A MATERIAL FLOW AND TRANSPORT ANALYSIS ON IMPORTANT MATERIAL FLOWS IN AMSTEL III AND AN ALTERNATIVE WASTE SYSTEM FOR THE AREA

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ABSTRACT

The era, society and environment in which we live are characterized by rapid, successive changes. For a large part, the economy thrives on fast-moving consumer goods. Problems of these goods are the mass production, inexpensiveness and short lifespan. In the Netherlands, only 22% of the total waste is recycled. In addition, the country is largely dependent on the import of materials from abroad. By consuming less, separating waste better and recycling more materials, a contribution can be made to a healthier environment with less polluting emissions. Alternative waste management can contribute to a healthier environment, better waste separation and material recycling. Office waste offers the largest opportunities in the Amstel III area in Amsterdam. Mitigating office waste provides the highest-impact opportunity. However, awareness must be created to increase participation of residents. Therefore the focus must be directed to both business waste and household waste to successfully decrease the footprint of the area.

KEYWORDS: *MATERIAL FLOW ANALYSIS, CIRCULAR ECONOMY, WASTE MANAGEMENT*

I. INTRODUCTION

The era, society and environment in which we live are characterized by rapid, successive changes. For a large part the economy thrives on fast-moving consumer goods. Problems of these goods are the mass production, inexpensiveness and short lifespan. Examples are plastic bags, cups, clothing but also food and drinks and the packaging and organic waste to match. After short use, sometimes even seconds, they are considered as waste. (Haffmans, van Gelder, van Hinte, & Zijlstra, 2018)

Also, production processes are part of the enormous amounts of pollution in Western civilizations. These processes in turn, cause a lot of waste in themselves. In 2018, waste management together with energy management and water companies were responsible for more than 25 percent of the total co2 emissions in the Netherlands. Households and the transport sector were likewise in the top 5 of the most polluting actors. To achieve a circular economy in an environment-friendly society, collaboration between different organizations, governments, institutions and individuals on every possible scale is necessary. Where technology and innovation have led to the problem of massive production and consumption, it can also lead to a solution of the problem. However, what might be just as important is changing the behaviour of its users. To develop sustainable environments it is important to understand the fundamentals of material flows in these specific areas and the waste management that comes with it.

This research paper is part of a graduation project that aims to develop architectural interventions that facilitate change in consumer behaviour to reduce material use and waste and stimulate reuse and recycling.

Policy for waste processing differs per city in the Netherlands. In the city of Amsterdam it even differs per district. The Amstel III area in Amsterdam is going to be transformed from a formal business area into a dynamic work-live area with a focus on sustainability and circularity. Since the development is still at an early stage it can serve well as an area to apply new systems that support a circular economy.

1.1. Amstel III

Amstel III is a large area along the railway track between the Amsterdam ArenA and the Amsterdam UMC with the metro stations Bullewijk and Holendrecht as entry gates. It encompasses two types of areas: a typical business district along the A2 highway and an area which is to be transformed from an office zone to an urban living area. In this zone 15.000 new homes will be realized in the coming years: at least 5000 before 2027 and the other 10.000 before 2040. Currently, more than 37.000 people commute to the area for work every day. In total 50.000 people work in the area. Amstel III will be transformed from an area where people only work to a dynamic urban area where people will live, work and recreate. This includes accessible public facilities and high-quality public spaces. (Gemeente Amsterdam, 2018)

The municipality of Amsterdam wants to gain a leading position in the transition to a more circular economy, with a focus on value chains, construction and organic flows. A chain is the process of production, transport, consumption and waste. The municipality also wants to stimulate innovation with a focus on the construction chain, the organic flow chain and circular energy generation. The start of the realization of this vision has already begun. The municipality has made Buiksloterham, a district in the North of Amsterdam, the largest circular test area in the country. In addition, the municipality is a partner in the Circle City Green Deal, in which work is being done to investigate how restrictive regulations for circular development can be resolved. Finally, the municipality has started circular procurement. By being both facilitating others and initiating new developments, the municipality takes its responsibility in driving the circular transition. (Circle Economy, TNO, Fabric, & Gemeente Amsterdam, 2015)

The ambitions for Amstel III are to attract new residents, small businesses and start-ups, connect slow transport and create healthy and sustainable green areas. At the moment 59% of the office objects is vacant (appendix A ‘Tables’) and by creating an economically strong, multifunctional and vivid area this vacancy can be managed. To create a vivid area also public sports facilities and more green areas will be created. In addition to the existing program, 45% houses, 45% offices and 10% services will be added to the area.

II. METHODOLOGY

Various methods have been used to support the research. These methods have led to possible input for a change in consumer behaviour in order to reduce material use and waste and stimulate reuse and recycling. Therefore, this paper aims to answer the following research question:

What is the current situation and what is the future scenario of material flows and waste management in the Amstel III Area?

To answer this question a material flow analysis in quantity and composition is carried out on average households and businesses in Amsterdam and the Amstel III area. Available data is processed in Excel models (Appendix ‘Tables’) to generate specific results concerning the amount of waste and transport emissions. This data has been visualized in various material flow schemes (Appendix ‘Material flow schemes’ and Material Flows Amstel III). Data based on expected programming of the area is used to make a statement about the future scenario of Amstel III. Also, a transport analysis is carried out on waste management in Amsterdam and research is done on possible alternatives for waste management an material re- and upcycling in Amstel III. The municipality of Amsterdam provided a lot of information concerning the research. Furthermore, the OIS Amsterdam (Research, Information and Statistics) service has been used to obtain specific information about Amstel III. Finally, online sources and literature have been consulted for additional information.

III. WASTE MANAGEMENT AMSTERDAM

In the Netherlands 549 billion kilograms (kg) of material end up in the economy in one year. 130 billion kg is domestic extraction and 221 billion kg is being consumed in the Netherlands. This implies that the Netherlands is largely dependent on materials from foreign economies. Only 22 percent of this consumption is being recycled, which in contrast with other European countries is even a relatively high percentage. An unprecedented amount of 59 billion out of 146 billion kg material production ends up as waste in one year. (CBS, 2018)

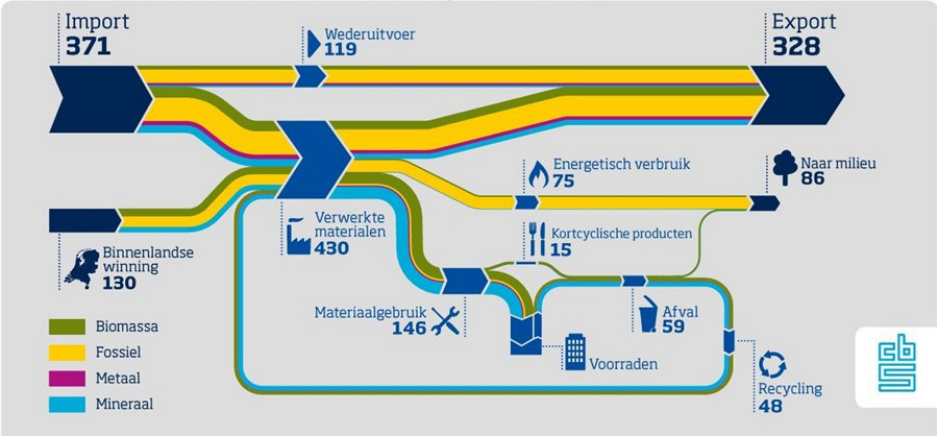

Figure 1 Annual amount of material ending up in the economy in the Netherlands (CBS, 2018)

3.1. Waste management Amsterdam

The city of Amsterdam produces more than 300.000 tons of household waste per year. Therefor waste collecting trucks of the municipality have to drive a total of 2.5 million km per year. In Amsterdam the logistic chain of household waste in short is as follows. After consumption, waste is being collected in containers in the public space. Weekly, trucks of the municipality and trucks of other collection companies empty the containers and transport the waste to waste sorting facilities. In some cases residual waste and plastic waste is being collected at specific times and locations in waste bags on the streets. Waste of business that is comparable in composition to household waste can be offered in the same way if they meet a certain requirement that is called 'het reinigingsrecht' (Gemeente Amsterdam, 2015).

