D.T1.2.1 – Collection systems

An assessment exploring collection systems in the regions of the four partners in NWE.

D.T1.2.1 – Collection Systems

Collection mechanisms and their effectiveness of plastic waste capture

The aim of this report is to conduct a comparative analysis exploring the different collection systems implemented in Germany, Belgium, The Netherlands and the United Kingdom. The results obtained will enable the effectiveness of plastic waste capture in each region to be determined, whilst commenting on any potential additional mechanisms required to increase the volume of plastic collected.

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Deliverable WP.T1 D.T1.2.1 Collection mechanisms and their effectiveness of plastic waste capture.

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Executive Summary

This report has been prepared through the creation and distribution of a questionnaire and data gathering tool to four partner regions: Belgium; The Netherlands; The United Kingdom; and Germany. The questionnaire aimed to identify any significant similarities and differences between each regions dedicated kerbside plastic collection service. This information was combined with the results attained from the data gathering tool, which looked to gather quantifiable data on the process of plastic waste from kerbside collection to high quality recycling. Importantly, local authorities provided information on the quantity of plastic material sent to a materials recovery plant (MRF) and reprocessing plant. This allowed for rejection and contamination rates to be calculated, highlighting how different collection mechanisms successfully capture varying levels of plastic waste materials to be used in intrusion-extrusion moulding (IEM) and additive manufacturing (AM).

Questionnaire key findings

The results from the questionnaire revealed that both Manchester (UK) and Almere (NL) run an in-house kerbside collection service, whereas Mainz (DE) and Wallonia (BE) operate their service via a waste management company.

All four regions use a dedicated refuse collection vehicle to collect waste, with Manchester operating the most vehicles - 83 vehicles over a total of 9 local authorities. In addition, Wallonia utilises a further 3 caged vehicles in addition to the 7-10 dedicated refuse vehicles.

Furthermore, Manchester and Almere both provide a 240-litre wheeled bin, with the former also offering a 180-litre bin in some districts. Conversely, Mainz offers a yellow non-reusable sack for plastic waste material, whilst Wallonia stated that multiple containers are offered depending on the waste sector. Importantly, all authorities collect plastic waste on a fortnightly basis with all authorities offering the service free of charge.

Data gathering tool key findings

In Almere, System 3 collected the largest volume of waste (10,600 tonnes per annum), which included PMD (plastics, metals, and drink cartons). Here, PMD was found not to be separated from refuse or other recyclables and collected as part of the residual waste. Importantly, this system recorded a 90% MRF contamination rate that can be explained by the lack of separation from residual waste. In contrast, System 2 offers both a co-mingled and HWRS (Household Waste Recycling Site) service, which both collect PMD separately from other recyclables. Moreover, the HWRS collects PMD separately from refuse, supporting the reduction in MRF rejection rate (7.5%) and contamination rate (10%), compared to System 3.

In addition, Manchester sent the largest volume of plastic to high quality recycling (9995 tonnes per annum). Manchester did not provide an initial figure for the quantity of plastic waste collected through their co-mingled kerbside collection service, however the volume of plastic (specifically PET, HDPE, PP bottles) sent to the MRF was provided. Therefore, it can be calculated that Manchester sent 82% of the plastic waste sent to the MRF to high quality recycling. Moreover, from the regions that offered a figure for the initial collection, System 1 in Almere sent 61% of the plastic collected to high quality recycling, compared to System 2 (29%) and System 3 (6%).

Conclusion

The feedstock for an IEM plant will normally need less processing to enable it to be used as an input material, whereas the input specification for an AM plant will mean that significantly more sorting and processing will be required. It is therefore incumbent on AM and IEM managers to be as specific as possible on the input specification to enable waste managers to configure systems to market materials to known facilities in confidence that this will be a long-term market that can sit alongside existing demands for recycled plastics.

1. Introduction

The TRANSFORM-CE project intends to divert 2,580 tonnes of plastic material away from landfill between 2021 to 2024, aiming to convert the plastic waste into recycled feedstock and designed into new products. This production will be assisted by two innovative technologies – intrusion-extrusion moulding (IEM) and additive manufacturing (AM). For a sufficient volume of plastic material to be captured for the creation of new products, an analysis of current plastic waste collection systems and sorting mechanisms is required.

This report has been prepared through the creation and distribution of a questionnaire and data gathering tool to four partner regions: Belgium; The Netherlands; The United Kingdom; and Germany. The questionnaire aimed to identify any significant similarities and differences between each regions dedicated kerbside plastic collection service. This information was combined with the results attained from the data gathering tool, which looked to gather quantifiable data on the process of plastic waste from kerbside collection to high quality recycling. Importantly, local authorities provided information on the quantity of plastic material sent to a materials recovery plant (MRF) and reprocessing plant. This allowed for rejection and contamination rates to be calculated, highlighting how different collection mechanisms successfully capture varying levels of plastic waste materials to be used in intrusion-extrusion moulding (IEM) and additive manufacturing (AM).

The report analysis will highlight what factors influence the volume of plastic material being collected and sent to sorting facilities to be successfully recycled.

Importantly, within this report, high quality recycling is understood to be plastic waste that can be collected and re-processed into a similar or new product.

2. Aims and objectives of this report

2.1 Aims

The aim of deliverable T1.2.1 and this report is to determine what collection system is most effective in capturing the greatest volume of plastic waste which can be used in intrusion-extrusion moulding and additive manufacturing.

2.2 Objectives

a. To create a comprehensive data gathering tool and questionnaire to obtain high-quality data that can be used to evaluate different collection systems.

b. To analyse the results of the data to determine which plastic waste collection system captures the greatest volume of waste.

c. Comment on other mechanisms and suggest recommendations that could potentially increase the volume of materials available for IEM and AM.

3. Methodology

This section highlights the methodological approaches that were used to obtain data for the analysis. Two types of collection methods were adopted: qualitative and quantitative, which were in the form of a questionnaire and data capturing tool.

3.1 Questionnaire

Firstly, a short questionnaire was created using the software, 'Survey Monkey'. Here, the questionnaire comprised mostly of tick box answers, covering the region's dedicated plastics recycling kerbside collection service. Authorities were asked to provide information on the characteristics of the collection service, such as container size and colour, demonstrated in Table 1. Moreover, numerical data regarding the number of households and businesses currently operated on the service was requested as this was used to the calculate participation rates.

The questionnaire was then distributed, via email, to either a local authority/council member or a waste management specialist.

Question	Question
1	Who undertakes your dedicated recycling Kerbside Collection Service?
2	If outsourced or community group, please provide operator name
3	Do you collect commercial and industrial waste in this service?
4	Is the commercial and industrial plastics of a better quality?
5	Number of households on service (Please enter number)
6	Number of businesses on service (Please enter number)
7	How many vehicles are used to operate the plastic kerbside collection service?
8	What type of vehicles are used to operate the plastic kerbside collection service?
9	How many crew members are used for this service?
10	What is the frequency of the plastic kerbside collection service
11	Do any other plastic collection providers operate in your authority area?
12	What is the type of container used for the plastic kerbside collection service?
13	What is the container/bag colour?
14	Do you charge annually?
15	What is the participation rate?

Table 1. A table showcasing the list of questions included within the questionnaire.

