Towards more circular material flows at RAI Amsterdam

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Abstract

RAI Amsterdam is an international exhibition and congress organisation that organises and facilitates events. They aim to reduce their waste generation to zero, but have no clear overview over the waste they generate. Therefore, this research aimed to identify the incoming and outgoing flows of RAI, evaluate these on their circularity, and find feasible measures to increase the circularity of these material flows. To do this, the concepts of Circular Economy, Material Flow Analysis and a simplified feasibility assessment were combined.

The first part of this research examined the material flows and how RAI is related to them. This showed that there is insufficient information on the materials entering RAI because of a lack of procurement monitoring. Additionally, time pressure and insufficient space make it difficult to work in a circular way. Investigating the material flows in more detail provided insights in how the waste is generated and processed. Of these flows residual materials, wood, unsorted building and construction materials, carpet, and paper, cardboard and foils are the largest volume and show promising improvement opportunities. Therefore, these flows were evaluated on their circularity and analysed in more detail. This showed that most materials are still incinerated or recycled, are only used for a short time, and travel long distances before they are processed.

Generally, to increase their circularity, RAI should first clarify its priorities and communicate these through the organisation, they should also collaborate with other event locations, create more time and space for circularity and make (more) circular options more attractive for exhibitors. To decrease material flows RAI should redesign its procurement system or create a new one that facilitates circular procurement. Furthermore, they could e.g. use carpet tiles more often. To increase the reuse of materials RAI should collaborate with a company that reuses materials from demolition activities, and build more circular in the future. Finally, to increase and improve recycling, RAI could improve the contract with their waste processing company, tender waste flows separately, and collaborate with companies that can recycle wood and carpet. Of these measures, circular procurement could achieve most circular and financial impact and shows only small barriers for implementation.

It is expected that the formulated measures could significantly increase the circularity of RAI. It is also expected to increase the awareness of people at RAI of the waste they create, which might lead to the identification of more circular improvements in the future.

Executive summary

RAI Amsterdam is an international exhibition and congress organisation that both organises and facilitates events. They aim to reduce their waste generation to zero by reusing waste and recycling their waste to new end products as much as possible. If possible, they want to use these products themselves. This goal relates strongly to the concept of the circular economy. However, RAI has no clear overview over how the waste they generate relates to the inputs in the company, what currently exactly happens with the waste, and which effective and efficient ways can help them to make their material flows more circular. Therefore, this research aimed to identify the incoming and outgoing flows of RAI, evaluate these on their circularity, and find feasible measures that can increase the circularity of these material flows. To do this, the concepts of CE, MFA and a simplified feasibility assessment were combined in the research design.

In the first part of this research, the material flows of RAI and how RAI is related to them is explained. This part shows that many different actors are involved in these material flows and that the flows differ a lot over a year. It also showed that there is a lack of information on the materials entering RAI because of a lack of procurement monitoring and that it is hard for RAI to hold stand builders and exhibitors accountable for the materials ending up as waste at RAI. Additionally, time pressure and a lack of space make it difficult to separate waste, reuse it, or use the best way to process the waste. Looking at the material flows in more detail provided a lot of information how the waste is generated and how it is processed after it leaves RAI. Of these material flows the residual materials, wood, unsorted building and construction materials, carpet, and paper, cardboard and foils cover the largest volume and show promising improvement possibilities. Therefore, these flows were evaluated on their circularity and analysed in more detail as basis for the identification of improvement measures.

The evaluation of these material flows increased the insight in how the material flows currently score on circularity. It showed that most materials are still incinerated or recycled, and less often refurbished, remanufactured, reused or maintained. In addition, many materials are only used for a short time and travel a long distance before they are processed. So there is much room for improvement.

The improvement opportunities show feasible ways in which RAI can work towards circular material flows. Four categories of improvement measures are identified: general measures, measures decreasing material use, measures increasing reuse, and measures improving recycling. As general measures RAI should first clarify its priorities and communicate this through the organisation, they should also collaborate with other event locations, create more time and space for circularity and make options that are (more) circular more attractive for exhibitors. To decrease material flows RAI should redesign its current procurement system or create a new one that facilitates circular procurement. Furthermore, they could use carpet tiles more often and push suppliers to decrease the amount of outer packaging that has to be disposed of at RAI. More digital communication, decreasing the amount of plastic packaging in catering, and reducing the amount of waste during construction activities could also decrease the amount of material use. To increase reuse of materials RAI should collaborate with a company that reuses materials from demolition activities, and build more circular in the future. Finally, to increase and improve recycling, RAI could improve the contract with their waste processing company, tender waste flows separately, separate more of their office waste, and collaborate with

companies that can recycle their wood and carpet. Of these measures, circular procurement could achieve most circular and financial impact and shows only small barriers for implementation. So RAI should first focus on implementing this measure.
Some measures, for instance the different measures for carpet and for wood, compete with each other. For example, RAI could either use carpet tiles or recyclable carpet, or partly tiles and partly recyclable carpet. For the building and construction material, RAI can either build completely circular and not be the owner of the buildings and therefore not create construction and demolition waste, or be the owner and hire a party that tries to reuse as much of the building as possible during demolition. For these waste flows RAI should first decide what they want to achieve on circularity in the long term and then choose the option (or combination of options) which is most in line with the goal.

It was not possible to formulate improvements for all material flows, but it is expected that the formulated measures could significantly increase the circularity of RAI. It is also expected to increase the awareness of people at RAI of the waste they create, which might lead to more improvement measures for other material flows in the future.

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List of abbreviations

BPA	bisphenol A
CE	Circular Economy
DEHP	diethylhexyl phthalate
MDF	Medium-Density Fibreboard
MFA	Material Flow Analysis
n.d.	no date
p.c.	personal communication
PP	polypropylene
RAI Amsterdam	RAI
SDG	Sustainable Development Goal
UN	United Nations
WOF	wet organic fraction

1. Introduction

In 2015, the 193 member states of the United Nations (UN) launched the Sustainable Development Goals (SDGs). These 17 goals aim to stimulate action until 2030 in areas that are of critical importance for humanity and the planet (United Nations, 2015). One of these goals is to ensure sustainable consumption and production patterns (goal 12). The targets connected to this goal focus on halving the per capita global food waste by 2030 in the whole supply chain, achieving the environmentally sound management of all wastes throughout their life cycle by 2020, and substantially reduce waste generation through prevention, reduction, recycling and reuse by 2030 (United Nations, 2015).

Since the European Union is part of the UN, European countries have to execute the SDGs on national and international level. In the Netherlands, the different ministries work together with parties from society on these goals (Rijksoverheid, n.d.c). For instance through the National Waste Management Plan in which they aim to minimise waste generation, minimise the environmental pressure of production chain, and optimise the use of waste in a circular economy (Rijkswaterstaat, n.d.). One of the organisations who wants to contribute to reaching these goals is RAI Amsterdam (further referred to as RAI') (Moens & Hulscher-Dooper, personal communication (p.c.), 5 February 2018). RAI is an international exhibition and congress organisation that both organises and facilitates events (RAI Amsterdam, n.d.a). They do not only want to substantially reduce their waste generation, but reduce it to zero by reusing waste, and recycling their waste to new end products as much as possible (RAI Amsterdam, n.d.c). These end products should be kept at the highest utility feasible (Moens & Hulscher-Dooper, p.c., 6 March 2018). If possible, they want to use these products themselves. In doing this, they include all people who are involved with their waste (RAI Amsterdam, n.d.c). This goal relates strongly to the concept of the circular economy. According to the Ellen MacArthur Foundation (2015) the concept of the circular economy *"is characterised, more than defined, as an economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles"*. It focuses on shifting from a linear to a circular material flow. Next to this definition, there are many more definitions for a circular economy, which makes it hard for governments and businesses to make policy in this area (Kirchherr et al., 2017). However, in this research, the above definition is used as this is the most employed definition according to the analysis of 114 definitions by Kirchherr et al. (2017) and it takes the whole system into account.
By working circular, the European industry can halve their CO_2 emissions by 2050 (Material Economics, 2018). To achieve this, the Dutch Government aims to work towards a circular economy in cooperation with businesses (Rijksoverheid, n.d.b). At a lower level, Amsterdam Metropolitan Region, the region in which RAI is located, wants to be a forerunner in working towards a circular economy (Metropoolregio Amsterdam, n.d.). So with their goal, RAI also contributes to achieving the broader goal of Amsterdam Metropolitan Region, the Netherlands and the SDGs. And with aiming for circularity RAI does not only contribute to reaching SDG 12 (by reducing waste), but also to goal 9 by focusing on making industries more sustainable, and to goal 11 by reducing the per capita environmental impact by paying attention to municipal waste management (United Nations, 2015).

Even though they aim for zero waste, RAI has no clear overview over how the waste they generate relates to the inputs in their company, what currently exactly happens with their waste, and which effective and efficient ways can help them to make their material flows more circular (Moens & Hulscher-Dooper, p.c., 5 February 2018). Many other big exhibition and congress organisations in the Netherlands, Germany and France also look at their waste management. However, many of them mainly focus on waste separation and recycling (Viparis, n.d.; Messe Berlin, n.d.; Messe Stuttgart, n.d.; Hamburg Messe und Congress, n.d.; Leipziger Messe, n.d.). Some also specifically mention waste reduction (Messe München, n.d.) and the reuse of material (Messe Frankfurt, n.d.; Koelnmesse, n.d.) as focal point. Jaarbeurs is the only other organisation that also aims for zero waste in the future according to the circular economy principle (Jaarbeurs, 2016). Research on this subject shows that there are no papers available on the on solid waste management and changing towards circular operations at exhibition and congress organisations. Also for the broader hospitality industry, still little scholarly publications are available for solid waste management in general (Pirani & Arafat, 2014). Only on food waste management a bit more information is available (Pirani & Arafat, 2016; Papargyropoulou et al., 2016).

This shows that there is a knowledge gap in the area of circular operations and waste management at exhibition and congress organisations and a need for more research on this topic in the broader hospitality sector. In this research, a clear overview of the material flows of RAI is created. For this purpose, there is looked at both the incoming and outgoing flows of the operations, which are connected to each other. All outgoing flows of RAI are mapped and as much as possible related to the large incoming flows. This makes it possible to look at improvement measures that can make these flows more circular. Therefore, this research aims to answer the following research question:

Which measures can help RAI Amsterdam to work towards circular material flows?

To answer this research question the following sub questions are used:
- What are the outgoing material flows of RAI Amsterdam?
- How do the outgoing material flows relate to incoming material flows?
- What is the current level of circularity of the material flows?
- Which measures exist in the market to make the material flows more circular?
- What is the potential effect of these measures on the material flows?

To answer these questions, the incoming and outgoing material flows over 2017 are considered as this is the most recent year over which numbers are available. The flows over a whole year are considered as the kind and number of exhibitions and congresses differ from period to period, which makes their waste flows different. Since many exhibitions and congresses are organised annually, different years are comparable. The considered flow categories are based on the categories currently used by RAI in their waste management system. These are 14 waste flows that are subdivided in more specific flows (RAI Amsterdam, 2017c). An attempt is made to match all outgoing flows to their respective incoming flows (which products and from which companies are they sourced) and map what happens with these flows after they leave RAI. So the system boundaries are from materials entering RAI until they eventually end up in a waste incinerator. For the material flows covering the largest volume and showing promising improvement possibilities the current level of circularity is indicated based on a method that is described in chapter 3. Based on these levels, measures existing in the market needed to improve the level of circularity or reducing material use are identified. When the possible level of circularity is relatively low, this shows possibilities for research to find more circular measures.

The results of this research are relevant for society as the outcomes give a clear overview of the material flows of RAI and measures to make them more circular. For some of the measures already first steps for implementation are taken. Other measures are also expected to be used in the future. This means that less waste will be generated by RAI, contributing to the goals of Amsterdam Metropolitan Region, the Netherlands, and the SDGs. Less waste generation is expected to lead to considerable cost savings (Ashwood et al., 1996). The waste reductions of RAI might also create awareness among visitors, exhibitors, the organisers of events at RAI, and other organisations like RAI and stimulate them to reduce their waste. Furthermore, it will stimulate the companies providing the solutions to RAI (mainly the start-ups) to grow, and enable them to expand their business. Also, the negative impact on the environment will reduce as less outgoing materials will be incinerated which leads to less air pollution, CO_2 emissions, and emissions of heavy metals (Morselli et al., 2008).

Scientifically, this study fills a knowledge gap in the area of circular operations and waste management at exhibition and congress organisations and adds to the current body of literature in the broader hospitality sector. In addition, this research shows that the used method combining the concepts of Material Flow Analysis (MFA), the Circular Economy (CE) and a simplified feasibility analysis is useful in analysing the circularity of organisations like RAI. An MFA was not yet much applied to the organisational level (Diener et al., 2013), but this research shows it is an efficient tool for mapping the material flows of RAI and a good basis for analysing the circularity of these flows. Also, the application of CE in the evaluation of the current material flows gives a good overview of the different routes "travelled" by the materials and what kind of effect this has on the circularity of the flows. Furthermore, the simplified feasibility assessment based on Lohri et al. (2013) shows to be well applicable to assessing the feasibility of the improvement measures. However, future research could still improve the application of the concept of CE and apply the full feasibility assessment tool to see whether this affects the results. Finally, this research presents improvement measures that can make the material flows more circular. Future research could focus on how these measures can be brought into practice in an efficient and effective way.

In the next section, the theoretical framework used in this study is presented. Then, chapter 3 presents the research design and methods that are used to answer the research question. Chapter 4 and 5 show the results of the research with chapter 4 describing how RAI is related to their material flows and chapter 5 describing the different flows in general and in detail. In chapter 6 these material flows are evaluated on their circularity. Then, chapter 7 discusses measures that can improve the circularity of these material flows, including their impact and feasibility. In the last two chapters, the research is discussed and a conclusion is given.

2. Theoretical framework

This chapter gives an overview of the theoretical framework that is used in this research. This framework is composed of different theories used in previous studies on similar subjects. On these theories is critically reflected.

As the goal of the research is to make the material flows of RAI more circular, it is important to look more into depth in the concept of the circular economy to find ways to 'measure' circularity. In addition, there is a need for an assessment method to analyse the material flows of the organisation and to measure the feasibility of possible improvement measures. However, as already mentioned, only little research is available on changing towards circular operations and waste management at similar organisations or the broader hospitality industry (Pirani & Arafat, 2014). The review paper by Allesch & Brunner (2014) on assessment methods regarding waste management shows that there are different ways in which the material flows of companies can be analysed. Based on the results of the review, the authors recommend to consider *"(i) a mass balance approach based on a rigid input-output analysis of the entire system, (ii) a goal-oriented evaluation of the results of the mass balance, which takes into account the intended waste management objectives; and (iii) a transparent and reproducible presentation of the methodology, data, and results"* (Allesch & Brunner, 2014). An assessment method that considers all these points is material flow analysis (MFA). This is *"a systematic assessment of the flows and stocks of materials within a system defined in space and time"* (Brunner & Rechberger, 2004). Although this method is widely used on national and regional scale, it is not much used on the organisational level (Diener et al., 2013). However, the research field is growing. The main goal of the organisational studies is to evaluate the throughput of companies in order to find major areas of inefficiency, support priority setting, look for measures to improve, and provide tools to monitor the effectiveness of these measures (Bringezu & Moriguchi, 2002). The studies show that MFA is a useful tool for mapping flows at individual firms (Diener et al., 2013; Ha et al., 2016). Furthermore, it serves as a good basis for decision making at firms through which it can contribute to enhancing their environmental and economic performance (Kósi & Torma, 2005). These advantages show that an MFA would be a good tool to map the material flows of a company on which efficient measures can be based which make the company operate in a more sustainable way (Kósi & Torma, 2005).
The current material flows and possible efficient measures can be analysed on their 'level of circularity' using the concept of the circular economy. This concept is analysed in more detail to define how the circularity of the material flows can be determined.
It is also important to look at the feasibility of these measures. Most feasibility assessment tools are limited to technical and financial criteria while there are many more criteria important for the success of certain measures. Neglecting these other criteria could be one of the main reasons for the difference between theoretical and observed feasibility in past studies (Lohri et al., 2013). The feasibility assessment tool developed by Lohri et al. (2013) does consider other important criteria. It is a very complete tool that has a broader sustainability focus and takes the following criteria into account: technical-operational, environmental, financial-economic, socio-cultural, institutional, policy and legal (Lohri et al., 2013). However, since it is not feasible to apply the complete tool to all improvement measures, the tool is simplified to only include the most important aspects.
In the next sections, the concepts of the circular economy and MFA, and the feasibility assessment tool by Lohri et al. (2013) are discussed in detail.

2.1 Circular economy

Many concepts and theories focus on sustainable material flows. One of these concepts is the concept of the circular economy. This concept presents an alternative to the currently more linear economic system where natural resources are used to make products after which these products are used and end up as waste. This system currently puts pressure on the environment as new materials are harvested unsustainably, there is more extracted than regenerated. In addition, the waste generation leads to environmental pollution (Murray et al., 2017). The principle of the circular economy, on the other hand, focuses on changing this system to be restorative or regenerative by intention and design, reduce the ecological footprint of production and counter degradation of natural systems. This can be achieved by using the output of one system as input of another. The concept also aims to redesign products and produce them in a way that makes them suitable for reuse and easy to disassemble to be able to harvest materials for future use (MacArthur, 2013; McDonough & Braungart, 2000; Srivastava, 2007; Xiao & Huang, 2010). It is seen as a new kind of business model that is expected to contribute to sustainable development and a more harmonious society (Geng & Doberstein, 2008; Ness, 2008; Mathews & Tan, 2011; Naustdalslid, 2014; Zhijun & Nailing, 2007). Since many materials are entering and leaving RAI, this concept can contribute to change the material flows of RAI to reduce its ecological footprint and counter degradation of the natural system.

The circular economy distinguishes two types of materials; biological materials and technical materials (see Figure 1). Biological materials are materials from the biosphere that should eventually return to the natural environment. Before returning to the biosphere, they can first cascade through different applications like technical materials before returning to the biosphere (Ellen MacArthur Foundation, 2015). The successive cycles through which technical materials can cascade are shown in Figure 1. The aim is to use these technical materials as long as possible in one cycle before moving to the next cycle, and to keep the utility of the materials as high as possible (Stahel, 2013; Xiao & Huang, 2010). Furthermore, the loops need to be as small as possible (both activity-wise and geographically). Activity-wise this means for instance that companies should not remanufacture when maintenance is possible, and geographically the material flows have to be kept as local as possible (Stahel, 2013). These successive cycles can indicate where RAI stands now and where there is room to improve. The only loop missing in Figure 1 is the recycling of a share of the residues from incineration with energy recovery. However, since the recycling of those residues does not have many application possibilities next to road construction (Christensen, 2011) and does not lead to significant primary energy savings (Dornburg & Faaij, 2006), this loop is not taken into account. To optimise the cascading possibilities for technical materials products should be designed in a smart way to make it possible to disassemble them and separate the different materials. These materials can then be reused, refurbished and recycled separately and thus use the smallest loop possible (Lacy & Rutqvist, 2015; Webster, 2015).

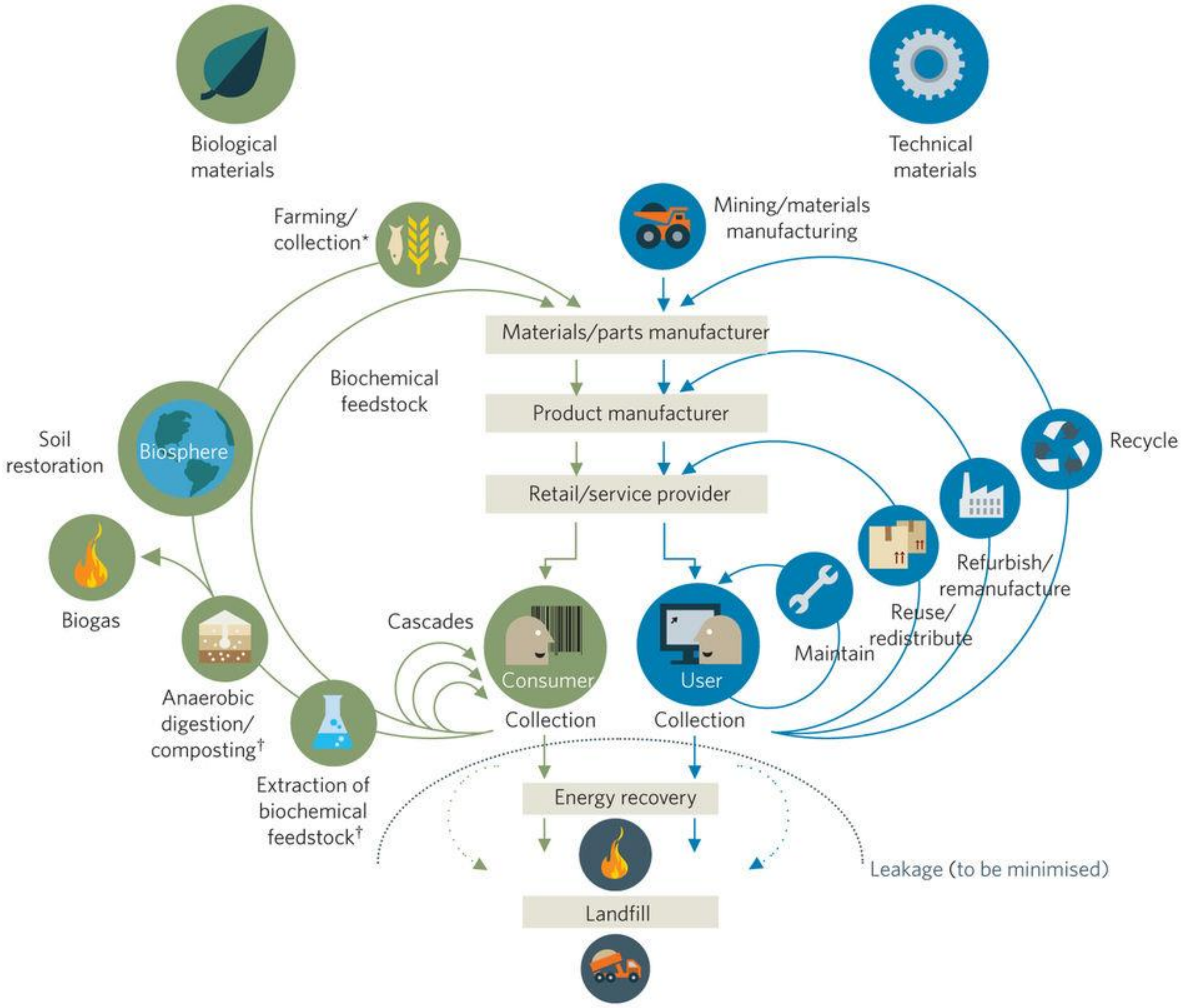

FIGURE 1: CYCLING OF MATERIALS IN THE TECHNO-AND BIOSPHERE IN A CIRCULAR ECONOMY (ELLEN MACARTHUR FOUNDATION, 2015). ADAPTED FROM THE CRADLE-TO-CRADLE DESIGN PROTOCOL BY BRAUNGART & MCDONOUGH. *HUNTING AND FISHING. †CAN TAKE BOTH POST-HARVEST AND POST-CONSUMER WASTE AS AN INPUT.

In order to make this type of system possible, it is important that different actors collaborate. Both cross-sector and cross-cycle collaborations are essential to close the loops. Different organisations can for instance create new logistic infrastructures to collect materials together (MacArthur, 2013; Ness, 2008; Preston, 2012). Therefore, when looking at measures for increasing circularity, these type of collaborations are also taken into account.

In the circular economy concept, it is assumed that circling materials does eliminate the use of primary materials 1:1. However, this is often not the case (Zink & Geyer, 2017). Materials circling back may for instance displace another type of material or lower the prices in the market, increasing the overall demand (Ekvall, 2000; Zink et al., 2016). This shows that it is also important to look at primary material reduction next to the circular economy concept when looking at material flows. Therefore, this research also focuses on the incoming flows of RAI where possible.

2.2 Material flow analysis

Material flow analysis (MFA) builds on earlier theoretical concepts of material and energy balancing (Hinterberger et al., 2003). From practice can be viewed that the material flows in society are radically different from those in nature as flows in society are open while in nature they are closed. Managing societal material flows more like in nature can reduce the pressure on the environment drastically (Kósi & Torma, 2005). To achieve this, it is first important to trace the material flows. In this way, current material management processes can be evaluated (Kósi & Torma, 2005).

MFA is often used as a synonym for material flow accounting as the analysis is based on accounts of the inputs and outputs of processes. However, the accounting is only one of the steps. The input and output flows are substances (like carbon or nitrogen), technical compounds, or 'bulk' materials (like coal or wood). The primary interest of the analysis differs from study to study (see Table 1). From a more technical engineering perspective, the primary focus can be on the specific environmental impacts related to the material flows. However, the focus can also lie primarily on the environmental problems related to the throughput of firms, sectors or regions. This type of analysis is more from the perspective of socioeconomic relationships (Bringezu & Moriguchi, 2002). Table 1 shows these two types of primary interest and the more specific types of MFA related to them. In this research type IIa is the most suitable type of analysis as the main focus is on RAI and not on certain material flows. As already mentioned before, the main goal of this specific type of analysis is to find the biggest problems, help setting priorities, see where improvement measures are possible, and provide monitoring tools to measure the effectiveness of these measures.

TABLE 1: TYPES OF MATERIAL FLOW-RELATED ANALYSIS (BRINGEZU & MORIGUCHI, 2002).