This type of waste collection and management causes a number of problems. To collect waste in Amsterdam, 11.000 containers are needed in the public space while garbage trucks emit around 80 kton of CO2 and 86 ton NOx per year (Appendix B). Sometimes containers are overloaded what leads to litter in public space as a result. Also the other way around; half empty trucks instead of full trucks drive to waste processors. The containers in the public space often smell bad and are poorly designed within their environment. Finally, this system is not stimulating separation of waste. Still, a big problem is the lack of space within homes. A lot of people, especially in high density areas, don't have enough space to collect all household waste separately. With the expected number of 15.000 new households in Amstel III it would lead to the requirement of 38 new containers in the public space (Gemeente Amsterdam, 2015).

A different problem concerning waste separation and processing is the incineration system of residual waste. In the Netherlands there are 12 waste incineration plants (AVIs) of which the AEB in Amsterdam is one. This waste incineration system limits waste separation because the capacity of the installations are too large and can no longer be used economically if they cannot run at full capacity. Therefore the AVIs even obtain a large part of waste from abroad because the amount of waste in the Netherlands isn't sufficient. Ideally, therefore, less energy should be consumed and natural energy sources

such as sun, water and wind should provide as much as possible instead of fossil energy sources. Currently, one of the largest waste streams is organic waste. In Amsterdam almost all organic waste produced is incinerated in these institutions, while the energy yield from incineration is almost zero in mixed waste installations (Wise, 2017).

3.2. Alternatives

There are a few existing and new innovative alternatives for waste transportation. For example in Amsterdam Oost, Den Bosch and in Groningen the municipality has implemented a system where public containers and trucks communicate with each other. Containers can record how much waste is collected per type of waste, by whom and when the container is full. For example, by means of ID cards that give access to the containers it is personally registered how much residual waste is thrown away. Based on this amount, the amount of waste tax is personally determined. Separated material flows are free. This has led to a reduction of 1/3 of the garbage trucks in Amsterdam Oost, fewer car kilometres in Groningen and therefore less CO2 emissions and in Den Bosch to less litter, less odour caused by containers and a 13 percent reduction in waste tax per person (de Jong & Smorenburg, 2014; Natuur & milieu, n.d.).

Another existing and more sustainable alternative for waste management is an underground vacuum system for waste handling. The leading company involved in such waste systems is Envac. The system addresses the problems that come with different types of waste management and is applied on large-scale residential and commercial developments by transporting waste trough an underground network of pipes. Collection operatives don't come in direct contact with the waste, there are no unpleasant smells and no unsightly bins because the systems, apart from a few inlets, are underground (Envac, 2012).

A completely different alternative to waste processing is the exchange of materials between companies. The waste stream of one company can be used as resource material for another company, which results in less or no waste processing. This system won't cover the entire waste management but can help to reduce waste in other waste processing systems. The problem with material exchange is that there is not enough knowledge and insight into certain material flows. The majority ultimately ends up in waste incineration facilities. In addition, companies that can exchange materials are not strategically located in the urban context. Therefor it still requires a lot of transportation. An example of this is a collaboration between Tata steel and the chemical company Minnessma. During the production of steel a lot of carbon dioxide is emitted, which is a raw material for certain chemical processes. This collaboration is called industrial symbiosis. The problem in this case is that the companies have to be located close to each other to make it feasible. A start-up that maps material flows from large companies is the Excess Material Exchange. They managed to create a 'material passport' in fast moving goods and waste. In collaboration with a number of large companies in the Netherlands, supply and demand of material flows are matched to create a no waste environment. In the urban planning, these kinds of considerations can be taken into account in the future to minimize transport.

IV. Material Flow Analysis amsterdam & amstel III

Several studies have been carried out on material flows in household and business waste. On the basis of these various studies, the most important material flows can be determined. Therefore, the material flow analysis in this paper is focused on plastic, paper, organic waste and textile for household waste (Gemeente Amsterdam, 2015) For business waste also some waste streams within these sub streams have been researched. The businesses are being arranged according to the 'KWD' sector. This sector encompasses Offices, Retail and Services. Furthermore, the number of people working more than 12 hours a week in the different sectors is based on an assumption of 1 FTE (full-time equivalent, see Appendix A). Results from the study of business waste of Stimular is used to make assumptions regarding the amount and type of waste in the area. In addition, assumptions have also been made about noteworthy waste streams in the area. In order to make statements about the quantity of the different material flows within the future perspective of Amstel III, the national average of 2 persons per household is calculated.

4.1 Household waste

Amsterdam residents produce 370 kg of waste per year. 27 percent is being offered separately by its consumers. The other 73 percent is going directly to the AEB for incineration (Gemeente Amsterdam, 2015). Remarkable is that organic waste is not being separated and therefor ends up in residual waste for incineration. The largest part of plastic waste ends up as residual waste. From the amount of plastic that is separated, 85 percent is actually being recycled. This loss of 15 percent is caused for instance because black plastic cannot be detected by the infra-red camera of the sorting machine and bio-degradable cracker plastic ends up as residual waste. The problem with the latter is that it must compost for 12 weeks while composting companies only compost for 6 to 7 weeks in the Netherlands (Reijn, 2018).

If residents in the Amstel III area can be stimulated to recycle all plastic, paper, textile and organic material it could have a big impact on the circular economy of the district. If the data from the researched material flows is applied on the future perspective of Amstel III, hypothetically, about 5836 tons of plastic textile, paper and organic waste (Appendix D), which, in the current waste system, would lead to a reduction of 1560 ton co2/year in transportation emissions (Appendix B). This is in the optimal situation, when it is assumed that all the separated waste can be transported without CO2 emissions. By processing this locally as much as possible, this number can be approximated. Ideally, material must be separated as much as possible and has to be recycled in the area and used again to reduce transportation. In this, the emissions of recycling processes aren't compared with the emissions of waste incineration. Furthermore, when recycling on a local scale regions are less dependent on other regions, which is an advantage in global economic crises. Before 2030 in Amstel III AB Noord 2390 residential units will be developed, which is remarkable because it is almost 3 times larger (80 hectares) as Amstel III AB Zuid (38 hectares), where 2875 residential units will be developed in the coming years. This implies that Amstel III Zuid will have a much higher residential density which should be taken into account in the waste management of the area.

4.2 Business waste

Amstel III counts 1488 locations in the KWD sector. In 2017, the Bijlmer Center (which includes Amstel III) area had a total of nearly three thousand locations and 68.6 thousand jobs. These are 13% of all jobs in Amsterdam and only 3% of all locations. This implies that the companies on average, have many employees. In Amstel III this is an average of 23 employees per company where the average in Amsterdam is 5 employees (Amsterdam Gemeente, 2017). For the material analysis, the area is divided into 4 subareas (Appendix H): Hoofdcentrum Zuidoost, Amstel III A/B Noord, Amstel III A/B Zuid and AMC. In the following text, this area is simply referred to as Amstel III. The largest share within the KWD sector is the sector of business services. The creative sector, IT sector and tourism sector also have a large share in the area. As the ambition for the area is 50% residential and 50% business facilities, this paper does not include the retail sector. In addition, the proportion of stores in the sector is currently so low that it is negligible (Gemeente Amsterdam, 2019). 227 kg of waste per FTE is produced in business services according to the SBI index (Engelen et al., 2016). The total number of waste per sector per year in the area is therefore approximated as follows (more information about the various sectors can be found in the appendix E1,E2 'Tables'):

$$\textit{Number of FTEs per sector} \times 227 \times 52 = \textit{Total amount of waste in kg per sector / year}$$

With the current office facilities in the KWD sector, 437,7 kilotons of waste is produced in Amstel III every year (Appendix E1, E2 'Tables'). The amount of residual waste that is separated at these companies is low. In offices, the ratio is 77 percent. The percentage of separated waste is 2.9%. The other 20.9 percent is separated paper and cardboard. The three most important waste flows within the business sector are organic waste, plastic and paper. Coffee-grounds form a large share of organic waste. This is probably due to the presence of a catering facility in the form of a restaurant, coffee corner or canteen. The total amount of coffee grounds in business waste according to the current total FTEs in Amstel III is 5,46 kiloton per year. To compare, this is 1,80% of the total household waste collected in the entire city of Amsterdam in one year (Appendix F). Compared to the CO2 emissions of transport of household waste this would result in a reduction of 144 kton annual CO2 emissions when coffee grounds are recycled in the Amstel III area (Appendix B).

