Final Report

Minimum thickness of plastic bottles to be recycled – research findings

Calculation of minimum thickness of rigid plastic packaging in order to be recycled

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Front cover photography: Plastic bottle and plastic flakes

Executive summary

A study was undertaken to determine whether there is a minimum thickness that rigid plastic packaging should be in order for it to be recycled effectively. Light weighting through the reduction in material usage has a positive environmental impact as less raw material is used, however there are concerns that some packaging may be so thin that it cannot be recovered and recycled.

The study took a qualitative and quantitative approach to assess the impact thin packaging was having at the sorting stage at Material Recovery Facilities (MRFs) and the recycling stage at Plastics Recycling Facilities (PRFs).

Surveys were conducted with 11 household and Commercial and Industrial (C&I) MRFs operated by 9 different waste management companies, representing 1 million tonnes of MRF capacity.

All MRF operators indicated that thin packaging was no more difficult to recover than thicker packaging. The most important thing for effective recovery is the presentation of the material to the Near Infrared (NIR) sorters. Packaging should be flattened to enable effective sorting as this creates a more stable area for ejection using air jets. If the material is round it can roll on belts leading to a loss in efficiency during sorting. The feedback reaffirms the most effective way for a bottle to be presented for recycling is: empty, flattened with the lid on.

The MRFs did identify other issues effecting yield including black plastics, full body sleeves and bottles containing liquid. One MRF surveyed had an issue with the sorting of HDPE bottles, but the cause for this was unknown. Sampling of the HDPE was carried out to determine if bottle thickness was likely to be causing the issue.

Surveys of the UK PRFs also suggested there was no negative impact from light weighting, however sampling and analysis was carried out at two PET PRFs. Feedback from European PET recyclers was different from the UK recyclers. The European recyclers have encountered the following issues, which they attribute to light weighting:

- Difficulty in handling/feeding thin material leading to loss of productivity;
- Higher moisture levels in bales leading to lower overall yields;
- Lower throughput due to lower bulk densities; and
- More fines generation from more brittle material

Although these issues were not expressed by the UK recyclers, the reduction in overall yield from higher moisture and the reduction in throughput are issues that would affect the overall economics of recycling. It may not mean that the thin packaging is not recycled, just that recycling the thin packaging has a higher cost. Accounting for this is challenging, and should be considered further in terms of the wider discussions on Extended Producer Responsibility (EPR) and how the true cost of recycling can be reflected.

Sampling and analysis of materials being sorted at three MRFs showed that there was no significant loss of thin packaging. Some lightweight and thin packaging was sorted into fibre lines, however, this material is generally recovered via 2D NIR sorting. Therefore, from a MRF perspective, there is no minimum thickness in order to be recovered.

Sampling and assessment was done on material from two PET PRFs. The assessment showed that flakes with a thickness of <0.05 mm were not recovered to the product stream and were removed with the label material. Therefore, in order to be recycled, material should be 0.05 mm or thicker.

A thickness of 0.05 mm is thin for rigid PET bottles, with only ≈2% of bottles analysed in this project having a mid-section of <0.05 mm.

A high-level carbon footprint comparison showed that in order to justify reducing the thickness of a PET bottle beyond 0.05 mm, a weight reduction of 44% - 51%[1] is required. Since only 2% of bottles have a mid-section of <0.05 mm currently, this level of further light weighting would be very extreme, and not likely to be feasible.

This study provides qualitative and quantitative evidence that packaging designers and specifiers should aim to achieve a minimum thickness of 0.05 mm for the packaging to be recycled. This is based on the data obtained for the PET bottle recycling process. When infrastructure and processes have been developed and installed specifically for PET tray recycling, it may be necessary to repeat this study to see if a different minimum thickness is required. The feedback from the polyolefin recyclers was that providing any PP or HDPE was rigid and not a film, it would be recycled effectively. Therefore, the same limit of 0.05 mm is suggested for these materials, as the sampling from the PET recyclers showed this was the point below which the material behaves more like a film. The inefficient sorting observed by one MRF for natural HDPE was unlikely to have been as a result of light weighting.

The loss of material in PET recycling processes is therefore unlikely to be caused by thin PET bottles and may be a wider issue of low Intrinsic Viscosity (IV) material, most commonly used in PET thermoforms. Previous WRAP projects have shown this to break up easily in the recycling process, generating fines which are then more difficult to recycle. The previous WRAP work showed the design of the process is vital. Any modern PET recycling facility should account for lightweight and brittle material and use techniques such as wet granulation, less aggressive friction washing and a combination of gentle mechanical and then thermal drying.

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[1] *44% reduction in weight is required if 20% PCR is used in the bottle and 51% reduction is required is 0% PCR is included*

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Glossary

C&I	Commercial and Industrial
HDPE	High Density Polyethylene
MRF	Materials Recovery Facility
NIR	Near Infrared
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PRF	Plastics Recycling Facility

Acknowledgements

Axion would like to thank the MRF and PRF operators who took part in the surveys and facilitated sampling of material.

1.0 Introduction

As part of WRAP's programme to achieve greater consistency in household recycling, research is being carried out to tackle issues in packaging design that may be causing inefficiencies in the sorting and recycling process.