Type of analysis	I		
	a	b	c
Objects of primary interest	Specific environmental problems related to certain impacts per unit flow of:		
	substances e.g. Cd, Cl, Pb, Zn, Hg, N, P, C, CO_2, CFC	materials e.g. wooden products, energy carriers, excavation, biomass, plastics	products e.g. diapers, batteries, cars
	within certain firms, sectors, regions		
	II		
	a	b	c
	Problems of environmental concern related to the throughput of:		
	firms e.g. single plants, medium and large companies	sectors e.g. production sectors, chemical industry, construction	regions e.g. total or main throughput, mass flow balance, total material requirement
	associated with substances, materials, products		

There is no general consensus on a methodological framework for performing MFAs. However, the procedure and some elements of previous studies have some essential elements in common (Bringezu

& Moriguchi, 2002). Usually, an MFA consists of four steps: goal and systems definition, process chain analysis, accounting and balancing, and modelling and evaluation (Bringezu & Moriguchi, 2002). These steps are explained below:

- Step 1: Goal and systems definition
  In this part, the target questions are formulated and the scope and system boundary are defined. For the target questions, the flow categories that have to be analysed must be determined. The scope determines the spatial, temporal and sometimes functional focus of the study. In addition, the system boundary determines the begin and the end of the analysed material flows. The boundary is partly determined by the scope but can also include other elements. Therefore, the scope and system boundary could be identical, but can also differ. (Bringezu & Moriguchi, 2002)
- Step 2: Process chain analysis
  In the process chain analysis, the processes are defined for which the inputs and outputs have to be determined (Bringezu & Moriguchi, 2002).
- Step 3: Accounting and balancing
  In this step, the inputs and outputs are determined in a quantitative way. The principle of mass conservation is used to balance the inputs and outputs of the analysed processes and systems (Ayres & Ayres, 1999). In this way the accuracy of empirical data can be checked, consistency can be improved, and missing data can be filled in (Bringezu & Moriguchi, 2002).
- Step 4: Modelling and evaluation
  Modelling can be done in the basic way using 'bookkeeping' or in the complex way using static and dynamic modelling. The evaluation is related to the interests and assumptions at the basis of the research. The criteria of the evaluation can focus on (1) indications of known impacts per unit of flow. For this purpose impact coefficients can be applied. (2) The criteria can also indicate a generic environmental pressure potential based on the volumes of the flows (Bringezu & Moriguchi, 2002). This step is adapted for this research to serve the goal better. In this research the evaluation is namely based on the level of circularity. This level is based on the size of the loops, both activity-wise and geographically (as explained in 2.1) and on the time the materials remain in the loop. The aim of the circular economy (as explained before) is namely to use materials as long as possible in one specific cycle and go through as many cycles as possible before the material ends up as waste. In addition, the transport of materials should be limited.

This shows that this type of analysis, combined with the circular economy concept, is suitable to analyse the material flows of RAI in a structured way and find areas where RAI needs to improve the circularity of these flows.

2.3 Feasibility assessment

To see whether the identified measures that can improve the circularity of RAI are feasible, a feasibility assessment is needed. The feasibility assessment tool developed by Lohri et al. (2013) can be adapted to assess the feasibility of the improvement measures identified for RAI. Since it is not possible in this research to apply the whole tool to the different improvement measures only the most relevant (final) part of the tool is used in an adapted way. This part focuses on six categories of sustainability aspects, which are divided into sub-categories, and aspects that can assess the feasibility. The six categories and their aspects are:

- Technical-operational: issues related to the supply chain.
- Environmental: System conditions from The Natural Step framework (Robèrt, 2000).
- Financial-economic: Funding sources, market situation, etc.
- Socio-cultural: Willingness to changes or adopt new behaviour, acceptance, etc.
- Institutional: Institutional capacity, stakeholder cooperation.
- Policy and legal: Related policies, legislation and standards.

These categories can be assessed by determining for every aspect whether there are barriers present and to what extent these barriers affect the feasibility of the measure.

3. Research design and methods

In this chapter, the methods that are used to answer the research question are described. In the next section, the steps of the research are explained followed by the methods for data collection needed to complete these steps.

3.1 Research design

Based on the analysis of the theories discussed in the previous section the research design is built which is used in this research. This research design consists of six steps (see Figure 2). The first four steps describe the current system and thus the *Status Quo*. These steps are based on the concepts of Material Flow Analysis (MFA) and the Circular Economy (CE). The fifth and sixth step are added to formulate measures and determine their potential impact, and thus focus on *Improving* the system. In these steps, the feasibility assessment discussed in the previous chapter in included. Below is explained what the steps entail.

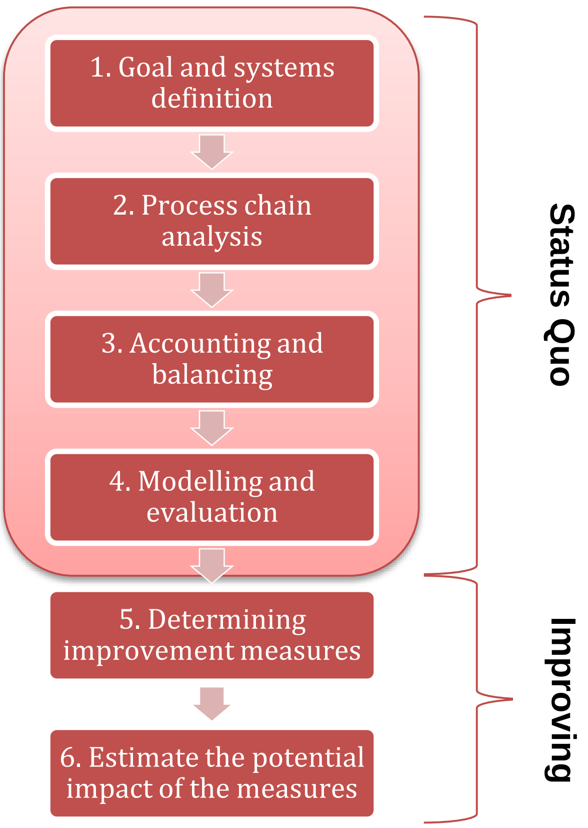

FIGURE 2: RESEARCH DESIGN.

Process chain analysis

In this step, an overview is made of the system under study. So the materials entering RAI, the materials exiting RAI, and the processes the materials go through after they leave RAI. The overview is made as complete as possible based on the available information.

Accounting and balancing

In this step, data is gathered on the material flows defined in the process chain analysis. The inputs and outputs are balanced and expressed in mass (in tonnes). The largest material flows covering at least 80% of the volume and/or showing easy improvement possibilities (further referred to as the focal material flows) are analysed in more detail. For the other flows more assumptions are accepted. In case no numbers are available, they are based on scientific literature or educated guesses.

Modelling and evaluation

In the modelling part of this step, the results of the previous step are visualised in a Sankey diagram. Sankey diagrams are increasingly used to graphically depict material flows. The diagram shows the distribution of the materials over various sources or sinks and represents the flows by lines of which the width indicates the volume of the flow (Schmidt, 2008). An example of a Sankey diagram of the expected material flows of RAI is shown in Figure 3.

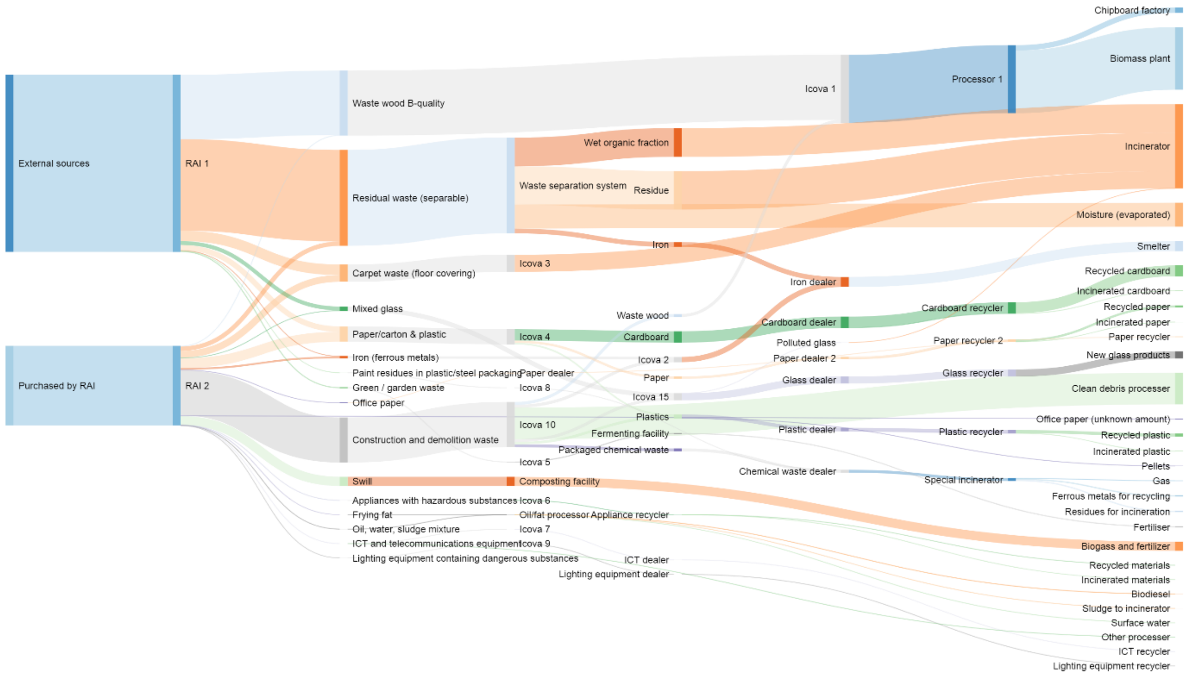

FIGURE 3: SANKEY DIAGRAM OF EXPECTED MATERIAL FLOWS OF RAI (READABLE VERSION IN APPENDIX I).

The evaluation part looks at the level of circularity of only the focal material flows. Here is evaluated how 'big' the current cycles are both activity-wise and geographically. Activity-wise, the size of the loops is evaluated based on the loops in Figure 1. For every outgoing material flow is evaluated whether the smallest loop possible is used. For the technical materials, level 0 is assigned to the linear practice of landfilling and incineration with energy recovery, level 1 to recycling of materials, level 2 to refurbishing/remanufacturing, level 3 to reuse/redistributing, and level 4 to maintenance. Non-toxic biological materials which are returned back to the biosphere via composting and anaerobic digestion are scored with level 1 as they are completely biodegradable and do not lose value, which is similar to high-grade recycling. These materials can also first cascade through different applications like technical materials before returning to the biosphere (Ellen MacArthur Foundation, 2015). In this case, they are scored like technical materials. Biological materials contaminated with toxic substances cannot return to the biosphere as they contaminate the environment (Ellen MacArthur Foundation, 2015). These materials are therefore scored like technical materials.

Geographically is analysed whether the materials are sourced or kept as close to RAI as possible. Here, five levels of transport distance are distinguished from source to the location where the materials incinerated, processed into a new product, or stored and/or repaired for reuse. Here, level 0 is > 500 km, level 1 is 150 – 500 km, level 2 is 50 – 150 km, level 3 is 25 – 50 km, and level 4 < 25 km.
Furthermore, it is analysed for how long the materials were used by the same actor before moving to the next cycle. Using materials for a longer period namely reduced the need for new materials. Since it is difficult to determine the period the materials are used, the scoring is based on an estimation of the use time. For the scoring five levels are distinguished; level 0 is < 1 week, level 1 is 1 week – 6 months, level 2 is 6 months till 1 year, level 3 is 1 – 5 years, and level 4 is > 5 years.

Determining improvement measures and their feasibility
Previous studies never formulated measures based on the results of a company MFA combined with CE. However, the results of the MFA are very useful for determining the areas in which improvement is needed (Kósi & Torma, 2005). The results of the previous step showed for the focal material flows their score on circularity. With the use of desktop research, possibly feasible improvement measures for these focal material flows were indicated which avoid material use, make the loops smaller, or keep the materials in the loop for a longer time. In case a measure focussed on recycling there was determined whether the measure results in higher grade recycling than the current situation. There is looked for cross-sector and cross-cycle collaborations since this is essential to close the loops. Then, the actors active in the current flows and other actors with expertise in the field were interviewed to see if there are other possibly feasible improvement measures for the material flows.
To determine which improvement measures are interesting for RAI, a simplified feasibility assessment tool developed by Lohri et al. (2013) is used which is presented in section 2.3. In this simplified version only the part that is most relevant for this research is taken into account. This feasibility assessment is based on six main categories:

- Technical-operational aspects
- Environmental aspects
- Financial-economic aspects
- Socio-cultural aspects
- Institutional aspects
- Policy and legal aspects

There are several aspects related to these categories on which the different measures score differently. These aspects are presented in Appendix II. The feasibility assessment is performed with data from interviews. Looking at the number of barriers and the extent to which they make the measure impossible, the feasibility of the measures can be determined.

Estimate the potential impact of the measures
In the previous step, improvement measures for the focal material flows are identified. For these measures the potential impact is identified by investigating how the scores on circularity are affected, how much direct waste can be avoided on annual basis, and how much this is compared to the current waste flow. If possible, also the financial impact is calculated. For this purpose, it was not possible to look at the average costs over several years, as this data was not available. Determining the impact was not possible for all measures due to a lack of data on the current waste flows, the improvement measure, or the extent to which the measure is expected to be implemented. In these cases, assumptions were made.

3.2 Methods for data collection

As is apparent from the previous section, both quantitative and qualitative data is gathered. The quantitative data mainly consists of data on the waste flows of RAI. The qualitative data mainly consists of texts from reports, internet resources and interviews with important actors in the field. In the next sections, the different forms of data collection are described.

3.2.1 Desktop research

With desktop research, mainly quantitative data is gathered on the material flows. This data is mainly gathered from company reports (public and in-house). For the last two steps (on measures and their potential impact), for several measures data is gathered from reports of reliable organisations, and other publicly available reliable data.

3.2.2 Interviews

The most important part of the data is collected with semi-structured interviews. With these interviews, qualitative data on the current material flows and data on improvement measures is collected. For information on current material flows, employees of RAI, Renewi Icova (the waste processing company) and specific processors used by Renewi Icova are interviewed as they work with the material flows. To increase the reliability of this research the information is gathered from multiple interviewees if possible. For the improvement measures experts in the field, people from current suppliers and other possible suppliers or material processors are interviewed. The list of interviewees is shown in Table 2. This table contains both the interviews conducted in person or over the phone, and the interviews conducted in writing. The interviews that were conducted in person or over the phone are recorded and transcribed into summaries containing the relevant data for this research. An overview of the general set-up of the interviews can be found in Appendix III.

TABLE 2: LIST OF INTERVIEWEES INCLUDING THEIR NAME, THE COMPANY THEY WORK FOR, THEIR FUNCTION, AND THE DATE OF THE INTERVIEW.

Organisation	Name(s)	Function	Date of interview
RAI Amsterdam	Josieke Moens & Suzanne Hulscher-Dooper	Manager Planning Support & Supervisor Hospitality Crew Centre	05-02-2018 & 06-03-2018
	Josieke Moens	Manager Planning Support	13-02-2018 & 06-06-2018
	Gerard van Bemmel	Planning Manager	19-03-2018
	Lisa Koopman	Account Executive	11-04-2018
	Remco Sint	Floor Manager Facilities	24-04-2018
	Miriam Kolken	Facility Coordinator Cleaning	30-04-2018
	Herman Nietvelt	Manager Technical Services	02-05-2018
	José van Eenbergen	Manager Procurement	18-05-2018
	Wilco van den Born	Construction and Engineering Manager	18-05-2018
	Rientz Mulder	Executive Chef	21-06-2018*
Companies currently active in the processing of materials of RAI			
Renewi Icova	Cor Gerritsen	Commercial Director	02-03-2018, 22-03-2018 & 30-03-2018*

	Jana Dekker	Assistant Location Manager RAI	19-03-2018, 29-03-2018, 12-04-2018 & 18-06-2018
	Jurriën de Pijper	Senior Sales Support	26-04-2018*
Biodiesel Amsterdam	Arnold de Jong	Manager Operations	12-04-2018*
Rouwmaat	Stef Tuinte	Company Director	24-04-2018*
Renewi Van Vliet	Peter Verhaal	Site Supervisor CCD Nieuwegein	22-05-2018*
	Johan Peter Post	Recycling Manager	24-05-2018*
Renewi KLOK	Edwin Kolk	Site Manager	15-06-2018*
Theo Pouw	Henk Stigter	Environmental Manager	25-06-2018*
Preferred suppliers of RAI			
Schreuder	Erik Schreuder	Company Director	22-03-2018* & 24-05-2018
Hapéco	Jeroen Altink	Managing Director	29-06-2018
A-booth	Peter Noordman	Company Director	18-05-2018
Hestex	Naomi Bik	Policy Officer/Commercial	22-05-2018*
The Inside	Mariska van Dasselaar	CEO & Sales Assistant	22-05-2018*
Bidfood	Sarika Jagan	Project Leader/Process Manager	24-05-2018*
Companies possibly providing improvement measures			
Noble Environmental Technologies/ECOR	Navied Tavakolly	Circular Economy Business Developer	17-05-2018
New Horizon	Michel Baars	Company Director	06-06-2018
DSM-Niaga	Lukas Hoex	Manager Strategic Growth	19-05-2018*
Experts			
MVO Nederland	Mike van den Hof	Manager Business Development & Acquisition	19-04-2018
Amsterdam Economic Board	Marjolein Brasz	Challenge Lead Circular Economy	08-06-2018
Rijksdienst voor Ondernemend Nederland	Maurice Goudsmith	Category Manager Waste Care and Raw Materials Management	16-05-2018
Group interviews			
RAI – Schreuder – Interface – MVO Nederland	Josieke Moens (RAI), Erik Schreuder (Schreuder), Cees van Gelder (Interface), Mike van den Hof (MVO Nederland)	Cees van Gelder: Technical Support Manager. Others: see above.	12-02-2018
RAI – Renewi Icova – Schreuder	Josieke Moens (RAI), Cor Gerritsen, Jurriën de Pijper, Raymond Mangold (Renewi Icova), Erik Schreuder (Schreuder)	Raymond Mangold: Supervisor Projects. Others: see above	30-05-2018
Afwerking – Renewi Icova	Jaime de Zwart & Jana Dekker	Owner & Assistant Location Manager RAI	24-05-2018

*) INTERVIEWS CONDUCTED IN WRITING.

3.2.3 Field research

The last type of data collection that is used is field research. For this purpose, the author looked what happens with the materials during a build-up and demolition of an exhibition together with an employee of RAI (on 26-02-2018) and the waste processing company (Renewi Icova, on 05-03-2018 and 19-03-2018), and went to Renewi Icova (on 02-03-2018 and 21-06-2018) to see what happens with the waste at their site. In this way a better understanding of the material flows is gathered which was for instance used when estimations on the composition of waste flows was needed. The increased insight also led to a more meaningful assessment of the feasibility of possible improvement measures. The most interesting results from the field research are written down in elaborate summaries.

3.3 Methods for data analysis

Much data is gathered with the desktop study, interviews, and field research. To extract all relevant information the data had to be analysed in a structured way. To create the Sankey diagram, from much different sources quantitative and qualitative data is extracted which clarify the volume and direction of the different flows. The overview of this data in the Sankey diagram makes it possible to identify the circularity of the flows. Other relevant data (on for instance improvement measures and their potential impact) from the interviews, desktop study, and field research is first written down in separate summaries and then combined in the report. This data contained extra information on the material flows and information on possible improvement measures, their impact, and their feasibility.

3.4 Reliability and validity

The results of this research are very time specific as the waste industry is changing a lot over time. For instance, a waste processing company can switch between different processing companies for the different waste flows over time. This makes this research less repeatable and therefore less reliable. However, the reliability and validity of the results for the current situation is increased using triangulation (Walker, 1997). This was done by gathering the data from different sources; desktop research and (multiple) interviews.

Looking at the conducted interviews, there could be problems related to the reliability. According to Saunders et al. (2007), the reliability when conducting interviews could have been affected by:

- Subject or participant error: during some of the interviews, there was only limited time available. This could have caused that the interviewee was not able to elaborate upon his/her answers to certain questions.
- Subject or participant bias: the questions that were asked could have steered the interviewees in their answers (Salzmann et al., 2005). In addition, the attitude of the interviewer could have steered the answers.
- Observer error: the possibility for errors during interviews was limited by having all interviews conducted by the author. In addition, the cultural differences between the interviewer and interviewees were small, further reducing the possibility for errors. However, the responses of the author could have been biased by the importance of sustainability to the author. To gather as much information as possible the interviews were held in the native language of the interviewer and interviewees, which is Dutch. This could have led to translation and interpretation errors when writing it in English, which might have affected the results.
- Observer bias: the author and probably also a large share of the interviewees believe that moving towards circularity is important. This could have affected the results.

During the research, these possible pitfalls were kept in mind and avoided if possible.

4. RAI in relation to its material flows

RAI Amsterdam Convention Centre is an international exhibition and congress organisation that both organises and facilitates events (RAI Amsterdam, n.d.b). For all these events a lot of materials are needed, for example for the carpet, the stands and the catering. For all these events there are roughly four parties involved which create waste. These are:

- *RAI*
  Most events at RAI are only facilitated by RAI. For these events, they only provide a location where the organisation is obligated to purchase water, electricity, and ICT from RAI. Other services are optional. From these services, some are provided by RAI itself, like catering, others are provided by preferred suppliers or other external suppliers (Moens, p.c., 13 February 2018). Therefore, in case of an external organisation, the only waste RAI might create comes from catering. For the events organised by RAI itself, RAI also purchases things like carpet and congress catalogues which (partly) end up as waste. However, a large part of the products used by RAI are rented and therefore do not end up as waste (Bemmel, p.c., 19 March 2018).
- *External event organisers*
  In case RAI facilitates an event, there is an external organisation that purchases things needed for the event like the carpet and catalogues. The things they buy or rent is virtually everything needed for the event besides the things exhibitors buy or rent for their stands and promotion. The organisation purchases these things as optional service via RAI or they purchase them from external parties. Not all these services cause waste, like security and personnel. However, things like carpet do (Moens, p.c., 13 February 2018; Dekker, p.c., 19 March 2018).
- *Exhibitors*
  The exhibitors cause a significant part of the waste from the events. The exhibitors are the ones who build stands and bring things like flyers and samples for the visitors. Mainly during the build-up and the breakdown of the event these actors cause waste, like carpet for the stand, foils, cardboard, and leftover promotional material. But also during the event waste is created but this differs a lot between the different (kinds of) exhibitors (Moens, p.c., 13 February 2018).
- *Visitors*
  The visitors of the events also create waste at RAI. This is caused by for instance food packaging, drinking cups, and thrown away flyers (Moens, p.c., 13 February 2018).

Next to this waste related directly to the events, RAI also produces waste from other activities. There are namely also waste flows coming from the offices, construction and demolition activities, maintenance, and the disposal of appliances (Moens, p.c., 13 February 2018). Figure 4 shows per month for 2017 both the total amount of materials transported from RAI and the share of these materials from internal RAI activities, so excluding the waste generated by external organisations, exhibitors and visitors. They are subdivided in different categories of materials. From this figure can be derived that RAI produces a lot of residual waste, waste wood, and construction and demolition waste (which is subdivided into unsorted construction and demolition waste, roofing waste, clean debris, debris bigger than 100cm, and contaminated debris). Furthermore, it is clear that during the summer less waste is generated. This is caused by the lower number of events during this season (Moens, p.c., 13 February 2018). However, it is also clear that during this season most waste consists of construction and demolition waste, as during this period there is time for big building and renovation activities. Due to the low number of events in this period, most waste is generated by internal activities. This in contrast to the periods in which many and large events are organised which is in February and September (Moens, p.c., 13 February 2018).

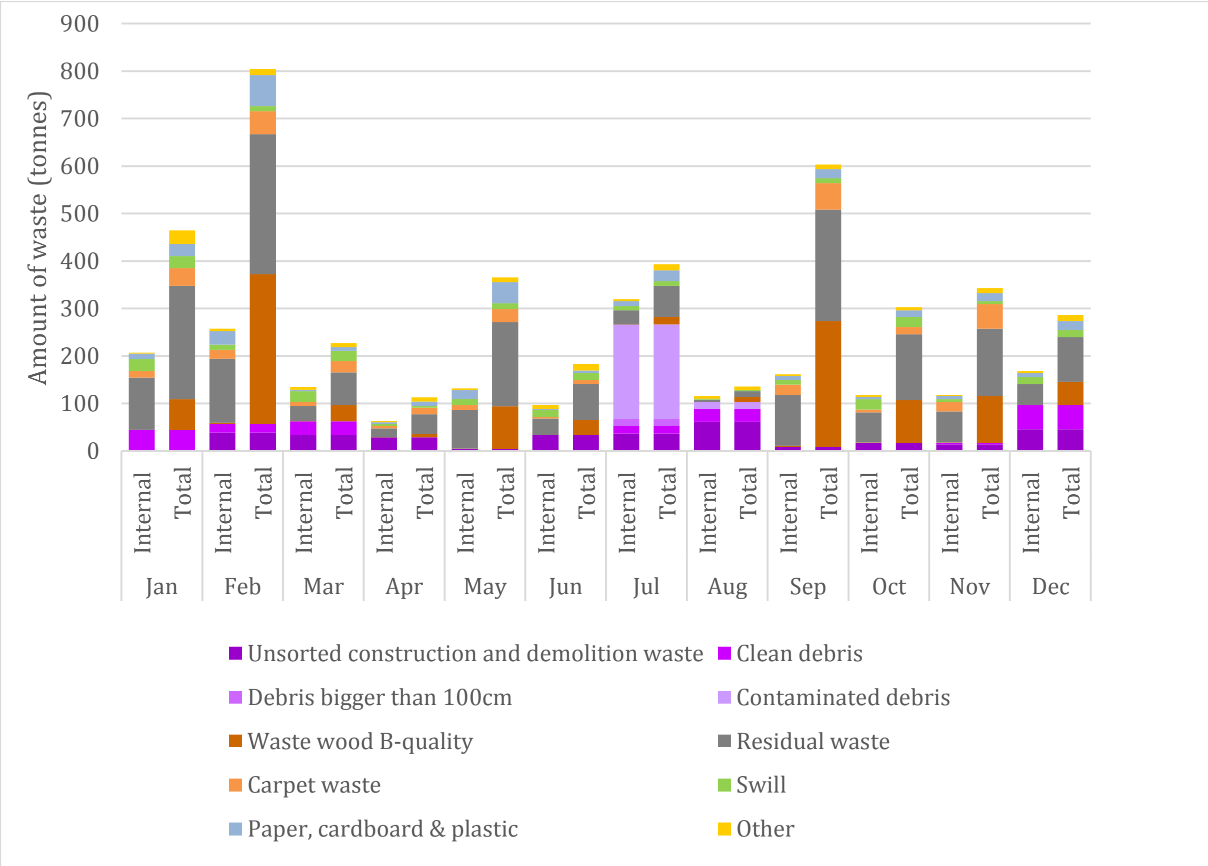

FIGURE 4: WASTE EXPORT FROM RAI IN 2017 PER MONTH. BOTH THE TOTAL WASTE EXPORT AND THE SHARE OF INTERNAL WASTE IS SHOWN (RAI AMSTERDAM, 2017C; DEKKER, P.C., 19 MARCH 2018; RENEWI, 2018). THE DATA (ALSO OF THE WASTE FLOWS PART OF THE CATEGORY 'OTHER') CAN BE VIEWED IN APPENDIX IV.