Furthermore, plastic is an important material flow. The latter mainly consists of packaging and office supplies, of which archive boxes, insert covers, view folders and pens form a large share (Engelen et al., 2016). Finally office furniture is an important material flow that can still be classified as fast moving. On average, office furniture is replaced every seven years (Desko, n.d.). From the number of FTEs assumed in the area, this, for instance, results in the replacement of approximately 5300 office chairs only each year.

The area Hoofdcentrum Zuidoost has a completely different type of business composition. These companies mainly are referred to as the cultural and leisure sector. Examples are the Amsterdam Arena, Afas live and Ziggodome. In addition, this is also an area where many festivals are held. This sector brings other waste flows with it. The percentage of residual waste here varies from 53% to 82% because a lot of waste ends up in the public space. Types of plastic waste that mainly occur here in high peaks due to the presence of many events are polypropylene and polycarbonate. Applications include plastic cups, disposable tableware and plastic bags. A noteworthy waste stream within this sector is bulky waste from decors for events and exhibitions (Anteur, 2018; Engelen et al., 2016).

V. OPPORTUNITIES

5.1 Waste transportation

Due to the fact that Amstel III was originally developed as a 100% business area and the ambition for the coming years is 50% residential and 50% business facilities, a considerable amount of underground wires, tubes and pipelines must be laid. Many districts in Amsterdam face a major problem considering the underground infrastructure through the warren of tubes and pipelines. Therefor it is important to construct this properly in areas that are being newly developed or redeveloped. A solution can be to construct an underground technical street to centralise the network. This would also have a beneficial impact on the area's green plan. Besides, in this technical street the underground waste system can be implemented. Since the ambition for the area is one with a high density and a lot of high-rise buildings, such a system can be very sufficient. This system is preferable to the smart container system because it contributes to a cleaner, healthier and greener environment, which is another priority of the municipality for Amstel III. Co2 emissions will decrease because garbage trucks have to drive much fewer kilometres and can also drive more efficiently, also the NOx emissions will decrease, which contributes to cleaner air. The inlets of this system must therefore also be designed in homes, offices and the public space. The system outlet must also be designed.

5.2 Organic waste

Products that consist of raw materials of paper and plastic are easier to reduce or replace. Because stimulation of the consumption of these goods in large numbers is not preferable, it is better to not prioritise this type of initiative. For instance, separating, processing and recycling a plastic or paper cup is better than buying cups made from primary raw materials, but it would be even better to reuse the cup. This is different with organic waste. Products where organic material, such as vegetable and fruit peel, is the waste product are much harder to replace or reduce. There are a few simple implementation to reduce organic waste within businesses. For instance, meals can be offered in smaller portions and the use of smaller plates can also prevent food spillage because people do not brag too much.

Due to the enormous amount of organic waste it is a logical step to keep and process this within the area. There are several methods to compost organic waste. ‘Le Compostier’ is an initiative where organic waste is being composted in ‘worm hotels’ in the city. Le Compostier designs and builds worm hotels for neighbourhood compost projects and for small hospitality entrepreneurs who want to process their own organic waste in a sustainable way (Le compostier, 2019). Another initiative are the heated compost benches, designed by students of the Willem de Kooning academy. They have developed a prototype of a

wooden bench that is filled with pruning waste, which is broken down on the inside by bacteria. During that breakdown, heat is generated, which can rise to as much as sixty to seventy degrees. The heat is led to the seat by means of terracotta panels. The composting process takes two years, so the waste can generate heat for two years, then the compost can be used again in surrounding parks. Compost can be used for soil enrichment in the desired 'HoBu' park in Amstel III. This park can be a place to create awareness and an area to realize composting initiatives. Even if organic waste is not recycled, it is important to collect it separately because it generates more heath and energy in separate biogas plants than in a mixed incineration plant. Coffee grounds should be collected separately. Currently, coffee grounds ends up as residual waste in incineration plants, while it can be used with a much higher quality than what it is currently used for. Coffee grounds are suitable for growing food. Furthermore, there is an interesting chemical effect in coffee grounds. It is suitable for making new materials (Coffee Based, 2015). Coffee Based is an initiative, based in Blue City in Rotterdam, that produces notebooks out of coffee grounds.

5.3 Plastic waste

Likewise, there are several opportunities to recycle plastic waste on a more local scale. As well in households as in offices plastic is a large waste flow which for the biggest part isn't being separated and therefor goes directly to the AEB. In household waste plastic mostly consists of packaging waste. In offices also office supplies are an important plastic material flow. In the Netherlands there are several initiatives that provide a more local system of plastic recycling. 'Precious Plastic' is an initiative of Dave Hakkens who has developed a machine where everyone can collect, separate, process and upcycle plastic in new products. The machines are made of different components that can be repaired, replaced, or customized (Precious Plastic, n.d.). Architectural firm 'Bureau Sla' developed a building tile from plastic waste in a similar way, which has been used in several building projects. A similar start-up 'Plastic whale' collects plastic waste in the canals of Amsterdam with boats made out of this plastic waste. Therefor they clean the environment with boats of recycled material. In addition, they design and produce office furniture in collaboration with these offices with the Amsterdam canal plastic waste. All three start-ups find education in what they do an important aspect. That is why all three of them have a free educational program for both the older and younger generations. It is important to create awareness about consumption at all scales and therefore it is important to continue to focus on separating waste from households, even though this waste stream has a lesser impact on the environment than business waste.

5.3 Fabrication & material exchange

The municipality of Amsterdam stimulates these kind of initiatives and aims to attract start-ups in the circular sector. By consulting the demand with bigger companies, these start-ups can also develop into making other products. Other office items can be produced from coffee grounds, instead of just notebooks. Furthermore, in the case of office furniture, the furniture can also be created out of plastic waste of these particular offices, which results in a 'upcycled' material flow. These systems must be researched very well because there is a risk of stimulating more business waste. If a company remains the owner of its waste and only pays for labour, this would be economically advantageous for the company. Therefore, waste reduction is not necessarily encouraged. However, if it is cheaper to bring waste to the above-mentioned start-ups than to have it processed in the current waste system, then consumption is in any case not encouraged, it saves transport and processing emissions and costs and it reduces waste that ends up in the environment. Finally it stimulates the local circular economy. The exchange of material flows from companies and households should be considered. Retail is not included in this study, but the ambition of a new city centre will lead to the development of more retail in the coming years. In the end, this sector as well should be taken into account concerning material flows.

Ideally, an exchange of waste streams within the various sectors can be considered. Business sectors can dispose of their waste in for instance, the creative sector. In the area the development and redevelopment or residential facilities already started. However, proposals for other facilities are much less definitive. Examples are the cultural and sports sector, parks and public space facilities, the hospitality sector and the retail sector. Here too, there are opportunities for circularity. It could be interesting for other companies and start-ups that can exchange resources from each other. Moreover, The Amstel III business district; Amstel III CD north and south, west of the Amstel III office area has not been included in this study. In further research, it may be interesting to not only research the current exchange of materials, but also do research in material flows of companies who can settle in the area in the future due to the fact that it's a strategic location for the exchange of materials. The Amstel III CD area is interesting because this area currently, has a greater focus on manufacturing and distribution. Purely functionally, the urban context lends itself well to more local production processes and the placement of companies that can exchange materials.

VI. CONCLUSION

There are several reasons why it is important to investigate material flows within an area. The current society in which we live is one that thrives on fast moving consumer goods, with a lot of waste and pollution to match. In the Netherlands, only 22% of the total waste is recycled. In addition, the Netherlands is largely dependent on the import of materials from abroad. By consuming less, separating waste better and recycling more materials, a contribution can be made to a healthier environment with less polluting emissions and greater local independence .

