Sorted	• 49.9% recycling A, 20.5% recycling B, rest to landfill	• 18% recycling A, 39% recycling B, rest to landfill	
Organic waste	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 100% to landfill	• 25% recycling A, 25% recycling B, 50 landfill	
PVC	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 100% sent to landfill	• 14% recycling A, 14% recycling B, 31% incineration, and rest to landfill	• To separator, with MRF efficiency of 85% separation efficiency and 90% purity. Separated plastic goes for 50% to recycling A and 50% recycling B. Rest goes to landfill
Cables	• 100% recycling A	• 14% recycling A, 14% recycling B, 31% incineration, and rest to landfill	•
PE	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 100% sent to landfill	• 14% recycling A, 14% recycling B, 31% incineration, and rest to landfill	• To separator, with MRF efficiency of 75% separation efficiency and 85% purity. Separated plastic goes for 50% to recycling A and 50% recycling B. Rest goes to landfill
PS	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 100% sent to landfill	• 14% recycling A, 14% recycling B, 31% incineration, and rest to landfill	• 100% incineration
PP	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 100% sent to landfill	• 14% recycling A, 14% recycling B, 31% incineration, and rest to landfill	• 100% incineration
Cooling appliances	• 100% recycling A	• 28% recycling A, 64% ends up in incineration, rest goes to landfill	

ABS/other	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 100% sent to landfill	• 14% recycling A, 14% recycling B, 31% incineration, and rest to landfill	• 100% incineration
Cooling appliances	• 50% recycling A, 50% recycling B	• 14% recycling A, 14% recycling B, 64% incineration, and rest to landfill	
Display Equipment	• 50% recycling A, 50% recycling B	• 14% recycling A, 14% recycling B, 64% incineration, and rest to landfill	
IT& Telecommunication	• 100% incinerated	• 14% recycling A, 14% recycling B, 65% incineration, and rest to landfill	
Furniture	• 18% used for RDF in cement kiln, the rest is sent to landfill	• 49% recycling B, 26% cement plant, 25% to landfill	
Textile from carpets and fabrics	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 18% used for RDF in cement kiln, the rest is sent to landfill	• 10.85% recycling A, 20.15% energy recovery, rest to landfill	• 100% to cement kiln minus the contamination, that goes to landfill
Textile from mattresses	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 74.4% recycled, of which 70% recycling A and 30% recycling B. 7% is for energy recovery, and the rest is send to landfill	• 16% recycled, of which 70% recycling A and 30% recycling B. 11% is for energy recovery, and the rest is send to landfill	
Textile from furniture	**Enviro Waste**	**National Average**	**Circular Principles**
General	• 18% used for RDF in cement kiln, the rest is sent to landfill	• 49% recycling A, 26% recycling B after incineration, 25% to landfill	• 50% recycling A, 25% incineration, 25% to landfill
Display Equipment	**Enviro Waste**	**National Average**	**Circular Principles**
	• 39% refurbished, 61% send for disposal (see the disposal of individual materials above)	• 4% refurbished, 88% send for recovery purposes (see the disposal of individual materials above), and 8% send to landfill directly	
Display Equipment	**Enviro Waste**	**National Average**	**Circular Principles**
	• 39% refurbished, 61% send for disposal (see the disposal of individual materials above)	• 4% refurbished, 88% send for recovery purposes (see the disposal of individual materials above), and 8% send to landfill directly	
Cooling appliances	**Enviro Waste**	**National Average**	**Circular Principles**
	• 27% refurbished, 73% send for disposal (see the disposal of individual materials above)	• 4% refurbished, 88% send for recovery purpose (see the disposal of individual materials above), and 8% send to landfill directly	

IT & Telecommunication	Enviro Waste	National Average	Circular Principles
	• 87% refurbished, 13% send for incineration (see the disposal of individual materials above)	• 8% refurbished, 86% send for recovery purpose (see the disposal of individual materials above), and 6% send to landfill directly	
Furniture	**Enviro Waste**	**National Average**	**Circular Principles**
	• 27% refurbished, 73% send for incineration (see the disposal of individual materials above)	• 8% refurbished, 45% send for recovery purpose (see the disposal of individual materials above), 24% energy recovery, and 23% send to landfill directly	

Appendix F: Questionnaire

<u>Questions</u>

1. How important is being environmentally friendly in your life?
2. How would you rate Enviro Waste in their environmental performance?
3. Do you think Enviro Waste can do more to become environmentally friendly?