One issue identified was the potential impact that light weighting of rigid packaging through the reduction of wall thickness may be having on sorting and recycling issues. This project looked to determine, through qualitative and quantitative analysis whether there is a minimum thickness packaging should be in order for it to be recycled.

In combination with this, the study also determined at what point the carbon reduction benefit obtained through light weighting outweighs the benefit gained from recycling the material. This is important when considering light weighting or other carbon reduction methods that may negatively impact recycling, as the whole life cycle of a product is the most important factor.

2.0 Methodology

The project was carried out in a two-stage approach to determine the effect light weighting of packaging through the reduction in thickness may be having on the recycling process:

- Qualitative surveys with Materials Recovery Facility (MRF) and Plastics Recycling Facility (PRF) operators; and
- Quantitative analysis of materials taken from MRFs and PRFs

Following the analysis, a high level carbon footprint comparison was carried out to determine the point at which the carbon benefit gained through the reduction in raw material usage outweighs the benefit gained from recycling the material. The methodology for this exercise is given in section 4.1.

2.1 MRF and PRF surveys

To ensure feedback was gained from the major MRFs in the UK Axion reviewed MRF code of practice (CoP) data to identify the operators which handle the largest quantities of recyclables. Using the reported tonnages processed by facilities in England and Wales, Axion identified a list of 12 operators who represented 64% of MRF capacity.

This list was used to target the specific operators and MRFs in order to carry out surveys. Axion spoke with either operations managers, plant managers or general managers to obtain feedback. The information asked for included:

- What material is processed through the facility? Is it Household or Commercial and/or Industrial (C&I) waste?
- High level information on the types of separation units used in the MRF to recover plastic packaging and other materials
- Whether the facility is experiencing any difficulty in recovering lightweight or thin plastic packaging
- Any other aspects of plastic packaging that may be leading to ineffective sorting and recovery

The responses were recorded and where appropriate Axion worked with the operators to plan the sampling activities.

For the PRF surveys Axion aimed to contact all PRFs processing household post-consumer packaging in the UK. Due to the limited number of PRFs processing post-consumer household packaging in the UK[2], some facilities in Europe were also included in the surveys. As with the MRF surveys, feedback was gained on the impact that light weighting and thin walled packaging was having on the recycling process.

2.2 Quantitative analysis

Following the surveys, Axion carried out practical sampling and analysis of materials at those MRFs and PRFs, who in the course of the surveys had expressed the view that light weighting may be having an impact on the sorting efficiency of their plant.

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[2] *Axion estimate there are 6 facilities focused on post-consumer household packaging waste*

To conduct the sampling, a site visit was carried out to identify points in the process at which material may be miss sorted or lost. Once identified, samples of the target material (for example PET bottles) were taken from the product and reject streams. Samples of around 20 kg were taken and transported to Axion for analysis.

To analyse samples from the MRF, a random selection of 200 bottles was taken from each sample. Each bottle was weighed and then an incision made into the mid-section of the bottle. A pair of calibrated callipers accurate to 0.01 mm was used to measure the thickness of the bottle at the mid-section.

Samples from the PRF were in the format of flake rather than whole bottles. For the flake samples, first manual sorting was carried out to remove any non-target material such as polyolefin (PE or PP) flakes and paper. After this, the thickness of the target material was measured. As with the MRF samples, 200 items were measured from each sample.

Once the data was obtained, a thickness distribution for items in each stream was calculated. In order to determine the actual thickness distribution for the material as a whole, an estimated mass balance based on feedback from the processor and historic data was used for each process to scale the various output streams.

3.0 Results and discussion

3.1 MRF surveys

Axion carried out a high-level survey with UK MRF operators to discuss any impact light weighting may be having on their recovery. MRF code of practice data was used to identify the largest UK MRFs processing either household or C&I dry mixed recyclables.

In total 30 different facilities operated by 12 different waste management firms were targeted for the survey. From these 30 facilities 11 participated in the survey. The 11 sites were operated by 9 different waste management firms and represent over 1 million tonnes per annum of dry mixed recyclables processing.

All MRFs felt that lightweight packaging was not more difficult to recover than thicker packaging. One MRF had an issue with HDPE sorting and this was further investigated during the practical sampling.

The sites did however comment on the importance of the shape of packaging and how this effects the sorting efficiency, which is discussed below. Another consideration is how the reduction in weight impacts the overall throughput.

Some MRFs had positive comments for light weighting in that it is easier to bale the thinner material and fewer broken bales are seen.

3.1.1 Presentation of packaging to sorting machines

Flattened or flat packaging may tend to report to the fibre stream following ballistic or 2D/3D separation. Because of this, MRFs are typically equipped with a Near Infrared (NIR) sorter on the fibre line to recover the plastic. Flatness does not necessarily depend on how thick the packaging is, although thinner lighter packaging may be more likely to be flattened.

Although flat packaging may report to the fibre line, it is significantly easier for NIRs to eject flat material than rolling or round material, and this is preferential for the MRF and PRF.

3.1.2 Plant throughput

One UK MRF has seen an increase in the number of bottles received and processed, presumably due to increased consumption by the consumer. However, as the bottles in general are becoming thinner and lighter, they commented they have not seen an increase in weight of sorted bottles. This MRF is therefore looking to increase the capacity of the sorting line to deal with the increased number of bottles, even though the overall mass of product has remained the same

This can work the other way, and it is possible in some instances the number of items will remain the same, however the overall mass will go down. This was not identified as a problem by any of the MRFs surveyed but it is a possibility.