From all the different material flows, RAI has most influence on the flows caused by the products they buy themselves, and less on the flows caused by the external event organisers, exhibitors and visitors (Moens, p.c., 13 February 2018). Therefore, the material flows of RAI and of the other parties are treated separately in this research. In the next chapter, the different material flows and their origin are discussed in detail.

5. Material flows RAI

In this chapter, the material flows of RAI are described and visualised in a Sankey diagram (see Figure 7). First, the incoming flows are described, followed by a description of the outgoing flows. In the second part of this chapter, the outgoing flows are discussed in detail including the process after the materials have left RAI. They are also linked to the incoming flows as much as possible.

5.1 General information on material flows

5.1.1 Incoming material flows

From Figure 7 can be derived that many incoming materials (71%) that end up as waste at RAI come from organisers and exhibitors (external waste). The smaller part (29%) is generated by RAI itself (internal waste). From the incoming material flows caused by organisers and exhibitors, it is not possible to get a full overview of what kind of products it consists as this is not tracked and differs from event to event and between exhibitors. Only limited information on this is available. RAI tries to influence the material flows by informing the organisations and exhibitors about more circular options for certain products and ways in which they could contribute to avoiding waste generation (RAI, 2017c). The available information on the material flows is mentioned in section 5.2 where the different outgoing material flows are discussed in detail and connected to the incoming material flows.
The other incoming materials are purchased by RAI itself. They do this as much as possible at existing suppliers to keep overview and to limit risks and logistical pressure. RAI does not have an overview of the different products they purchased in 2017 as they only track their financial data (the money spent per supplier). However, they plan to make this possible in their system to be able to do more with data, use dashboards, and communicate more in this area (Eenbergen, p.c., 18 May 2018). Since the data was not available, some employees of RAI were interviewed to gain a broad overview of the most important items purchased by RAI. The information gained with this is also mentioned in section 5.2.

5.1.2 Outgoing material flows

Much of the incoming flows of RAI eventually leave RAI as waste. Waste separation is an important topic for RAI as can be viewed in their waste management policy. For each event, a new waste plan is developed, and the *polluter pays principle* is used. This means that the organisation of an event pays for the waste they generate at RAI. The organisation can assign part of the waste to the exhibitors. In this way, the people causing the waste have to pay for it, which lowers the costs for the organiser and leads to higher separation rates. The costs for unseparated waste are namely higher than for separated waste. Assigning the waste to the different stakeholders is done by environmental inspectors. They advise organisations and exhibitors how they can best dispose of their waste and sell containers for waste to exhibitors. The waste not paid for by exhibitors is charged to the organisation. These tools to reach maximum waste separation are explained clearly to organisations in the Handbook Sustainable Organising (RAI Amsterdam, 2017b). However, a big problem still exists during the build-up and breakdown of an event. During these periods, around 70% of the total amount of waste of an event is generated (Moens, 2018). Figures 5 and 6 show examples of a build-up and breakdown of two different events at RAI. Previously, big paper containers were made available during these periods. However, this is not done anymore as this showed to lead to a highly polluted (all kinds of materials together) waste flow (Gerritsen, p.c., 2 March 2018). Now, stand builders and exhibitors can rent containers for different types of waste (paper, wood, unseparated) from Renewi Icova whereby containers for unseparated waste are most expensive (Dekker, p.c., 19 March 2018). In addition, they get big bags in which they can put their foils. However, during the build-up a lot of waste of the stand builders is not put in containers but is left behind on the floor, even though the exhibitors are paying the stand builders disposal costs for their waste. In this way, the stand builders make more profit (Dekker, p.c., 19 March 2018). It is hard to hold stand builders and exhibitors accountable for their waste as most of the times it is not clear who is responsible. During their own events, RAI is less strict to the stand builders and exhibitors leading to more (unseparated) waste. From this waste, the foils, wood and carpet, and sometimes the paper and cardboard are separated manually (except from the small parts). The remaining part ends up as residual waste. When there is a lot of time pressure, which is very often, fewer materials are separated. Only large pieces of wood are always separated, as the press container used for residual waste cannot handle wood. The time pressure is caused by the limited amount of space and the large number of events at RAI (Dekker, p.c., 19 March 2018).

<u>Other waste flows</u>

Besides the waste from events, there are also waste flows generated by the offices, maintenance, construction and renovation, and the disposal of appliances (Moens, p.c., 13 February 2018). In the offices, there are separate bins for plastics, paper, residual waste, and coffee cups. The plastic waste is not processed separately but put together with the residual waste after collecting. There are only separate bins for awareness creation (Dekker, p.c., 18 June 2018). Up until June 2018, the coffee cups were only collected separately to save space. Currently, new coffee cups are used which can be recycled to toilet paper or paper towels (Kolken, p.c., 30 April 2018). However, the volume still has to increase to make the logistics feasible (Dekker, p.c., 18 June 2018). In the cafeteria most often everything is disposed of as residual waste, but since May 2018, also a green waste bin is available. The Technical Services, which is responsible for the maintenance at RAI, is the main source of the iron waste, and a small part of the waste wood (Dekker, p.c., 29 March 2018). They also use a small part of the wood and iron waste when they see that useful materials are thrown away (Nietvelt, p.c., 2 May 2018). Furthermore, during construction, demolition and maintenance waste is created. In addition, RAI also disposes of appliances (RAI Amsterdam, 2017c). Because of the size of RAI and all the different activities, it is hard to keep an eye on everything in the waste area. For example, sometimes (for instance when the price of iron is high) waste is stolen, or companies having an office at RAI dump their waste in the containers of RAI (Dekker, p.c., 29 March 2018).

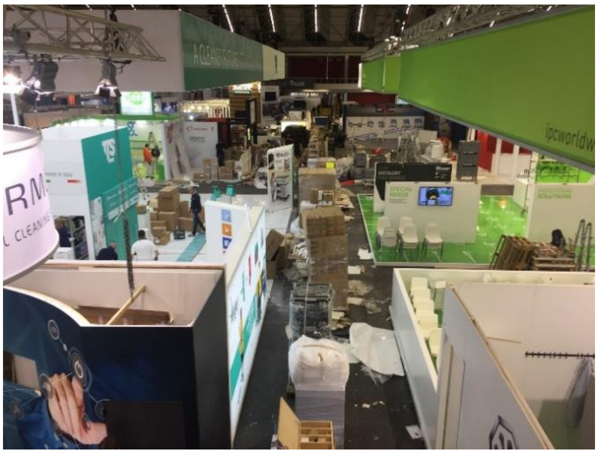

FIGURE 5: BUILD-UP INTERCLEAN.

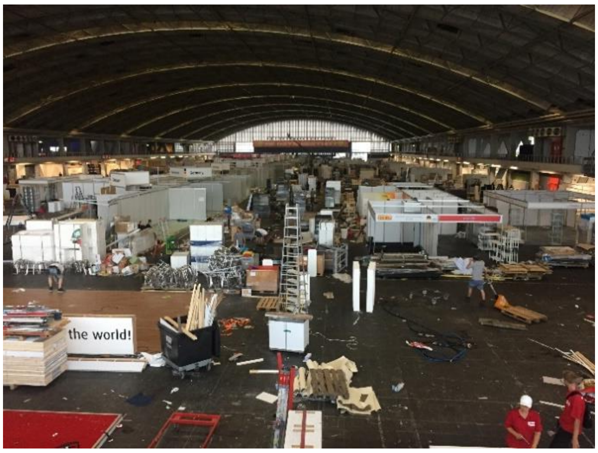

FIGURE 6: BREAKDOWN PLMA.

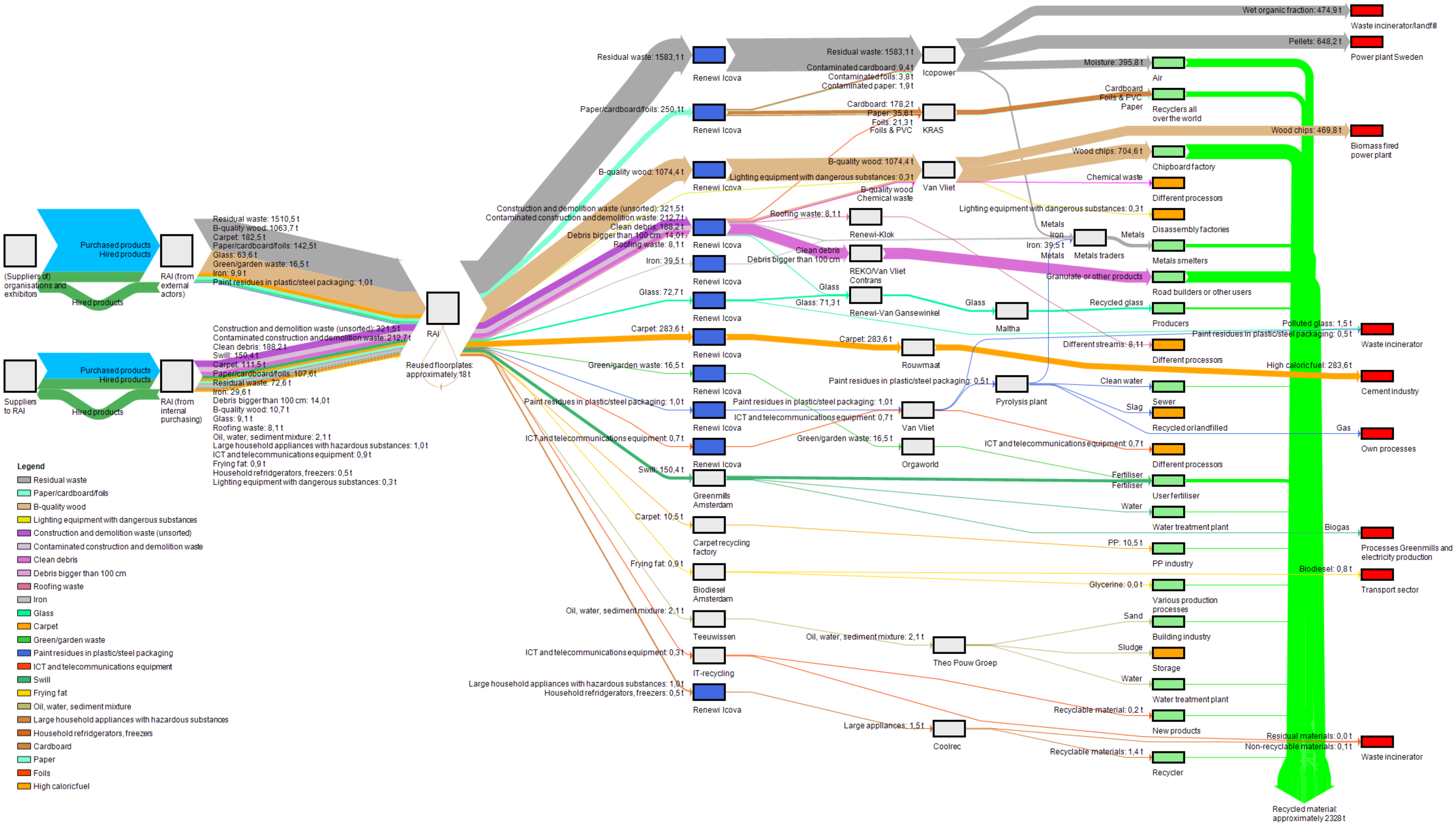

FIGURE 7: SANKEY DIAGRAM OF THE MATERIAL FLOWS GENERATED BY RAI. RENEWI ICOVA IS SHOWN IN BLUE BOXES. GREEN BOXES SHOW RECYCLING OF MATERIALS WHILE RED BOXES SHOW INCINERATION OR LANDFILLING. FOR FLOWS ENDING IN ORANGE BOXES IT IS NOT CLEAR WHETHER THE MATERIAL IS (PARTLY) RECYCLED, INCINERATED OR LANDFILLED.

5.2 Description specific material flows

Figure 7 shows the outgoing material flows of RAI over 2017 and what happens with them. It shows that RAI has many different outgoing flows and that still a large part of the total waste is unseparated (37%). Below, for every material flow is described, from large to small, what happens with them and their link to the incoming flows as far as possible. Residual materials, wood, unsorted building and construction materials, carpet, and paper, cardboard and foils together take up 83% of the waste. After quick research, some of these materials also show promising improvement possibilities. Therefore, these are the flows on which the main focus lies and are therefore discussed in more detail.

5.2.1 Residual materials

1583 tonnes
37%

Residual waste is the largest outgoing material flow. Only a small part of the residual waste is internal waste. The other part is external waste. The internal residual waste consists of residual and plastic waste from the offices, and catering waste. Looking at weight, the residual waste consists mainly of paper, PET bottles and swill (organic waste) (RAI Amsterdam, 2016). So better separation should be possible. Since such a large share consists of swill, in 2018 a pilot will be run to also separate green waste in the offices (Kolken, p.c., 30 April 2018). The external waste consists partly of waste from the build-up and breakdown of events, and partly of waste from the events themselves. From the waste from the build-up and breakdown, the waste collectors often get out the foils, wood, cardboard and carpet, which are the largest flows. The remaining part is mostly residual waste and (if reasonably possible) cannot be separated further due to time pressure. The remaining waste consists mainly of small parts of polluted wood, laminate, vinyl, plastic, coffee cups and other things generally ending up as residual waste. The residual waste from the events themselves consists mainly of plastic bottles, disposable plates and flyers (Dekker, p.c., 12 April 2018).
Part of the waste (from places where much internal waste is generated) is collected in so called EcoCassettes which are mobile press containers which press the waste together and thereby strongly reduce the volume of the waste and thus transport movements. These EcoCassettes are transported with an electric boat to Renewi Icova. The rest of the waste is collected in containers that are emptied in a big stationary press container, which also strongly reduces the volume of the waste and thereby transport movements (Dekker, p.c., 19 March 2018). Pressing the waste does not affect the possibilities for post-separation of the material (Gerritsen, p.c., 30 March 2018). This waste is transported with trucks to Renewi Icova. Here, the waste is post-separated at the post-separation plant: Icopower. First, materials not belonging in the waste are removed manually or with the use of a crane, like PVC and things which could clog up the plant (like carpet) (Gerritsen, p.c., 2 March 2018). In this research is assumed that these types of pollution are not present in the residual waste of RAI. In the plant, ferrous metals (5%), wet organic fraction (30%) (wood, glass, stone, etc.), and moisture (25%) are extracted from the residual waste (Gerritsen, p.c., 2 March 2018; RAI Amsterdam, 2017c). The ferrous metals are extracted using magnets and sent to metal traders who sell it to a smelter. The wet organic fraction is a difficult material flow. There is continuously tried to use it for fermenting or composting purposes. However, currently the material is still incinerated at AEB (Gerritsen, p.c., 30 March 2018) or landfilled (Utrecht Sustainability Institute, 2017; Brasz, p.c., 8 June 2018). Moisture

makes up 23-24% of the waste. This is too high to make it a good fuel. Therefore, this moisture is evaporated to get a moisture content of 7-8%. The remaining material mix (40%) (called fluff) is compressed to small pellets. Due to the friction, again some water is evaporated resulting in a moisture content in 4-6% which makes it dry enough for a fuel and wet enough to keep the material together (Gerritsen, p.c., 2 March 2018). The pellets are sent to different power plants of Vattenfall in Sweden. The distribution over the power plants varies, but the largest part of these pellets is transported to the Idbäcksverket plant in Nyköping, Sweden. Here, the pellets are burnt in a plant with a grate-fired boiler. The pellets are not used in the Netherlands, as there are not enough biomass-fired power plants and because the pellets are too expensive compared to other materials. This makes the domestic market for this type of fuel is not big enough (Gerritsen, p.c., 2 March 2018).

5.2.2 Wood

1074 tonnes
25%

The second biggest material flow is B-quality wood. This is wood which is of average quality. It can be all kinds of wood, treated or not, but not impregnated (Van Vliet Groep, 2016). Nearly all waste wood separated at RAI is external waste, less than 1% is internal waste caused by the Technical Services of RAI. The precise amount of internal waste is not clear as the Technical Services dump their wood in the container that is also used for the external waste wood (Dekker, p.c., 29 March 2018). The external waste is mainly waste from stands during the build-up and breakdown of events. This waste can be generated by three kinds of parties:

- Preferred suppliers (uniform stands): RAI has three stand builders who are their preferred suppliers; Hestex, The Inside and A-Booth. When building uniform stands, these suppliers do not create waste at RAI (Bik, p.c., 22 May 2018; Dasselaar, p.c., 22 May 2018; Noordman, p.c., 18 May 2018).
- Preferred suppliers (configuration/free-built stands): Sometimes, exhibitors also hire one of the preferred suppliers of RAI for building configuration stands or free-built stands. Hestex does not create waste in this area as they only build with fixed parts that are reused (Bik, p.c., 22 May 2018). A-Booth also does not create waste. They take everything back and reuse their materials (Noordman, p.c., 18 May 2018). The Inside does create some waste. After an event, the materials they use are partly included in their collection but also partly disposed of as waste at RAI or at their own location (Dasselaar, p.c., 22 May 2018).
- External stand builders (configuration/free-built stands): Most wood waste is generated by external (not preferred) stand builders from Eastern European countries that are hired by exhibitors. They leave much more (sometimes everything) of the stands they built behind at RAI (Noordman, p.c., 18 May 2018).

Not only for stands there is wood used. At big events there are pavilions built on the square in front of RAI. In these pavilions the floors are made of wooden plates. After an event 10% of the plates have to be disposed of. The rest is stored and reused for the next time (Nietvelt, p.c., 2 May 2018).

All wood that has to be removed from RAI is collected in a container with a roll packer that makes the wood more compact. This crushes the wood, which minimizes the volume and thereby transport movements with 60% compared to containers without roll packers (RAI Amsterdam, 2015). However, this makes the wood less useful for reuse (Zwart & Dekker, p.c., 24 May 2018). The wood is first transported to Renewi Icova and from there to Renewi Van Vliet Groep in Nieuwegein. Here, first other possible valuable materials are filtered from the material flow. Then, the wood is shredded and filtered on quality. It is not clear what share of the shredded wood is used for chipboard production, and what share ends up in biomass power plants. According to Renewi Icova, around 8% is used for chipboard production. For this destination, only the wood with the best quality is used. The other 92% is used as biomass in power plants for the production of green energy (Gerritsen, p.c., 22 March 2018). However, according to Johan Peter Post (p.c., 24 May 2018) of Renewi Van Vliet (where Renewi Icova transports their wood to) 60% of the wood goes to chipboard production in Germany and Belgium, and 40% is used as biomass for power plants in the Netherlands and Germany. According to Jurriën de Pijper (p.c., 26 April 2018) the percentages fluctuate continuously depending on the outlet opportunities. Since Renewi Van Vliet operates further down the material chain, their percentages for the destination of the wood chips are used in the remaining of this study. The high share of wood chips used as biomass in power plants is caused by a subsidy on co-firing of wood in coal-fired power plants (RVO, n.d.) combined with a low price for wood to make chipboards, which is partly caused by the increasing production of plates from other materials (Gerritsen, p.c., 22 March 2018).

5.2.3 Construction and demolition materials

744 tonnes
18%

This is a mixed material flow generated during building, renovation, maintenance and demolition projects (Born, p.c., 18 May 2018). Part of the waste is separated at RAI, but also partly at Renewi Icova (Gerritsen, p.c., 2 March 2018). Five different material flows are transported from RAI to Renewi Icova (RAI Amsterdam, 2017c):

- Unsorted construction and demolition waste
- Contaminated debris
- Clean debris
- Debris bigger than 100cm
- Roofing waste (tar contaminated).

The unsorted waste is the biggest flow. This is waste containing things like packaging waste, metals, wood and glass. This flow is post-separated at Renewi Icova. The stone-like material and glass (about 50% of the material) can be separated automatically with vibration technology and sieving techniques. Foils, PVC, metals and wood are separated manually on a belt conveyer. The PVC is sent to KRAS, which sells the material to final processors of which one is Van Werven in Oldebroek (Gerritsen, p.c., 2 March 2018). The way the other materials are processed is discussed in the other sections specific to these flows. The containers contaminated waste contain chemical waste like caulking guns and paint that is not completely hardened. Containers contaminated waste are separated at Renewi Icova just like the unsorted waste. Only here the chemical waste is sent to Van Vliet Groep in Nieuwegein (Gerritsen, p.c., 2 March 2018). Here, this waste is sent to different processors depending on the specific flows present in the chemical waste (Verhaal, p.c., 22 May 2018). The processing of the paint residues is discussed in section 5.2.12. Clean debris on the other hand can be used in many different ways. Most is processed to granulate which is used in the foundation of roads, but it is also used in dike reinforcement or as filler material for cement (Gerritsen, p.c., 2 March 2018). Debris bigger than 100cm is first broken into smaller pieces and then processed in the same way as clean debris. The clean debris (among others separated from the unsorted waste) and bigger debris are sent to different companies (for instance Recycling Kombinatie REKO B.V. or Van Vliet Contrans in Wateringen) which process it to granulate or other end products (Gerritsen, p.c., 2 March 2018). A difficult flow is the tar contaminated roofing waste, which is generated every year when part of the roofs are renewed. This type of waste is currently sorted at Renewi KLOK. All recyclable materials like wood, stone, and non-ferrous materials are disposed of separately. The two big fractions remaining are roofing felt and a sieve fraction (Renewi KLOK, n.d.). It is not clear what the share is of these different fractions and what happens with them as this informations is not public (Kolk, p.c., 15 June 2018).

5.2.4 Carpet

294 tonnes
7%

This is already a much smaller waste flow that is partly external and partly internal as some events are organised by RAI itself. The flow consists of carpet used in the aisles, in stands, and carpet from the workshop of Schreuder.

<u>Carpet used in the aisles</u>
Most carpet waste processed by Renewi Icova is generated by the carpet used in the aisles. This is mainly carpet of Schreuder as this is the preferred supplier of RAI who lets the carpet be processed by Renewi Icova. When the carpet for the aisles is laid by another company, this company often takes back the carpet as it is expensive for the organisation to process it via Renewi Icova (Dekker, p.c., 29 March 2018). Schreuder uses two types of carpet for the aisles, depending on the quality needed. One is made of 100% polypropylene and the other is made of polypropylene with a lime backing (Schreuder, p.c., 22 March 2018). The first one is recyclable to PP (polypropylene) products and can be brought back to the factory when more than 20.000 m2 is used. When less carpet is used, it is financially not attractive to recycle due to relatively high transport costs (Schreuder, p.c., 24 May 2018). As can be derived from Figure 7, in 2017 10,5 tonnes is recycled in this way. This number is not higher as this type of carpet is mostly used for small trade shows and not for big public fairs, which makes the number of events with a large amount of carpet small. Additionally, the carpet is only accepted by the factory when it is not polluted, which is almost impossible at big public fairs. The carpet that is not recycled is transported to Renewi Icova (Schreuder, p.c., 22 March 2018). From here it is transported to Rouwmaat in Groenlo in 2017 (currently they use another processor where it is processed in a similar way). This company shredders the carpet together with other waste to a high caloric fuel, which can be used in cement production. This fuel is used in three different cement ovens in Germany (Tuinte, p.c., 24 April 2018).

<u>Carpet used in stands</u>
Next to the carpet used in the aisles, there is also different carpet used in the stands. When Schreuder lays this, carpet tiles are used (Bemmel, p.c., 19 March 2018). These tiles are cleaned and reused after an event. Each year there is a loss of 6-7% of the tile stock. These tiles are processed by Rouwmaat or sometimes used as insulator in sound booths. However, this is transported directly from Schreuder to Renewi Icova, and not via RAI, so this flow is not visible in Figure 7. Next to the tiles of Schreuder, there

is also other carpet laid in the stands, this is often taken back by the carpet company or the exhibitor, but sometimes it is also left behind. This carpet is also processed by Rouwmaat (Dekker, p.c., 29 March 2018).

<u>Carpet from workshop Schreuder</u>
A small part of the material flow is caused by carpet waste from Schreuder, as their workshop is located at RAI. This waste is not related to activities of RAI. Sometimes they throw small amounts of carpet waste together with carpet waste from RAI. When they have large amounts of carpet waste from other activities, they do buy a separate container from Renewi Icova (Dekker, p.c., 29 March 2018).

5.2.5 Paper, cardboard and foils

250 tonnes
6%

These materials are combined in one material flow as the (transparent and black) foil collected separately in bags at RAI is put together with the paper and cardboard in containers that are weighed at Renewi Icova. Next to the foil there is no other plastic collected. This because the flow from the office is too limited and is often polluted with for instance food waste. Also, there is no room for a separate plastics container for all plastic from RAI. Bags with mixed plastic waste cannot be put together with the bags of foil waste in the paper and cardboard container as the different bags cannot easily be separated at Renewi Icova. Therefore, the 'plastic' waste from the offices is currently put together with the residual waste.
Looking at the total waste flow, about half is internal waste. This is mainly caused by cardboard boxes from the production kitchen which takes care of the catering, but also the leftover catalogues cause a lot of paper waste (Dekker, p.c., 19 March 2018). The external waste is mainly generated by cardboard boxes thrown away by exhibitors (Dekker, p.c., 29 March 2018). Only a small part of the internal and external waste consists of foil waste. These foils are coming from rental products or other products that are transported in foil (Bemmel, p.c., 19 March 2018). Like with the residual waste, part of the paper, cardboard and foil is collected in EcoCassettes which are transported by boat, and part of it is collected in normal containers which are emptied in a large stationary press (Dekker, p.c., 19 March 2018). At Renewi Icova, the cardboard (75%), paper (15%), and foil (10%) are separated.