The following questions will be ONLY about our direct jobs. This questionnaire is related to ADDITIONAL environmental initiatives for Enviro Waste. These include

- More separation of waste in the yard
- Partnering with more environmentally friendly organisations
- Encouraging more separation from customers
- Finding alternative usages/destinations for specific waste streams
- Directly delivering sorted stream to manufacturers

The questionnaire is divided in SIX CATEGORIES that can all influence the implementation of these initiatives.

1 - Social challenges

4. *The public pressure for waste management companies to implement environmental initiatives is high*
5. *Recycling and/or reusing waste is considered important in the UK*
6. *There is a high demand for waste management companies with exceptional environmental initiatives*

2A - Organisational challenges - Management and partners

7. *The environmental awareness of the directors is high*
8. *The department managers are committed to change in order for Enviro Waste to become more environmentally friendly*
9. *Partnership with waste processors are primarily focused on environment considerations*

10. *There is a sufficient number of environmentally friendly waste processors Enviro Waste can partner with to realize environmental initiatives*

2B - Organisational challenges - Vision and mission

11. *At Enviro Waste, there is a high focus on corporate image and social responsibility*
12. *Internal environmental initiatives and goals support our vision and corporate values*

2C - Organisational challenges - Employees

13. *Employee attitudes towards environmental initiatives is positive*
14. *Employees are highly motivated to contribute to environmental initiatives*
15. *There is enough staff available to implement environmental initiatives*

3 - Information challenges

16. *I understand that environmental initiatives can result in the growth of Enviro Waste*
17. *There is sufficient information to do my job when changes are implemented at Enviro Waste*

4 - Legal challenges

18. *Future legislation (for example with Brexit) forms risks for Enviro Waste**
19. *Regulation makes it difficult to implement environmental initiatives**

5 - Technological challenges

20. *I believe that Enviro Waste is active in finding technologies that can benefit environmental initiatives*
21. *I think that there is new technology and equipment that Enviro Waste can use for the implementation of environmental initiatives*

22. *Technical knowledge from our employees to implement environmental initiatives is sufficient*
23. *In general, employees from Enviro Waste are open towards innovation and technological change*

6 - Economic challenges

24. *Enviro Waste has sufficient financial capabilities for investment in environmental initiatives*
25. *Partnering with more environmentally friendly waste handlers to treat our waste means higher costs**
26. *I believe that it takes a long time for environmental initiatives to show benefits for Enviro Waste**

27. *Can you rank the biggest challenge (1) to the smallest challenge (6) for the implementation of environmental initiatives?*

Organisational challenge	management, partners, vision and culture, and employees
Technological challenge	knowledge, know-how, availability
Economic challenge	high investments, insufficient capabilities
Legal challenge	future legislation changes
Informational challenge	knowledge of the benefits
Social challenge	market preference and demand

28. *When did you start working for Enviro Waste?*
29. *What part of the company do you work for?*

Table 28: Calculated significance for the variables between the different departments