3.1.3 Additional concerns

In addition to the light weighting issue, MRFs provided some further feedback on problems caused by plastic packaging. These issues include:

- Black plastics which cannot be identified by NIRs
- Full body sleeves made from PP, PS or PVC
- Bottles with liquid left in which are too heavy for the NIRs to eject
- Bottles that are not flattened are more difficult for NIRs to eject and can move around on belts

Regarding the detection of bottles in full body sleeves, some operators commented that they are able to positively identify these even if the sleeve is not PET. This is likely because there is a compound signal from the sleeve material and the PET bottle underneath. Further work is suggested in this area.

The initial surveys therefore strongly suggested there was no negative impact from light weighting on MRF recovery, however two MRFs agreed to take part in the sampling trial and the MRF with the issue on separation of HDPE also provided samples.

3.2 PRF surveys

Surveys were also conducted with three of the major plastics recyclers in the UK and further conversations have been held with a selection of European recyclers.

One recycler surveyed has been processing HDPE and PP for many years and commented that they have seen no decrease in yield following the continued light weighting of packaging such as HDPE milk bottles.

A HDPE/PP recycler in Europe was also interviewed and although light weighting was not causing an issue, they do have a separation process to remove film. Therefore, if the packaging moved from a rigid HDPE or PP pack into a PE or PP film, it would not be recycled in their process. Recycling of PE or PP film is possible, however due to economic challenges there are few processes doing this.

The other recyclers interviewed processed PET. Two UK based PET recyclers and two European recyclers were interviewed.

One UK recycler was confident that light weighting was not resulting in any yield loss, and trials had previously been carried out on processing only lightweight bottles with no negative impact seen. The second UK recycler was unsure whether there was an issue with light weighted bottles. Both recyclers agreed for sampling to be carried out at their facilities.

The feedback gained form the PET recyclers in Europe did not fully correlate with that gained from the UK recyclers. The European recyclers felt that light weight packaging was causing an issue in terms of yield loss. Higher moisture levels and more brittle material have been given as the primary reasons for a reduction in yield. More detail on this feedback is given in 3.6.

3.3 MRF sampling

Sampling was carried out at three MRFs, two focusing on the PET line and one on the HDPE line.

3.3.1 HDPE

One of the MRFs interviewed had seen a recent loss in the efficiency of natural HDPE sorting. The unit used to sort the HDPE from other plastics is a transmissive NIR. This means that instead of using the signal from the infrared light that is reflected from the surface of the packaging, the unit uses the infrared light that is transmitted through the packaging. This is significantly less common type of detection for sorting post-consumer plastics than reflective.

Samples of bottles that were correctly detected and ejected were taken and samples of bottles that were not detected and were sorted to the reject stream were also taken. Figure 1 shows where the samples were taken

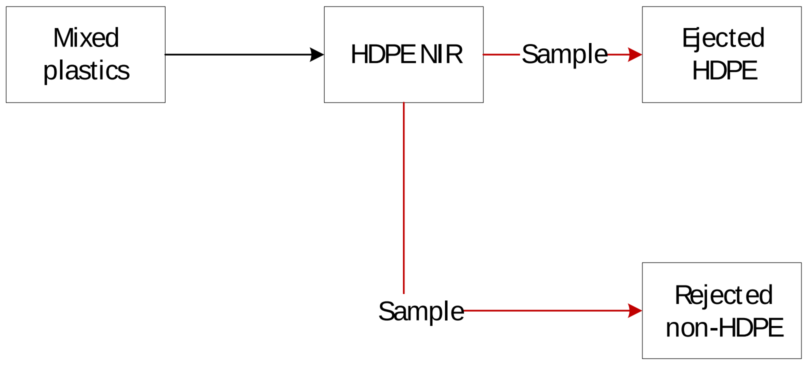

Figure 1 Section of the process the HDPE sample was taken from

The samples were analysed using the method detailed in section **Error! Reference source not found.**. Figure 2 shows the thickness distribution of bottles in the eject and reject streams and Figure 3 shows the weight distribution.