3.2 Data gathering excel spreadsheet

Secondly, an excel spreadsheet was created, aiming to gather detailed quantitative data on the process of plastic waste from kerbside collection to being sent to high quality recycling. Five categories: material collection methodologies, transfer points, processing, reprocessing and material end destinations were used as headers to showcase the flow of materials, illustrated in Figure 2 and 3. Authorities were requested to input data into the light blue coloured cells. With the input of such data, white cells, already containing mathematic formulas, would be automatically filled out. Furthermore, authorities were asked to provide multiple spreadsheets if they had access

to data for multiple municipalities or collection systems in the region. Within the spreadsheet, exemplar answers were supplied to provide guidance and help.

The excel spreadsheet was also distributed to each authority, contained within the same email as the questionnaire. The email provided information and advice on how to fill out the spreadsheet and set a deadline for when both the questionnaire and excel spreadsheet should be sent back by.

Authority Name:					Financial Year Data:				Data Owner:				
Materials			**Collection methodology**								**Transfer point**		
Material Category	Sub Material type	Polymer targeted	Collection Channel	Collected separately from refuse?	Collected separately from other recyclate?	Collected in sub-streams?	tonnes put out for recycling	Contamination at kerbside (%)	Potential rejected (tpa)	tonnes collected (tpa)	Transfer point	Transfer contamination rate	Sent to re-processor (tpa)
EXAMPLE Dense Plastic	Bottles Tubs & Trays	PET, HDPE, PP	comingled	Y	N	N	10,000.00	1%	100.00	9,900.00			
EXAMPLE Dense Plastic	Bottles Tubs & Trays	PET, HDPE, PP	HWRS	Y	Y	N	2,500.00	3%	75.00	2,425.00	AN bulking station	2%	2,376.50
Dense Plastic									0.00	-			-
									0.00	-			-
									0.00	-			-
									0.00	-			-
									0.00	-			-

Figure 2. The first half of the data gathering tool distributed to local authorities.

	Processing					Reprocessing				Material destination				
MRF name	material sent to MRF (tpa)	MRF rejection rate (%)	MRF Processed (tpa)	MRF contamination rate (%)	MRF output (tpa)	Reprocessor name	Recyclate sent to reprocessor (tpa)	Reprocessor rejection rate (%)	Reprocessor output (tpa)	End product	Where is material reprocessed	Is end destination High Quality?	Tonnage sent to high quality recycling	%age of collected material sent to high quality recycling
Low grade MRF	9,900.00	2.5%	9,652.50	3%	9,411.19	Open Loop Reprocessing ltd	9,411.19	0.50%	9,364.13	Low grade plastics	China	No	-	0%
						Closed Loop Reprocessing Ltd	2,376.50	1%	2,352.74	Food grade plastics	UK	Yes	2,353	94%
			-		-		-		-				-	#DIV/0!
			-		-		-		-				-	#DIV/0!
			-		-		-		-				-	#DIV/0!
			-		-		-		-				-	#DIV/0!
			-		-		-		-				-	#DIV/0!

Figure 3. The second half of the data gathering tool distributed to local authorities.

4. Results

This section presents the responses attained from each of the four regions. The questionnaire responses are illustrated in Table 2 and the excel gathering tool results are showcased in a variety of figures.

4.1 Questionnaire

After each of the four regions filled out and sent back their responses to the questionnaire, the results were analysed and illustrated in excel. This allowed for the easy comparative analysis between regions, whereby similarities and differences could be visualised.

The questionnaires were completed by a range of representatives from each country.
- For Germany, the managing director of waste management for the City of Mainz completed the questionnaire.
- For the UK, a member of the Greater Manchester Combined Authority completed the questionnaire.
- For Belgium, a waste management company 'in BW' provided the data for the Walloon Brabant province.
- And, for The Netherlands, one of the Dutch partners completed the questionnaire.

Table 2 showcases the responses from each region. Noticeably, Manchester has considerably more households on their collection service than the other three regions, due to a significantly larger population. As a result, Manchester operates 83 dedicated refuse collection vehicles over 9 local authorities, compared to only 2 vehicles utilised in Mainz. All four authorities operate a dedicated refuse collection vehicle for their collection services, yet in Wallonia an extra 3 caged vehicles are also used.

It has been observed in some case studies, that by introducing single-pass resource recovery vehicles, such as those outlined in the introduction, the number of vehicles required to operate waste collection reduces by a third (Welsh Government, 2020). It is estimated that RRV's would

decrease operational mileage by approx. 80,000 kilometres annually, while saving 15,000 litres of fuel and reducing exhaust and CO_2 emissions by nearly 50 tonnes (Welsh Government, 2020).

Moreover, Manchester and Almere provide a wheeled bin, either 240 litres or 180 litres, both free of charge. Mainz offers a yellow, non-reusable sack that is also free of charge, yet the size of the sack was not provided. In contrast, the results from Wallonia revealed that multiple containers are used. For example, non-reusable sacks, wheeled bin of 240 litres and 1100 litres can potentially be used dependant on the waste sector. Furthermore, Wallonia, was the only region where alternative plastic collection providers operated. This was due to 'Remondis Belgium' – the outsourced company responsible for kerbside collection- only collecting from small businesses and not large businesses.

Table 2. An overview of the results gathered from the questionnaire.

	Manchester - England	Almere - Holland	Mainz - Germany	Wallonia -Belgium
Who undertakes your dedicated recycling kerbside collection service?	Mostly inhouse. 2 outsourced and 1 arms-length co	In house	System operator with private waste management company	Outsourced (waste management company)
If outsourced or community group, please provide operator name	Manchester - Biffa Trafford - Amey Stockport - Totally Local Company	n/a	Knettenbrech und Gurdulic	Remondis Belgium
Do you collect commercial and industrial waste in this service?	Yes	No	Yes	No
Is the commercial and industrial plastics of a better quality?	n/a	n/a	n/a	n/a
Number of households on service (Please enter number)	1,100,000	82,000	113,621	185,000
Number of businesses on service (Please enter number)	n/a	0	n/a	n/a
How many vehicles are used to operate the plastic kerbside collection service?	83 over 9 LA's	4	2 to 4	7-10 and 3

What type of vehicles are used to operate the plastic kerbside collection service?	Dedicated Refuse Collection vehicle	Dedicated Refuse Collection vehicle	Dedicated Refuse Collection vehicle	Dedicated Refuse Collection vehicle and Caged vehicle
How many crew members are used for this service?	Varies	Driver +2	Driver +2	Driver +3
What is the frequency of the plastic kerbside collection service	Fortnightly	Fortnightly	Fortnightly	Fortnightly
Do any other plastic collection providers operate in your authority area?	No	No	No	Yes
What is the type of container used for the plastic kerbside collection service?	240 L and 180 L	240 L	Non-reusable sack	Multiple
What is the container/bag colour?	Varies	Mainly blue	Yellow	Blue sack
Do you charge annually?	No	No	No	No
What is the participation rate?	n/a	>95% of low-rise buildings	n/a	Unknown but close to 100%

4.2 Data gathering excel spreadsheet

This section presents the results obtained from the data gathering tool. It should be noted that some of the data is not comparable. This is due to the variation in waste data reporting systems and accessibility to such data. Currently, Belgium have not supplied any data, and have been left out of the results analysis.