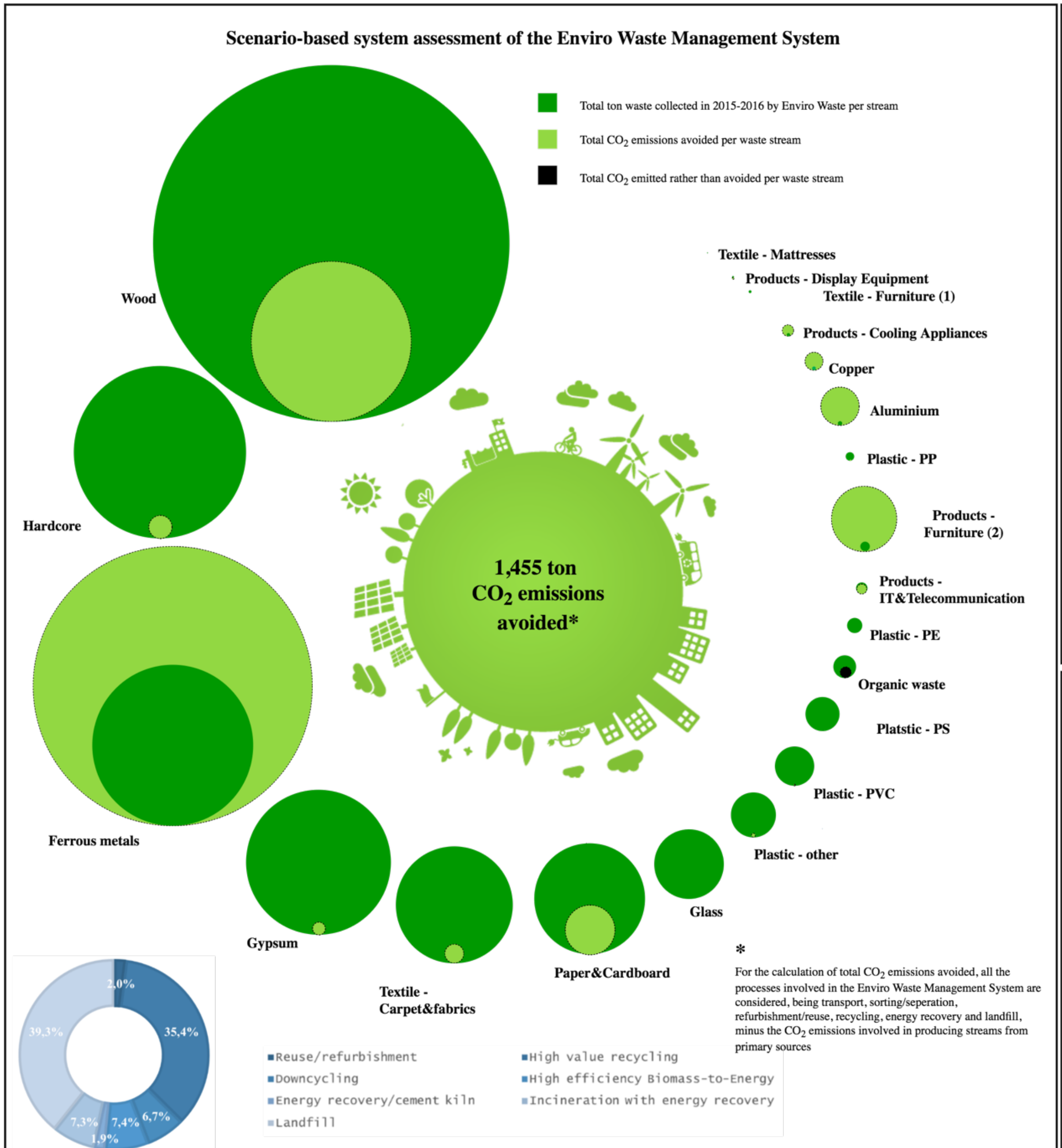
Variable	Significance	Difference
Social	0.389	Not significant
Organisational	0.498	Not significant
Informational	0.026	Significant
Legal	0.325	Not significant
Technical	0.799	Not significant
Economic	0.258	Not significant

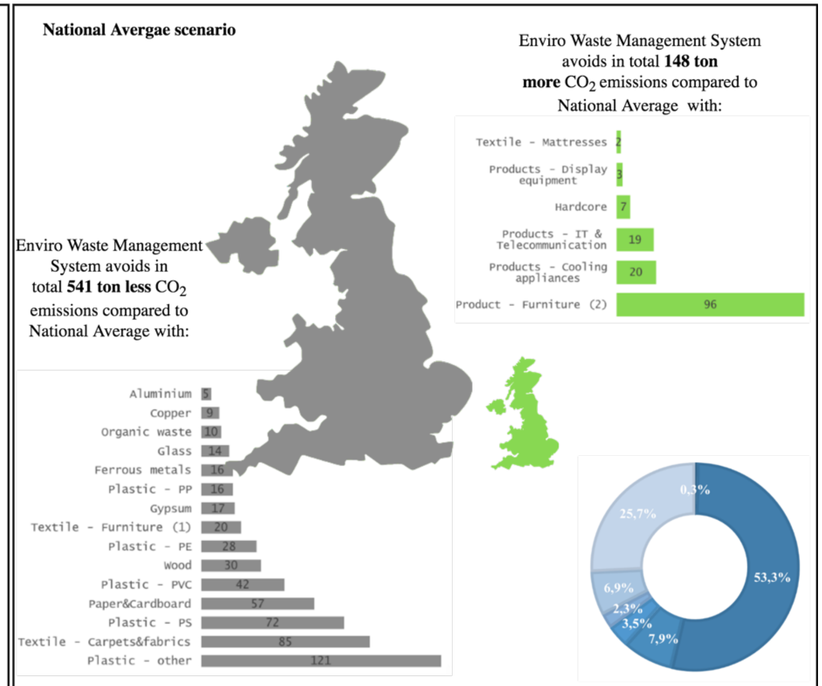
Table 29: The mean, standard deviation and significance per sub barrier category