The amount of household waste is much lower than comparable waste produced by business. Waste is often not separated within households and businesses. Even waste flows that are collected separately in organisations, such as paper, end up as residual waste. In homes and in offices, lack of space and little attention to waste are important arguments for not separating waste. Many disposables are disposed of together with organic waste and paper waste. A large part of residual waste is suitable for reuse and recycling. The most promising waste streams for better separation within businesses are paper, organic waste and plastic packaging material and disposables. Remarkably, organic waste is not separated in Amsterdam, while there is a considerable amount of useful material in organic waste that can be used for high-quality applications. Moreover, organic waste often ends up in a mix of materials in an incineration waste plant where it produces almost no energy. Even if organic waste is not recycled, it is important to collect it separately because it generates more energy in biogas plants than in a mixed incineration plant. Because Amstel III has a high FTE density, the waste streams primarily consists of business waste. The highest-volume and therefore most important waste streams are organic, plastic and paper waste. Specific flows such as coffee grounds, office supplies and office furniture play an important role in material flows in this area. The total amount of coffee grounds in business waste according to the current total FTEs in Amstel III is 5,46 kiloton per year. To compare, this is 1,80% of the total household waste collected in the entire city of Amsterdam in one year. Compared to the CO_2 emissions of transport of household waste this would result in a reduction of 144 kton annual CO_2 emissions when coffee grounds are recycled in the Amstel III area.

The rigidity of the current waste system and the presence of 12 waste incineration plants in the Netherlands hinder the separation of waste. In addition, waste management in highly urban areas such as Amstel III can be arranged more efficiently to reduce waste and transport. Alternative waste management can contribute to a healthier environment, better waste separation and material recycling. Smart systems with communicating containers, underground waste system and material exchange are examples of alternative waste management. Office waste offers the largest opportunities in the Amstel III area in Amsterdam. Mitigating office waste provides the highest-impact opportunity. However, awareness must be created to increase participation of residents. Therefore focussing on both business waste and household waste is key to successfully decrease the footprint of the area.

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APPENDICES

Appendix A Tables

Statistics Stock Office space per area									
Area	Stock Large scale (m2)	Stock Large scale (objects)	Stock Small scale (m2)	Stock Small scale (objects)	Vacancy (%m2) Large scale	Vacancy(objects) Large scale	Vacancy(%m2) Small scale	Vacancy (objects) Small scale	Total in use
Hoofdcentrum Zuidoost	81.727	45		4		7			42
Amstel III A/B Noord	530.998	290	3493	20	23	124	40	11	175
Amstel III A/B Zuid	150.047	93	2073	11	41	45	23	4	55
AMC*		1		1					2
Total	762.772	429	5.566	36		176		15	**274**
Amsterdam	**6.519.470**	**9136**	**582.819**	**5.351**	**16**	**1696**	**16**	**827**	**11.964**

Number of locations per sector									
Area	Creative Business Services	Media & Entertainment	Arts	Creative Industry**	ICT	Tourism	Business		Total
Hoofdcentrum Zuidoost	2	5	2	9	11	30	37		87
Amstel III A/B Noord	25	18	8	51	132	32	283		498
Amstel III A/B Zuid	12	9	9	30	42	7	67		146
AMC	0	0	3	3	0	2	18		23
Totaal	39	32	22	93	185	71	405		**754**
Amsterdam	**10.799**	**9022**	**17.607**	**37.428**	**21.063**	**11.001**	**38.277**		**107.769**

Number of employees (>12h/week) per office sector									
Area	All sectors***	Cultural sector	Sports sector	Creative Industry	ICT	Tourism	Business		Total
Hoofdcentrum Zuidoost	5.083	0	0	338	498	1207	928		2.971
Amstel III A/B Noord	25.830	0	0	830	2937	446	7347		11.560
Amstel III A/B Zuid	4.197	6	0	66	386	18	1225		1.701
AMC	1971	0	0	0	0	0	1395		1.395
Totaal	37.081	6	0	1234	3821	1671	10895		**17627**
Amsterdam	**545.268**	**11998**	**2.043**	**68.430**	**62.138**	**69.195**	**136.202**		**267.535**

* Not sufficient data

** Creative Business Services, Media&Entertainment, Arts

(Gemeente Amsterdam, 2019)

*** Includes Health sector and other smaller sectors

Appendix B Tables

Table B1

Estimation of annual CO2 & NOx emissions garbagetrucks Amsterdam		
Distance km	C02 em. kton	NOx em. ton
820.000	2,6 kton	-
2.500.000	80 kton	86 ton*

*13% of heavy traffic is garbagetrucks, 100% Nox = 662 ton Nox *(Rijke, 2017)*

Table B2

Estimation of annual emissions garbagetrucks Amstel III concerning Transportation of paper, plastic, textile, organic waste of households				
	Waste ton	Distance km	C02 em. kton	NOx em. ton
Amsterdam Oost*	-	820.000	2,6	-
Amsterdam*	304.032	2.500.000	80	86
Amstel III**	5.836	47.988	1,54	1,65

* Concludes all waste streams

** Concludes only paper, plastic, textile and organic waste

(de Graaff, Janssen, van Raaij, & van Lochem, 2018; Rabobank, 2009)

Appendix C Tables

Annual amount of household waste in kilogram per person in Amsterdam								
Resource *Source*	Total	Separated	Residual	Residual after separation	Recycling	Reuse	Incineration	Energy recycling
Paper	62,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	23,40 *Afvalketen in beeld, Gemeente Amsterdam 2015*	38,60 *Afvalketen in beeld, Gemeente Amsterdam 2015*	3,51 *PRN Research https://prn.nl/*	19,89 *PRN Research https://prn.nl/*	-	42,11 *PRN Research Gemeente Amsterdam 2015*	
Textile	16,90 *Afvalketen in beeld, Gemeente Amsterdam 2015*	2,70 *Afvalketen in beeld, Gemeente Amsterdam 2015*	14,20 *Afvalketen in beeld, Gemeente Amsterdam 2015*	0,14 *ASN bank voordewereldvanmorgen.nl*	0,68 *ASN bank voordewereldvanmorgen.nl*	1,89 *ASN bank voordewereldvanmorgen.nl*	14,34 *Gemeente Amsterdam ASN Bank*	
Organic material *Total waste ton/year in amsterdam**	75755,92 *Afvalketen in beeld, Gemeente Amsterdam 2015*	13515,47 *Afvalketen in beeld, Gemeente Amsterdam 2015*	62241,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	-	337.887 m3 biogas*** *Ekwadraat*	****	62241,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	
Plastic	23,50 *Afvalketen in beeld, Gemeente Amsterdam 2015*	1,80 *Afvalketen in beeld, Gemeente Amsterdam 2015*	21,70 *Afvalketen in beeld, Gemeente Amsterdam 2015*	0,32 *Volkskrant, Suez*	1,48 *Volkskrant, Suez*	-	21,97 *Volkskrant, Suez Gemeente Amsterdam 2015*	
Total	194,53	27,90	74,50	3,97	22,04	1,89	62319,42	

* Is not collected separately in Amsterdam, 92,18 kg pp/year *Afvalketen in beeld*

** Only Amsterdam west, 146.700 residents *Afvalketen in beeld*

*** In optimal situation 25 m3/ton if collected separately, Ekwadraat

**** Reuse or recycling can be done in de form of composting, only individual initiatives compost organic material in Amsterdam, this is a small amount and therefor not calculated *Afvalketen in beeld*

Assumptions annual amount of household waste in ton in 2050 Amstel III								
Resource *Source*	Total	Separated	Residual	Residual after separation	Recycling	Reuse	Incineration	Energy recycling
Paper	1860,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	702,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	1158,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	105,30 *PRN Research https://prn.nl/*	596,70 *PRN Research https://prn.nl/*	-	1263,30 *PRN Research Gemeente Amsterdam 2015*	
Textile	507,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	81,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	426,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	4,05 *ASN bank voordewereldvanmorgen.nl*	20,25 *ASN bank voordewereldvanmorgen.nl*	56,70 *ASN bank voordewereldvanmorgen.nl*	430,05 *Gemeente Amsterdam ASN Bank*	
Organic material	2763,90 *Afvalketen in beeld, Gemeente Amsterdam 2015*	- *Afvalketen in beeld, Gemeente Amsterdam 2015*	- *Afvalketen in beeld, Gemeente Amsterdam 2015*	-	-	-	2763,90 *Afvalketen in beeld, Gemeente Amsterdam 2015*	
Plastic	705,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	54,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	651,00 *Afvalketen in beeld, Gemeente Amsterdam 2015*	9,72 *Volkskrant, Suez*	44,28 *Volkskrant, Suez*	-	659,10 *Volkskrant, Suez Gemeente Amsterdam 2015*	
Total	5835,90	837,00	2235,00	119,07	661,23	56,70	5116,35	