The respondent from The Netherlands provided 3 sets of data for the municipality of Almere. Each set of data corresponded with a different collection system.
For instance;

- System 1 related to source separation of PMD at the kerbside
- System 2 covered PMD+ pilot and PMD high rise areas
- System 3 consisted of residual waste high rise areas.

Therefore, within the results, abbreviations will be used to highlight the different systems.

- System 1 will be referred to as Almere 1
- System 2 will be referred to as Almere 2
- System 3 will be referred to as Almere 3.

Furthermore, the respondent from Germany provided data for 5 different municipalities in the Rhineland-Palatinate region.

- Altenkirchen will be referred to as Rhineland-Palatinate 1
- Mainz will be referred to as Rhineland-Palatinate 2
- Rhein-Lahn-Kreis will be referred to as Rhineland-Palatinate 3
- Neuwied will be referred to as Rhineland-Palatinate 4
- Westerwaldkreis will be referred to as Rhineland-Palatinate 5.

4.2.1 Total tonnage of plastic waste collected per annum from the dedicated kerbside collection service.

Data was not available from Manchester or Wallonia on the quantity of plastic waste collected per annum and therefore, cannot be included in this part of the discussion.
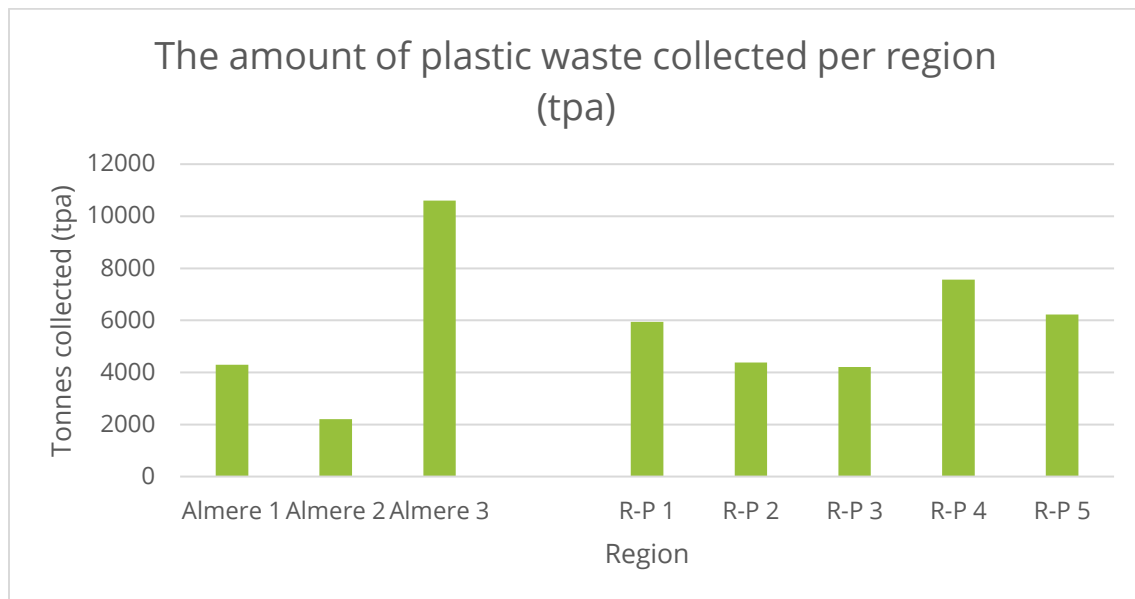
Figure 1. A graph showcasing the total tonnage of waste collected per annum from Almere and Rhineland-Palatinate dedicated kerbside plastic collection service.

System 3 in Almere collected the largest volume of plastic waste with 10,600 tonnes per annum. This system collected PMD alongside residual waste in high rise areas and was the only system in Almere that did not collect PMD separately from other recyclables. Furthermore, Neuwied (Rhineland-Palatinate 4) collected the largest volume of PMD in Rhineland-Palatinate, totalling 7576 tonnes per annum. Each region in Rhineland-Palatinate operated the same collection system, consisting of a comingled collection channel.

Across the 3 regions, the average tonnes of collected plastic waste in Almere was 5,700 per annum, in comparison to 5,664 tonnes per annum across Rhineland-Palatinate.

Total tonnage of plastic waste collected per household (tpa)
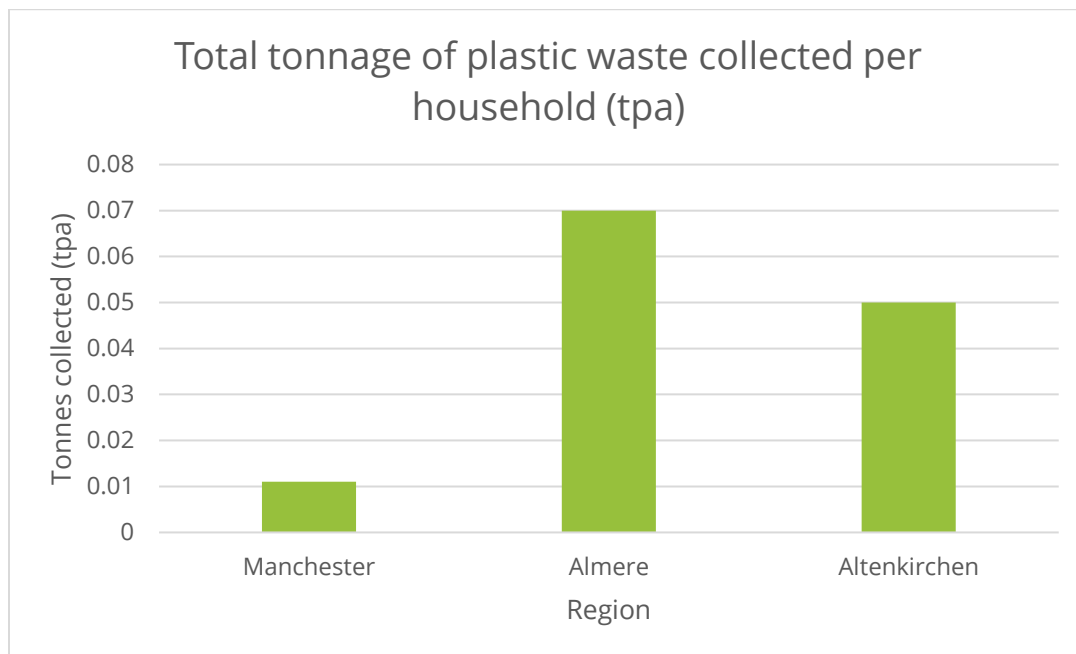
Figure 2. A bar chart illustrating the total tonnage of plastic waste collected per household for each of the three regions.

In addition, the volume of waste collected per household was also calculated. This was determined by dividing the amount of waste collected by the number of households on the service. Since Manchester did not provide data, the volume of waste sent to the MRF was used.

Therefore, it can be concluded that Almere collected the greatest volume with 0.070 tonnes per household. Rhineland-Palatinate collected 0.050 tonnes and Manchester collected the least with 0.011 tonnes per household, per annum.

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4.2.2 Plastic input and output rates from a MRF plant.