		Social barriers			Organisational barriers										
At what part of the company do you work?		Low public pressure	Lack of awereness	Lack of market preference and demand	Limited environmental awereness directors - James	Limited environmental awereness directors - Eli	Limited environmental awereness directors - Marc	Limited top management commitment and support for sustainability initiatives	Poor partnership formation and management	Limited development of the environmental supply sector	Lack of focus on corporate image and social responsibility	Unclear/weak strategic and business goals, lack of environmental goals in company vision and corporate values, and misalignment of short- and long-term strategic goals	Negative employee attitudes	Limited environmental motivation and awareness among employees	Lack of human resources and time
	Sig.	*0.605*	*0.321*	*0.698*	*0.444*	*0.004*	*0.307*	*0.081*	*0.100*	*0.134*	*0.005*	*0.003*	*0.271*	*0.623*	*0.238*
REC/IT	Mean	**2.50**	**1.88**	**2.38**	**1.63**	**2.63**	**2.25**	**2.50**	**2.63**	**2.38**	**2.88**	**2.75**	**2.88**	**3.00**	**3.38**
	Std. Deviation	0.756	0.835	0.518	0.744	0.916	1.165	0.756	0.744	0.518	0.641	0.707	0.354	0.535	0.744
Office	Mean	**2.42**	**2.37**	**2.11**	**1.32**	**1.89**	**2.05**	**1.84**	**2.84**	**2.53**	**2.05**	**2.26**	**2.42**	**2.63**	**2.63**
	Std. Deviation	1.261	0.831	0.937	0.582	0.875	1.079	0.688	0.898	0.772	0.705	0.806	0.902	0.761	1.165
Operations	Mean	**2.08**	**2.00**	**2.08**	**1.33**	**1.33**	**1.58**	**1.75**	**2.08**	**1.92**	**1.75**	**1.58**	**2.25**	**2.75**	**2.75**
	Std. Deviation	0.793	0.953	0.793	0.492	0.492	0.793	0.866	1.084	0.996	0.754	0.515	0.965	1.215	0.965
Total	Mean	**2.33**	**2.15**	**2.15**	**1.38**	**1.87**	**1.95**	**1.95**	**2.56**	**2.31**	**2.13**	**2.15**	**2.46**	**2.74**	**2.82**
	Std. Deviation	1.034	0.875	0.812	0.590	0.894	1.025	0.793	0.968	0.832	0.801	0.812	0.854	0.880	1.048

		Informational barriers		Legal barriers		Technological barriers				Economic barriers		
At what part of the company do you work?		Lack of information, e.g., regarding environmental legislation or collection and disposal options	Insufficient technical and environmental training, education and reward systems	Uncertainty regarding future legislation, e.g. Brexit	Difficulties associated with the process of applying/complying with legislation	Trade-offs and difficulties in balancing	Lack or scarcity of advanced technology and equipment with lower-environmental impacts	Technical and detailed knowledge from employees, e.g., waste material awareness	Aversion to innovation and technological change	Limited financial capability for environmental investments	High costs of environmentally firendly waste handlers	High short-term costs and low short-term economic benefits
	Sig.	*0.735*	*0.256*	*0.739*	*0.017*	*0.702*	*0.333*	*0.787*	*0.846*	*0.002*	*0.560*	*0.326*
REC/IT	Mean	**1.63**	**2.50**	**3.63**	**3.13**	**2.75**	**1.75**	**3.13**	**2.25**	**3.38**	**3.38**	**3.50**
	Std. Deviation	0.518	0.926	1.408	0.641	0.707	0.707	0.354	0.463	0.744	0.744	0.535
Office	Mean	**1.63**	**2.37**	**3.32**	**2.53**	**2.53**	**2.11**	**2.89**	**2.11**	**2.58**	**3.58**	**3.37**
	Std. Deviation	0.496	1.065	0.885	0.697	0.841	0.658	0.937	0.459	0.769	0.769	0.684
Operations	Mean	**1.83**	**1.83**	**3.58**	**3.42**	**2.42**	**1.83**	**2.92**	**2.17**	**1.92**	**3.75**	**3.75**
	Std. Deviation	1.115	0.937	1.311	1.084	0.996	0.577	0.793	0.835	0.996	0.754	0.754
Total	Mean	**1.69**	**2.23**	**3.46**	**2.92**	**2.54**	**1.95**	**2.95**	**2.15**	**2.54**	**3.59**	**3.51**
	Std. Deviation	0.731	1.012	1.120	0.900	0.854	0.647	0.793	0.587	0.969	0.751	0.683