<u>Cardboard and paper</u>
The material is first (partly by hand) checked on quality and pollution. About 5% is rejected for recycling and processed in Icopower. The suitable cardboard and paper is baled together and sent to KRAS, where it is put together with cardboard and paper from other parties and sold to final processors all over the world (Gerritsen, p.c., 2 March 2018). These are mainly processors in Asia and Europe, depending on supply, demand and quality (Gerritsen, p.c., 30 March 2018). The acceptance criteria at the processing companies are becoming increasingly strict, as there is more supply than demand for paper and carton waste. This causes that less pollution is allowed causing the returns for Renewi Icova to go down. Therefore, Renewi Icova pushes on better separation at the source. Currently, around 5% of the bales are rejected and processed as industrial waste (Gerritsen, p.c., 30 March 2018). In this case, the middleman has to pay instead of being paid for it (Gerritsen, p.c., 2 March 2018). The paper and cardboard that is recycled can be used for all kinds of new products (PRN, n.d.).

Foils

Transparent foils are collected separately from the black foils in bags. These bags, when separated from the paper and cardboard, are first visually checked on quality (Gerritsen, p.c., 2 March 2018). 10-15% of the foils from RAI is of insufficient quality for recycling. They are further processed in Icopower for the production of pellets (Gerritsen, p.c., 30 March 2018). The content of the approved bags is first put on belt conveyors where pollution is manually removed and sent to Icopower. The remaining recyclable foils are baled and sent off to KRAS where they are put together with other foils and sent to final processors all over the world. For clear foil it is easy to find a processor (Gerritsen, p.c., 2 March 2018). For other plastics the acceptance criteria are getting increasingly strict, currently only less than 2% pollution is allowed (Pijper, p.c., 26 April 2018).

5.2.6 Swill

150 tonnes
4%

With their own catering, RAI produces a lot of swill, which consists of cooked food remains. RAI actively aims to reduce food waste by purchasing proportional to the need and send food remains to the Voedselbank. In addition, the aim is to not let food waste end up as residual waste (RAI Amsterdam, n.d.a) but as swill. All swill is considered internal waste as almost no organisation uses an external party for the catering (Moens, p.c., 13 February 2018). For this waste flow RAI has a swill tank underground. This tank is drained when it is full. The truck emptying the tank also empties the grease traps located at RAI (Pijper, p.c., 26 April 2018). This mix is then transported to the anaerobic fermenting facility of Greenmills in Amsterdam (Gerritsen, p.c., 2 March 2018). Here it is fermented which creates biogas, which, in the form of steam, heat and green energy, is partly used in the own processes of Greenmills. Part of the heat is used to convert the residue of the fermentation process into a high-quality fertilizer. The rest of the heat is used in a district heating network of Amsterdam (Gerritsen, p.c., 2 March 2018). The electricity is partly used by themselves but mainly put on the electricity grid (Orgaworld, n.d.).

5.2.7 Glass

73 tonnes
2%

The largest part of the glass disposed of by RAI is external waste and consist mainly of glass bottles (mainly wine bottles). A small part of the flow consists of deposit-return-packaging. These are bottles that are not returned to the supplier. This is only a small share in the total amount of deposit-return packages at RAI, which are normally returned to the supplier (Sint, p.c., 24 April 2018). The returned deposit-return packages are included in the return flow of hired products from RAI to its suppliers in Figure 7. Glass is a perfectly recyclable material as it can be recycled repeatedly to new glass without quality losses (Milieu Centraal, n.d.). It is well separated at RAI resulting in a clean glass stream. The glass containers are first transported to Renewi Icova where it is bulked and checked on pollution (Gerritsen, p.c., 2 March 2018). The pollution is removed as much as possible. When this is not possible, the polluted glass is incinerated (Pijper, p.c., 26 April 2018). The clean glass is transported to Van Gansewinkel and from there shipped to one of the locations of Maltha in the Netherlands or Germany, depending on the capacity and planning. These containers are not often rejected. At Maltha the glass is broken into little pieces, remaining pollution is removed, and the different types of glass are separated on colour using laser technique. Then, the glass is granulated and transported to a glass factory where it is molten and made into new glass (Gerritsen, p.c., 2 March 2018). Of the total amount of glass collected, 98% can be used to make new glass products. The other 2% is lost due to pollution. Pollution due to metals is not a big problem as they can be filtered from the glass flow, but pollution due to ceramics is the biggest problem. The rejected materials are processed as industrial waste (Gerritsen, p.c., 22 March 2018).

5.2.8 Iron

40 tonnes
0,9%

The iron waste is a waste flow consisting of ferrous metals (metals mostly containing iron) mainly produced internal by the Technical Services of RAI (around 75%). Only a small part is caused by events. The division internal/external waste is not entirely clear as the iron container is freely accessible and people from Technical Services dispose of their iron waste there without mentioning it to Renewi Icova (Dekker, p.c., 19 March 2018). The iron is first transported to Renewi Icova. From there it is transported to local or regional metals traders that eventually sent it to (foreign) smelters where it is molten for new steel production (Gerritsen, p.c., 22 March 2018).

5.2.9 Green/garden materials

16 tonnes
0,4%

This type of waste is mainly generated at specific events, for instance at horse events where a lot of hay bales end up as waste, or at events where schoolchildren build gardens which constantly have to be cleared for the new group (Dekker, p.c., 19 March 2018). This type of waste has different characteristics than swill and is therefore processed separately. The waste is first transported to Renewi Icova and from there to Orgaworld Lelystad where they have a biocel that composts this waste to a fertilizer (Gerritsen, p.c., 22 March 2018).

5.2.11 Oil, water, sediment mixture

2 tonnes
0,05%

RAI has a few oil separators that clean wastewater to avoid that mineral oils end up in the sewer. In these separators, a mixture of sand, sludge (with pollution) and water accumulates. When these separators are emptied, the mixture is transported to Teeuwissen in Huizen. Here it is bulked and from here transported to Theo Pouw in Utrecht where extractive cleaning is carried out (Pijper, p.c., 26 April 2018). In this process the sand, sludge, and water are separated. The sand can be reused, and the water is cleaned. The sludge is sent to a processor that bulks it up and stores it for times when new techniques are available to process this flow (Stigter, p.c., 25 June 2018).

5.2.12 Large household appliances containing hazardous substances and household refrigerators and freezers

1,5 tonnes (1 tonne and 0,5 tonnes)
0,04%

During the year, RAI disposes of large household appliances like dishwashers, ovens, etc. which might contain hazardous substances. These are processed the same way as refrigerators and freezers (Gerritsen, p.c., 22 March 2018). The appliances are disposed of by RAI because they are broken or because new appliances perform more effective or efficiently. The appliances are first transported to Renewi Icova and from there sent to Coolrec, which is part of Renewi (Gerritsen, p.c., 22 March 2018). Here, more than 95% of the materials is recovered and recycled for the production of new appliances (Coolrec, n.d.).

5.2.13 Paint residues in plastic/steel packaging

1 tonne
0,02%

Next to the chemical waste in the construction and demolition material flow, there is a separate material flow for paint residues in plastic/steel packaging. This type of waste is caused during the build-up of events when much stands are painted (Dekker, p.c., 19 March 2018). This type of waste is first transported to Renewi Icova and from there to Van Vliet in Nieuwegein. This company in turn transports part of the paint residues to an incinerator (Verhaal, p.c., 22 May 2018). The other part is sent to ATM in Moerdijk where it is shredded and processed in a pyrolysis plant (Verhaal, p.c., 22 May 2018; Gerritsen, p.c., 22 March 2018). Here the materials are heated with a low oxygen concentration. This causes incomplete combustion. The ferrous metals from the packaging are won back for recycling and the water is cleaned. The remaining residues are disposed of for further recycling or are landfilled (ATM, n.d.).

5.2.14 ICT and telecommunications equipment

0,9 tonnes
0,02%

Like almost every company, RAI also produces waste from ICT and telecommunications equipment. This because every employee has a laptop and phone from RAI which need to be replaced after some time. In addition, computer screens on workplaces and other equipment sometimes need replacement (Koopman, p.c., 11 April 2018). Phones that are still worth enough are returned to the supplier. Printers and cartridges are also returned to the supplier (Xerox). From the other products, a part is processed by IT-recycling. These are products like monitors, laptops and cables (Koopman, p.c., 11 April 2018). They are processed according to the "Ladder van Lansink" which is comparable to the different activity-levels of the circular economy. The company recycles at least 85% of the materials (IT-recycling, 2018). However, the largest part of the products that are not returned to the supplier is transported to Renewi Icova and from there to Van Vliet in Nieuwegein, which sends the different types and qualities of equipment to different processors (among which Coolrec and Arrow Value Recovery).

5.2.15 Frying fat

0,9 tonnes
0,02%

With their catering activities, RAI produces used frying fat. This frying fat has a high energy content, which makes it a useful energy source (Gerritsen, p.c., 2 March 2018; Gerritsen, p.c., 22 March 2018). The frying fat is transported by Rotie to Biodiesel Amsterdam (Dekker, p.c., 12 April 2018). Here some additional substances (like sulfuric acid, KOH, and methanol) are added to make it possible to produce biodiesel (about 95%), glycerin (about 5%), and a small amount of organic wastewater and fertilizer. The fertilizer is then used in the agricultural sector and the organic (polluted) wastewater (which might include vegetable food remains) is transported to Orgaworld where it is fermented and converted into biogas and soil improver (Jong, p.c., 12 April 2018).

5.2.16 Lighting equipment containing hazardous substances

0,3 tonnes
0,01%

The last material flow is lighting equipment containing hazardous substances. This type of waste is caused by the replacement of the lighting needed in the different buildings of RAI. This type of waste contains hazardous substances and is therefore stored in chemo bunkers at RAI and then directly transported to Van Vliet in Nieuwegein. From here, the flow is sent to factories where the lighting equipment is disassembled in glass, metal and plastics amongst others (Pijper, p.c., 26 April 2018).

6. Evaluation material flows

From the previous chapter can be derived that a lot of material flows through RAI and that there are a lot of different waste flows and end products. As already mentioned, the focal material flows (based on their size and possibility for improvement) are the residual materials, wood, unsorted building and construction materials, carpet, and paper, cardboard and foils. In this section, these flows are evaluated on their circularity.

6.1 Residual materials

With 37% of the total amount of waste, residual waste is the number one largest waste flow of RAI. Looking activity-wise at the circularity of this material flow, so at the size of the loops, Figure 8 shows that the material flows score level 0 and level 1 (for explanation on the scoring see chapter 3.1). The largest share of materials score level 0 as they are incinerated or landfilled. Since the flow consists of much different materials that are hard to separate, it is hard to reach level 2, 3 or 4. However, procurement that is more circular, and better separation at RAI, can decrease the amount of residual materials and therefore the amount of materials scoring low on circularity.

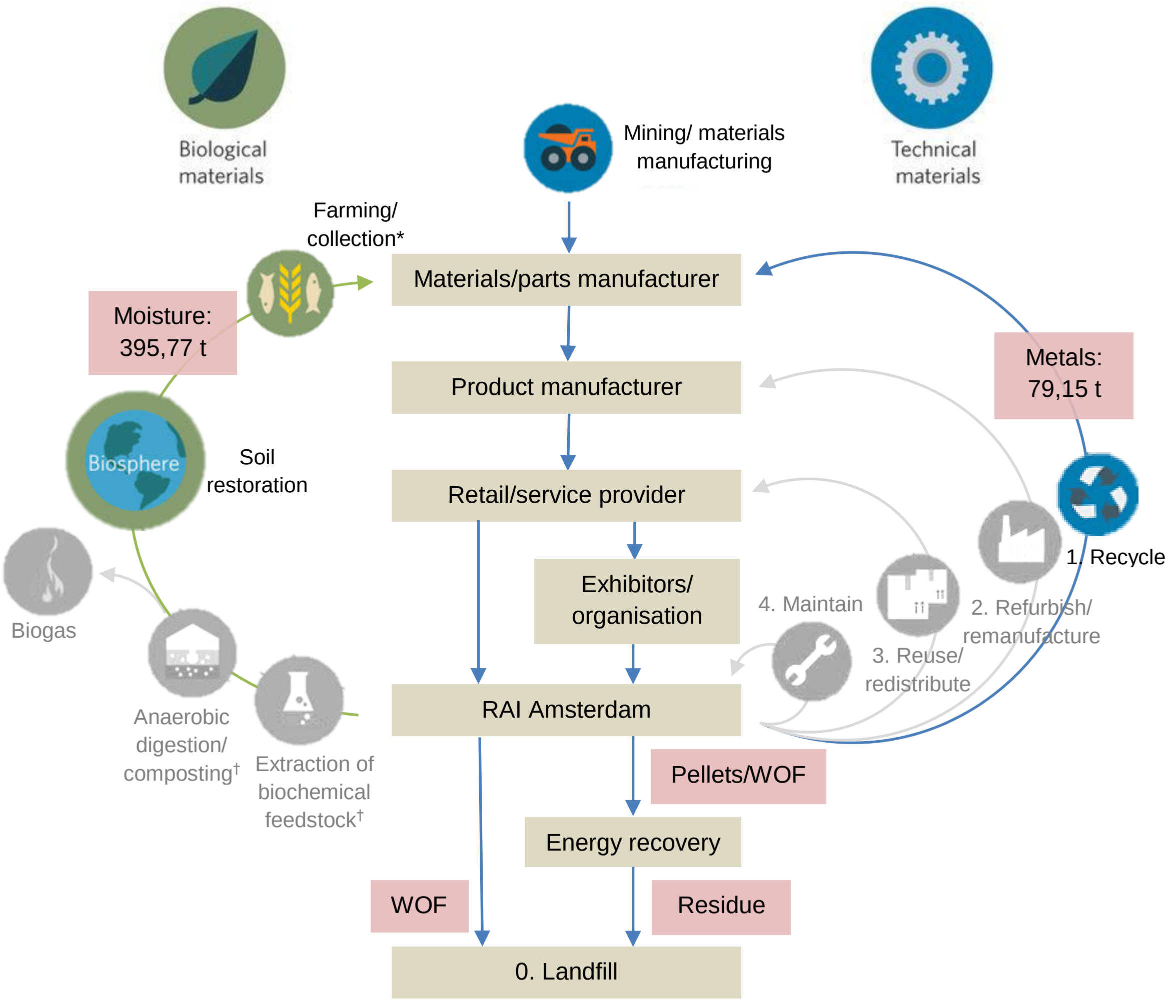

FIGURE 8: ACTIVITY-WISE CIRCULARITY RESIDUAL MATERIALS.

The distance the different materials travel is shown in Figure 9. The material flows score high on geographical circularity when they travel shorter distances (for the scoring see chapter 3.1). The moisture that is evaporated and part of the wet organic fraction (WOF) score level 4 as the moisture evaporates directly at Icopower and part of the WOF is incinerated very close to Icopower. The other part of the WOF scores level 1 as it is landfilled in the east of The Netherlands or Germany (Brasz, p.c., 8 June 2018). The distance traveled for this flow is an estimation. The pellets score level 0 as these are shipped over a long distance to Sweden to be incinerated. The ferrous metals also score level 0 as this material is shipped all over the world (but mostly to Turkey), which makes it likely that the average distance is longer than 500 kilometers (Port of Amsterdam, n.d.). For the distance to the metals trader, it is assumed that these metals are traded by HKS Scrap Metals B.V., as this company was mentioned by Jurriën de Pijper (p.c., 26 April 2018) as one of the trading companies.

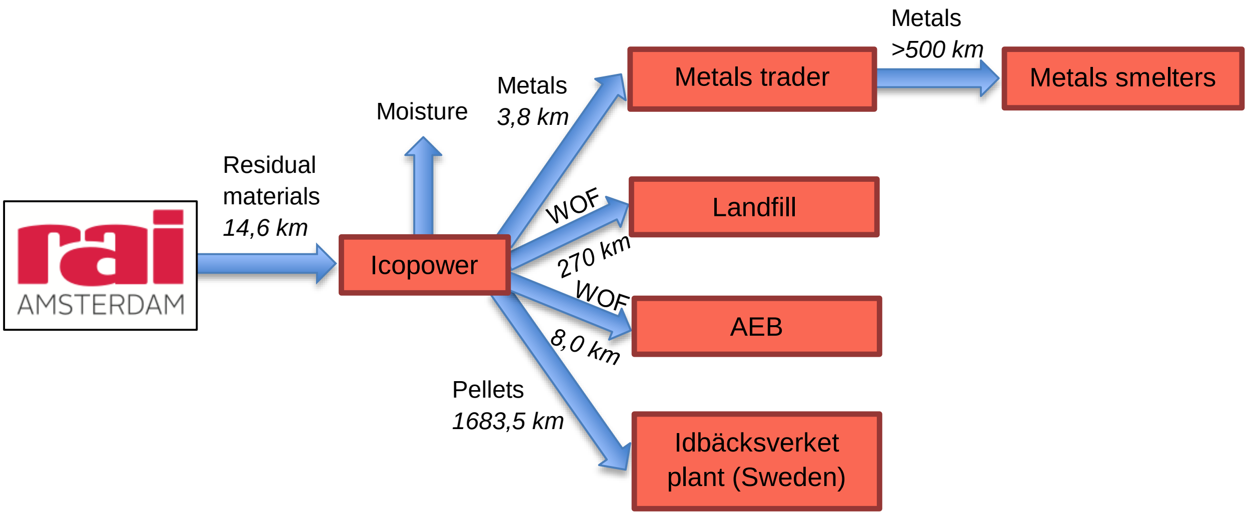

FIGURE 9: MATERIAL FLOWS RESIDUAL MATERIALS INCLUDING DISTANCES.

The time the materials remain in the loop is very short and therefore they score level 0 in this area. The internal waste consists mainly of materials only used for one day. Only the paper might be used for a long time. The external waste from the build-up and break down is used for only one day or for the duration of the event (of which the duration of often maximum 1 week). The residual waste from the events is also only used for one day.

6.2 Wood

Wood is the second largest material flow of RAI covering 25% of the total amount of outgoing materials. Activity-wise, the wood cannot be used as input in the biological materials cycle as the flow contains toxic substances from for instance paint and glue which makes it not suitable for composting and anaerobic digestion. Instead, it is used as a technical material or is incinerated. The material flow scores level 0, 1 and 3 (see Figure 10). The amount of wood reused (level 3) for uniform stands and wooden plates is unknown. From the wood that is disposed of, 60% is recycled (level 1) to chipboard and 40% is incinerated (level 0). Higher scores in circularity can for instance be reached by selling the wood that is currently incinerated or recycled to companies or organisations that can reuse the wood or recycle a higher percentage. Nevertheless, the first priority should be to reduce the amount of wood waste.

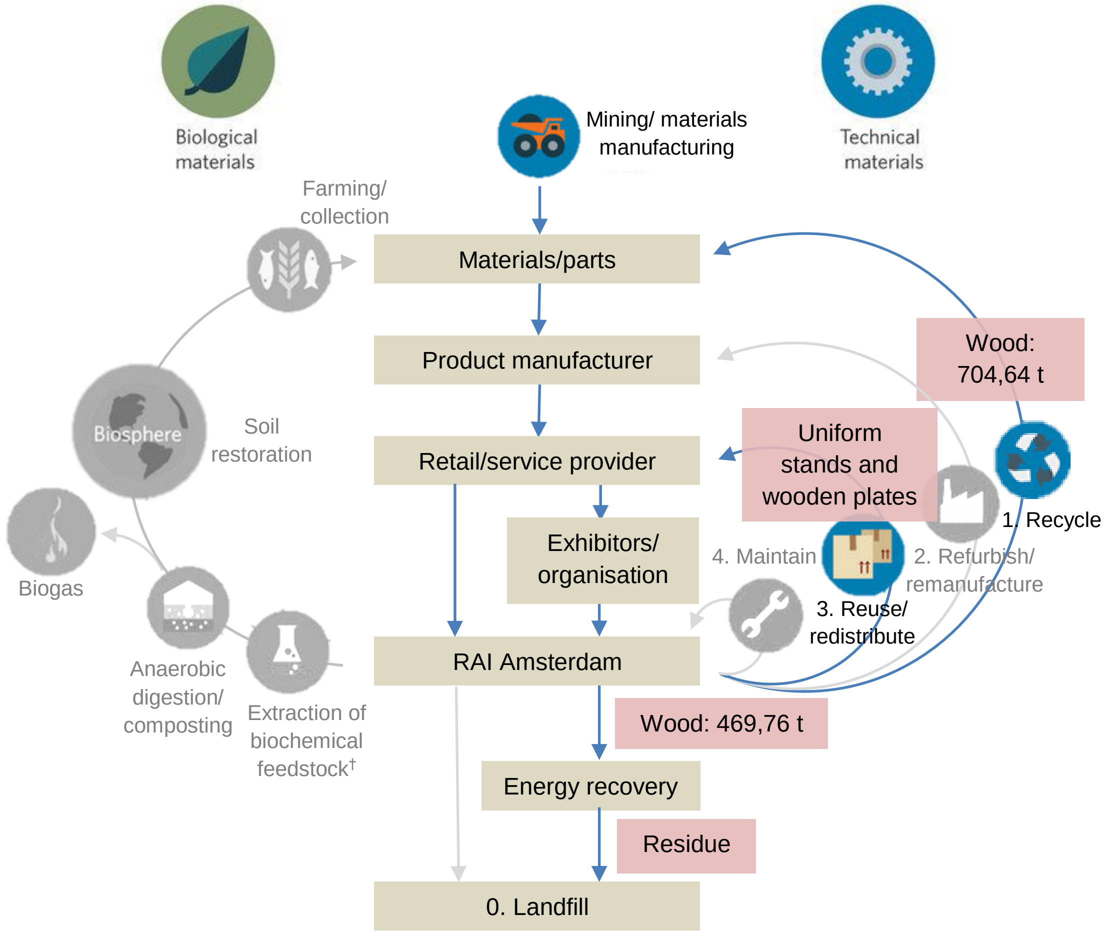

FIGURE 10: ACTIVITY-WISE CIRCULARITY WOOD.

The distance the wood travels is shown in Figure 11. Distances from Renewi Van Vliet further to the chipboard factory and biomass fired power plant are estimations as the precise location of processing is not known. The wood chips for chipboard production are sent to factories in Belgium or Germany while the other woodchips can end up in The Netherlands or Germany (Post, p.c., 24 May 2018). Because of the long distances, the recycled and incinerated wood scores level 1 on geographical circularity. The reused wood travels a shorter distance to and from the preferred suppliers, which are located on average on 70 kilometers from RAI. This results in a level 2 score on geographical circularity. The wooden plates score level 4 as are kept at RAI.

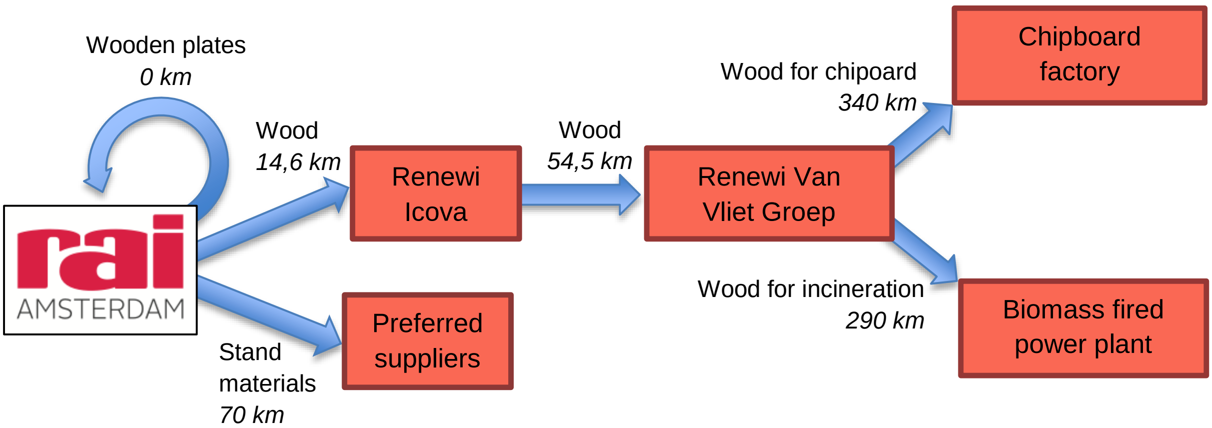

FIGURE 11: MATERIAL FLOWS WOOD INCLUDING DISTANCES.

The time the wood remains in the loop is generally short. For non-uniform stands the duration can be one day (wood left behind after the construction of stands), one event (whole stands) or longer (stands or stand parts used on more events). It is not clear which share of this wood is used for a longer time. It is expected that the material is used for a maximum of 6 months, which results in level 0 and 1 on the time remaining in the loop for the wood used in non-uniform stands. The uniform stands remain much longer in the loop. A wooden panel can be used approximately 30-40 times (Noordman, p.c., 18 May 2018). It is estimated that these panels are used on average for 1-5 years, which results in level 4.

6.3 Construction and demolition materials

Construction and demolition materials are currently the third largest waste flow of RAI (covering 18%). This category consists of five different flows: unsorted waste, contaminated debris, clean debris, debris bigger than 100 cm, and roofing waste (tar contaminated) (RAI Amsterdam, 2017c). These flows combined score levels 0, 1 and 4 on activity-wise circularity (see Figure 12). The materials that are recycled or incinerated reach level 0 and 1. The part that is incinerated is the chemical waste in the unsorted waste, the roofing waste, and most likely a large part of the contaminated waste. The amounts could not be included in Figure 12 as information on this subject is lacking. The maintenance of the buildings of RAI causes that less waste is created causing a level 4 score. Higher scores for the materials scoring level 0 and 1 can be reached by the reuse of materials when they leave RAI.