Total tonnage of plastic waste sent to and from a MRF plant.
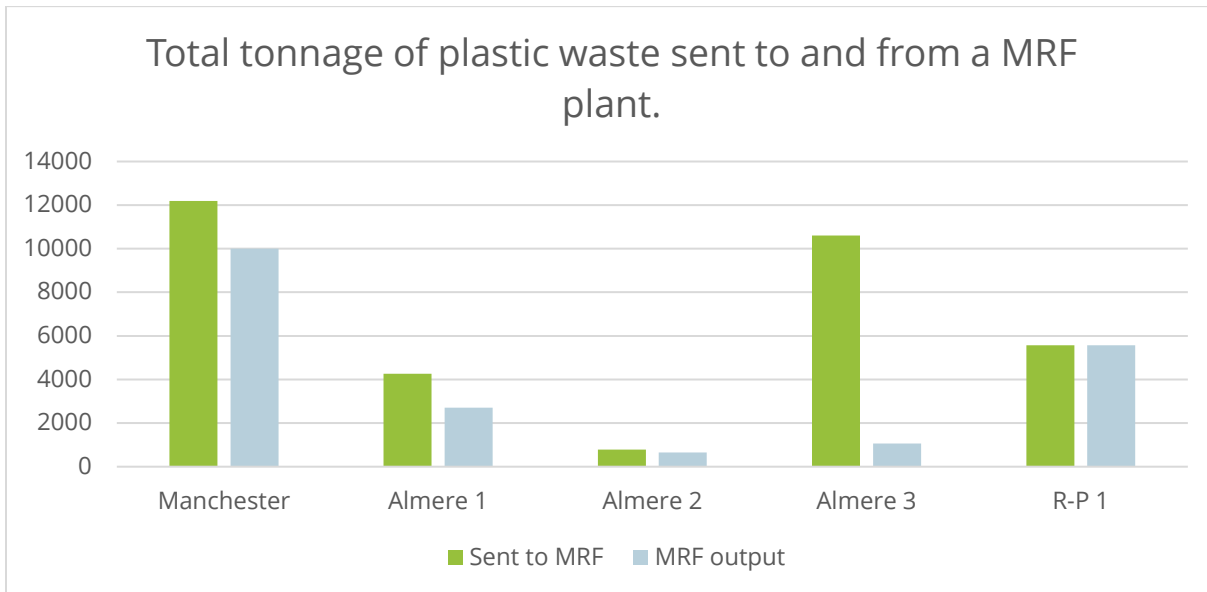
Figure 3. A graph showcasing the total tonnage of plastic waste sent to a MRF plant and the subsequent output in Manchester; Systems 1, 2 and 3 in Almere; and Altenkirchen (Rhineland-Palatinate 1).

Most noticeably, it can be observed that System 3 in Almere has a much higher input rate than output rate. From the data gathered for this system, it was revealed that the MRF had a 90% contamination rate, explaining the very low output rate. This high contamination could potentially be as a result of the plastic waste being collected as part of the residual waste. In comparison to the other systems in Almere, System 2 only had a 7.5% rejection rate and 10% contamination rate, showcased in Figure 8.

Manchester had a 18% MRF rejection rate, with an output of 9996 tonnes per annum. Furthermore, Altenkirchen was the only municipality in Rhineland-Palatinate to provide information on the input and output rates. As illustrated in Figure 5, there was a 100% output rate, thus, no rejection or contamination was observed.

4.2.3 Input and output rates of plastic waste from a reprocessing plant.

Mixed plastics are often baled at the MRF or plastics recycling facility and transported to specialist plastics recovery facilities/plastic reprocessing plants for further sorting (NLWA, 2020). At the reprocessing plant, the plastic is shredding into small pieces and washed. After, it is run through an additional metal detector and density unit to remove any lighter particles (SUEZ, n.d.).

The clean plastic pieces are dried and melted, before being filtered to remove any remaining contaminants. It is then extruded to form fine strands. Alternatively, the plastic strands can be cut into pellets, cooled in water, then dried and sorted ready to be processed and moulded into new plastic items (SUEZ, n.d.).

Figure 4. A graph showing the total tonnage of plastic waste sent to a reprocessing plant and the subsequent output rates in Almere.

In Almere, a large gap between material input (1060 tonnes per annum) and output (636 tonnes per annum) is revealed for System 3. This can be explained by a high reprocessor rejection rate of

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40%. In comparison, System 1 and 2 both had a rejection rate of 10%, showcased by the closer input and output rates.

Total tonnage of plastic waste sent to and from a reprocessor plant in Manchester.

Figure 5. A graph showing the total tonnage of plastic waste sent to a reprocessing plant and the subsequent output rates in Manchester.

Markedly, In Manchester, 9996 tonnes of plastic material were sent to a reprocessing plant, per annum. As illustrated in Figure 7, it can be observed that all plastic waste was successfully outputted, demonstrating that there was no contamination or rejection.