(ASN Bank, n.d.; Ekwadraat, 2019; Gemeente Amsterdam, 2015; PRN, 2019; Reijn, 2018)

Appendix D Tables

Assumptions annual amount of household waste in ton in 2030 Amstel III AB Noord								
Resource *Source*	Total	Separated	Residual	Residual after separation	Recycling	Reuse	Incineration	Energy recycling
Paper	295,99 *Afvalketen in beeld, Gemeente Amsterdam 2015*	111,71 *Afvalketen in beeld, Gemeente Amsterdam 2015*	184,28 *Afvalketen in beeld, Gemeente Amsterdam 2015*	16,76 *PRN Research https://prn.nl/*	94,95 *PRN Research https://prn.nl/*	-	201,03 *PRN Research Gemeente Amsterdam 2015*	
Textile	80,68 *Afvalketen in beeld, Gemeente Amsterdam 2015*	12,89 *Afvalketen in beeld, Gemeente Amsterdam 2015*	67,79 *Afvalketen in beeld, Gemeente Amsterdam 2015*	0,64 *ASN bank voordewereldvanmorgen.nl*	3,22 *ASN bank voordewereldvanmorgen.nl*	9,02 *ASN bank voordewereldvanmorgen.nl*	68,44 *Gemeente Amsterdam ASN Bank*	
Organic material	439,83 *Afvalketen in beeld, Gemeente Amsterdam 2015*	- *Afvalketen in beeld, Gemeente Amsterdam 2015*	- *Afvalketen in beeld, Gemeente Amsterdam 2015*	-	-	-	439,83 *Afvalketen in beeld, Gemeente Amsterdam 2015*	
Plastic	112,19 *Afvalketen in beeld, Gemeente Amsterdam 2015*	8,59 *Afvalketen in beeld, Gemeente Amsterdam 2015*	103,60 *Afvalketen in beeld, Gemeente Amsterdam 2015*	1,55 *Volkskrant, Suez*	7,05 *Volkskrant, Suez*	-	104,88 *Volkskrant, Suez Gemeente Amsterdam 2015*	
Total	928,69	133,19	355,66	18,95	105,22	9,02	814,18	

Assumptions annual amount of household waste in ton in 2030 Amstel III AB Zuid								
Resource *Source*	Total	Separated	Residual	Residual after separation	Recycling	Reuse	Incineration	Energy recycling
Paper	356,50 *Afvalketen in beeld, Gemeente Amsterdam 2015*	134,55 *Afvalketen in beeld, Gemeente Amsterdam 2015*	221,95 *Afvalketen in beeld, Gemeente Amsterdam 2015*	20,18 *PRN Research https://prn.nl/*	114,37 *PRN Research https://prn.nl/*	-	242,13 *PRN Research Gemeente Amsterdam 2015*	
Textile	97,18 *Afvalketen in beeld, Gemeente Amsterdam 2015*	15,53 *Afvalketen in beeld, Gemeente Amsterdam 2015*	81,65 *Afvalketen in beeld, Gemeente Amsterdam 2015*	0,78 *ASN bank voordewereldvanmorgen.nl*	3,88 *ASN bank voordewereldvanmorgen.nl*	10,87 *ASN bank voordewereldvanmorgen.nl*	82,43 *Gemeente Amsterdam ASN Bank*	
Organic material	529,75 *Afvalketen in beeld, Gemeente Amsterdam 2015*	- *Afvalketen in beeld, Gemeente Amsterdam 2015*	- *Afvalketen in beeld, Gemeente Amsterdam 2015*	-	-	-	529,75 *Afvalketen in beeld, Gemeente Amsterdam 2015*	
Plastic	135,13 *Afvalketen in beeld, Gemeente Amsterdam 2015*	10,35 *Afvalketen in beeld, Gemeente Amsterdam 2015*	124,78 *Afvalketen in beeld, Gemeente Amsterdam 2015*	1,86 *Volkskrant, Suez*	8,49 *Volkskrant, Suez*	-	126,33 *Volkskrant, Suez Gemeente Amsterdam 2015*	
Total	1118,55	160,43	428,38	22,82	126,74	10,87	980,63	

(ASN Bank, n.d.; Ekwadraat, 2019; Gemeente Amsterdam, 2015; Gemeente Amsterdam, 2018; PRN, 2019; Reijn, 2018)

Appendix E1 Tables

Business Services Sector						
Subject	FTE	Total waste/year **kton**	Unsorted residual waste **kton**	Separated paper & cardboard **kton**	Other Separated waste **kton**	
Amount	10.895	128,60	99,03	26,88	2,70	
Percentage		100%	77%	20,90%	2,10%	
Distribution unsorted separated waste						
Subject	Paper & cardboard	Glass	Organic (GFT)	Wood	Plastic	Residual
Amount	24,76	3,96	21,79	3,96	6,93	36,64
Percentage	25%	4%	22%	4%	7%	37%

IT Sector						
Subject	FTE	Total waste/year **kton**	Unsorted residual waste **kton**	Separated paper & cardboard **kton**	Other Separated waste **kton**	
Amount	3.821	45,10	34,73	9,43	0,95	
Percentage		100%	77%	20,90%	2,10%	
Distribution unsorted separated waste						
Subject	Paper & cardboard	Glass	Organic (GFT)	Wood	Plastic	Residual
Amount	8,68	1,39	7,64	1,39	2,43	12,85
Percentage	25%	4%	22%	4%	7%	37%

Creative Sector						
Subject	FTE	Total waste/year **kton**	Unsorted residual waste **kton**	Separated paper & cardboard **kton**	Other Separated waste **kton**	
Amount	1.234	14,57	11,22	3,04	0,31	
Percentage		100%	77%	20,90%	2,10%	
Distribution unsorted separated waste						
Subject	Paper & cardboard	Glass	Organic (GFT)	Wood	Plastic	Residual
Amount	2,80	0,45	2,47	0,45	0,79	4,15
Percentage	25%	4%	22%	4%	7%	37%

(Gemeente Amsterdam, 2019; Gemeente Amsterdam 2018; Engelen et al., 2016)

Appendix E2 Tables

Tourism Sector						
Subject	FTE	Total waste/year **kton**	Unsorted residual waste **kton**	Separated paper & cardboard **kton**	Other Separated waste **kton**	
Amount	1.671	19,72	15,19	4,12	0,41	
Percentage		100%	77%	20,90%	2,10%	
Distribution unsorted separated waste						
Subject	Paper & cardboard	Glass	Organic (GFT)	Wood	Plastic	Residual
Amount	3,80	0,61	3,34	0,61	1,06	5,62
Percentage	25%	4%	22%	4%	7%	37%

Total Business, IT, Creative, Tourism						
Subject	FTE	Total waste/year **kton**	Unsorted residual waste **kton**	Separated paper & cardboard **kton**	Other Separated waste **kton**	
Amount	17.621	208,00	160,16	43,47	4,37	
Percentage		100%	77%	20,90%	2,10%	
Distribution unsorted separated waste						
Subject	Paper & cardboard	Glass	Organic (GFT)	Wood	Plastic	Residual
Amount	40,04	6,41	35,23	6,41	11,21	59,26
Percentage	25%	4%	22%	4%	7%	37%

Total KWD Sector Amstel III						
Subject	FTE	Total waste/year **kton**	Unsorted residual waste **kton**	Separated paper & cardboard **kton**	Other Separated waste **kton**	
Amount	37.081	437,70	337,03	91,48	9,19	
Percentage		100%	77%	20,90%	2,10%	
Distribution unsorted separated waste						
Subject	Paper & cardboard	Glass	Organic (GFT)	Wood	Plastic	Residual
Amount	84,26	13,48	74,15	13,48	23,59	124,70
Percentage	25%	4%	22%	4%	7%	37%