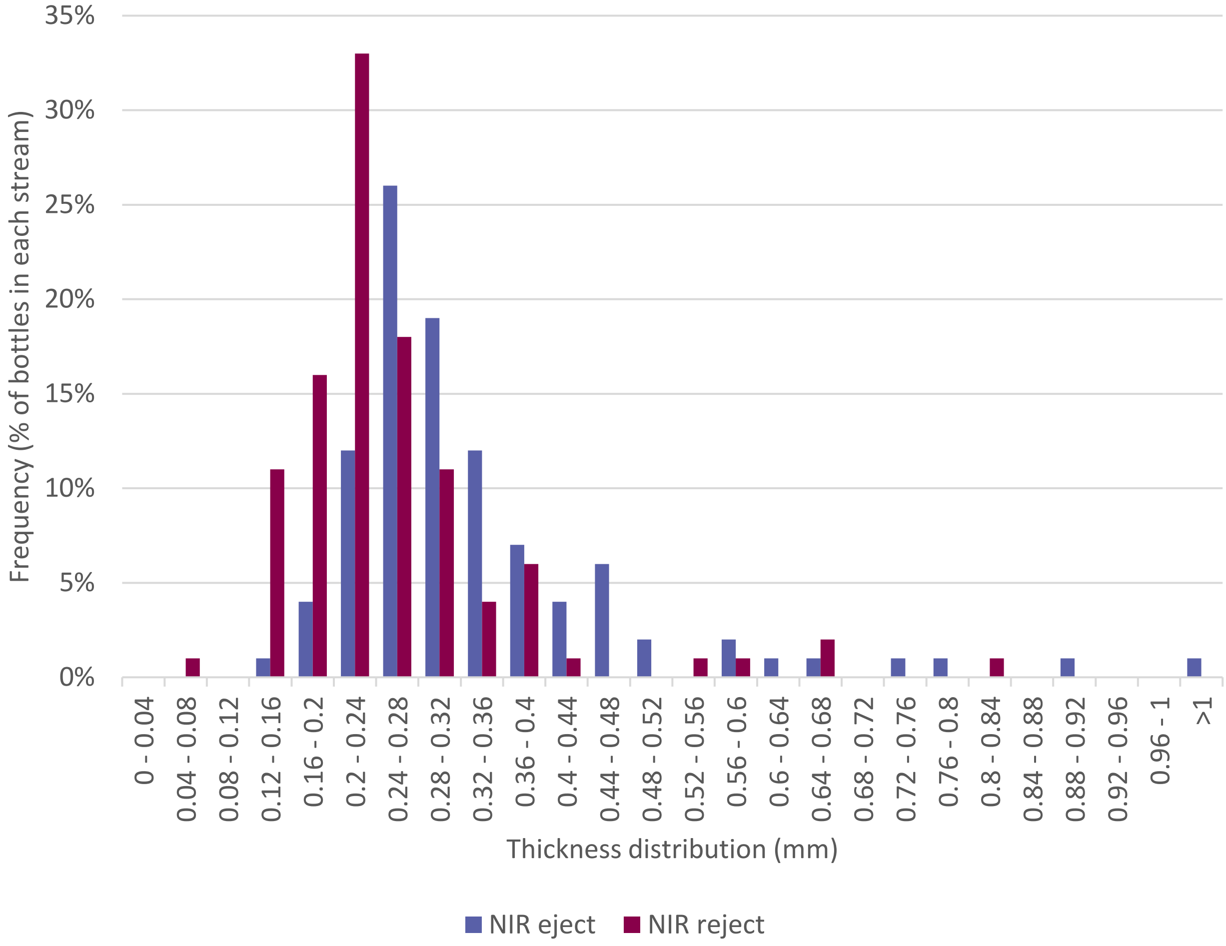

Figure 2 HDPE thickness distribution in each stream

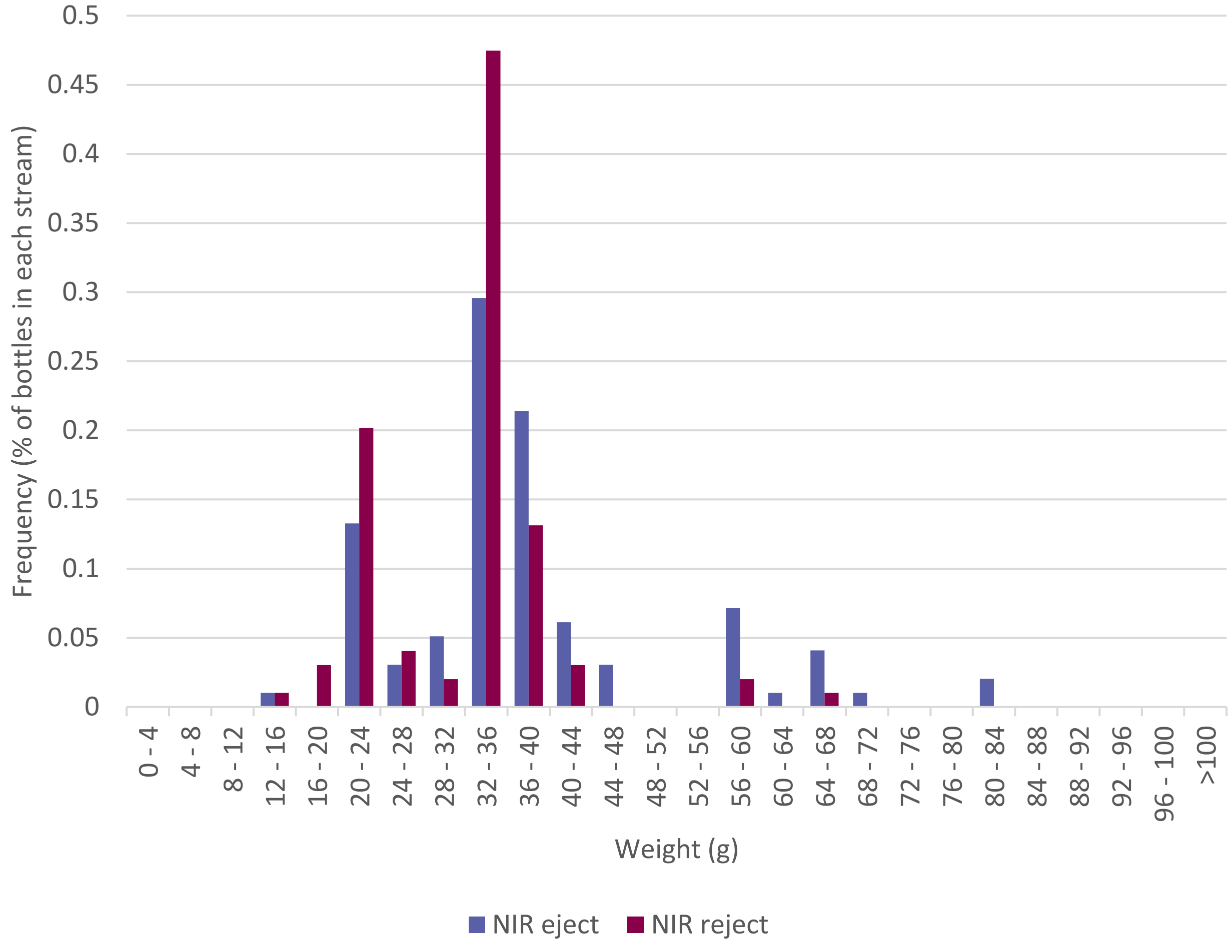

Figure 3 HDPE weight distribution in each stream

The analysis shows that with regards to weight, there is no difference between the material being correctly sorted and that being incorrectly rejected.

There is however a slight difference in the thickness of the packaging that was being rejected as shown in Figure 2, with thinner material found in the