Total tonnage of plastic waste sent to and from a reprocessor plant in Rhineland-Palatinate.
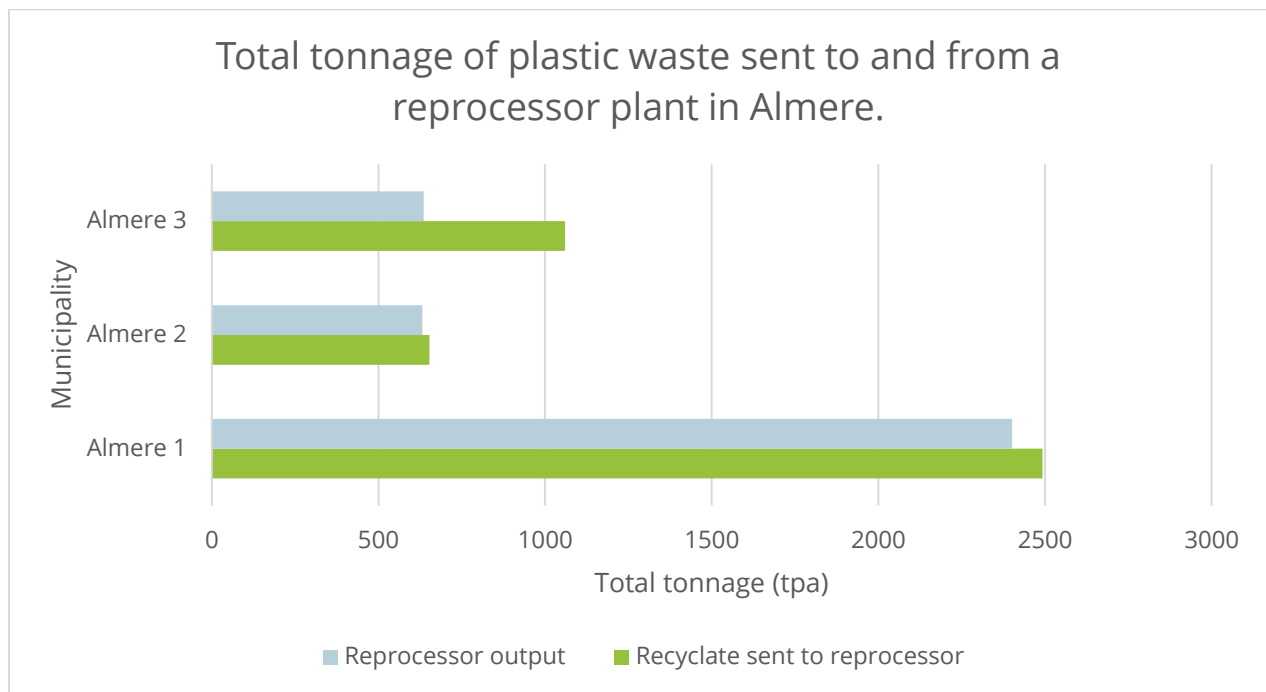
Legend:
- Reprocessor output
- Recyclate sent to reprocessor
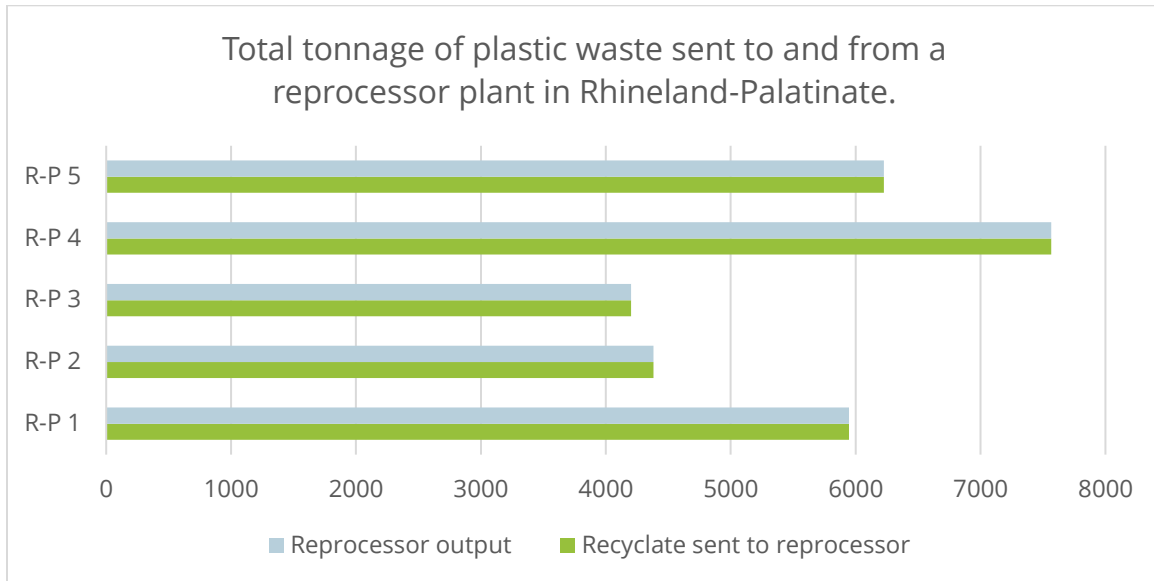
Figure 6. A graph showing the total tonnage of plastic waste sent to a reprocessing plant and the subsequent output rates in Rhineland-Palatinate.

Likewise, the input and output rate of all regions in Rhineland-Palatinate had a 100% output rate, further displaying no rejection or contamination at the reprocessing plant.

4.2.4 Total tonnage of plastic waste sent to high quality recycling.
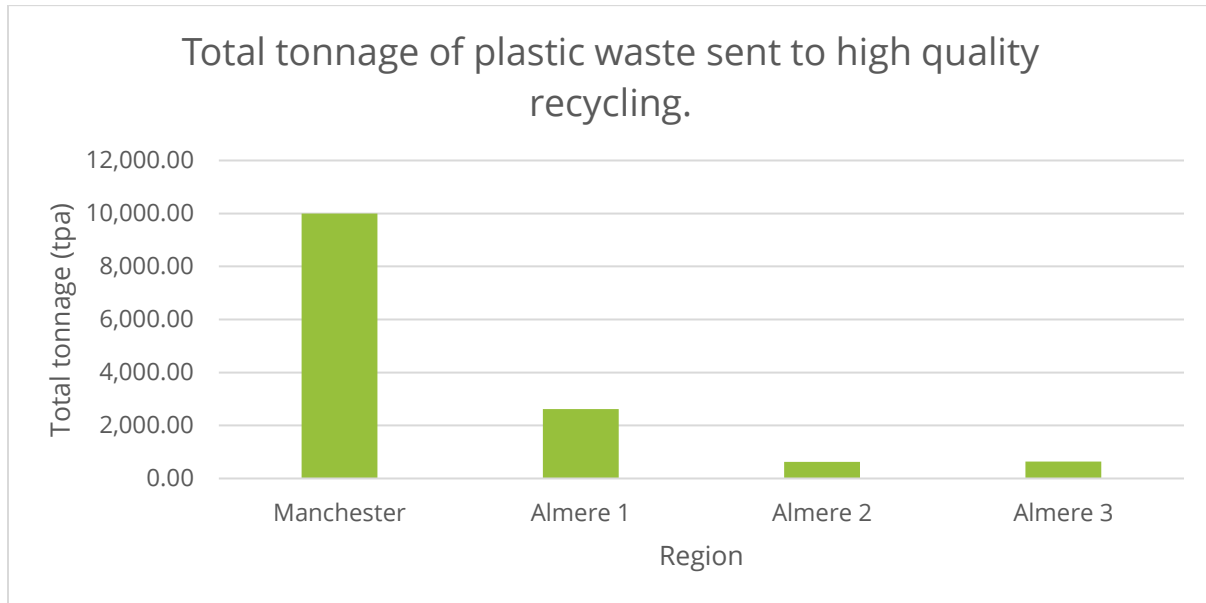
Figure 7. Bar chart illustrating the total tonnage of plastic material sent to high quality recycling from the dedicated kerbside collection service in Manchester and Almere.

As seen, Rhineland-Palatinate did not provide any information on the volume of plastic waste sent to high quality recycling. However, from the regions that did, Systems 1, 2, and 3 in Almere sent 61%, 29% and 6% of the plastic waste collected to quality recycling, respectively.

Furthermore, Manchester sent a large quantity of their collected plastics to high quality recycling, yet, as we were not provided with the initial collection data, it is not possible to determine the percentage of collected material sent to quality recycling. However, it can be calculated that 82% of the material sent to the MRF was successfully sent to high quality recycling.

5. Discussion

The results attained from both the questionnaire and data gathering tool have been combined to produce a detailed discussion that aims to determine the effectiveness of plastic waste collection systems in each of the partner regions.

Firstly, although Manchester did not provide any information on the volume of plastic waste collected, it was revealed that they sent the largest quantity of plastic material to an MRF. This indicates that Manchester collected the largest volume of waste, which can be supported by the large number of households on the service and the inclusion of industrial and commercial waste. To successfully collect plastic waste from the kerbside, the number of vehicles used can potentially help increase rates. The results of the questionnaire established that Manchester operated the most dedicated refuse collection vehicles, which can potentially increase volume capacity and decrease the time taken to collect waste.

However, when determining the tonnage of waste collected per household, it was calculated that Manchester collected the smallest volume, estimating 0.011 tonnes per annum. In comparison, Almere collected the largest volume per household, approximating 0.070 tonnes per annum.