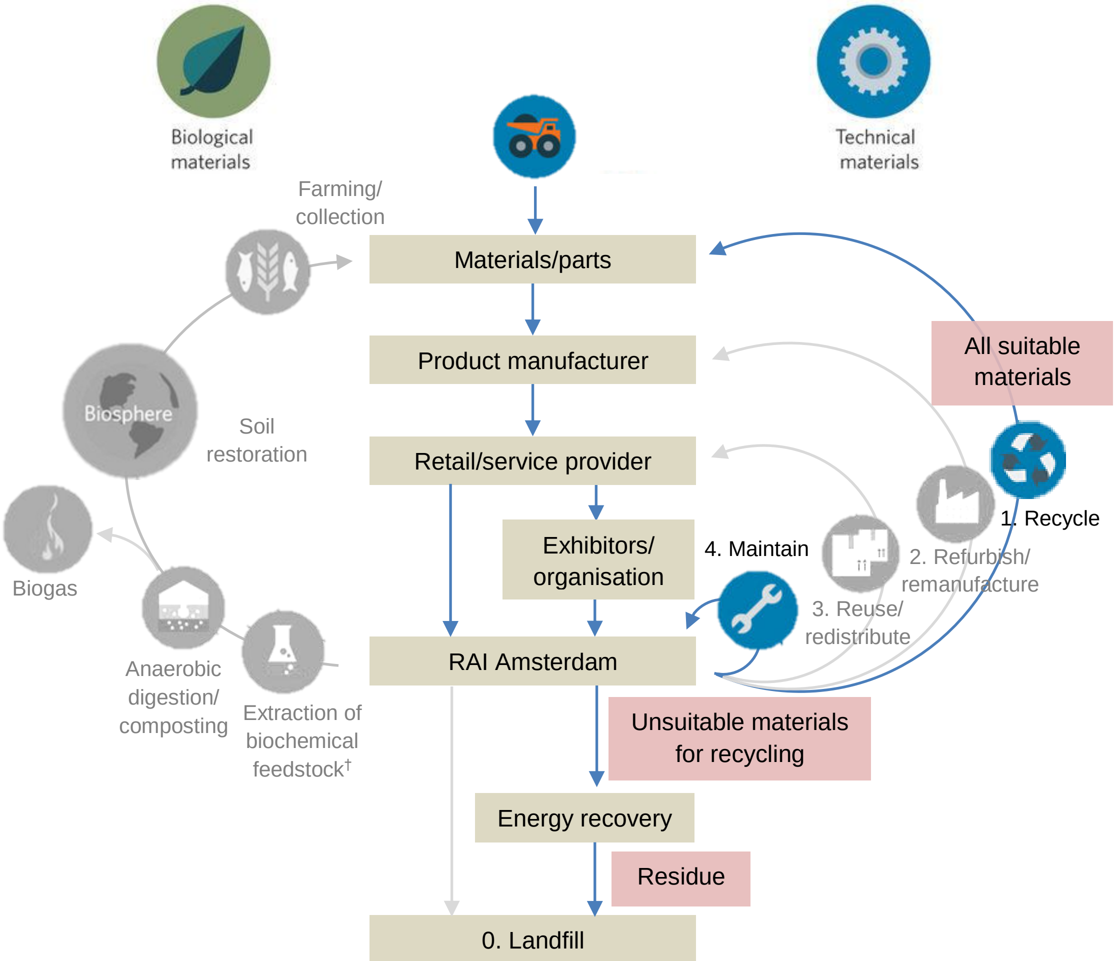

FIGURE 12: ACTIVITY-WISE CIRCULARITY OF CONSTRUCTION AND DEMOLITION MATERIALS.

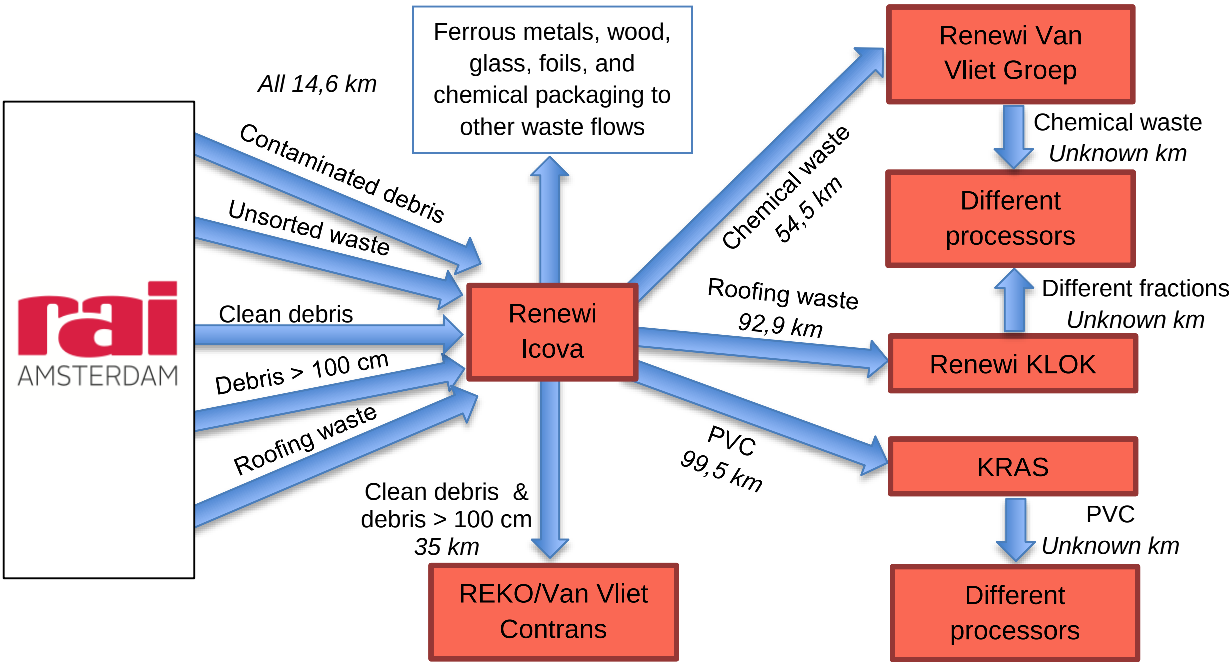

FIGURE 13: MATERIAL FLOWS CONSTRUCTION AND DEMOLITION MATERIALS INCLUDING DISTANCES.

Figure 13 shows the distances the different materials of the building and construction flow travel. The distance the clean debris and the debris bigger than 100 cm travel is an estimation as this is not always sent to the same processor. Most likely the processor is in Amsterdam or Wateringen (Gerritsen, p.c., 2 March 2018). The scores on geographical circularity are level 2 for roofing waste and PVC, and level 3 for the clean debris and debris bigger than 100 cm. For PVC the distance traveled is based on the distance to the only processor that is known to process part of the waste. For chemical waste and roofing waste the level cannot be determined, as for chemical waste the waste is transported to many different processors depending on the specific flows. For roofing waste the information is not public. Nevertheless, the level is 2 or lower as Renewi KLOK is already located on 92,9 km from Renewi Icova. The time the building and construction materials remain in the loop is generally very long as they are used in buildings that stay there for a long time. The buildings are expected to be used for more than 5 years, which results in a level 4 on the time remaining in the loop.

6.4 Carpet

Carpet is a smaller waste flow at RAI (covering only 7%). The scores of this material flow are shown in Figure 14. Most carpet (in weight) is hired and reused and therefore scores level 3 on activity-wise circularity. However, also much carpet is converted to a fuel and then incinerated and therefore scores level 0. A small flow of polypropylene (PP) carpet is recycled to PP products and scores level 1. Higher scores can be reached when a larger amount of carpet is maintained, reused or recycled. However, it is not attractive to recycle the carpet that is used in the aisles because the transport costs are very high because carpet cannot be transported in a compact way. The carpet cannot be rolled up to save space as it has to be removed from the halls at RAI as fast as possible and rolling it up takes a lot of time (Moens, Schreuder, Gelder, Hof, p.c., 12 February 2018).

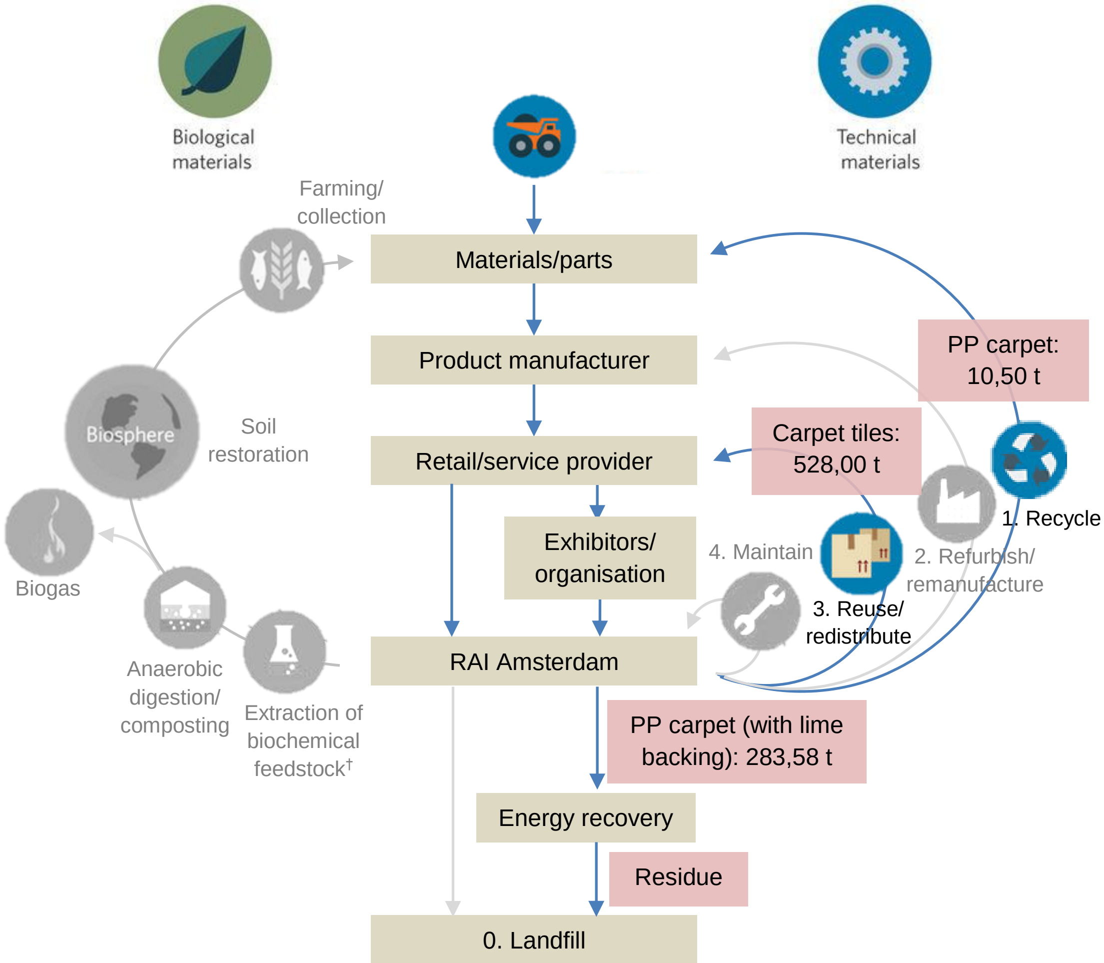

FIGURE 14: ACTIVITY-WISE CIRCULARITY CARPET.

Figure 15 shows the distances the carpet from RAI travels. These distances are very long compared to other material flows resulting in a score of level 1 on geographical circularity. A carpet processor or recycling factory closer by would result in a higher level.

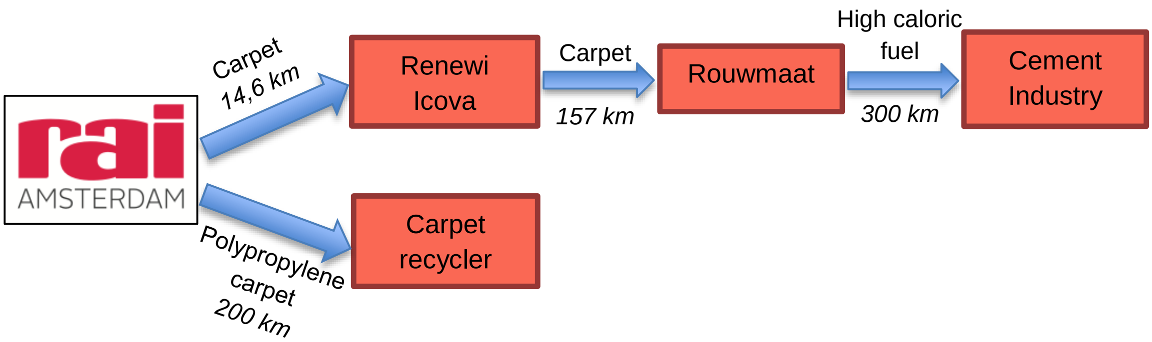

FIGURE 15: MATERIAL FLOWS CARPET INCLUDING DISTANCES.

36% of the carpet is bought by RAI. The time this carpet remains in the loop is very short; namely the duration of one event. This results in a level 0 score on the time remaining in the loop. The rest of the carpet (the carpet tiles) is hired and remains in the loop for about 3 years (Schreuder, p.c., 22 March 2018). This results in a level 3 score. Therefore, the focus for improvement measures should mainly be on the carpet used in the aisles to see if other flooring than the current type can be used, if the current type can be reused or if more can be recycled, possibly to higher-grade products.

6.5 Paper, cardboard and foils

This combined material flow covers 6% of the total waste of RAI. The score of the materials on activity-wise circularity is shown in Figure 16. The paper and cardboard are not part of the biological loop as they contain toxic substances like BPA and DEHP (EEA, 2017) which makes the material not suitable for composting and anaerobic digestion. Instead, the paper and cardboard are go through the technical material loop for recycling. Together with the foils, the material flow scores level 0 and level 1 on activity-wise circularity. It is hard to reach higher levels for this material flow as it is often not possible to maintain, reuse or refurbish the materials used at RAI. Therefore, the goal should be to reduce the volume used at RAI and to recycle the materials to higher-grade products. This could be achieved by improved procurement practices.

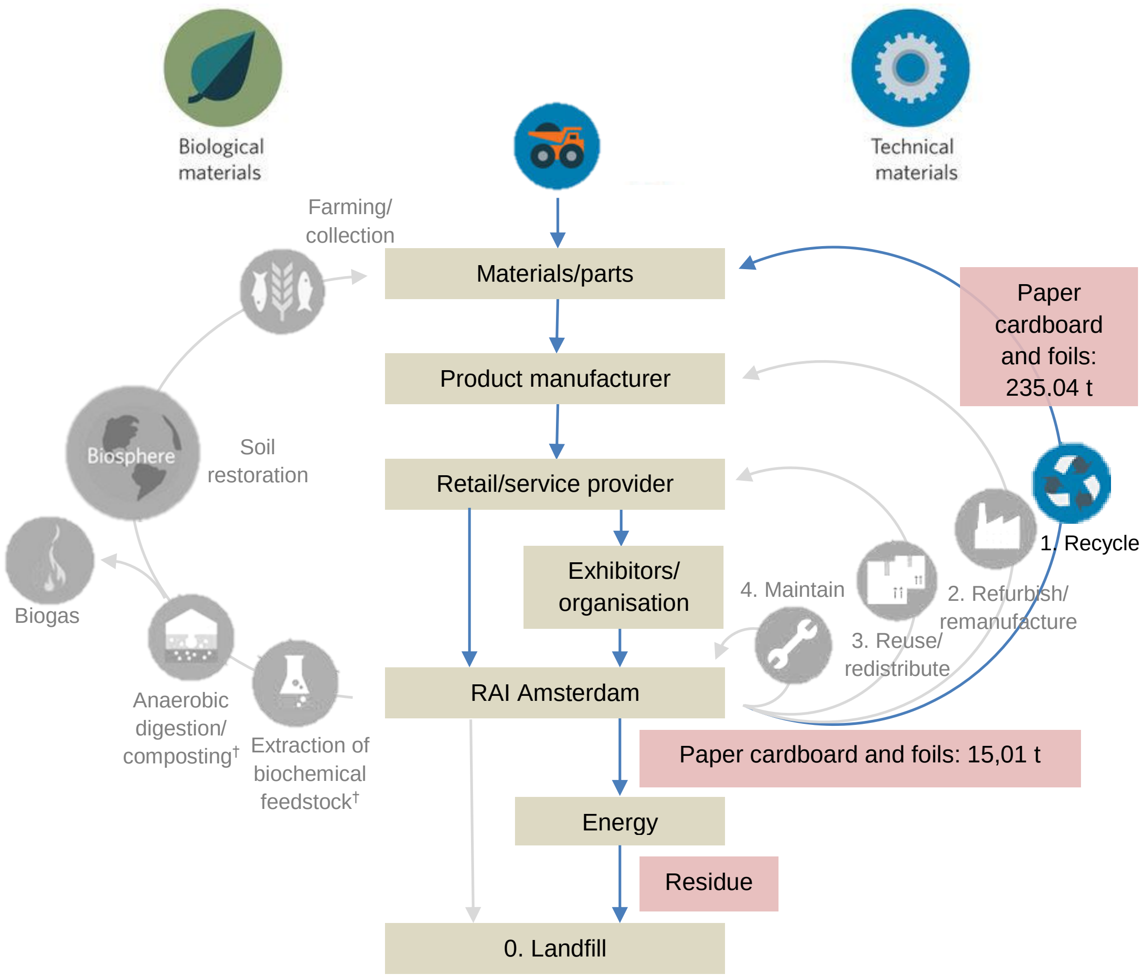

FIGURE 16: ACTIVITY-WISE CIRCULARITY PAPER, CARDBOARD AND FOILS FLOW.

Figure 17 shows the distances the materials travel when they leave RAI. Here the polluted materials and the high-grade materials both score level 0 on geographical circularity even though it is not clear who the final processors of the materials from KRAS are. According to Cor Gerritsen (p.c., 30 March 2018) the materials are namely transported all over the world (mainly to Asia and Europe), so an average distance of more than 500 kilometers is likely.

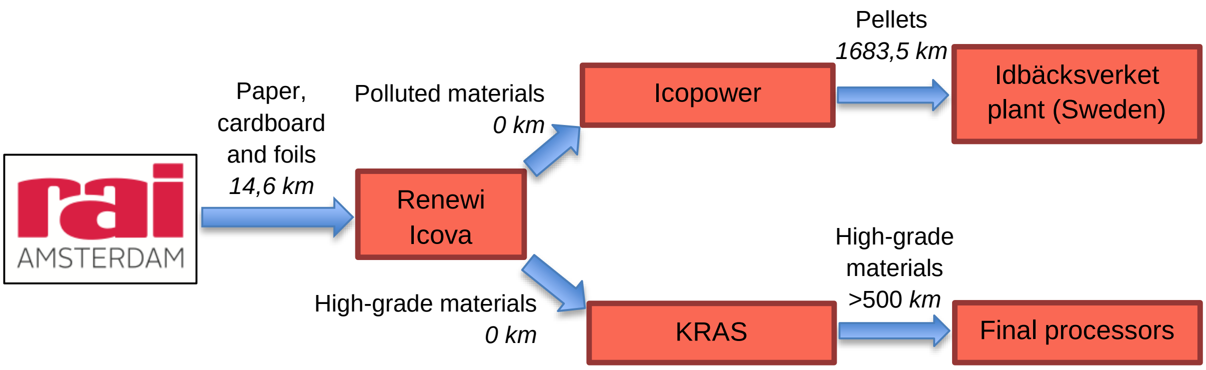

FIGURE 17: MATERIAL FLOWS PAPER, CARDBOARD AND FOILS INCLUDING DISTANCES.

The time the materials remain in the loop is assumed to be very short. They are most of the times used for only one or a few days. The foils and cardboard are mainly used as packaging for products and only used for a short time. Only the paper might be used for a longer time although the catalogues left behind at RAI are not even used at all. So on average the materials score level 0 on time remaining in the loop.

6.6 Summary

Table 3 below shows a summary of the geographical and activity-wise circularity scores of the focal material flows. This table shows that most mass of the focal material flows is located in the upper left corner that matches a low score on circularity. To improve the circularity of RAI more volume has to be moved to the lower right of the table. However, it should not be forgotten that it is also important to look for measures that can decrease the material use at RAI since this avoids the need for finding solutions for the materials at the end of their use.

TABLE 3: OVERVIEW GEOGRAPHICAL AND ACTIVITY-WISE CIRCULARITY SCORES FOCAL MATERIAL FLOWS.

		Activity-wise circularity score				
		0	**1**	**2**	**3**	**4**
Geographical circularity score	**0**	Residual materials (pellets): 648,23 t Paper, cardboard and foils (polluted): 15,01 t	Residual materials (ferrous metals): 79,15 t Paper, cardboard and foils (high-grade): 235,04 t			
	1	Wood (biomass): 469,76 t Carpet (non-recycled carpet): 283,58 t	Wood (chipboard): 704,64 t Carpet (recycled PP): 10,50 t		Carpet (tiles): 528,00 t	
	2	Construction and demolition materials (part of contaminated-, chemical- and roofing waste): unknown amounts			Wood (uniform stands): unknown amounts	
	3		Construction and demolition materials (clean debris, debris >100 cm and part of other flows): unknown amounts			
	4	Residual materials (WOF): 474,92 t			Wood (wooden plates): unknown amounts	Construction and demolition materials (maintenance): amounts not possible to determine.

Increasing circularity

Table 4 shows the time the materials used at RAI remain in the loop. This shows that many materials remain in the loop for only a short time. For these materials, the time they are used should be extended to increase their circularity score, or the use of these materials should be prevented.

TABLE 4: OVERVIEW TIME IN LOOP OF DIFFERENT MATERIAL FLOWS.

Time in loop	**Level 0: Very short**	**Level 1: Short**	**Level 2: Medium**	**Level 3: Long**	**Level 4: Very long**
Materials	Residual materials Wood (non-uniform stands) Carpet (for aisles) Paper, cardboard and foils	Wood (non-uniform stands)		Wood (uniform stands and wooden plates) Carpet (tiles)	Construction and demolition materials

The next chapter looks into measures that can prevent material use or increase the circularity score of the different material flows at RAI.

7. Improvement measures

The previous chapter evaluated the focal material flows on their circularity. In this section the improvement measures are analysed which can improve the circularity scores of these flows. For these measures is discussed what their impact would be, and how feasible they are for RAI. The measures are subdivided into general measures, measures decreasing the material flows, measures increasing remanufacturing, measures improving reuse, and measures improving recycling. There are no measures on maintenance (the highest level in activity-wise circularity) as many materials at RAI are only used for a short time, and the ones that are used longer are already maintained properly. There are also no measures on refurbishment or remanufacturing (level 2) as these are often related to complex appliances and not to the materials investigated in this research.

7.1 General measures

Below, the general improvement measures are presented which could not be subdivided according to the activity-wise circularity scores. In the subsection 7.1.1, the feasibility for each of these measures is discussed.

Clarify priorities

In its yearly report over 2017, RAI mentions that sustainability is important for them and that they aim for zero waste (RAI Amsterdam, 2017a). However, the priorities of RAI still seem to be mainly to host as much events as possible and allow their customers everything (Dekker, p.c., 29 March 2018). When they want to change to more circularity they have to demand more from organisers and exhibitors, create more time or money for waste processing, and reserve more room for storage capacity. According to Renewi Icova, the current policy of RAI only allows them to increase separation rates slightly for the coming 1,5 years. After this, only a change in policy can improve separation rates. Already now, Renewi Icova is not able to reach their KPIs due to the little time and storage capacity they get (Dekker, p.c., 29 March 2018). For instance, Renewi Icova does not have enough storage space to optimally separate the waste and process it more circularly (for instance, pallets could be reused, but are currently crushed as they cannot be stored). Another example is that the environmental inspectors that walk around during build-up and breakdown are not allowed to be strict to stand builders about their waste separation (especially at the own events of RAI). RAI is also not strict to organisers. This shows that RAI attaches more value to renting out as much space as possible and making sure organisers and exhibitors come back next time than increasing their circularity. This is also understandable as some organisers are very important for the revenues of RAI. However, with circularity RAI could also attract new organisers and exhibitors and reduce their costs.

Therefore, the management of RAI should decide how far it is willing to go in the area of circularity and communicate this clearly through the organisation. Currently it looks like they want a lot in this area but are not willing to make (fundamental) changes. Because of this, some measures proposed in this chapter might not be implemented, as they require changes that are more fundamental. However, the management should not forget that aiming for circularity is only a tool for reducing the environmental impact of their organisation. For this goal, the prevention of waste should be the first step, especially for materials for which higher-level circular solutions are not available.

Impact

The impact of this measure is cannot be determined precisely as it mainly affects the implementation of other measures. When the priorities are more shifted towards circularity and reducing the environmental impact, more fundamental changes can be implemented.

Collaborate with other event locations

For much of the improvement measures analysed during this research an important barrier is that exhibitors or organisations might oppose and go to another location for their event. RAI already has contact with other event locations related to other topics, but they could also discuss the possibility to collaborate on increasing circularity. They could set the same requirements for organisations and exhibitors, which would make their circular ambitions not a barrier in doing business. For instance, they could prohibit handing out paper catalogues or other hand-outs to visitors. Alternatively, they could limit the choice exhibitors have for stand builders (except when they have a reusable stand that they take back again). In this case, RAI could make arrangements with these stand builders on the waste they leave behind. In addition, RAI and other event locations could ban the use of carpet in the aisles and instead invest in their floors to make them acceptable for their clients without carpet.

Impact

The impact of this measure could be very large depending on the agreements with other event locations. When there would be agreed on limiting the amount of stand builders (making agreements on zero wood waste possible) and on banning the use of carpet this could make the amount of carpet and wood waste close to zero. This would reduce the total amount of waste with 32% and avoid the costs for waste disposal with €78.500 per year (€43.300 for wood waste and €35.200 for carpet waste).

Create more time and space for circularity

Time and space are very scarce at RAI. Every stakeholder wants more time and space. However, with the large number of events directly following each other people are already working day and night, which makes extra time almost impossible to get. Space will get even scarcer in the future when a new hall is built in 2019 on the location where currently equipment is stored. However, when circularity is important for RAI, they should give certain parties more time and space for storage. For example, with more time, Renewi Icova can reach higher separation rates during build-up and breakdown, and valuable materials could be reused. When they would get more storage space, they could for instance increase the reuse of materials by storing pallets, which can be picked up by a company (like Ruiter kisten en pallets) which sells used pallets for reuse. Schreuder would also like more space which they can use for a baling machine to produce bales of carpet. This would make it attractive to transport the carpet to a recycling factory instead of using it as fuel (see section 7.4).

There already exists a plan to work with a hub outside the city centre to decrease the transport around RAI. In this case, more room would be available for storage.

Impact

Since more time and space could be used for many purposes, the precise impact cannot be determined. However, since the wish for more time and space was mentioned almost every interview, the impact is expected to be large. More separation could result in less residual waste. Also, more reuse and high-grade recycling is expected. Since residual waste is the most expensive waste type (except for carpet, which costs approximately the same), RAI would also reduce waste disposal costs.