reject stream. Figure 4 shows the thickness distribution of all the bottles when the mass balance is taken into account.

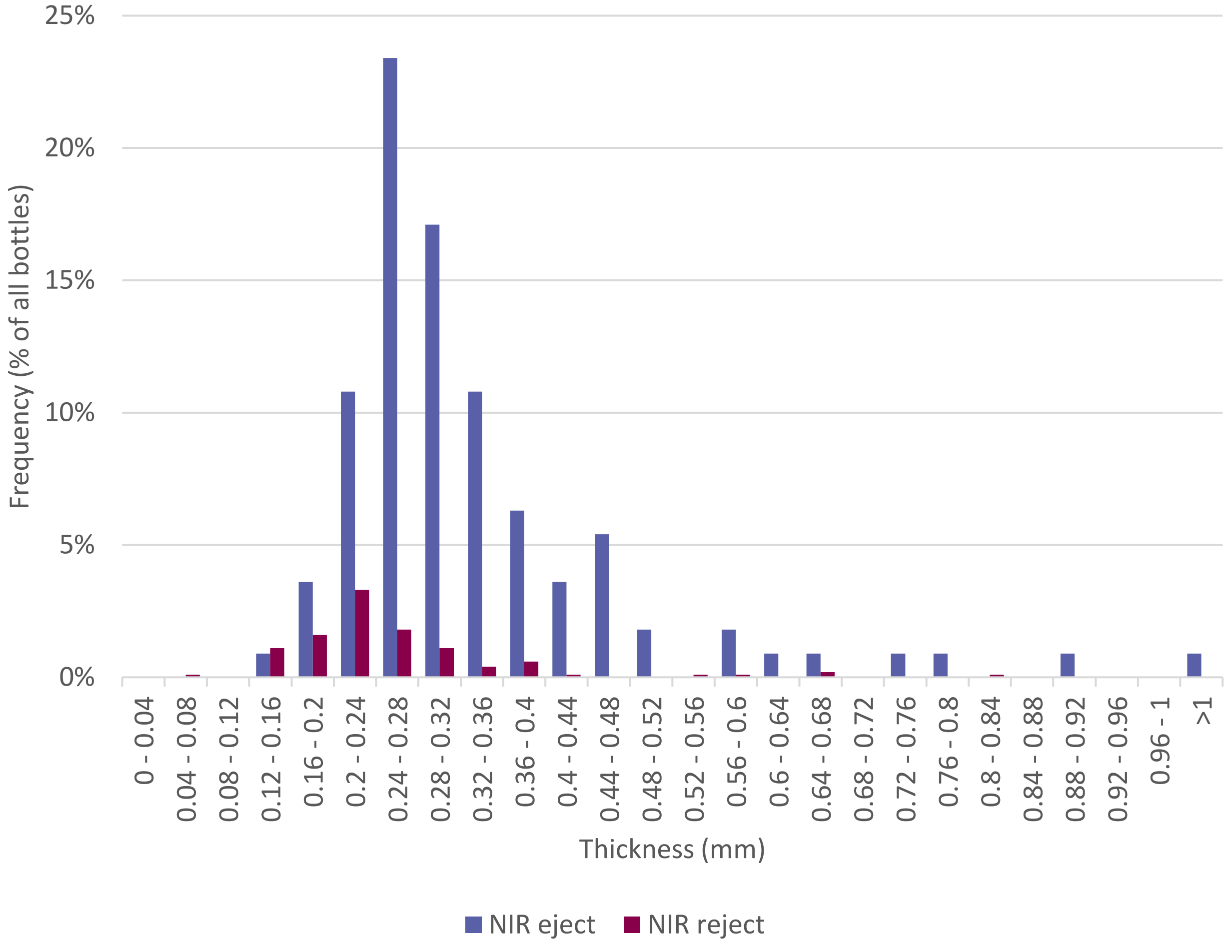

Figure 4 HDPE thickness distribution for all material scaled to the mass balance

When the mass balance is considered, it shows that still significantly more of the thin material is recovered to the correct stream, and it therefore suggests that there is another factor causing the miss-sorting of the HDPE in this instance.