Moving forward, in Almere, System 3 collected the largest volume of waste, reporting a total of 10,600 tonnes per annum. System 1 collected 4,300 tonnes per annum, the second largest volume, yet there is a noticeably large difference between the two. It must be noted that System 3 does not collect plastic material separately from refuse or other recyclables as it is collected as part of the residual waste, whereas the other two municipalities are separated. Hence, there is a greater opportunity for contaminated materials to be collected at the kerbside, adding to the total volume. Therefore, as no source separation or segregation occurred, System 3 experienced a 90% contamination rate at the MRF, resulting in a very limited output rate. Rejected materials can have a negative impact on recycling performance and can be introduced at various stages of the

segregation at source, collection and sorting and recycling processors (Hahladakis et al, 2018). Similarly, Manchester's kerbside collection service did not collect plastic waste separately from other recyclables, thus, a rejection rate of 18% was reported. In comparison, System 2 in Almere, which was described as a co-mingled and Household Waste Recycling Site service, reported only a 7.5% rejection rate. Therefore, it can be stated that municipalities that require residents to sort their waste at kerbside witness less rejection and contamination, resulting in more material being sent to high quality recycling, increasing productivity. Additionally, System 1 in Rhineland-Palatinate reported a 0% rejection and contamination rate at the MRF, where plastic waste was collected as a co-mingled service.

In order to reduce the levels of contamination at the MRF, Artificial Intelligence (AI) can be used. When waste materials are co-mingled, it can be difficult to identify the specific type of material class to which they belong. Computer vision driven by AI can do this as effectively as the human eye, which is particularly useful in an MRF. AI-powered sorting robots enable MRFs to capture valuable clean materials more efficiently from the waste stream, ultimately increasing recycling rates and reducing the volume of materials sent for landfill (Dewulf, 2022). As the volume of materials processed by the AI system increases, the 'brain' identifies more waste stream and sub-streams. This results in uncontaminated, more-specific secondary raw materials being fed back into production processes. Some examples of AI companies include Zenrobotics, Recycleye and Greyparrot. Whilst these AI systems are not fully perfected, they are starting to show very promising results, which if funding were secured to reduce post processing wastes going landfill and incineration, would be a very sensible return on investment.

Furthermore, in regard to the quantity of plastic materials sent to high quality recycling, System 3 in Almere sent a considerably small percentage of the total initially collected. From collecting 10,600 tonnes, only 636 tonnes were sent to high quality recycling, revealing a 6% success rate. This could have possibly been influenced by the collection system not being collected separately from other recyclables and other refuse. On the other hand, System 1 had a 61% success rate

demonstrating that a co-mingled system captures a significantly larger volume of high-quality plastics.

Furthermore, Manchester sent the largest volume of material to high quality recycling (9996 tonnes per annum) using a co-mingled collection system. Here, plastic waste was collected separately from refuse but was still collected with other recyclables, explaining the 18% rejection rate.

Importantly, many European countries, including The Netherlands and Germany, have an already established Deposit Return Scheme (DRS) in place. Deposit returns help to maximise the volume of plastic materials collected as the scheme gives an incentive to recycle plastic, especially bottles.

As a result, DRS may potentially be an external factor in explaining how Almere and Rhineland-Palatinate collected greater quantities of waste per household than Manchester. Additionally, The United Kingdom aims to implement deposit returns by 2024.

6. Conclusions and Recommendations

Based on the evidence gathered, Manchester, Almere, Rhineland-Palatinate and Wallonia currently have collection systems in place that successfully capture plastic material that can be made available for IEM and AM. However, the results have showcased that some systems are more effective than others. Below presents some recommendations that can help to increase the volume of plastic collected.

a. The current capture rates for the municipalities show that there is still a large amount plastic that can be collected for traditional recycling, as well as AM and IEM feedstock

b. The AM and IEM facilities should produce an input specification for plastics that enter their facilities to enable waste management processers to determine which facility their facility can send plastics to.

c. Systems that collect plastic waste separate from refuse and other recyclables generally have a smaller percentage of contamination and rejection at the MRF and reprocessor and therefore are most suitable for use as AM feedstock (subject to meeting the AM input specification).

d. Deposit Return Schemes and Extended Producer Responsibility can be an effective incentive to increase the volume of plastic material collected, albeit with some levels of contamination and are therefore suitable for use as AM feedstock (subject to meeting the AM input specification).

e. Co-mingled collection systems that use MRF techniques to produce mixed material bales, plastic film bales that are sent for incineration d and bales of lightly contaminated plastics will be most suitable for the IEM Plant.

f. The availability and accessibility of sufficient data has been a slight limitation. There is a requirement for a universal way for countries to report and present data, eliminating comparability issues.

g. Future consumer trends may impact plastic arisings and subsequent material compositions. This is observed from a transition away from single-use and problematic plastics towards alternatives such as biodegradable packaging. AM and IEM facility managers should be monitoring consumption habits over the next decade to see if there is a decrease in feedstock that may affect the ability to operate at full capacity.

The feedstock for an IEM plant will normally need less processing to enable it to be used as an input material, whereas the input specification for an AM plant will mean that significantly more sorting and processing will be required. It is therefore incumbent on AM and IEM managers to be as specific as possible on the input specification to enable waste managers to configure systems to market materials to known facilities in confidence that this will be a long-term market that can sit alongside existing demands for recycled plastics.

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Appendix 1: Detailed review of plastic recycling collection and processing methods

Waste and recycling collection systems, such as those dedicated for plastics, differ between countries and even among neighbouring municipalities. The most commonly used collection method for the capture of recycling and residual waste from households is via a kerbside collection. This is organised by local authorities either through an in-house (council/municipality) team or contracted to a waste management company. There are different types of kerbside collection, all dependent on the local authority.

- Firstly, a source separation can be carried out by residents, who sort materials into the specified material types.
- Secondly, a single stream or co-mingled method collects all materials into the same compartment, which then is then taken for sorting at a Material Recycling Facility (MRF), or transfer station, for onward transport to a Plastic Recycling Facility (PRF).
- Thirdly, a two-stream co-mingled method asks residents to sort materials into two containers which are kept separate but collected at the same time.
- Additionally, plastic waste can be taken to recycling centres, such as a HWRS (Household Waste Recycling Site), where residents can dispose of waste into designated bins at a dedicated site.

Notably, a handful of local authorities have introduced specialist trucks, that include several containers within the body of the vehicle, to collect recyclable material from the kerbside. This allows for source segregation of waste at the kerbside, which has been proven to maximise collection efficiency and reduce cross-contamination (Zhang et al, 2021); increasing the availability of material sent for recycling.

As an example, the Terberg Kerbloader, pictured below, makes safe and efficient collection of multiple recyclable waste streams possible by the combination of a high-level automated plastic press system, various removable stillages, a cardboard press unit and various storage compartments (Terberg Environmental, 2022). The Kerbloader's bespoke design eliminates cross-

contamination of segregated materials, with a total volume of 15 – 37.5m^3 and between 7 – 9 compartments. Terberg Matec Group is a Dutch company (founded in Utrecht) yet serves worldwide.

Figure 8. Image of the Terberg Matec Kerbloader (Terberg Environmental, 2022).