(Gemeente Amsterdam, 2019; Gemeente Amsterdam 2018; Engelen et al., 2016)

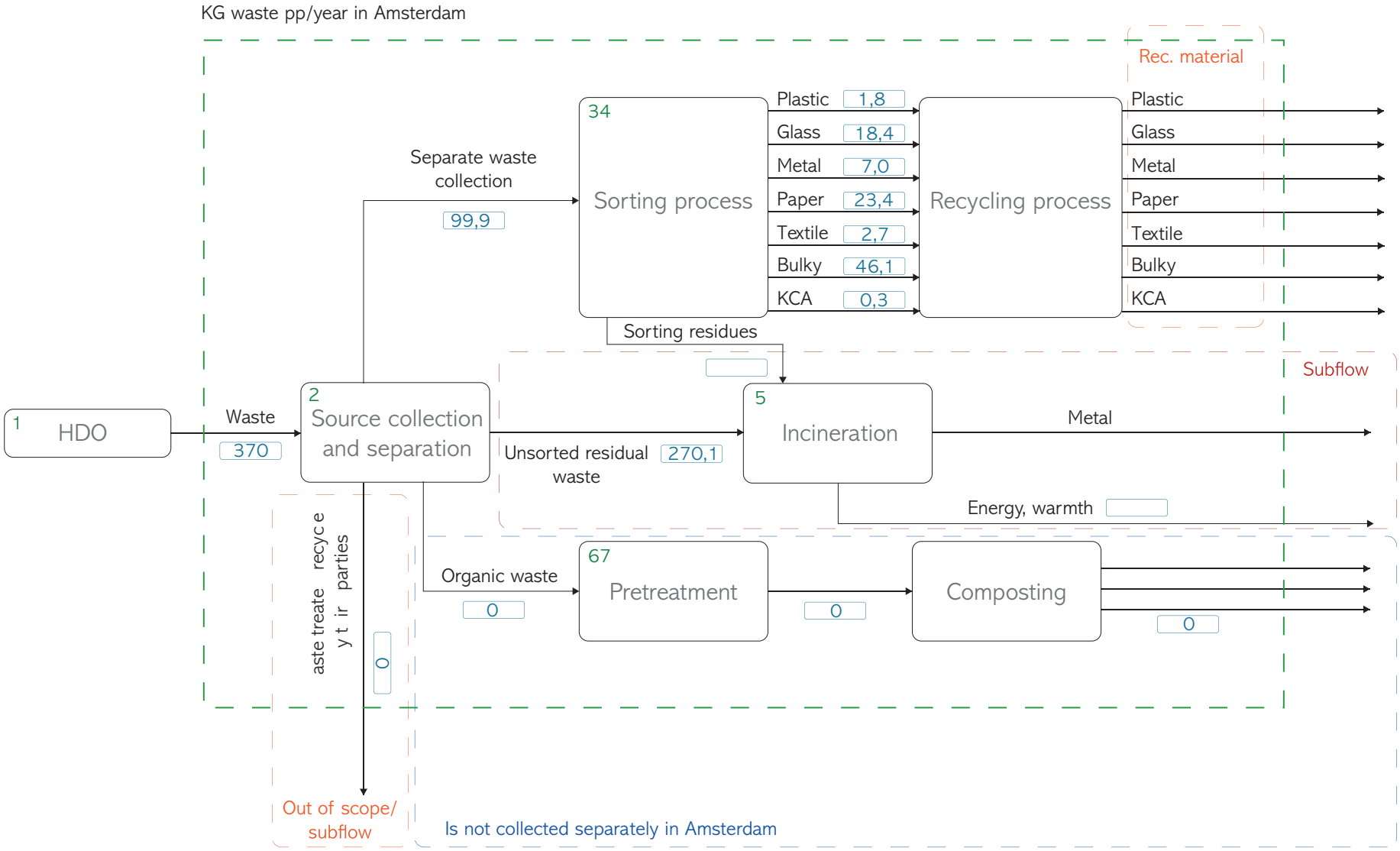
Appendix F Tables

Coffee grounds						
Subject	FTE	kg/day	**ton**/year			
Rabobank	491	198,00	72,27			
Amstel III	37.081	14953,23	5457,93			

Office chairs						
Subject	FTE	chairs/year				
Average office	1	0,14				
Amstel III	37.081	5297,29				

(de Graaff, Janssen, van Raaij, & van Lochem, 2018; Rabobank, 2009)

Appendix G Material Flow Schemes in the Amsterdam Waste System, Household waste



(ASN Bank, n.d.; Ekwadraat, 2019; Gemeente Amsterdam, 2015; PRN, 2019; Reijn, 2018)

Appendix G1 Material Flow Schemes in the Amsterdam Waste System, Household waste

1. Consuming actors in this case are residents in Amsterdam, the flows show the material flow of household waste per person per year in Amsterdam.

2. Source collection and separation is different in different parts of Amsterdam. Companies that work in this area of the flow are Gemeente rotterdam, also private companies collect waste like deposite material and chemicals.

Companies	Methodes
	
Private Companies	
Heineken	Deposit and reuse
	Deposit and recycle
wecycle	Recycle

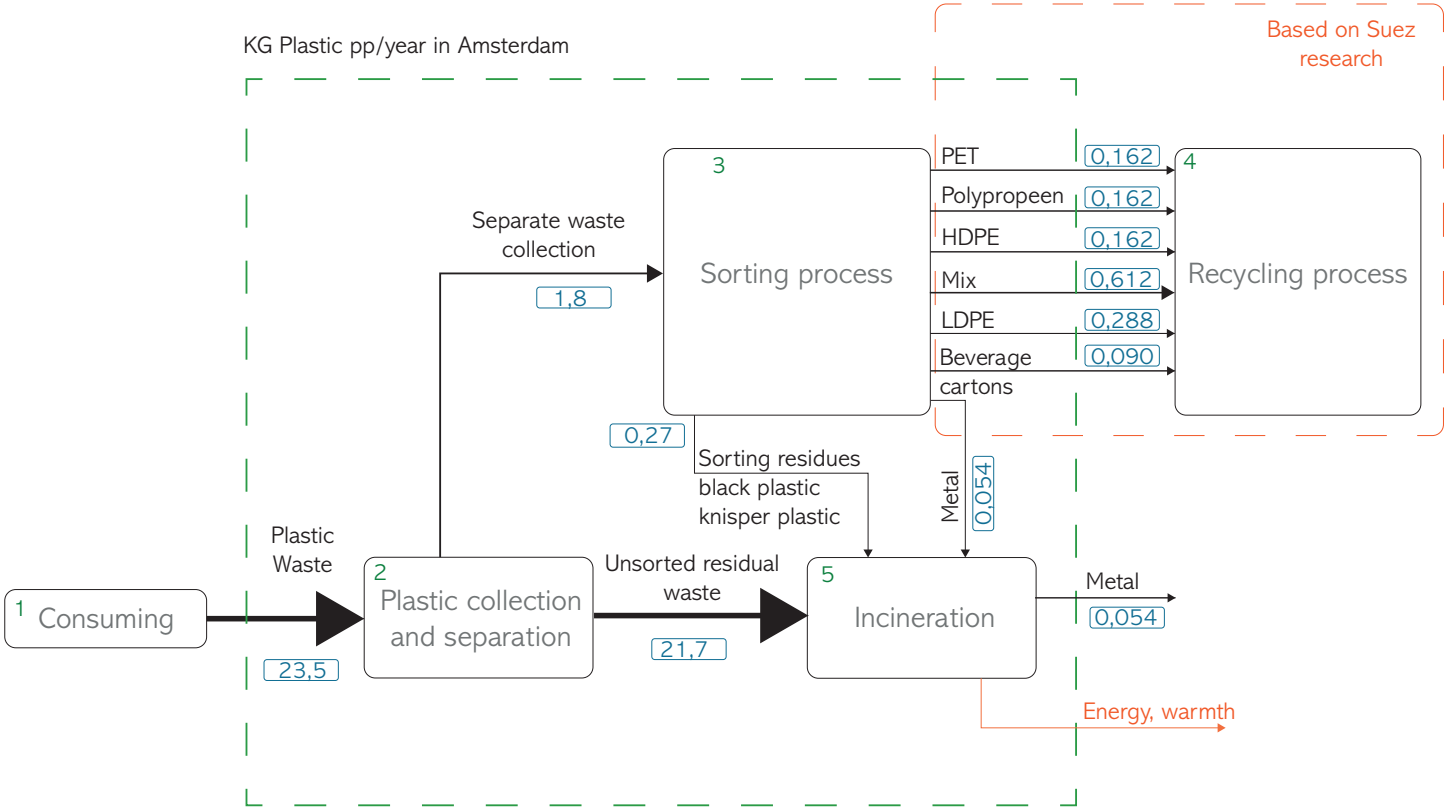
3./4. The sorting process encompasses different companies for different material. In the sorting process a small part flows to incineration. Some companies sort the material and recycle them, some only do the sorting or the recycling. An overview is given for a few materials in the MFA's per material.