This could be unique to transmissive NIR as other MRFs did not report the same concerns for HDPE. It is likely through optimisation of the NIR that efficiency could be increased, and since the issue seems isolated to this facility, applying a minimum thickness to HDPE bottles would not be justified.

3.3.2 PET: Household MRF

At the household MRF, samples of PET bottles reporting to the fibre line were taken. As an NIR unit is used to recover plastic from the fibre line, samples were taken from both the ejects (the plastic that is removed from the paper) and the rejects (the paper stream which is then passed through a Quality Control (QC) hand picking station). Figure 5 shows a flow diagram of a small section of the MRF from which the samples were taken.

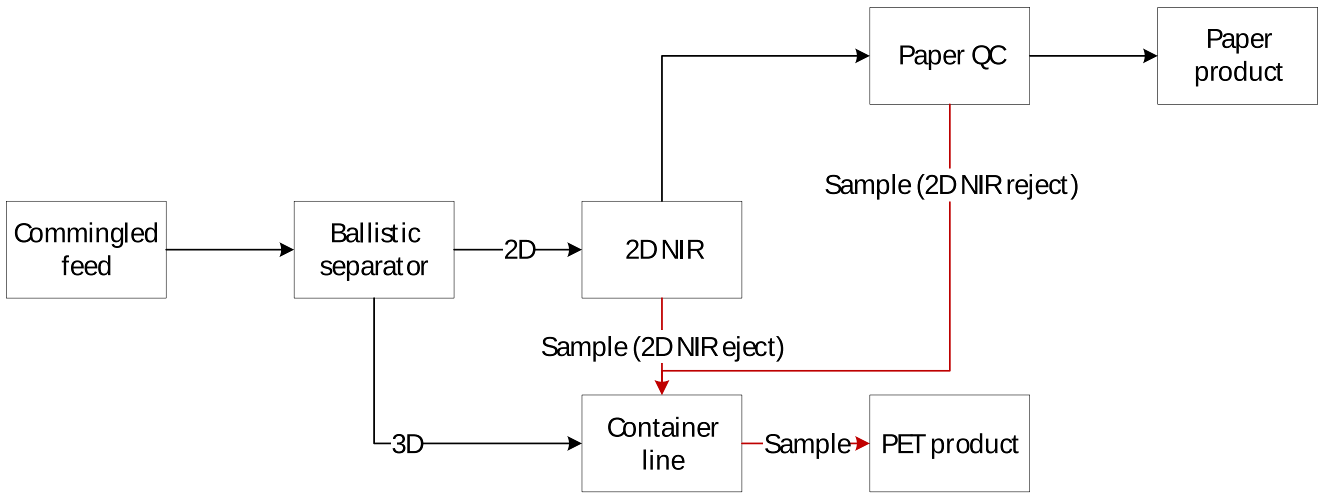

Figure 5 Section of process PET sample was taken from in household MRF

The three samples were analysed. Figure 6 shows the thickness distribution in each stream and Figure 7 shows the weight distribution.