Appendix G: Infographics





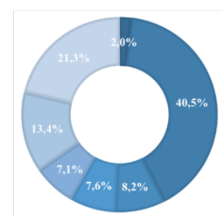
Circular Principles scenario

Opportunities...?

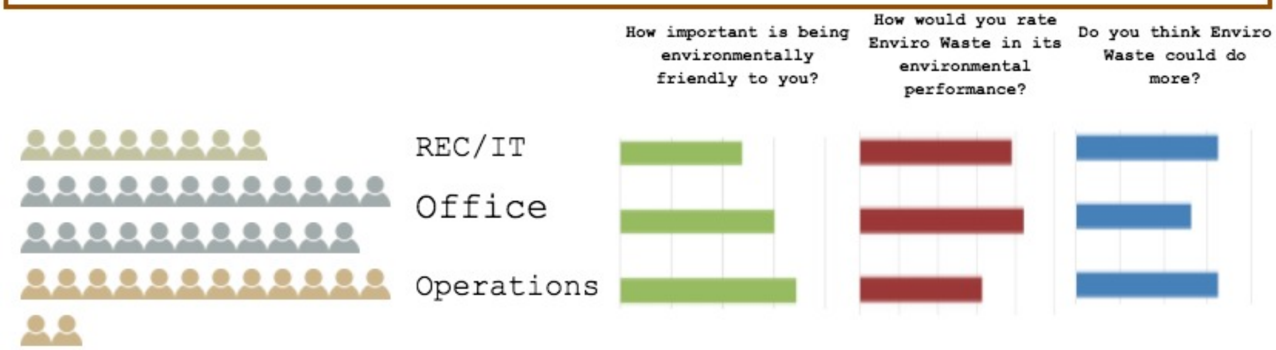
We could avoid **39% more CO_2 emissions** compared to the reference scenario

We could avoid **9% more CO_2 emissions** compared to National Average

- Better separation at the yard of paper&cardboard, plasterboard and wood
- Sending IT to shredder that also separates the different streams
- Disassembly of furniture in the different streams
- Plastics to separator (PVC and PE), PS, PP and other plastics to incineration
- Carpets and fabrics used as RDF in cement kilns



2017 Questionnaire results



Social barriers

Barrier	Rating (low / med / high)
Low public pressure	low
Low public awareness	low
Lack of market preference and demand	low

Informational barriers

Barrier	Rating (low / med / high)
Lack of information, e.g. regarding environmental legislation	low
Insufficient technical and environmental training, education and reward system	low

Legal barriers

Barrier	Rating (low / med / high)
Uncertainty regarding future legislation (for example Brexit)	med
Difficulties associated with the process of applying /complying with legislation *	med

Technical barriers

Barrier	Rating (low / med / high)
Trade-offs and difficulties in balancing	med
Lack/scarcity of advanced technology and equipment	low
Technical and detailed knowledge from employees	med
Aversion to innovation and technological change	low

Organisational barriers

Barrier	Rating (low / med / high)
Limited environmental awareness directors *	low
Limited management commitment and support	low
Poor partnership formation and management	med
Limited development of the environemntal supply sector	low
Lack of focus on corporate image and social responsibility *	low
Unclear/weak strategic and business goals *	low
Negative employee attitudes	med
Limited environmental motivation and awareness among employees	med
Lack of human resources and time	med

Economic barriers

Barrier	Rating (low / med / high)
Limited financial capabilities for environmental investment *	med
High costs of environmentally friendly waste handlers	med
High short-term costs and low short term economic benefits	med

* On these barriers there is a significant difference in opinion among the departments. REC/IT sees Eli as less environmentally aware than the other directors, and feel that the 'lack of focus on corporate image and social responsibility' and 'unclear/weak strategic and business goals' as a medium barrier. The office finds complying with legislation less of a barrier than the other departments, and the financial capabilities are considered a high battier by REC/IT and the office, but less by the operatives.