5. 73% of all waste ends up as residual waste. The municipality of amsterdam did a reseacrh on the different components within this categorie. In household residual waste the separating of plastic, textile and paper can make a big difference in polluting emissions, organic material organic waste has a large share in volume and mass.

6./7. At the moment the municipality of Amsterdam does not facilitate the seperate collection of waste. Therefore it is always being incinerated. It could be interesting to do research on the use of organic waste when separated.

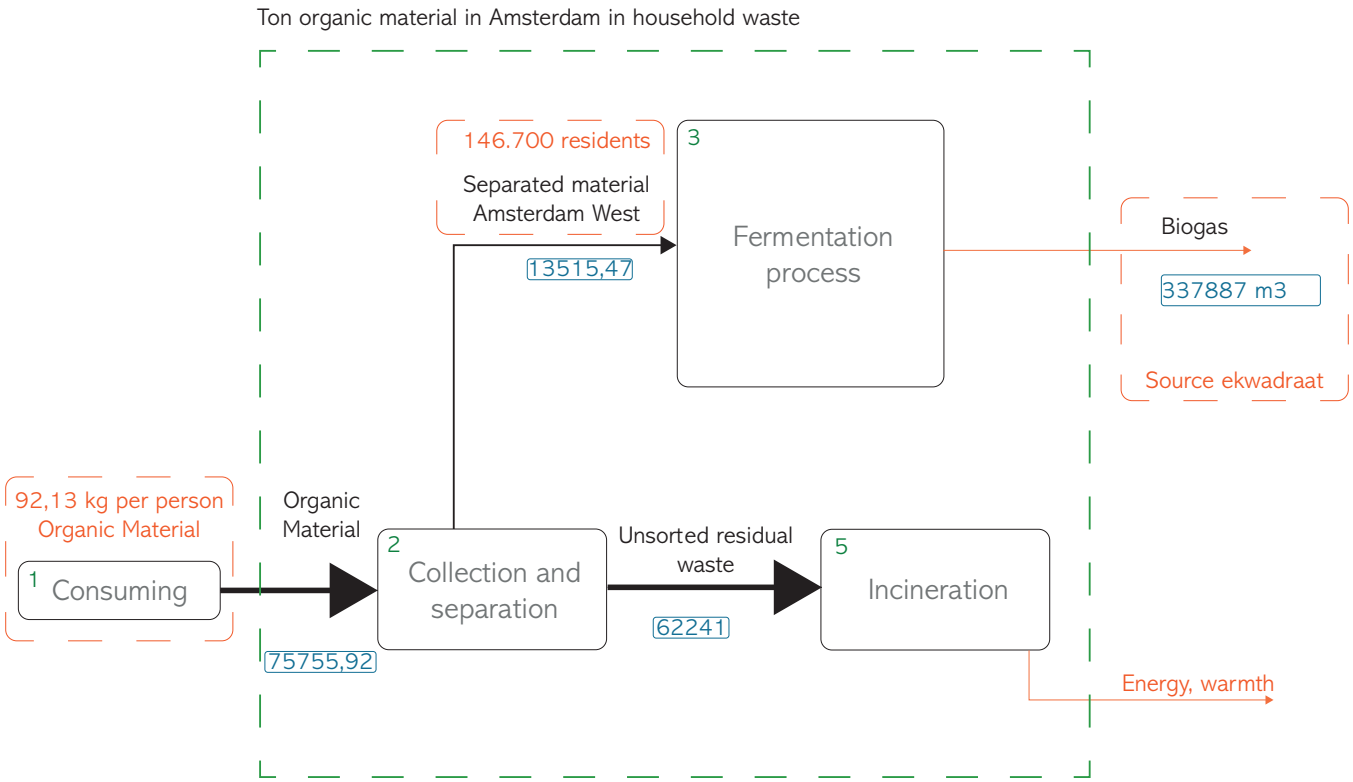
(ASN Bank, n.d.; Ekwadraat, 2019; Gemeente Amsterdam, 2015; PRN, 2019; Reijn, 2018)

Appendix G2 Material Flow Schemes in the Amsterdam Waste System, Household waste



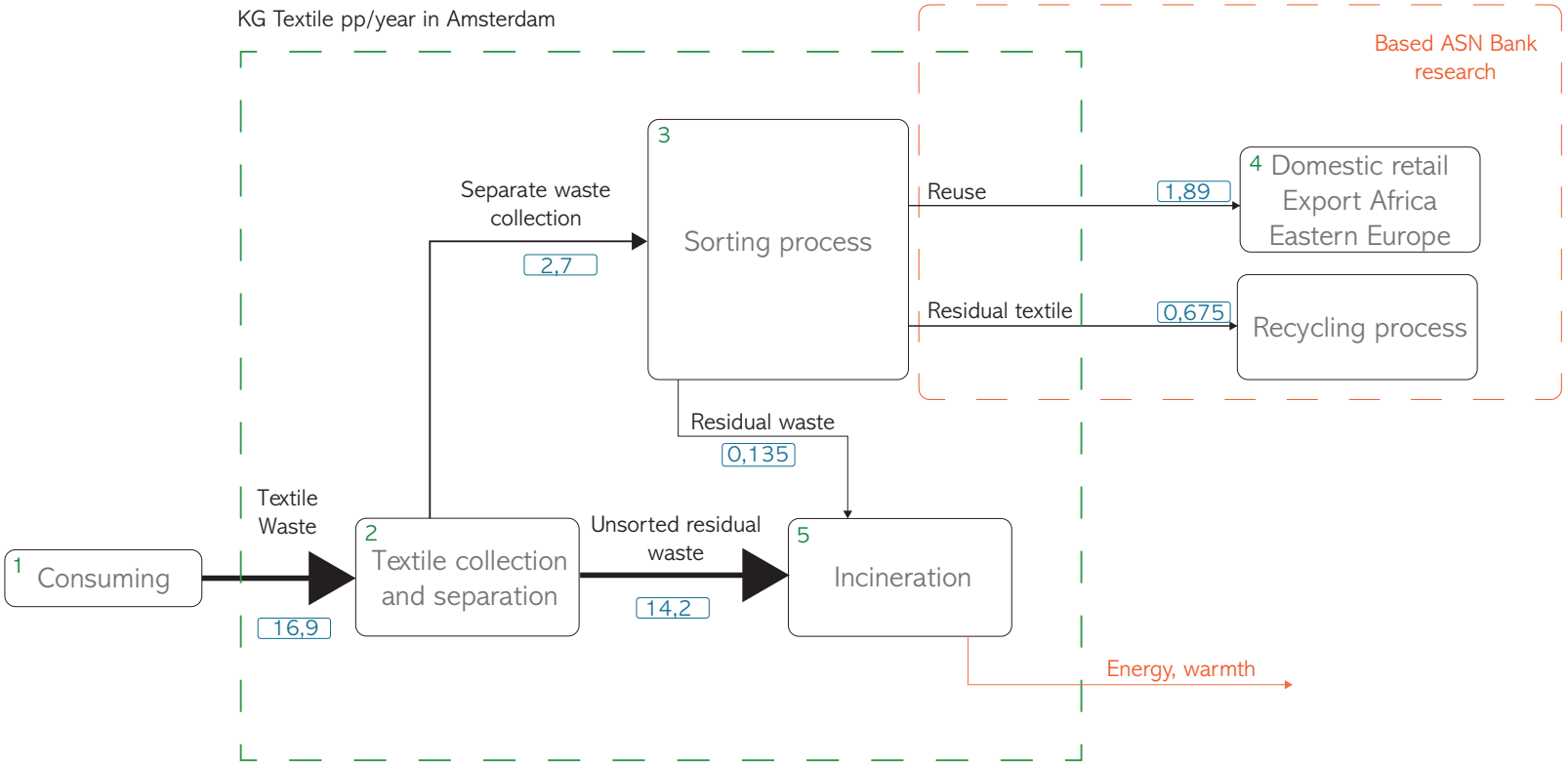
(Gemeente Amsterdam, 2015; PRN, 2019)