Another example to highlight is the single-pass resource recovery vehicles introduced by the Isle of Anglesey County Council in Wales. Source segregation at kerbside allows the collection of a wide range of materials in one go. Within the vehicle, illustrated below, sits compartment boxes for each of the materials. When the compartment for lighter materials, mixed cans and plastic bottles becomes full at operative height, the side doors are closed and a scissor mechanism pushes the plastic and the cans into a roof space, where a ram pushes it back. This creates additional space in the truck for maximised collection (Welsh Government, 2020).

Figure 9. Image of the single-pass resource recovery vehicles used in Isle of Anglesey County Council (Welsh Government, 2020).

For those councils that collect using a single pass or kerbloader vehicle, the recycling will be taken directly to a transfer station for hand separation of contaminates and bulking and baling for onward processing. In many cases, this will involve being sent directly to a Plastics Recycling Facility (PRF) or to a Materials Recycling Facility (MRF) for further separation.

Where councils collect recycling in a co-mingled stream, the mixed recycling will be taken to the MRF for sorting.

Sorting at Materials Recovery Facility (MRFs)

The basic processes used in MRFs are shown below in Figure 3. Each MRF is configured to the local area recycling system, so for example some MRF's will process plastic, paper and card, glass and metals, whilst others will separate just metal, plastics and paper and card, other combinations are

also implemented. The diagram in figure 3 gives an indication of a common combination of processes used to sperate the mixed fractions of recycling into their individual streams.
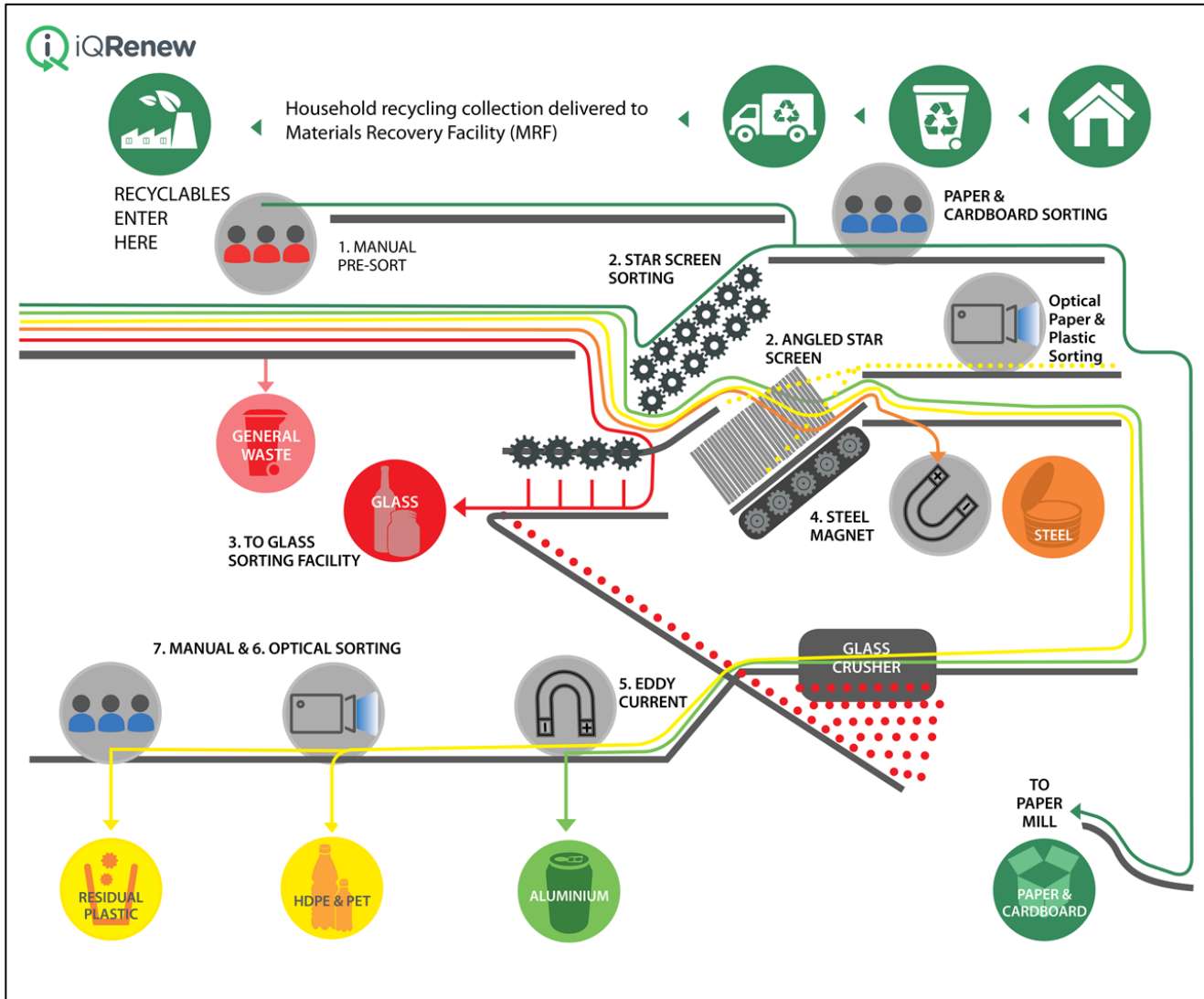
Figure 10. A typical MRF configuration (iQRenew, 2017).

The types of MRF used across the four regions will therefore vary in regard to each of the individual configurations. The following sections explain all the possible types of equipment a MRF will contain:

Conveyors and material handling equipment to move material through the system

These are used throughout the MRF to transport different materials to the appropriate station in the MRF.

Screening equipment to sort material by size.

These include shaker screens, trommels, and air screens at various points in the process. Materials with two dimensions less than two inches are likely to pass through sorting screens in MRFs that are designed to separate other contaminants. These screens are designed to separate small contaminants and direct them away to waste, or separate pieces of broken glass and direct it to the glass stream (APR 2018).

Magnetic separation to remove ferrous metals

Magnets are used to remove ferrous metal. When the metal comes in close contact with the magnet, the magnetic attraction pulls it from the material stream. The removal is important to protect the grinder/granulator that sits further down the process. The grinder is an expensive, high-speed machine that cannot tolerate solid metal, so it is critical that it is protected. Metal removal in the flake processing stage is designed to improve plastics quality as metal is an undesirable contaminant (APR 2018).

Eddy current separation to remove non-ferrous metals

Removes non-ferrous metals such as aluminium, die-cast metal and copper from non-metallic materials. When non-ferrous metals pass over a separator, the magnets inside rotate at high speed. This creates eddy currents in the metal, which forms a magnetic field. The polarity of that magnetic field is the same as the rotating magnet, causing the metal to be repelled away from the magnet (APR 2018).

Trommel screens to remove glass

Where glass is collected in a co-mingled collection, when it is put in the MRF, glass gets shattered at the MRF and fed into 'trommel screens' which are large, inclined, rotating, cylindrical sieves that separate the broken glass from larger items. More advanced MRFs can separate glass into different types using cameras or Near InfraRed (NIR) spectroscopy to distinguish between colours (Rogoff and Clark, 2016).

Air classifies to sort materials by density

Air classifiers are linked to NIR systems and based upon the output of the NIR, separate light, two-dimensional materials such as paper, textile plastic film, aluminium, and pieces of cardboard, from heavier, bulkier materials. Those bulky materials can be screened in an automated devices called a de-stoner/air knife. The air knife uses directional air currents and a vibratory motion to stratify and separate lighter material from heavier material (Rogoff and Clark, 2016).