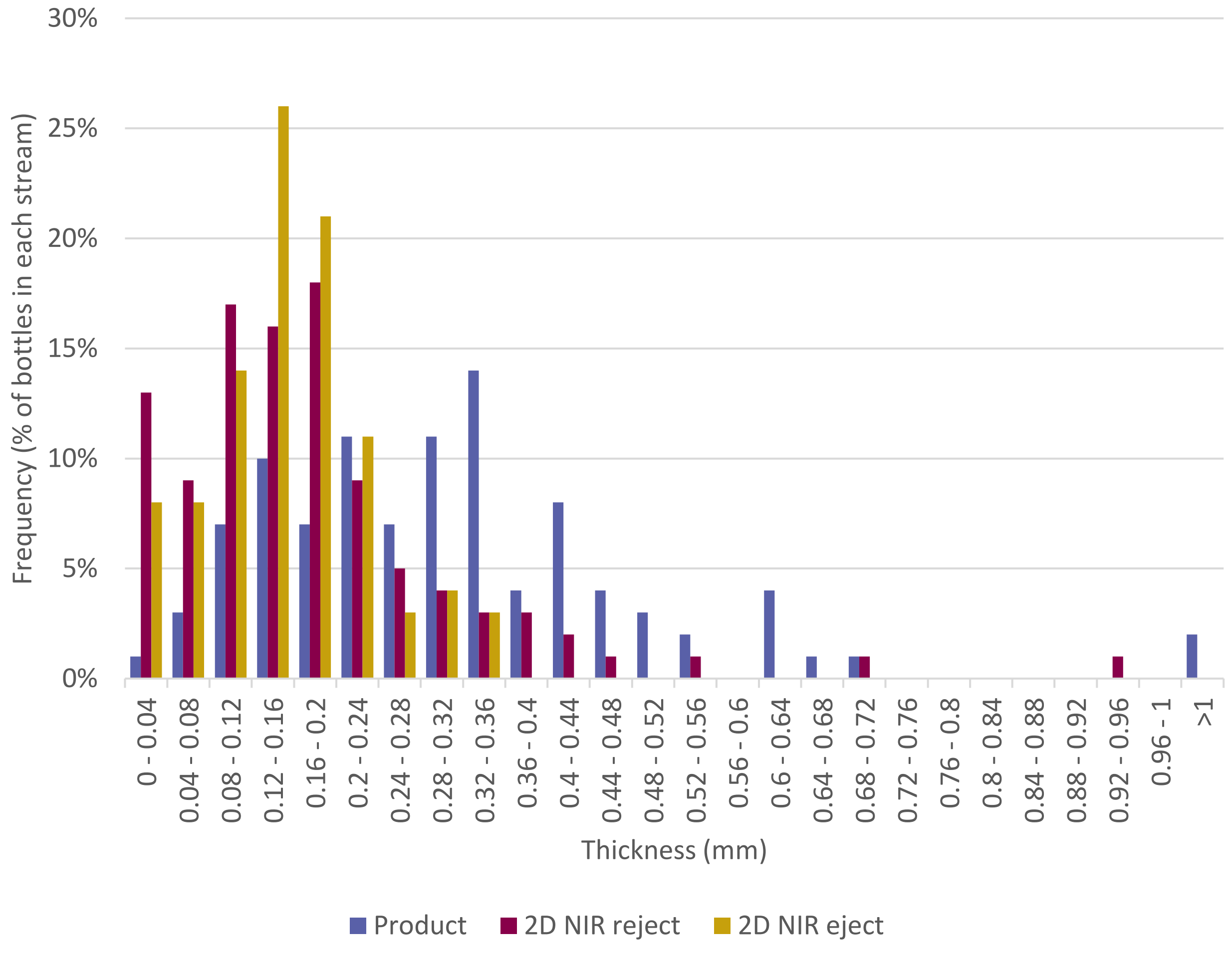

Figure 6 PET thickness distribution in each stream (Household)

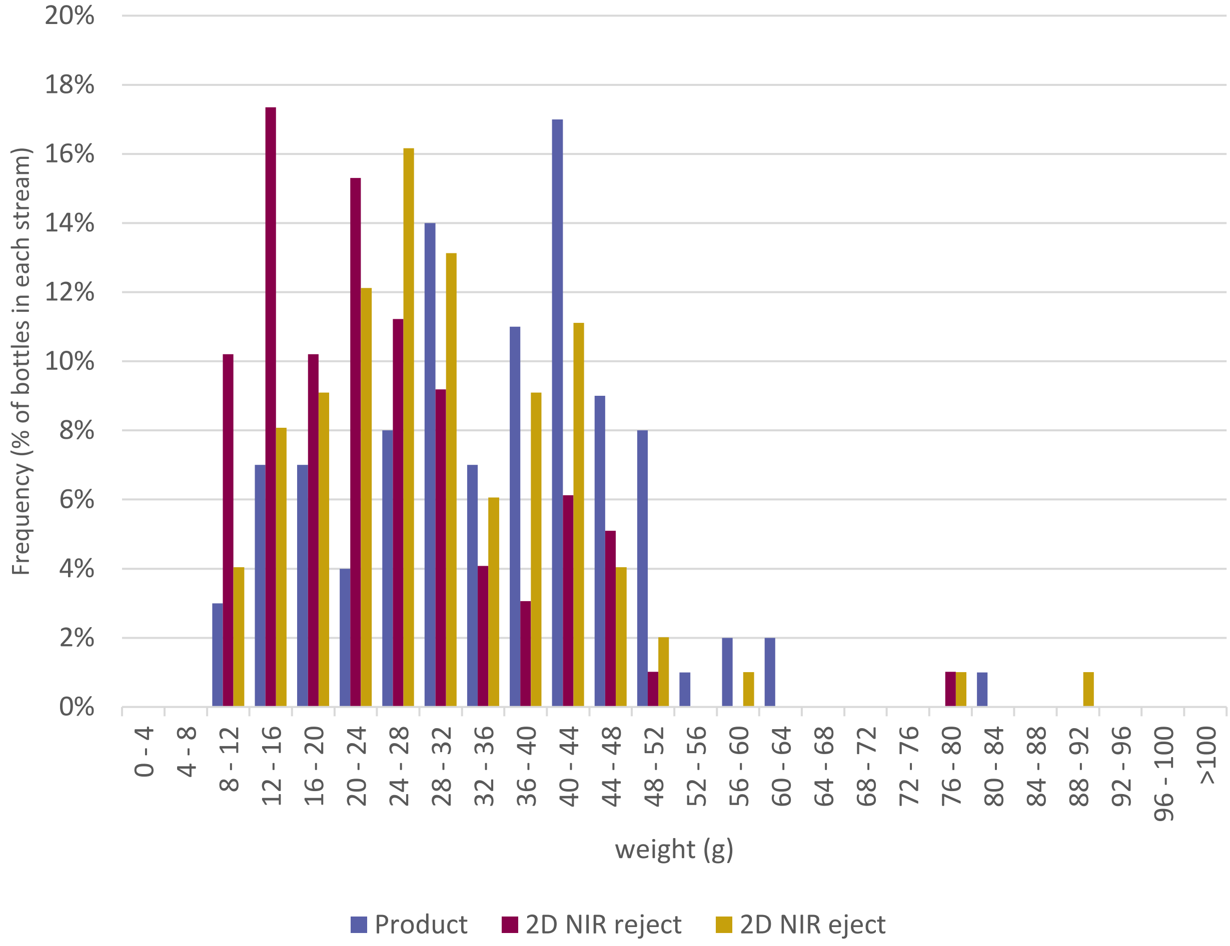

Figure 7 PET weight distribution in each stream (Household)

The data shows that the material reporting to the fibre line (the 2D NIR reject and the 2D NIR eject) is thinner and lighter. The NIR eject material is sorted back into the plastics sorting line so is not lost in the MRF, and the reject material is manually removed and fed back into the plastics line.