Appendix G3 Material Flow Schemes in the Amsterdam Waste System, Household waste



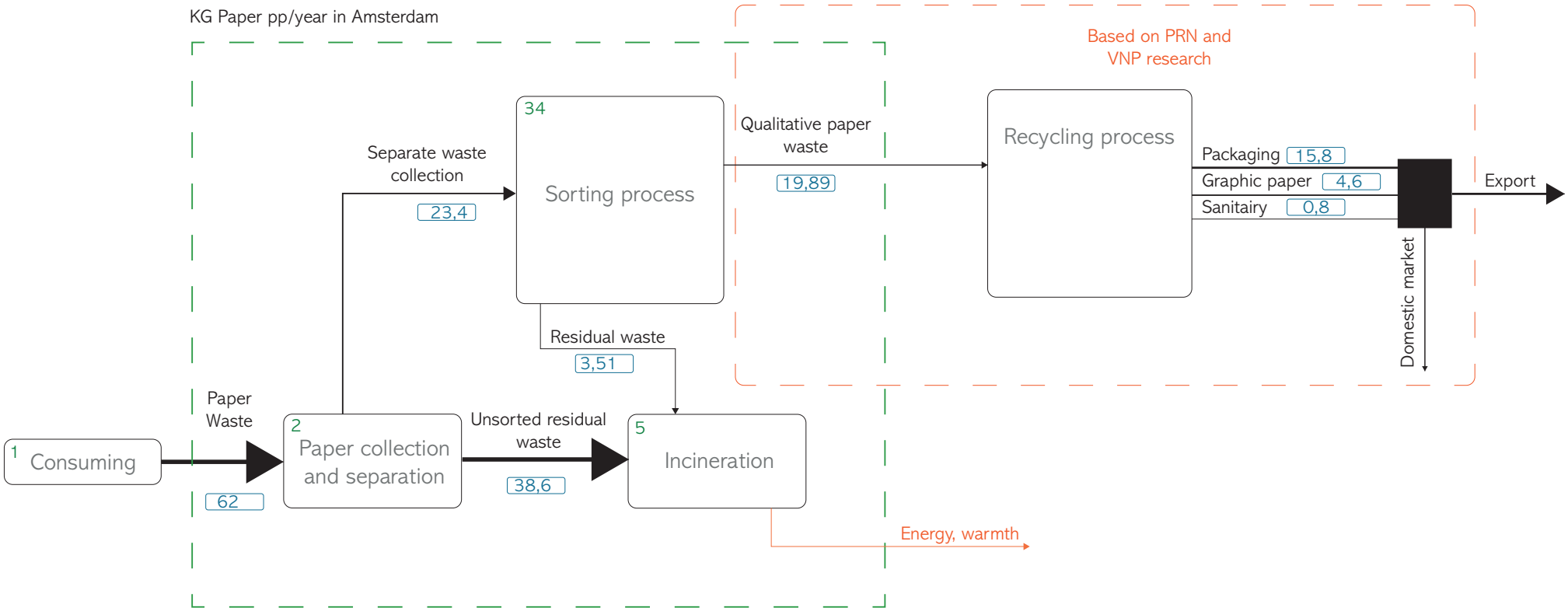
(Ekwadraat, 2019; Gemeente Amsterdam, 2015)

Appendix G4 Material Flow Schemes in the Amsterdam Waste System, Household waste



(ASN Bank, n.d.; Gemeente Amsterdam, 2015)

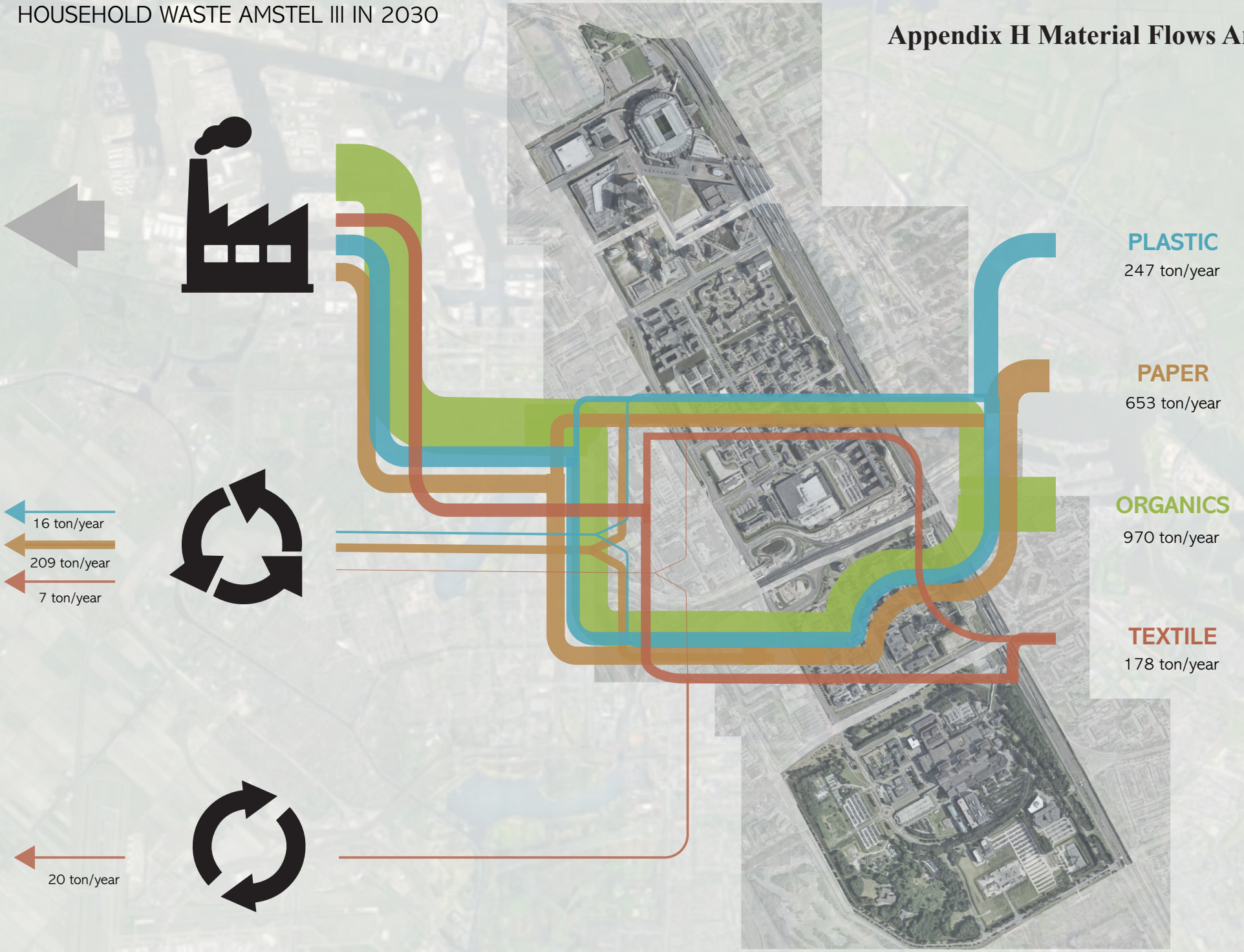
Appendix G5 Material Flow Schemes in the Amsterdam Waste System, Household waste



(Gemeente Amsterdam, 2015; PRN, 2019)

HOUSEHOLD WASTE AMSTEL III IN 2030

Appendix H Material Flows Amstel lll



HOUSEHOLD WASTE AMSTEL III IN 2019

Appendix H1 Material Flows Amstel lll