Make a larger amount of (more) circular options more attractive for exhibitors

Before an event, exhibitors have access to the online store of RAI where they can make choices between all kinds of options, for instance on the kind of carpet in their stand and the kind of waste bins they need. To increase the choice for (more) circular options, several changes could be made:

- Increase the amount of more circular options: For many product categories there are not yet (more) circular options available next to the regular options (Moens, p.c., 6 June 2018). The goals should be that each category should have at least one option that is (more) circular. This should not only focus on products but also on services. For instance, exhibitors choosing for a free-built stand can choose to donate the wood from their stand after the event to a local company that can reuse or recycle the stand.
- Increase the financial attractiveness of more circular options: Currently, it is not clear from the online store that the fine for dumping waste is higher than the costs for buying waste bins. This should be adapted to better steer exhibitors in their choices, like making dumping waste an option in the online store with very high costs.

  Furthermore, the circular options can only be a bit more expensive and the quality should be similar. A slightly higher price can namely be compensated by the green story around the product or service, which can serve as marketing value (Tavakolly, p.c., 17 May 2018). For this purpose, RAI should have a good deal with the supplier of the products. If it is a supplier that can provide large volumes for a low price, they could become preferred supplier, which causes more exhibitors to choose them. If it is a smaller supplier that wants to grow, RAI could sponsor it for a certain time by paying a part of the costs for the products to make it more attractive for exhibitors. This money is (partly) compensated by the reduced waste tax as less waste is generated. During this time the supplier has a larger customer base allowing them for instance to improve production and benefit from economies of scale.
- Increase the non-financial attractiveness of more circular options: The more circular options are currently shown with a green checkmark. However, not all more circular options (like carpet tiles) have this checkmark, while residual waste bins do have the checkmark. The green checkmark is also not very prominent, so a more prominent way to show that it concerns a 'green' product should be used to better steer the exhibitors, like green text or a green background.

  RAI could also stimulate exhibitors by creating a green label. This label could for instance state the percentage of money they spent on green products or services in the online store. Alternatively, they could only get the label if they spent at least a certain percentage of their money on green products or services. This could be made more attractive when the organiser of the event provides exhibitors with the highest score or the exhibitors with a label more marketing space. The organisation could use this as a sustainability marketing tool (Zwart & Dekker, p.c., 24 May 2018).

Impact

Implementing this measure will affect the material flows caused by external actors, which is the largest material flow. However, the precise impact of this measure cannot be determined as the specific options for the online store are not yet determined. The percentage of exhibitors choosing for the options can therefore also not be estimated yet.

7.1.1 Feasibility

Table 5 shows the feasibility assessment of the options mentioned before. Green cells show that there are no barriers. Orange cells show that there are barriers present. This overview shows that there is only a small barrier present in clarifying priorities. Therefore, this measure should be easy to implement. Collaborating with other event locations shows some barriers, but could have large financial benefits for RAI. Creating more time and space for circularity has most barriers and will therefore be the most difficult to implement. Nevertheless, this measure has much influence on the feasibility of other measures, which makes implementation very important. Including more attractive circular options for exhibitors in the online store shows some barriers. However, when the right options are implemented well, these barriers can be overcome.

TABLE 5: FEASIBILITY GENERAL MEASURES.

Feasibility assessment category → Improvement measures ↓	1. Technical-operational	2. Environmental	3. Economic-financial	4. Socio-cultural	5. Institutional	6. Policy and legal
Clarify priorities	Not applicable	Not applicable	There will only be costs for time of employees to determine and write down priorities.	Not all employees will be willing to accept the new priorities. Good communication is needed.	There is enough institutional capacity to clarify priorities.	No barriers expected.
Collaborate with other event locations	RAI already has a lot of contact with other event locations.	Reducing the amount of waste together results in environmental impact reduction stretching beyond only RAI.	Agreements between event locations can result in a reduction of the waste charges with €78.500 per year.	It is not clear whether other event locations and RAI are willing to make serious changes that can reduce the amount of waste.	It is not clear whether RAI and other event locations are willing to collaborate on waste reduction.	No barriers expected.
Create more time and space for circularity	More time and space is expected to improve the separation of materials and the way it can be processed.	Since better ways of handling the materials can be implemented, it is expected that the impact on nature will decrease.	In case less events can be hosted in one year, RAI will lose income. But they will also have less waste charges. It is not determined whether this offsets the missed income.	All supplier are willing to change. However, it depends on the priorities of RAI whether this measure will be implemented.	The suppliers of RAI are eager to cooperate with RAI to make the changes. However, it depends on the priorities of RAI whether they are willing to cooperate.	No barriers expected.

More attractive options for exhibitors	The system in which the options can be offered is already in place. Only the attractiveness of the options has to be increased.	When these options are used the impact on nature will go down	The costs and benefits depend on the options, but will only be included when acceptable.	When the options are attractive enough, exhibitors are willing to pick them. It will create employment at companies providing the options. However, logistics might be a problem (Zwart & Dekker, p.c., 24 May 2018; Moens, 6 June 2018).	There is enough capacity to implement the changes needed. But setting up the cooperation with new companies still requires some work and might provide difficulties	No barriers.

7.2 Measures decreasing material flows

When analysing specific material flows, there is mostly looked at end-of-pipe measures that improve the processing of materials after they are discarded. However, as explained in section 2.1, even fully circular solutions could still increase overall demand for materials (Ekvall, 2000; Zink et al., 2016) and thereby increase the environmental impact. Therefore, this research also looks at measures decreasing the material use at RAI. These measures are discussed in this section.

Redesigning current procurement systems or create a new one

As already mentioned in section 5.1.1 RAI has no overview of the products bought in a certain period. Since procuring products is the first step in the internal material flows of RAI, it is very important that this is changed. This could be done by either redesigning the current (event bound) procurement system, or creating something around the system (like coupling the contracts to the financial system) to make it possible. Redesigning the current system would be the most convenient, but is not easy since a family company owns the system and not many venues in the world use it. Therefore, when something needs to be changed it is not guaranteed that this is done (Eenbergen, p.c., 18 May 2018).
The management of RAI already agreed upon making it possible to have an overview of the purchased products. The new or redesigned system should be in place by the end of 2019. However, RAI has to make sure that they have the knowledge in house or hire the people with the required expertise in order to be able to guide EBMS (their current system) in redesigning the current system or to create something new (Eenbergen, p.c., 18 May 2018). When the new or redesigned system is in place, it will be possible to see which products (consisting of much material) are bought in large amounts and thus where the first steps have to be taken towards circular procurement. It can also make procurement more efficient as the data can show how much of certain products is used in a period and therefore how much has to be bought in a similar period. It will also make it possible to communicate progress on circularity to the outside world. Furthermore, it is not only beneficial for the circularity of procurement, but it could also be beneficial for benchmarking and having a better overview over what the specifics are of every supplier and product, also in areas like safety. Such a system is also needed in the context of ISO-certification (Eenbergen, p.c., 18 May 2018).

Impact

The impact of this measure cannot be determined precisely as it is not clear what the result will be of the new insights gained with the new or improved system. The large flows that are known are namely already part of this research. However, it is expected that improved insights will result in more circular and efficient procurement. In addition, the improved communication is expected to improve the engagement of employees, exhibitors, organisations and visitors in circularity, which in turn is expected to result in more circularity.

Circular procurement

After RAI has the new or redesigned system in place, the purchasing department can focus on circular procurement. Circular procurement means that RAI does not buy products or hires them, but that they buy a service for a certain time period. This implies that the producer of a product takes full responsibility for the product. He installs the product, pays for the costs of use (for instance electricity costs) and maintenance, and takes the product back at the end of the service contract. This ensures that the service provider (producer) provides the service in the most efficient way and therefore:

- Uses as few materials as possible
- Makes the costs of use and maintenance low
- Makes the products easy to disassemble to make reuse of parts possible
- Makes the lifetime as long as possible

Procuring circular products directly reduces the amount of waste at RAI. For the purchasing department this means that it should not focus on buying products, but that they have to write down which service they want to be fulfilled. Experts then have to determine in which way this service can be fulfilled most efficiently (Rau & Oberhuber, 2016). To set up these kind of contracts lawyers are needed (Amsterdam Economic Board, 2018). Since RAI has its own lawyers this should not be a problem.

When implementing circular procurement RAI should first focus on the products with which most impact can be achieved. Currently, RAI is already working on more circular procuring by phasing out single use plastics in their employee canteen. They should also extend this initiative to their catering during events to create more impact. It might still be necessary or more sustainable to have single-use products at RAI, like cups or plates that can be recycled, fermented or composted, but then the service provider would be responsible for processing the waste. To reach the highest circularity these products should be made of the same material as much as possible. In this way fewer different bins are needed which makes it clearer for people where they should dispose of their waste in (Dekker, p.c., 18 June 2018).

Impact

When everything RAI currently procures is done in a circular manner, the amount of internal waste would be reduced to zero. In addition, fewer materials will be needed to fulfill the services and the materials will remain in the loop for a longer time. Furthermore, the products will be easier to disassemble which makes it possible to keep every different material at the highest circularity level possible. Finally, the choice for local circular companies can greatly improve the geographical circularity since currently many materials are transported far away for recycling.

100% circular procurement would result in no internal waste, which currently amounts to 1242 tonnes of waste. This would save RAI approximately €110.700 per year on waste charges. These savings could compensate for the possibly more expensive circular products.

Use carpet tiles

Carpet tiles are much more circular than rolls of carpet as they can be cleaned and reused. However, according to Schreuder laying tiles in the aisles is not possible because of many reasons, of which the most important ones are first that there are no machines that can quickly lay the tiles and pick them up again. So many machines are needed which is a big investment. These machines can break down which is a big financial risk as limited time is available. The tiles would also be much more expensive than current carpet. However, when there is a breakthrough in this area Schreuder would be very interested, as machines are often better and cheaper than personnel is (Schreuder, p.c., 24 May 2018). However, according to Jeroen Altink (p.c., 29 June 2018) of Hapéco (a big furniture and carpet rental company) they would be able to lay (hired) carpet tiles in the aisles for the same price as current carpet. But these tiles will be laid by hand which means that it would cost more time. Therefore, it would only be possible at events where there is more time for build-up, which is only at a small percentage of events (Moens, p.c., 6 June 2018). Nevertheless, it would avoid a lot of waste. Testing it at the events where more time is available could give RAI insight in what the financial costs are, and how much time would be needed extra during build-up. Then they can see whether more events would be suitable for this measure (Moens, p.c., 6 June 2018). RAI could also decide to put these tiles not only in the aisles, but also in every stand. Then the exhibitor can still choose the colour(s) but not decide to use other carpet. This would also avoid waste from carpet left behind by exhibitors. Still some waste will be created by the cutting of tiles for reaching drains for instance, but this would be minor compared to the carpet waste currently created after events (Altink, p.c., 29 June 2018).

Impact
According to Moens (p.c., 6 June 2018) there is only a small number of events at which more time could be made available for laying carpet tiles. However, even when this is only possible for 5% of the events this would mean that approximately 15 tonnes of carpet waste can be avoided. This would mean a reduction in waste charges of approximately €1.400 per year. The use of carpet tiles instead of rolls of carpet will increase the activity-wise circularity from level 0 to level 3. In addition, the tiles would only have to be transported between Utrecht and Amsterdam (if Hapéco would be the supplier) while currently the carpet is transported from Belgium to Amsterdam and after the event back to Belgium or to Groenlo to be processed. This would increase the geographical circularity from level 1 to 3. Finally, since carpet tiles are used for a longer time, the circularity level on the time remaining in the loop will also increase from level 0 to level 3.

Decrease the amount of outer packaging
From the interviews was derived that most cardboard waste is created by the production kitchen, which throws away a large amount of cardboard boxes (Dekker, p.c., 19 March 2018). This waste flow can be reduced greatly by reducing the amount of outer packaging from products purchased by RAI. Most food used by the production kitchen is supplied by Bidfood, a wholesaler that is an important player in the market. They are already busy with the topic of outer packaging (Jagan, p.c., 24 May 2018) but it is not clear in what way. They could for instance stimulate their suppliers to deliver the products in reusable crates. Vrumona is also an important supplier as they supply most of the drinks to RAI. They are planning to pay a lot of attention to sustainability in the near future. Decreasing the amount of outer packaging or finding alternatives for this is one of the ways to do this (Eenbergen, p.c., 18 May 2018). The efforts of these two organisations will hopefully result in less cardboard waste at RAI.
Most foil waste comes from the roll cages with which for instance the soft drinks of Vrumona are transported. These roll cages are wrapped in foil to avoid the boxes or crates from falling off. The transport is not done by Vrumona but by Sligro. Therefore, RAI is now looking if and how they can convince Sligro to find alternatives for the foil. Other suppliers using roll cages are already using reusable sleeves for around the cage, so there are alternatives available (Eenbergen, p.c., 18 May 2018).

Impact
Approximately 20% of the cardboard waste is caused by the production kitchen (Renewi, 2018). So a decrease in their waste volume would have a big impact. If with this measure 50% of the cardboard waste from the production kitchen would be avoided this would be equal to 25 tonnes of waste. For this waste RAI would normally receive approximately €460 per year from Renewi Icova. So there would be no financial incentive for RAI to implement this measure. However, since the amount of money

received is only small, there would also be no reason to not implement the measure. Furthermore, RAI aims to eliminate the transport around the venue (Moens, p.c., 6 June 2018). Reducing the amount of waste will contribute to this goal.
It is not clear what the share of outer packaging of Vrumona is in the total foil flow and by how much they can decrease it. A decrease of 5% of the total flow would mean a decrease in costs of only approximately €185 per year. So decreasing this flow would also not be financially interesting, but implementing this measure would still increase the circularity of RAI, which could be used as a marketing tool.

Use more digital communication
Event catalogues cause much of the paper waste, but also flyers cause a lot of waste. Of the catalogues, which often are very big, always a lot is overproduced (Bemmel, p.c., 19 March 2018). When the catalogues and flyers are more digitalised a lot of waste could be avoided. The information could be distributed via email or via websites. This would save organisations and exhibitors costs for printing. At most own events of RAI the catalogues are already digitalised, but some sectors are still traditional and do not want that. In addition, external organisations are hard to influence. RAI cannot prohibit them to use paper catalogues and flyers (Moens, p.c., 6 June 2018). Nevertheless, they could recommend organisations to use digital catalogues because of the financial advantage, and advise their exhibitors to use digital communication instead of paper flyers.
Since RAI receives money for their paper and cardboard waste it would not directly be beneficial for them to avoid this type of waste. However, they would avoid printing costs at their own events, which are expected to be high. Furthermore, reducing the amount of paper waste will contribute to the goal of no transport around the venue as less waste trucks are needed.

Impact
Digitalising catalogues and flyers would be a good marketing tool for RAI to show that they work on circularity. As it is not clear what the share of catalogues and flyers is in the total amount of waste, and how much RAI pays for printing catalogues, the impact of this measure could not be determined precisely. It is expected that completely digitalising the catalogues and flyers will halve the amount of paper waste. This would mean a reduction of 125 tonnes of waste, which would normally generate €2.300 per year.

Decrease the amount of plastic packaging in catering
RAI uses a lot of plastic packaging in their catering. For instance, they sell their drinks in bottles, cheese is packaged per two slices, and yoghurt is sold in a plastic cup. This causes a lot of plastic waste that is processed as residual waste (Dekker, p.c., 18 June 2016). RAI already aims to drastically reduce the plastic waste from their employee canteen and use biodegradable packaging instead of plastic where packaging is needed (Moens, p.c., 6 June 2018). However, this still has to be communicated to the kitchen staff who has to work with this goal (Mulder, p.c., 21 June 2018). To drastically increase the impact, RAI should extend this goal to the catering during events. Here larger volumes are consumed, so more products could be bought in bulk. Then visitors can pick the amount they want. This could also reduce the amount of food waste as people are not forced to pick more than they want. For the products that need biodegradable packaging, a separate waste bin could be added which makes it possible to compost or ferment these packages.

To make this possible, Bidfood, which is the main food supplier, should have alternatives available or influence their suppliers to be able to provide alternatives. As with the outer packaging, Bidfood is busy to minimise the amount of 'normal' packaging or make it more sustainable (Jagan, p.c., 24 May 2018). When this does not provide RAI with the desired alternatives, they should look for alternative solutions to those offered by Bidfood.
Furthermore, RAI should not buy PET bottles anymore which end up as waste at RAI. Instead, they should buy taps or glass deposit-refund bottles (of which only very little end up as waste). Vrumona already has these products available (Vrumona, n.d.) so this should not be a problem.

Impact
During the check of three bags of waste from catering locations, the average share of plastic waste (in weight) was 15%. Numbers on the amount of waste from catering locations is not available. However, the total amount of residual waste from events is 1511 tonnes. When catering waste would cover only 10% of this flow, the total amount of catering waste would amount to 151 tonnes. When all plastic waste in this flow would be avoided this would result in a reduction of 22,7 tonnes of waste per year for which RAI would normally have to pay approximately €2.800.

Reduce the amount of waste during construction
The amount of waste from building projects can be reduced in many ways. For instance, the amount of material waste can be reduced by using BIM (Building Information Model) for making a 3D drawing of a building with which can be well estimated how much material is needed. Furthermore, wood waste can be reduced by not using this material for formwork, but reusable material like steel or plastic. Cardboard and plastic waste can be reduced by delivering products in reusable packaging or more efficient packaging (not everything per piece, but more in bulk). In addition, biodegradable packaging for material can be used shifting the packaging material from the technical to the biological loop. Finally, pallets can be delivered to a company selling or renting used pallets (Solve Consulting, n.d.).
When starting a new building project, RAI could ask different contractors whether they use these or additional ways to avoid waste. The answers should be taken into account when making the choice between the different contractors.

Impact
It is not exactly known how much waste is created during construction. Even contractors do not know which materials are disposed of during this period. A lack of data often indicates that a lot of progress can be made. When this measure would result in a decrease of unsorted and contaminated construction and demolition waste of only 10% this would already decrease the waste charges with approximately €4.800 per year.

7.2.1 Feasibility

Table 6 shows the feasibility assessment of the improvement options decreasing the material flows. The options focusing on redesigning the system and circular procurement have only minor barriers for implementation and RAI is already starting to implement them. The other options show more barriers and are harder to implement as for most of them many stakeholders are involved.

TABLE 6: FEASIBILITY MEASURES DECREASING MATERIAL FLOWS.

Feasibility assessment category → Improvement measures ↓	**1. Technical-operational**	**2. Environmental**	**3. Economic-financial**	**4. Socio-cultural**	**5. Institutional**	**6. Policy and legal**
(Re)design system	It is possible to make such systems (Eenbergen, p.c., 18 May 2018).	Not applicable.	The management of RAI agreed, so there is money available for changing the system or create new one. A better overview over the expenditures might create savings.	Management agreed so the willingness to change and acceptance are expected to be high.	There is more capacity and knowledge needed to change the system of create a new one (Eenbergen, p.c., 18 May 2018).	Not directly barriers expected.
Circular procurement	There are already many circular products that could be used by RAI.	The impact on nature will be lower when more circular products are used.	When this measure would reduce the amount of internal residual waste with 100%, RAI could save €110.700 per year.	The willingness to change is present in the purchasing department (Eenbergen, p.c., 18 May 2018).	Cooperation within RAI and institutional capacity need to be improved (Eenbergen, p.c., 18 May 2018).	Legal department needs to help with setting up purchase contracts.
Use carpet tiles	Carpet tiles are already often used and their quality is good enough. However, the time needed to lay them would be too much at a large share of events.	Carpet tiles can be reused and can already be made of materials that can be fully recycled. Therefore, the impact on nature will decrease.	The costs for tiles instead of rolls of carpet would not be very different (Altink, p.c., 29 June 2018). The waste charges will be reduced with approximately €1.400 per year.	RAI is willing to test with carpet tiles at these events where more time is available for the build-up.	RAI is already working together with Hapéco, which could lay the tiles. However, RAI should make some changes in the normal time planning when more time is available during build-up.	Not directly barriers expected.

Decrease the amount of outer packaging	There are already companies working on decreasing their outer packaging. For instance, by using reusable materials. So no barriers are expected.	Decreasing material use would decrease the impact on nature.	This measure will not necessarily decrease costs as RAI receives money for their paper/cardboard waste. But this is only a small amount. They do have to pay for their foil waste, so for this part there would be a (small) incentive.	Bidfood is willing to try to convince their clients to decrease the amount of outer packaging. Vrumona is also willing to cooperate. RAI will also try to convince Sligro to decrease their amount of outer packaging.	Bidfood is already looking at their supply chain to improve their environmental impact in which they also look at packaging. Vrumona is willing to cooperate. RAI is also trying to cooperate with Sligro.	Not directly barriers expected.
Use more digital communication	No barriers are expected. The distribution of the information could be done via the website of the event.	Decreasing material use would also decrease the impact on nature.	As RAI normally receives money for their paper/cardboard waste there is no financial incentive.	RAI is willing to change. However, it is not clear whether exhibitors and external organisations are willing to change.	RAI will have to cooperate with organisations and exhibitors at RAI for this purpose. This will be a challenge.	No barriers expected.
Decrease the amount of plastic packaging in catering	There are many alternatives for plastic packaging available. So it should be possible to decrease the plastic waste in the canteen and during events.	Decreasing material use, or replace it with biodegradable alternatives, decreases the impact on nature.	Decreasing the amount of waste will decrease the waste charges for RAI with approximately €2.800 per year.	Not all relevant employees for this measure are yet aware of the plan. So some might not accept it. But Bidfood and Vrumona are willing to cooperate.	Bidfood is already working on reducing the amount of packaging. If they will have alternatives available remains to be seen. Vrumona has alternatives available.	Not directly barriers expected.
Reduce the amount of waste during construction	RAI can consider this when choosing between contractors. This will also make contractors more aware of their waste generation.	With less excess use of materials and waste generation the impact on nature will decrease.	With less excess materials transported to the building location and less use of packaging the costs of construction will go down. Also, the waste charges will go down with approximately €4.800 per year.	Building companies are willing to change, but they still have to implement the changes (Solve Consulting, n.d.). With this, they also rely on the willingness to change of their suppliers.	Building companies could encounter barriers when they have to convince their suppliers to deliver their building material without or with less packaging material.	No barriers.

7.3 Measures increasing reuse

When, after implementing measures decreasing material use, there are still materials used, the amount of materials discarded can still be minimised by increasing reuse. Below, two measures are discussed which can increase the reuse of materials.

Collaborate with New Horizon

New Horizon is an organisation that mines useful materials and resources from buildings and tries to reuse and upcycle as much as possible. This company is, as far as the author knows, the only organisations that demolishes buildings in such a circular way. Their decommissioning projects are not more expensive, and do not take longer than regular projects. In these projects they take the role of main contractor, so they take the risks. Before the project they communicate transparently to their customers where and how the materials will be reused or processed (Baars, p.c., 6 June 2018). The mined materials and resources are partly processed into new building materials for renovation or new building projects (New Horizon, n.d.b). For instance, doors, window frames and system walls are reused (New Horizon, n.d.a). Furthermore, they can recycle 100% of the concrete to new concrete, also bricks can be recycled for 100% to new bricks (when glass waste is added) (Baars, p.c., 6 June 2018). The other materials are converted into consumer goods or used in industrial applications (New Horizon, n.d.b). Often the problem of warranty on products and materials is raised as an issue when using second hand building materials (Gerritsen, p.c., 2 March 2018). However, many products and materials in building projects are not covered by a warranty. For the products which do need warranty (like concrete and bricks) New Horizon can provide it (Baars, p.c., 6 June 2018). From utility buildings the most valuable materials and resources can be mined (Baars, p.c., 6 June 2018), so the buildings of RAI would be very suitable.

In order to see whether collaboration would work, RAI can do an upcoming project with New Horizon or evaluate a previous project at RAI to see how New Horizon would have done it differently. The advantage of evaluating a previous project is that there is no pressure and tender rules (Baars, p.c., 6 June 2018). It this case RAI could evaluate whether the added value of working with New Horizon is enough to also work with them in coming projects. Probably the added value is very large as currently most of the construction and demolition materials end up in road construction. Therefore, the circularity of this material flow would greatly increase (Baars, p.c., 6 June 2018).

To make projects with New Horizon more successful it would be beneficial when the buildings of RAI would all have a material passport. This makes it easier to disassemble a building or renovate one. Making such a passport during construction namely pushes to think about the end of life of a building. This affects for instance material choices and the ease of disassembly. Such a passport contains information of the type of materials in a building, the amount, the quality, the location and the financial and circular value (Rau & Oberhuber, 2016). This information makes it much easier to reuse materials and get as much value as possible out of a building. This minimises the amount of waste produced, which can significantly minimise the costs. RAI already has a material passport of their newest building. Therefore, it is expected that future buildings will also get one.

At the procurement side, RAI could also collaborate with New Horizon as almost every year there is a new construction project. They can ask the contractor to collaborate with New Horizon and use as much second hand or recycled material as possible. This should not be a problem as these materials are not more expensive and delivery does not take longer than usual (New Horizon, n.d.b).

Impact

It is not exactly known how much of the materials in the buildings of RAI can be reused or recycled into high-grade materials. Sometimes New Horizon can get value out of all material and dismantles buildings for free. Most of the material consists of clean debris, which often consists of a lot of concrete that New Horizon can recycle for 100% into new concrete. This would make the recycling much more high-grade. Furthermore, coming year a steel canopy will be removed for which New Horizon think they know a new destination where it can be reused (Baars, p.c., 6 June 2018). This would increase the activity-wise circularity from level 1 to level 3.

This measure only applies to the demolition activities and not to construction. It is not clear how much of the total construction and demolition waste of RAI can be assigned to demolition activities. However, when this would be 50% this measure would save RAI approximately €25.900 per year. New Horizon would namely be responsible for the total amount of materials that are generated during these activities. Therefore, when part has to be processed in the 'normal' way they would pay the costs.

Only build circular buildings

The Dutch Government wants to work towards more circularity in the building sector, also for utility buildings (Rijksoverheid, n.d.a) which include the buildings of RAI. In order to have fully circular buildings RAI should close circular contracts. In such a contract, RAI will not be the owner of the building, but only the user. Instead, the contractor will remain owner of the building. This stimulates the contractor to think about possible future uses for the building, and to make it easy to disassemble the buildings with keeping the value of the materials as high as possible. This makes it possible to reuse more of the material (BouwTotaal, 2016). The remaining waste is the responsibility of the contractor.