Optical sorting equipment to separate plastics or glass by materials composition

NIR Infrared spectrometry is also used to separate out the different type of plastic polymers such as film, PET, HDPE, or Mixed Plastics. Near infrared spectrometry can separate HDPE-N from either HDPE and/or mixed plastic streams; identifies PET, including thin-walled PET and wrapped PET. This process can also remove PVC, PS, PLA, PC, PE, and PP contaminants from a PET container. The function of the equipment is based on the principle that all solid materials have a unique surface "signature" that reflects and absorbs light rays in varying amounts (Rogoff and Clark, 2016).

Moreover, visual spectrometry uses a colour line scan camera which can detect, and sort materials based on colour analysis and sophisticated object recognition. Therefore, coloured PET can be separated from clear PET, and HDPE Natural can be distinguished from a HDPE container stream (Rogoff and Clark, 2016).

Baling equipment

Generally, plastic sorters and reprocessors will purchase mixed bales (HDPE, PET, and PP bottles and non-bottle rigid packaging) if subsequent bales are a high-quality output with minimum contamination and of measurable quality from MRFs (Zafar, 2021).

However, it has been revealed that mixed plastic bales can contain a relatively higher percentage of non-useful plastics such as PVC and PS. These polymers can contaminate the final product and/or cause implications for sorting infrastructure. Thus, it is crucial to supply sorting and reprocessing facilities with mixed bales containing PET, HDPE, and PP with contaminants, non-target plastics and large items removed (ZWS, n.d.).

Many MRFs will not accept plastic films as it can wrap and tangle around the sorting screens and clog the machinery at the facility. This will cause large economic implications for the MRF.

Artificial Intelligence (AI)

To enable optimal recycling, materials must be separated into individual flows. Where AI is being trialled in the UK, it is targeting the post processing wastes to refine them by adding machinery with Artificial Intelligence to material recovery facilities, that allows them to sort waste better and with greater quality to existing systems.

The introduction and development of Artificial Intelligence in waste management and recycling brings greater efficiency to the processes, which translates into cost savings for the different parties involved in the chain (collection companies, recycling companies, local governments, etc.) and an improved environment on several levels, by the reduction in waste sent to landfill and incineration.

There are several companies in the UK and the EU working in two of the targeted waste streams; C & I and C, D and E, these include ZenRobotics, Greyparrot and Recycleye.

ZenRobotics

They claim to be the first company to apply Artificial Intelligence (AI)-based sorting robots to a waste-sorting environment. Combines sensory data from multiple sensors to analyse the waste stream in real-time. The robots make autonomous decisions on what objects to pick and how.

Separates fractions including C&D, C&I, rigid plastics, scrap metals, inert, wood, and plastics bags fractions with the help of various sensors, heavy duty robot arms, and artificial intelligence.

Greyparrot

Combines visible image data with live image processing and analysis using AI deep learning techniques to recognise and distinguish waste types.

Offers a waste composition analysis solution that automates the manual process of sampling and auditing material through intelligent monitoring and analysis. The process is shown in figure 6.
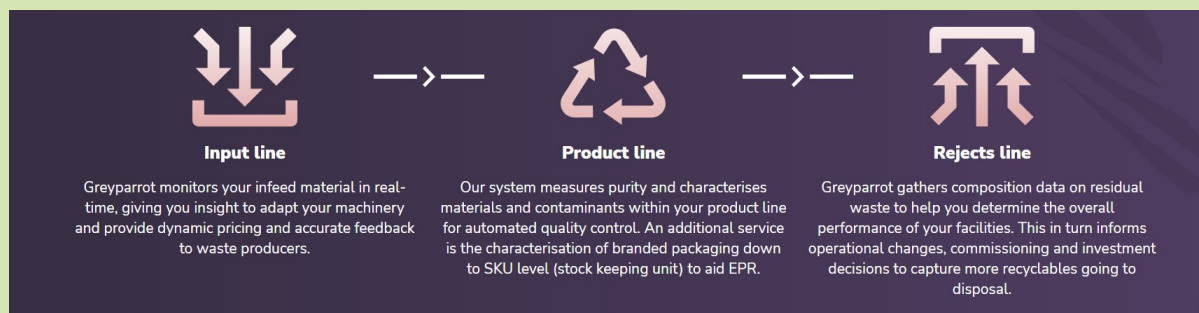

Input line

Greyparrot monitors your infeed material in real-time, giving you insight to adapt your machinery and provide dynamic pricing and accurate feedback to waste producers.

Product line

Our system measures purity and characterises materials and contaminants within your product line for automated quality control. An additional service is the characterisation of branded packaging down to SKU level (stock keeping unit) to aid EPR.

Rejects line

Greyparrot gathers composition data on residual waste to help you determine the overall performance of your facilities. This in turn informs operational changes, commissioning and investment decisions to capture more recyclables going to disposal.

Figure 6: Greyparrot process diagram.

Recycleye

A highly intelligent robotic waste system, designed to systemise, control, and automate manual sorting operations. The AI vision system identifies and classifies all items into waste streams – by material, object, and brand.

Whilst these AI systems are not fully perfected, they are starting to show very promising results, which if funding were secured to reduce post processing wastes going landfill and incineration, would be a very sensible return on investment.

Conclusion

The processes identified in this report are correct at the time of writing and depending on the reading of this document may have been superseded by newer versions of these technologies.

About the project

The problems associated with plastic waste and in particular its adverse impacts on the environment are gaining importance and attention in politics, economics, science and the media. Although plastic is widely used and millions of plastic products are manufactured each year, only 30% of total plastic waste is collected for recycling. Since demand for plastic is expected to increase in the coming years, whilst resources are further depleted, it is important to utilise plastic waste in a resourceful way.

TRANSFORM-CE aims to convert single-use plastic waste into valuable new products. The project intends to divert an estimated 308.35 tonnes of plastic between 2020 and 2023. Three pilot plants will be set up, one in Almere (NL), one in the UK and one in Belgium. The plants will make use of two innovative technologies – intrusion-extrusion moulding (IEM) and additive manufacturing (AM) – to turn plastic waste into recycled feedstock and new products.

Moreover, the project will help to increase the adoption of technology and uptake of recycled feedstock by businesses. This will be promoted through research into the current and future supply of single-use plastic waste from municipal sources, technical information on the materials and recycling processes, and circular business models. In-depth support will also be provided to a range of businesses across North-West Europe, whilst the insights generated through TRANSFORM-CE will be consolidated into an EU Plastic Circular Economy Roadmap to provide wider businesses with the 'know-how' necessary to replicate and up-scale the developed solutions.

Lead partner organisation
Manchester Metropolitan University

Partner organisations
Materia Nova
Social Environmental and Economic Solutions (SOENECS) Ltd
Gemeente Almere
Save Plastics
Technische Universiteit Delft
Hogeschool Utrecht
Hochschule Trier Umwelt-Campus Birkenfeld Institut für angewandtes Stoffstrommanagement (IfaS)
bCircular GmbH

Countries
UK | BE | NL | DE

Timeline
2019-2023

www.nweurope.eu/transform-ce