Impact

This measure will eliminate the construction and demolition material flow of RAI as they are not the owner of the buildings and thus the materials. The contractor would try to make all materials used in the buildings reusable or recyclable at a high grade, as this would save him money. So in the long term, when all the buildings would be completely circular, this measure would save RAI €51.800 per year (the total costs for all types of construction and demolition waste over 2017).

7.4.1 Feasibility

Table 7 shows the feasibility assessment of the improvement options increasing the reuse of materials at RAI. For both options there are some barriers present. The first barrier when collaborating with New Horizon seems to be easy to overcome. The second barrier more sense of urgency needs to be created. For the second measure, there is a more difficult barrier in the socio-cultural dimension since RAI wants to be the owner of their buildings. Furthermore, when building circular costs significantly more, RAI will be less eager to implement this measure.

TABLE 7: FEASIBILITY MEASURES INCREASING REUSE.

Feasibility assessment category → **Improvement measures ↓**	**1. Technical-operational**	**2. Environmental**	**3. Economic-financial**	**4. Socio-cultural**	**5. Institutional**	**6. Policy and legal**
Collaborate with New Horizon	Material quantity and quality from the buildings of RAI are good enough. However, RAI has not much space available. So the sorting of the materials on location should not take too much space.	The impact on nature will be decreased as the recycling of the materials to more high-grade products reduces the mining of raw materials. In addition, the energy use of recycling and reuse is lower (Baars, p.c., 6 June 2018).	New Horizon guarantees that they are cheaper than linear ways of demolition, and the materials they mine can compete in price with conventional materials. Furthermore, the waste charges will go down with approximately €25.900 per year.	RAI is willing to change the current way in which their buildings are demolished and built (Born, p.c., 18 May 2018). However, it seems difficult to change the way in which RAI is currently working due to a lack of time.	RAI and New Horizon are willing to cooperate. Cooperating with them does not require additional institutional capacity at RAI.	RAI currently has the policy to tender assignments that cost more than €50.000. However, this should not be a problem when New Horizon can show that they are the best party (Born, p.c., 18 May 2018).
Only build circular buildings	There already exist circular buildings that are not inferior to normal buildings (BouwTotaal, 2016).	Since all materials in the building are fully reusable and recyclable (BouwTotaal, 2016) the impact on nature will drastically decrease.	It is not clear whether circular buildings cost much more than conventional buildings. However, the waste charges will go down with approximately €51.800 per year.	RAI still wants to be the owner of the building. Nevertheless, they are willing to look for more circular ways of constructing the buildings (Born, p.c., 18 May 2018).	The previous circular building project in The Netherlands shows that the cooperation between the different parties went well (BouwTotaal, 2016).	Since there already exist circular building projects there are no barriers expected in this area.

7.4 Measures improving recycling

When after trying to decrease material use and reuse still waste is generated, this waste has to be processed in the best way possible keeping the highest value. For this purpose, it is important that more waste is separated at the source, in this case RAI. Currently, post-separation is namely not sufficient to replace source separation (Didde, 2017). Therefore, the measures below focus on increasing separation rates and keeping the separated materials at a high value.

More waste separation at events and at the offices

Only 5% of the total amount of residual waste is created internally, so by the employees of RAI. Of the other 95%, the largest part is generated during events (Dekker, p.c., 18 June 2018). At the offices, waste can currently be separated in plastics, paper, cups, and residual waste. But there is word going round that the plastic and cups are put together with the residual waste when collected (Eenbergen, p.c., 18 May 2018). This is true for the plastics (Dekker, p.c., 18 June 2018), but for the cups this was true up until June 2018. Before that, the cups were separated to minimise volume and prepare people for the time that the cups were going to be recycled (Kolken, p.c., 30 April 2018). Because of the rumour, people invest less energy in separating their waste (Moens, p.c., 6 June 2018). They accumulate waste in their coffee cups and at the end of the day do not want to separate it and therefore dispose it all off in the residual waste bin (Kolken, p.c., 30 April 2018). This causes that currently not enough cups are collected separately to recycle them, and that not all plastic is separated (Dekker, p.c., 18 June 2018). RAI tried to stimulate office waste separation by putting signs on the bins with directions on what is and is not allowed in the different containers. This helped for a short period, but after some time the employees were blind for the signs and separation numbers went down again (Kolken, p.c., 30 April 2018).

At events only residual waste is collected because in the past the recycling bins were too much polluted to process separately. This is caused by the many different nationalities and therefore cultures of the visitors, which complicates waste separation (Moens, p.c., 6 June 2018). Clearer signs can solve pollution of the bins, but RAI does not want waste separation to stand out too much during events (Dekker, p.c., 18 June 2018).

A new strong communication plan like Renewi Vliko and Suez (another waste collector) have for their customers should be implemented to improve waste separation, stop the rumour among employees, and make people aware of the impact waste separation has. Such a communication plan inspires people and triggers action (Suez, 2018). Part of the plan should be to separate plastic and paper waste at events. In addition, since much of the waste at events and in the offices consists of green waste (RAI Amsterdam, 2016), also a green waste bin should be added. At the event this can be a normal container that is emptied every day and replaced with a clean one. In the offices this should be a smaller bin that is emptied every day, as here less waste is created and emptying less frequently could cause odour nuisance (Dekker, p.c., 18 June 2018). This bin and the plastic and paper bin should be easier to access than the residual waste bin (by for instance putting a lid on the residual waste bin and not on the others). This should be combined with clear signage and instructions at the waste bins. It is expected that this will increase awareness and separation rates (Dekker, p.c., 18 June 2018). It might also increase the effort account managers put into convincing exhibitors and organisers to separate their waste at events (Eenbergen, p.c., 18 May 2018).

Impact

A good communication plan can decrease the amount of residual waste with 20-30% (Suez, 2018). A 25% reduction would mean a reduction of approximately 400 tonnes of residual waste per year. This waste would be separated in green waste, plastics and paper waste. RAI has to pay for their green waste but gets money for their paper waste. For plastics RAI has no waste tariff, so this is unknown, but it is assumed to be close to zero. On average, the total costs for the separated waste is also assumed to be close to zero. This would mean that RAI would save approximately €48.600 per year on waste charges.

The higher degree of waste separation would immediately result in a higher activity-wise circularity score as separated materials are less often incinerated. So a larger volume will score level 1 instead of level 0. Also, more geographical circularity will be reached as the pellets made from a large part of the residual waste are currently transported all the way to Sweden (scoring level 0) while swill, which represent a large part of the residual waste, scores level 4 on geographical circularity.

Improve the contract with Renewi Icova

Currently, the contract between RAI and Renewi Icova is only based on the degree of waste separation at RAI and not on the way the different material flows are processed (Moens, p.c., 6 June 2018). This causes that the materials transported from RAI to Renewi Icova are not expected to be processed in the best way possible for Renewi Icova and not as transparent as possible. In a manual published by Renewi (Waardevol boekje), they published the percentage of materials they can process into new resources (Goudsmith, p.c., 16 May 2018). RAI should at least use these percentages in their contract with Renewi Icova and make sure they can check if these requirements are met. These percentages can be increased (with for instance 2% increase every 5 years), but not too much as Renewi Icova needs room to look to solutions. This is also the way in which the Dutch Government makes contract agreements with waste collectors. These contracts can be found on the internet, which makes this measure easier for RAI to implement (Goudsmith, p.c., 16 May 2018). Additional to the approach of the Dutch Government, RAI can also give Renewi Icova restrictions on where the materials are processed to improve the geographical circularity. RAI could also sign the contract with Renewi collectively with other parties to make it less time-consuming to check whether Renewi complies with the agreements (Brasz, p.c., 8 June 2018).

Impact

This measure will decrease the amount of materials currently processed according to level 0 of activity-wise circularity and increase level 1 circularity. Higher levels are most likely not reached by waste processors. So to reach higher levels other solutions should be implemented. However, it is a simple measure to increase the circularity of all material flows. When also restrictions on the location of processing are implemented the geographical circularity will be improved as well.

Tender every waste flow separately

Most waste collecting companies like Renewi Icova and Suez are from origin transport companies and not recycling companies. They transport waste from companies and municipalities to processing companies (which they might have acquired and thus are part of their own company). So from origin they are not experts in processing materials and they could have incentives in ways of processing which are not most circular. Therefore, the Dutch Government is going to tender every waste flow separately from 2021. In this way, processing companies can also participate in the tender and the government

can choose the most circular one. Possibly, the waste collector can still provide the transport. Tendering waste flows separately clarifies the material flows and lowers the costs as the brokering in between is decoupled. Waste collectors namely often choose the party where they can process it for the lowest price and not the most circular party (Goudsmith, p.c., 16 May 2018). Partly due to this plan of the Dutch Government, there is a trend that the waste collecting companies take over processing companies to keep their income secure.
Tendering the flows separately could also be a good way for RAI to improve their circularity. To manage the different contracts with the processing companies RAI might have to hire extra personnel (Eenbergen, p.c., 18 May 2018). So it has to be calculated if this could still make it an attractive measure. But even when it is more expensive, RAI would still be interested in following the Dutch Government as the increase in circularity it could cause also has marketing value (Moens, p.c., 6 June 2018).

Impact
With this measure RAI will get more control over their material flows. They can choose the most circular option for every material flow, both activity-wise and geographically. In this way, fewer materials will end up in an incinerator or landfill and the way in which materials are recycled will probably be more high-grade.

Recycle all the wood
Wood is one of the largest material flows of RAI. Most of the wood consists of MDF and chipboard, for which not yet a large-scale solution is available to process it more circular (Hof, p.c., 19 April 2018). However, there are technologies emerging that might be able to recycle MDF and chipboard to high-grade products. In this research, two companies are discussed as example (Afwerking and Noble Environmental Technologies) which might be able to do this. These companies are discussed below.

<u>Afwerking</u>
Afwerking is a small company that aims to offer meaning to adolescents and young adults with a distance to the labour market by processing reusable wood. They collect this wood from different companies and sell it for prices lower than in the store, or process it into different products like furniture and decor. Because no new wood has to be harvested for these products, a lot of CO_2 emissions are avoided (Zwart & Dekker, p.c., 24 May 2018).
Since RAI generates a lot of wood waste, they could help Afwerking grow and work on their goals of creating an upcycle factory (circular hub) in the municipality of Amsterdam. In this hub they want to gather different resources and entrepreneurs who can make new products with this that can be sold on the market. This hub could provide circular procurement solutions to RAI in the future. However, MDF and chipboard are not very suitable for reuse as these materials cannot be painted or used outside. Only the pallets that are disposed of by RAI are valuable for reuse (Zwart & Dekker, p.c., 24 May 2018). However, these are currently put in a crusher making them useless for reuse. However, Afwerking recently got access to a technology with which they can press chips of different kinds of wood with water-based glue to strong boards. They could test whether this also works with chipboard and MDF and what the quality of this type of board would be. Then it would not be a problem to use the crushed material of RAI. When Afwerking can make products of this, they could rent them out while keeping ownership to improve circularity. However, this is more a long-term plan since there is no factory yet.

A problem is that Afwerking should know what materials they could expect in order to create a business case. However, RAI does not know in advance how much and which kind of materials will exactly end up as waste. They can only make an educated guess based on history and similar events (Moens, p.c., 6 June 2018). Getting this information is a big challenge as for this purpose RAI should get this information from the organisation, which in turn has to get it from their exhibitors. In turn, they have to get this information from their stand builders. RAI does not want to oblige this to organisations as they want to keep them as a customer. When they are the organiser themselves, they do not want to oblige this to their exhibitors as they do not want to lose them. For the short term this lack of information is not a problem as first will be tested with small volumes to optimise and standardise the processes (Zwart & Dekker, p.c., 24 May 2018). Possibly this shows that the composition of the material is predictable enough.

When going to larger volumes, another logistic process has to be invented as the waste collectors at RAI are paid per tonne. The material is currently weighed at Renewi Icova, so a solution could be to first drive the material to Renewi Icova and from there to Afwerking (Zwart & Dekker, p.c., 24 May 2018). Another solution would be to give Afwerking time after breakdown to get materials they can use out of the halls, this would also make reuse of part of the material possible as it is not crushed yet. This is only possible in times when there is no new event directly following the current event. In this case, the price of wood waste for RAI has to be changed or Afwerking has to pay for the waste in order to make it financially feasible for Renewi Icova (Dekker, p.c., 18 June 2018).

In the short term, the owner of Afwerking will take a look during the breakdown of an event together with the assistant location manager of Renewi at RAI to discuss the possibilities and expectations (Zwart & Dekker, p.c., 24 May 2018).

<u>Noble Environmental Technologies</u>

Noble Environmental Technologies is a company that invented an advanced environmental composite panel called ECOR. This non-toxic panel is formed by compressing cellulose fiber with water under heat. These fibers can be sourced from a wide range of materials containing fibers, like old corrugated cardboard, old new print, office waste, forest waste and agricultural fibers. After use, the panels are 100% recyclable to the same panels again (Noble Environmental Technologies, 2018). The panels can also be put together with paper waste and then be recycled to paper. However, to keep the panels non-toxic, they have to be made from non-toxic materials. Since the wood of RAI consists mostly of MDF and chipboard, which contain a lot of toxic glue, panels made from this material will also contain toxic elements. However, it would still be 100% recyclable to new panels, which is a big improvement as currently much of the wood is incinerated. Therefore, ECOR would be interested to start an R&D project with RAI to see whether it is possible to make panels from MDF and chipboard (possibly in combination with wood from pallets) and see what the material properties of these panels would be. Probably the process would eliminate a large share of the toxic ingredients and will capture them in the material so that they cannot escape and be inhaled like with MDF and chipboard. In their factory in Serbia, they already did some small tests that give the impression that it should be possible to make panels from MDF (Tavakolly, p.c., 17 May 2018). When this is also possible for chipboard combined with the wood from pallets, this would make it possible to recycle 100% of the wood from RAI.

RAI is now looking at whether their preferred suppliers can use ECOR at RAI in the future (Moens, p.c., 6 June 2018). For instance, as material for stands, signing, or decorations (Moens, p.c., 6 June 2018). Noble Environmental Technologies can work together with these suppliers to share their experience, guide them to people who already worked with it, and learn from it themselves (Tavakolly, p.c., 17

May 2018). The most recent trial where ECOR was used as stand material was not yet fully successful, but future pilots might be more successful (Noordman, p.c., 18 May 2018).
When ECOR is eventually used at RAI, and the goal is to recycle the material to panels again after use, RAI needs to change its waste separation process to be able to collect ECOR separately from the other materials. To also improve the geographical circularity, ECOR is planning to open a factory this year in The Netherlands, in Venlo. This would make it possible to recycle all the wood from RAI by the end of the year.
Using ECOR would probably also be financially attractive as the goal of Noble Environmental Technologies is to keep the costs for a panel equal to the costs for a substitute material, like MDF. This would determine the costs they can pay for the resources. The logistic costs are paid with the costs RAI does not have to pay anymore for waste charges. When the logistic costs are higher, or the resources are more expensive, this would cause ECOR to cost more than conventional materials. When the price difference is only small, environmental benefits would still make it an attractive option for customers. The price for ECOR can only be determined when the R&D stage is finished, and the average composition of the wood waste is clear (which is currently not the case). Then a contract can be made, production can start, and the panel price can drop (Tavakolly, p.c., 17 May 2018).

Impact
For both technologies discussed above it is not yet clear whether they can recycle chipboard and MDF. But when it is possible for at least one of these technologies, 100% of the wood waste of RAI could be recycled, which is currently only 60% (at a lower grade). It could divert 1074 tonnes of waste, which would save RAI approximately €43.200 per year on waste charges. In the case the wood is recycled to ECOR (part of) this money would have to be paid for the logistics. When the panels produced in one of these processes can be used for building stands, the loop will be closed.
When none of these technologies can recycle the wood, RAI could look for other companies as these were only examples. When these are not found, Afwerking could still reuse 10% of the wood and Noble Environmental Technologies could use this 10% for making panels. In this case, a way should be found to separate this useful flow from the other wood waste.
Currently, the wood travels a long distance before it is processed. Since both technologies provide solutions in the Netherlands (Afwerking is even located in Amsterdam), the geographical circularity will also improve from level 1 to level 2 or 3 in the case of ECOR and even 4 in the case of Afwerking.

Recycle a larger share of carpet to PP
For the carpet, the focus for improvement measures lies on the carpet laid by Schreuder in the aisles, which is currently processed in the cement industry. The carpet tiles are namely already reused locally (Schreuder, p.c., 22 March 2018) and therefore already score much higher on circularity. Furthermore, the carpet laid by other suppliers is taken back most of the times, as this is more cost-effective for them. Therefore, the share of carpet left behind not laid by Schreuder is only very small in the total carpet flow (Dekker, p.c., 29 March 2018).
Combining the information from the interviews with several people (with M. van den Hof of MVO Nederland, M. Goudsmith of RVO Nederland, E. Schreuder of Schreuder BV, and C. van Gelder of Interface, for dates see Table 2) showed that cleaning and reusing the carpet is currently impossible as there are no machines which can quickly clean it and roll it up at an affordable price. In addition, as discussed in section 7.2, laying tiles in the aisles is not always possible due to time shortage. There was also looked for alternatives for carpet. However, there are currently no alternatives available that meet

the high demands of organisations. Therefore, the focus is on high-grade recycling. There are two types of carpet used in the aisles; 100% polypropylene (PP) carpet, and PP carpet with lime backing. Which one is used depends on the quality demand. The carpet with lime backing is stronger but not recyclable, while the PP carpet without backing is recyclable. In 2017, 21% of the carpet used at RAI (in volume) was PP carpet without backing. This share is increasing as the quality increases and because of its recyclability. To reach an even higher share, RAI should adapt their policy on driving machines in the aisles as these rupture the carpet, which makes the use of carpet with lime backing needed. Forklifts can for instance use tyre covers that keep the carpet clean and intact. In addition, the events should pollute less. When this is done a share of 75% in the long term should be possible. A small part of the PP carpet without backing from the aisles is already recycled to PP products on request of the organisation (Schreuder, p.c., 24 May 2018). So this is also possible for the rest of the PP carpet without backing. Only at some events the carpet is too much polluted to be recycled. In addition, carpet used by exhibitors in stands should be kept apart from the carpet of Schreuder. Currently not more PP carpet without backing is recycled, as it cannot be folded up tight enough. So a lot of air is transported which is not cost effective. This can be solved by pressing the carpet together with a baling machine. This would drastically decrease the transport costs making recycling more attractive. Renewi Icova owns a baling machine that can be used for this purpose. A test already showed that it drastically reduces the volume. A next test (with only PP carpet without backing) will show by how much the volume can be decreased and thus how much Schreuder can save on transport costs. To decrease the transport distance and costs further it would be more advantageous to have a baling machine at RAI. For this purpose storage space would be needed which could be available in the future when the hub outside the city centre is in place (Moens, Gerritsen, Pijper, Mangold, Schreuder, p.c., 30 May 2018).
Before the bales can be sent to the recycling factory it should first be clear what their acceptation criteria are. For instance, if the size and weight of the bales are good (depending on the next test), which degree of pollution is allowed, etc. When with a lower pollution rate higher-grade products can be made, this rate should be kept as low as possible. Carpet factories (also the one of Schreuder) are already busy with developing a tape (used during laying the carpet) made of pure polypropylene that can be recycled with the carpet to reduce pollution. To accelerate this and other developments related to the recycling of carpet, also other venues should start with putting pressure on the factories. RAI is namely only a small client for these factories. More volume would also increase the economies of scale for the factories (Moens, Gerritsen, Pijper, Mangold, Schreuder, p.c., 30 May 2018).
When the specifics of the bales of carpet are clear RAI, Schreuder and Renewi Icova will visit the recycling factory to discuss the potential of using these bales for recycling and how the circularity could be increased in the future (Moens, Gerritsen, Pijper, Mangold, Schreuder, p.c., 30 May 2018).

Impact
Currently, 21% of the carpet (in m^2) is pure PP carpet. Of this carpet, 35% is already recycled. In the long term, with improved policies and quality, it should be possible to recycle 75% of this carpet. The other 25% would be too much polluted. With better policies, also the share of pure PP carpet in the total amount of carpet could be increased. When 30% of the carpet would be PP carpet without backing, and 75% of this carpet would be recycled, RAI would divert approximately 43 tonnes of waste and save €5.300 per year on waste charges. However, since Renewi Icova would probably bale the carpet at first, some of these savings will have to be paid to Renewi Icova for this service.
Since the distance to the carpet recycler is about equal to the distance the carpet currently travels, there will be no change in the geographical circularity.

Use cradle-to-cradle carpet

In the longer term, there could also looked more into the possibility of recycling the carpet to carpet again. For the carpet tiles Schreuder is already testing cradle-to-cradle tiles which are affordable for exhibitors to hire, but the quality of these tiles is not yet high enough (Moens, Gerritsen, Pijper, Mangold, Schreuder, p.c., 30 May 2018). For the carpet used in the aisles, DSM-Niaga is busy with R&D for a cradle-to-cradle alternative. Possibly, also other companies might be busy with this topic. When RAI would use the carpet from DSM-Niaga and recycles it every time, the price would not be very different from current prices as the raw materials would be free after the first use. The quality will probably not be a problem but would have to be tested at an event to see whether the quality is good enough. In addition, pollution of the carpet is not a problem for recycling, and the carpet can be stored at the recycling facility making storage space at RAI not necessary. However, DSM-Niaga pointed out that with their carpet standard colours should be used to avoid unnecessary energy use for decolourisation (Hoex, p.c., 19 May 2018).

RAI could also choose to recycle the mixed colour flow of pure PP carpet they currently use to anthracite carpet, which is already possible. This carpet might be possible to use at trade fairs as these kind of events already use this colour often. With the cradle-to-cradle story, possibly also more organisations might choose for this carpet. To make it more colourful and therefore acceptable the carpet can be decorated with coloured facets (Moens, Gerritsen, Pijper, Mangold, Schreuder, p.c., 30 May 2018). To recycle the used carpet to anthracite carpet, Schreuder would need to be able to offer a large volume of recyclable carpet to recycling factories. For this purpose, Schreuder would need more storage space at RAI and possibly also a baling machine as discussed in the previous measure. The recycled carpet would probably be of a lesser quality than the carpet currently used, but this might not be a problem at trade fairs. Furthermore, in order to get as little colour differences as possible, much carpet should be ordered at the same time to get carpet from the same batch. For this purpose, Schreuder would also need more storage space at RAI (Schreuder, p.c., 24 May 2018). This problem of storage space might be solved in the future when the plan for the hub outside the city centre is implemented.

Impact

When the carpet tiles used at RAI would be fully cradle-to-cradle no tiles will be incinerated anymore which would result in a cascade at the end of life from level 3 (reuse) to level 1 (recycling, but at high-grade) on activity-wise circularity instead of a cascade from level 3 to level 0 (incineration). Since the tiles do not end up as waste at RAI, no waste charges will be avoided.

Looking at the carpet used in the aisles the technology of DSM-Niaga might make it possible to recycle all carpet used at RAI cradle-to-cradle (level 1, but at high-grade). The other recycling option could only recycle the pure PP carpet (which is not too much polluted) to anthracite carpet (level 1, at lower grade). It will depend on the quality of the carpet from DSM-Niaga how big the share will be on the total volume, and thus what the total impact will be. For this type of carpet, quality and pollution is not expected to be a problem, so 100% of the carpet would be recyclable. Looking at 2017, 294 tonnes of carpet waste could have been avoided with this technology, which equals to approximately €36.500 of waste charges per year. With recycling the pure PP carpet to anthracite carpet, pollution would still be a problem. This would make the recycling to anthracite carpet only possible for 75% of the pure PP carpet, which amounts to 22,5 tonnes per year. Then, approximately €2.775 per year on waste charges can be avoided. Since the use of pure PP carpet is expected to increase in the future, the impact of this measure is also expected to increase.

7.3.1 Feasibility

Table 8 shows the feasibility assessment of the measures improving the recycling of the materials. For the waste separation at events and at the offices, the possibility to overcome the barriers mainly relies on the priorities that have to be determined by RAI. The second and third option focus on the cooperation between RAI and Renewi Icova. Both options might show barriers in the economic-financial area, but might be easy to overcome. The feasibility of the recycling of wood and the use of cradle-to-cradle carpet mainly relies on the R&D that has yet to be performed. Recycling the carpet to PP products shows to be more promising in the near future, as the barriers seem to be possible to overcome.

TABLE 8: FEASIBILITY MEASURES IMPROVING RECYCLING.

Feasibility assessment category → Improvement measures ↓	1. Technical-operational	2. Environmental	3. Economic-financial	4. Socio-cultural	5. Institutional	6. Policy and legal
More waste separation at events and at the offices	Communication plans for employees and visitors are already available. However, RAI still has to agree on clearer signs.	Due to a higher separation rate, the materials will be processed in a more environmentally friendly way.	The costs for such a programme will probably be compensated by the benefits (around €48.000 per year).	It is not clear if the waste flows at events will be clean enough, but logistically it is possible (Dekker, p.c., 29 March 2018).	Capacity to handle the waste flows should be present (Kolken, p.c., 30 April 2018).	No barriers.
Improve the contract Renewi Icova	No barriers when there is good communication with Renewi Icova.	The impact on nature will go down when less waste is incinerated, and recycling is improved.	A stricter contract might increase costs of material processing too much, depending on demands.	Willingness to change at RAI and Renewi Icova is present (Eenbergen, p.c., 18 May 2018; 29 March 2018).	Cooperation with Renewi Icova is currently sufficient and RAI has enough capacity to handle the change.	Legal department needs to help with changing the contract. However, this should not be a problem.
Separate tenders	The Dutch Government will start with separate tenders in 2021. RAI can use this as an example (Goudsmith, p.c., 16 May 2018).	The impact on nature will go down when the best way of processing the materials is chosen.	Implementing separate tenders will probably save costs in waste management, but it increases employee costs, which might be a problem (Eenbergen, p.c., 18 May 2018).	Willingness to change it is present, and it will probably be accepted by the board (Eenbergen, p.c., 18 May 2018).	Cooperation with Renewi Icova is sufficient, but capacity to handle change needs to be improved. This should not be a problem (except for the costs, see category 3).	Legal department needs to help with setting up the tenders and contracts.

Recycle all the wood	The suitability of the material for Afwerking and Noble Environmental Technologies, and the quality of the end product depends on the R&D phase. The quantity of wood is enough. The logistics have yet to be determined but can be solved.	The impact on nature will be lower as less new wood has to be harvested. During the production of ECOR no non-renewable or chemical compounds are used which is also an improvement compared to the current situation.	The price of the panels is not clear yet but ECOR aims for the same price as competing materials. The logistic costs can be paid with the costs which do not have to paid anymore for waste charges, which is about €43.200 per year when all wood can be recycled.	The willingness to find solutions for logistics is present. ECOR is currently tested as replacement for current materials. Collaborating with Afwerking will generate employment among young adults with a distance to the labour market.	Cooperation between RAI and both parties is evolving. Depending on the R&D and the tests for reusing wood by Afwerking, the cooperation will remain. Possibly the logistics at RAI has to be changed when the ECOR used has to be returned.	No barriers expected.
Recycle a larger share of carpet to PP	Depending on the acceptation criteria of the bales, it will be technically possible to recycle the bales. It is already possible to recycle the carpet to PP products when it is not baled. So it would probably be possible.	Since less carpet is incinerated in the cement industry, the environmental impact will decrease.	The financial construction is not yet determined. But the waste charges will go down with approximately €5.300 per year. It is not clear whether this will compensate the transport costs to the recycling factory.	Changing the logistics to keep the Schreuder carpet apart from other carpet still has to be thought through but they are willing to change. The use of this recyclable carpet is also increasingly accepted and even asked for.	The cooperation between Schreuder, RAI, and Renewi Icova is very good. Between Schreuder and the carpet factory also no barriers are expected. The institutional capacity at Schreuder is also expected to be enough.	No barriers expected.
Use cradle-to-cradle carpet	The quality of the cradle-to-cradle tiles is not sufficient. In addition, for the carpet for the aisles the quality still has to be determined. Both technologies still have to be developed.	The impact on nature will decrease as less carpet is incinerated in the cement industry. Compared with the previous solution the impact will decrease as the recycling is more high-grade and no raw materials are needed.	Using cradle-to-cradle tiles will not affect RAI financially as exhibitors pay for it. Cradle-to-cradle carpet for the aisles is not yet developed, but depending on the technology, savings on waste charges will lie between €2.775 and €36.500 per year.	Using cradle-to-cradle carpet tiles is widely accepted. How to keep the Schreuder carpet apart from other carpet still has to be thought through but RAI is willing to change. Recyclable carpet is also increasingly accepted and even asked for.	For the development of these types of carpet, Schreuder has a good cooperation with their factory and suppliers. There are also no barriers expected in the institutional capacity.	No barriers expected.

8. Discussion

In this section, the limitations of this research and the theoretical and practical implications are discussed. In addition, recommendations for further research are made.

8.1 Limitations and rival explanations

Several limitations can be identified in this research that might have affected the results. First, a significant number of interviews is conducted, but not all data needed for the description of the current material flows was gathered, which might also be the case for the identification of improvement measures. For the current material flows, it was not possible to get a clear and detailed overview of the incoming material flows due to a lacking system. This made it for instance more difficult to determine the materials that are reused. This in turn led to a less detailed evaluation and less specific measures that could improve the circularity of RAI. In addition, for determining the share of internal and external waste often assumptions had to be made as not every container is weighed. For determining the share of material from RAI going to different processors, also assumptions had to be made as the materials are sometimes divided in different quality categories or mixed with the materials collected from other organisations before they are processed. For instance, it was not possible to determine the share of wood waste from RAI that is recycled to chipboard or what the share of foils is in the paper and cardboard waste. So the exact amount of materials from RAI ending up at different processors can only be estimated, which makes the results less reliable. More interviews could have led to more detailed insights in the current material flows and, potentially, more improvement measures. For this purpose, more time should have been available to speak to more people or to some people who were already interviewed more often. However, it is not expected that additional interviews could have led to the most feasible measures or measures with a big impact.

For some material flows there was a lack of information on the location where they are processed. This made it impossible to determine the distance the materials travel precisely, and thus determine the geographical circularity of these material flows. This was for instance the case with the location where the wood is incinerated or processed into chipboard. This made it also harder to determine whether the improvement measures resulted in a better geographical circularity.

Furthermore, the impact of most improvement measures was based on assumptions on for instance the extent to which they are implemented, the share of different products in the total material flow, and how a technology will evolve in the future. When these measures are actually realised the impact could be different. The measures could for instance not be implemented well, the share of products in the total material flow could differ, or the technology could evolve in a different direction. Therefore, before implementing the measures, the assumptions should be kept in mind and adjusted if needed.

Additionally, in the report a preliminary feasibility analysis is included. With this analysis, some barriers related to the feasibility of the proposed improvement measures might not have been identified or opportunities making it more feasible could have been overlooked. This could have affected the conclusions based on the feasibility of the improvement measures. The selected measures should therefore be studied more in-depth to identify additional implementation barriers and opportunities.

Finally, due to a lack of time the focus during the evaluation of the material flows and the recommendation of improvement measures was limited to the material flows covering at least 80% of the total volume and/or showing easy improvement possibilities. This led to a less complete overview of the circularity of RAI and of measures that could increase the circularity of RAI.

8.2 Theoretical implications and further research

In this research, a method was proposed to analyse the material flows of an organisation like RAI, measure the circularity of these flows, and determine the feasibility of improvement options that could make these flows more circular. In this method, the concepts of Material Flow Analysis (MFA) and the Circular Economy (CE) were used, and a simplified feasibility assessment was applied. The analysis of the material flows was based on the MFA tool. This tool was not yet much applied to the organisational level but showed to be a useful tool for mapping flows of individual firms in previous studies (Diener et al., 2013). In these studies, this tool was mainly used to evaluate the throughput of companies in order to find inefficiencies, support priority setting, look for improvement measures, and provide tools to monitor effectiveness of the measures (Bringezu & Moriguchi, 2002). In this research, the method also showed to be an efficient tool for mapping the material flows of RAI and to be a good basis for analysing the circularity of these flows. Therefore, this research supports the further use of this method on the organisational level. The use of a Sankey diagram to present the results also showed to be of great added value and is therefore recommended for future research.

To evaluate the focal material flows the concepts of CE were used. This evaluation was based on three aspects; the activity-wise circularity, geographical circularity, and the time the materials remained in the loop. Activity-wise, the circularity was based on which loops of Figure 1 were used by the different materials. Geographically, the distance the materials travel from RAI to the location of processing or incineration was scored using 5 levels of distance. The time the materials remained in the loop was scored using 5 levels of time span the materials were used before they were disposed of.
Using this scoring system in the evaluation of the current material flows showed to be very useful. It gave a good overview of the different routes "travelled" by the materials and what kind of effect this has on the circularity of the flows. However, due to a lack of information it was not always possible to show the magnitude of all flows, and it was also hard to determine the time span the materials were used. Further research could analyse these shortcomings and improve the way in which the concepts of CE were applied in this research for the evaluation of material flows. Such an improved scoring system would be of great value in the field of MFA's applied to organisations. However, it should not be forgotten that circularity should be not a goal in itself, but a tool to minimise the environmental impact.

The scoring system was also used to determine the impact the improvement measures could have on the current material flows. This resulted in more insight in the magnitude of the impact and the difference in impact between measures. However, as already mentioned in section 8.1, the system does have limitations because of the assumptions made. The effect of many measures relies on the extent and the way in which they are implemented. Future research could focus on a better way of implementing the concepts of CE to determine the impact of improvement measures on the current situation. This could possibly be based on an improved scoring system for the current material flows.

To determine the feasibility of the improvement measures, a simplified feasibility assessment based on Lohri et al. (2013) was used as this is a very complete tool with a broad sustainability focus compared to other feasibility assessment tools. The tool takes technical-operational, environmental, financial-economic, socio-cultural, institutional, policy and legal criteria into account. However, since it was not feasible to apply the complete tool to all improvement measures, the tool was simplified to only include the most important aspects. The simplified tool showed to be well applicable to assessing the feasibility of the improvement measures. However, since some barriers might have been overlooked it is recommended to use the complete tool in future research when possible.

The combination of these different tools thus showed to be very useful to reach the goal of this research, but some improvements to the application of the concept of CE as well as applying the full feasibility assessment tool could have improved the results of this research. Future research should therefore look into possible adaptations of the methods and apply the improved methods resulting from this to similar research questions to see whether the adaptations lead to better results.

After these improvements, the combination of tools is expected to also be applicable to other organisations that want to transform their linear material flows into more circular flows. Future research should see whether this is possible. This might also lead to additional suggestions for improvement of the methods. Eventually this might lead to a method that could be applied to a wide variety of organisations. This method would be a relevant contribution to current literature.

This research found many improvement measures for the focal material flows. However, as already mentioned in section 8.1, the incoming material flows could not be analysed in detail, and not all material flows were evaluated and included in the search for improvement measures. So potential measures concerning the incoming materials were not identified. After a better procurement system is in place future research could also look at measures in this area. Furthermore, evaluating also the other material flows and looking for improvement measures for these flows could result in more ways in which RAI could become more circular. This could be done by building upon the overview of these material flows that was already built in this research.

Finally, many improvement measures were found that were not promising enough to be included in this research, but which might be more promising in the future. For instance, there is research done on more circular ways of processing wood waste contaminated with paint (for instance Rautkoski et al. (2016) and Fraunhofer WKI (n.d.) did research on this). Future research should therefore also look whether there are (new) emerging technologies in this area which are feasible to apply then or in the near future.

8.3 Practical implications

This research created insight in the material flows at RAI, how they currently score on circularity, and how the circularity can be improved. The increased insight in current flows made people at RAI more aware of their impact and on where action is needed. It also identified organisations that can provide a solution how they can be of value for RAI. Furthermore, other organisations that want to improve their circularity can learn from the results and might also be able to implement the improvement measures.

For some measures, the first contact with the company that could provide a solution is already made, or first steps for implementing the measure have been taken. However, for many measures it is important that RAI sets circularity as a higher priority or solves other barriers that make the measure more feasible. A large share of the identified improvement measures show only minor barriers for implementation and are therefore the lower hanging fruits. However, these measures might compete with other measures with a higher impact as they focus on the same material flow. These measures can therefore not be implemented together. For these measures, RAI should decide if they want to choose the most circular option or the easiest one.

Implementing the measures will result in less waste generation and will thereby contribute to the goals of Amsterdam Metropolitan Region, the Netherlands, and the SDGs. The calculations in chapter 7 for the different measures show that implementing these measures can also lead to considerable cost savings. Furthermore, the reduction in waste generation might also create awareness among visitors, exhibitors, the organisers of events, and other organisations like RAI. Implementing the measures will also stimulate the (mainly small) companies to grow and expand their business. Finally, with these measures fewer materials will be landfilled, incinerated and recycled reducing the impact of RAI on the environment.

9. Conclusion

This research aimed to answer the following research question: *Which measures can help RAI Amsterdam to work towards circular material flows?*

To answer this research question, the concepts of CE, MFA and a simplified feasibility assessment were combined in the research design. This design proved to be suitable for analysing the current material flows and evaluate them on their circularity. With this groundwork, it was possible to perform a targeted search for measures improving the circularity of the material flows at RAI, and assess these measures on their feasibility.

The research resulted in new insights that are valuable not only for RAI but also for other organisations that aim to improve their circularity. The analysis of the current material flows resulted in more insight in how the materials are processed after leaving RAI. This showed RAI their starting point from where they can work towards more circularity. The evaluation of the focal material flows (based on their size and possibility for improvement) increased the insight in how these flows score on circularity. The improvement measures showed feasible ways in which RAI can improve the circularity of these material flows.
Yet, the insights in the material flows can be improved by a better monitoring of procurement and the content of the material flows. This would further the opportunities for improvement.

Four categories of improvement measures were identified: general measures, measures decreasing material use, measures increasing reuse, and measures improving recycling. As general measures, RAI should first clarify its priorities and communicate these through the organisation. They should also collaborate with other event locations, create more time and space for circularity and make options that are (more) circular more attractive for exhibitors. To decrease material flows, RAI could redesign its current procurement systems or create a new one that facilitates circular procurement. Furthermore, they could use carpet tiles more often and push suppliers to decrease the amount of outer packaging that has to be disposed of at RAI. More digital communication, decreasing the amount of plastic packaging in catering, and reducing the amount of waste during construction activities could also decrease the amount of material use. To make reuse of materials possible, RAI could collaborate with a company that reuses materials from demolition activities, and they could build in a circular way in the future. Finally, to increase and improve recycling, RAI could improve the contract with their waste processing company, tender waste flows separately, separate more of their office waste, and collaborate with companies that can recycle their wood and carpet.

The circularity of RAI would drastically increase when all measures would be implemented. Looking at Table 3 in chapter 6.6, the volume of the materials mentioned in the column of level 0 on activity-wise circularity will drastically decrease. The volume of residual waste and cardboard, paper and foils will go down, and almost all carpet and wood currently scoring level 0 will go to level 1, and partly to level 3. The flow of construction and demolition waste could even be eliminated.
Geographically, tendering every waste flow separately might increase the score for every waste flow. Most measures focusing on individual flows also improve the geographical circularity, like recycling wood and collaborating with a company that reuses materials from demolition activities. Recycling the

carpet will not change the circularity score as the known recycling factory is not closer by than the cement factory.
Most measures do not have a big impact on the time the materials remain in the loop. Only the use of carpet tiles would greatly increase the time the materials are used. In addition, circular procurement might result in products that are more durable and can be used for a longer time.

Of all these measures, collaborating with other event locations, circular procurement, building circular buildings, separating waste and recycling all wood are the measures that could have the largest financial impact. These measures, including the use of carpet tiles and collaborating with a company that reuses materials from demolition activities, show also the most possibility for improving the circularity of RAI. However, there are still barriers that affect the feasibility of these measures. Many of these barriers can be overcome by creating more time and space, and putting more priority on circularity. The most feasible measures are clarifying the priorities, circular procurement, collaborating with a company that reuses materials from demolition activities, improving the contract with Renewi Icova, and implementing separate tenders. This shows that circular procurement has most circular and financial impact and is very feasible. So RAI should first focus on implementing this measure.

Some measures, for instance the ones focusing on carpet and building and construction materials, compete with each other. For carpet, RAI could use either carpet tiles or recyclable carpet, or a combination of both. For this choice RAI should first decide what they want to achieve on circularity in the long term and then choose the option (or combination of options) that is most in line with this goal.

Although it was not possible to formulate improvements for all material flows, it is expected that the formulated measures could significantly increase the circularity of RAI. It is also expected that this research increases the awareness of people at RAI of the waste they create, which might lead to more improvement measures (also for other material flows) in the future. However, RAI should keep in mind that circularity is only a tool, and that the final goal is a reduction of the environmental impact. So when looking at solutions that could improve the circularity, one should always analyse whether these solutions contribute to the final goal; reducing the environmental impact.

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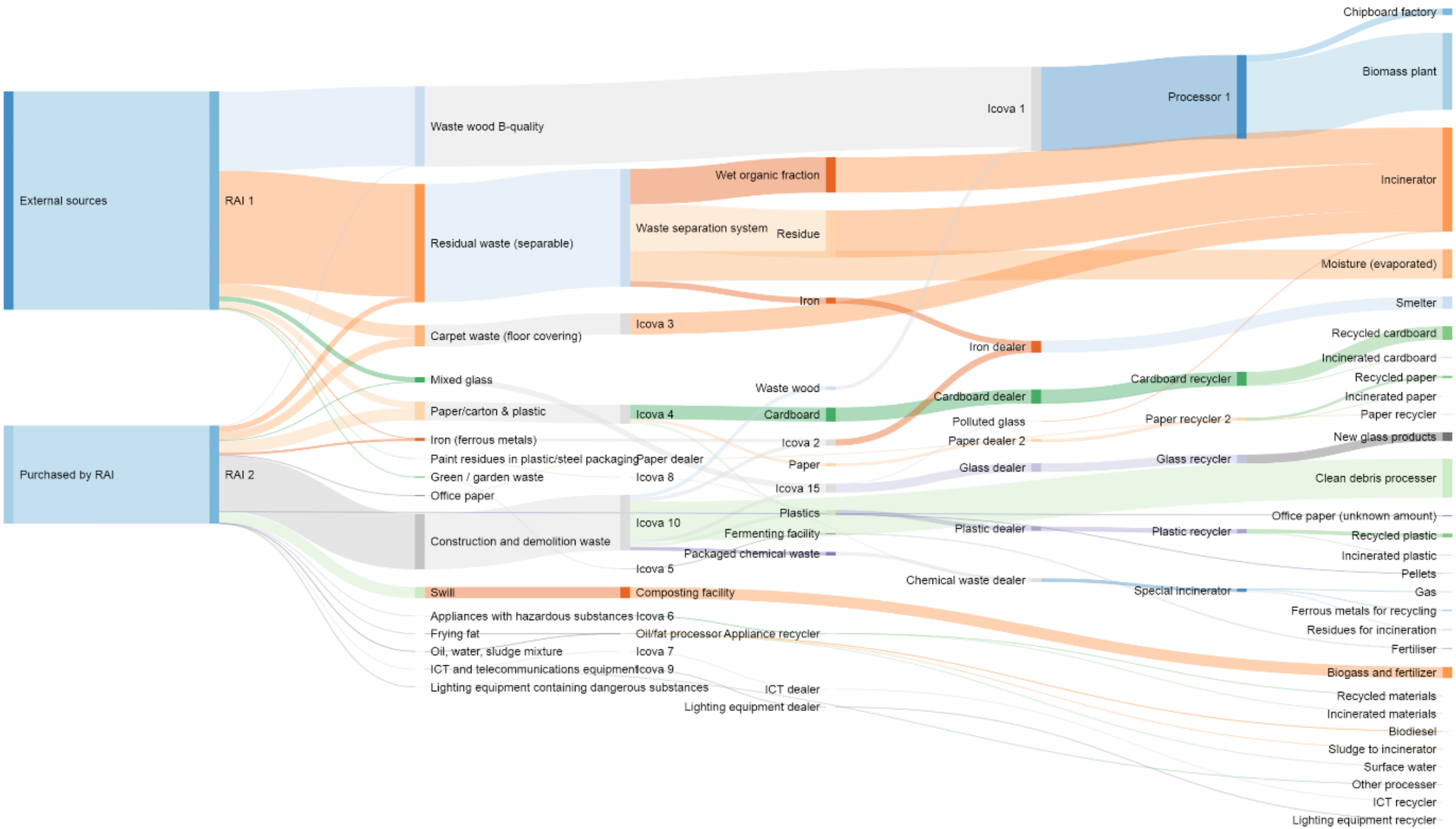
Appendix I: Readable version of expected material flows

The figure below shows the readable version of the Sankey diagram of expected material flows of RAI which was presented in section 3.1.



Appendix II: Aspects of feasibility assessment

The table below shows the aspects related to the different feasibility assessment categories which were used in this research to determine the feasibility of the different improvement measures. The feasibility assessment categories were first divided into different sub-categories. These sub-categories and the aspects related to these categories are based on the ones used in the feasibility assessment tool developed by Lohri et al. (2013), but adapted to fit this research.

Feasibility assessment category	**Sub-categories**	**Aspects**
1. Technical-operational	1.1 Material chain	Material quantity
		Material quality
		Transport of material
	1.2 Technology	Existence/proven
	1.3 Product chain	Quality end product
		Transport of product
2. Environmental	2.1 Use of non-renewable materials	In whole process (additives/packaging/etc.)
	2.2 Use of chemical compounds	In whole process (additives /etc.)
	2.3 Impact on nature	In whole process
3. Economic-financial	3.1 Cost-benefit analysis	Costs/benefits for RAI
		Savings for RAI
	3.2 Market situation	Supply and demand
		Competition
	3.3 Funding situation	Profitability
4. Socio-cultural	4.1 Willingness to change behaviour	Waste separation/logistics at RAI
		Use of product
	4.2 Impacts enhancing people's capacities to meet their needs	Employment generation
	4.3 Acceptance	Of new product
5. Institutional	5.1 Stakeholder cooperation	Cooperation within chain and with other customers
	5.2 Institutional capacity	At RAI and company to handle process and material flow
6. Policy and legal	6.1 Related legislation en standards	Supportive legislation
		Prospective legislation

Appendix III: General set-up of the interviews

The interviews are semi-structured. So not all questions are predetermined since they depend on the information given by the interviewee. Also, every interview requires different questions as all interviewees fulfil different functions in the material flow process. In this appendix the basic questions which are asked to every interviewee active in the material flows of RAI and the ones which are not active in this area are given. These questions aim to get information on possible improvement measures. The questions of the interviews aimed at obtaining information on current material flows were all specific to the situation and can be requester from the author.

Questions for the interviewees active in the material flows of RAI:

- What is your function and what does it entail?
- What is the role of your company in the material flows of RAI?
- Can you think of measures which could result in less waste, less transport, or higher quality destination of the waste? (check feasibility factors)
- What will be the potential impact of these measures? (annual volume of waste diverted/avoided, kilometres avoided)
- (suggestion of other measures) Do you think that these measures will be feasible and result in less waste/less transport/ a higher quality destination of the waste? (check feasibility factors)
- Are there other things on this subject which you think are interesting for my research?
- Can I send you extra questions which might arise after further research?
- This research will be publicised, is it okay when I cite you in the following way: …
- Are you interested in the report when it is finished?

Questions for the interviewees <u>not</u> active in the material flows of RAI:

- What is your function and what does it entail?
- (explanation of the material flows of RAI)
- Can you think of measures which could result in less waste or higher quality destination of the waste? (check feasibility factors)
- What will be the potential impact of these measures? (annual volume of waste diverted/avoided)
- (suggestion of other measures) Do you think that these measures will be feasible and result in less waste/less transport/ a higher quality destination of the waste? (check feasibility factors)
- Are there other things on this subject which you think are interesting for my research?
- Can I send you extra questions which might arise after further research?
- This research will be publicised, is it okay when I cite you in the following way: …
- Are you interested in the report when it is finished?

The summaries of the verbal interviews, the audio fragments, and the text from the interviews conducted in writing can be requested from the author.

Appendix IV: Data waste flows over 2017

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Int.	Total	Int.	Total	Int.	Total	Int.	Total	Int.	Total	Int.	Total	Int.	Total	Int.	Total	Int.	Total	Int.	Total	Int.	Total	Int.	Total
Unsorted C&D waste	0	0	38,5	38,5	34,2	34,2	28,5	28,5	4,2	4,2	33,4	33,4	36,7	36,7	61,8	61,8	8,2	8,2	16,6	16,6	13,7	13,7	45,7	45,7
Roofing waste	0	0	0	0	0	0	0	0	0	0	7,4	7,4	0	0	0,7	0,7	0	0	0	0	0	0	0	0
Clean debris	44,2	44,2	17,9	17,9	28,3	28,3	0	0	0	0	0	0	16,4	16,4	27,0	27,0	0	0	0	0	3,4	3,4	51,0	51,0
Debris > 100cm	0	0	0	0	0	0	0	0	0	0	0	0	14,0	14,0	0	0	0	0	0	0	0	0	0	0
Contamin-ated debris	0	0	0	0	0	0	0	0	0	0	0	0	199,1	199,1	13,6	13,6	0	0	0	0	0	0	0	0
Waste wood B-quality	0,6	64,9	3,2	315,7	0,3	33,9	0,07	7,3	0,9	89,5	0,3	32,2	0,2	16,6	0,1	11,1	2,7	265,5	0,9	90,3	1,0	98,5	0,5	48,8
Iron (ferrous)	0,9	1,2	4,1	5,5	4,8	6,4	2,6	3,4	2,9	3,8	0	0	2,7	3,6	2,9	3,8	2,7	3,6	2,3	3,0	0,9	1,2	3,0	4,0
Residual waste	109,5	239,1	135,2	295,1	31,5	68,8	18,8	41,1	81,4	177,7	34,5	75,4	29,8	65,1	5,6	12,3	107,4	234,4	63,5	138,7	65,0	141,8	42,9	93,6
Carpet waste	14,0	36,9	18,5	48,9	9,0	23,6	5,5	14,5	10,4	27,3	3,4	9	0	0	0	0	21,3	56,1	5,9	15,5	19,7	51,9	0	0
Swill	25,3	25,3	10,8	10,8	22,4	22,4	3,2	3,2	12,4	12,4	13,8	13,8	9,3	9,3	2,2	2,2	10,2	10,2	21,7	21,7	6,3	6,3	15,4	15,4
Frying fat	0	0	0,2	0,2	0,45	0,45	0	0	0	0	0,2	0,2	0	0	0	0	0	0	0	0	0	0	0	0
Paper, cardboard & plastic	11,1	25,9	28,0	65,0	3,2	7,3	4,2	9,8	19,1	44,4	2,4	5,6	10,0	23,1	0,1	0,2	8,2	19,1	5,7	13,4	7,2	16,8	8,4	19,5
Glass	1,3	10,4	0,8	6,7	0,2	1,2	0,7	5,2	0,8	6,1	0,8	6,6	1,0	8,2	0,1	1,0	0,8	6,2	0,4	3,2	1,2	9,3	1,1	8,7
Green/ garden waste	0	16,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refridgera-tors and freezers	0	0	0,1	0,1	0,1	0,1	0	0	0	0	0	0	0,3	0,3	0,02	0,02	0	0	0	0	0	0	0	0
Large applicances	0	0	0,5	0,5	0,3	0,3	0	0	0	0	0	0	0,1	0,1	0	0	0	0	0	0	0	0	0	0
ICT and telecomm.	0	0	0	0	0,2	0,2	0	0	0	0	0	0	0,3	0,3	0	0	0	0	0,2	0,2	0	0	0	0
Oil, water and sludgemix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,1	2,1	0	0	0	0	0	0	0	0
Paint residues	0	0	0	0,1	0	0	0	0	0	0	0	0	0	0,4	0	0	0	0	0	0,5	0	0	0	0
Lighting equipment	0	0	0,09	0,09	0,1	0,1	0	0	0	0	0	0	0,04	0,04	0	0	0	0	0,1	0,1	0	0	0	0

SOURCE: RAI AMSTERDAM (2017C)