However, this is an analysis of each stream on an equal basis. The mass balance must be taken into account to show where the material as a whole is reporting. Figure 8 shows the data adjusted to represent the mass balance.

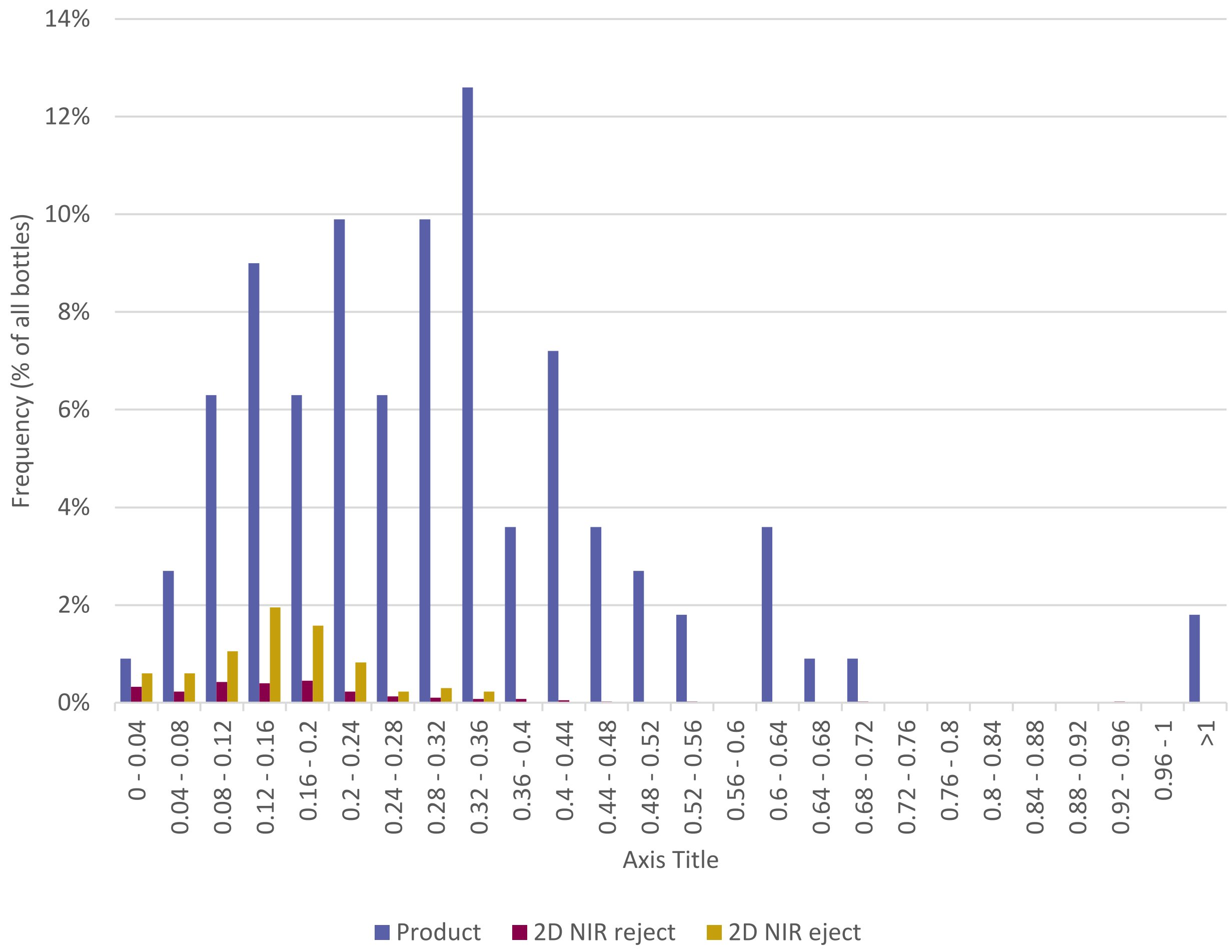

Figure 8 PET thickness distribution for all material scaled to the mass balance (Household)

When the mass balance is taken into account, it can be seen that although the fibre line does have thinner, lighter PET in it, the majority of this thin and lightweight material is still recovered to the product stream. Overall therefore, at this facility there is no issue with yield loss from this type of material, and the 2D NIR installed on the fibre line is sufficient to recover any miss-sorted PET.

3.3.3 PET: C&I MRF

Sampling of the PET stream was also carried out at a C&I MRF. In this instance, samples were taken from the PET bottles recovered in the two fibre streams which are manually removed during the QC stage. Figure 9 shows the flow diagram.

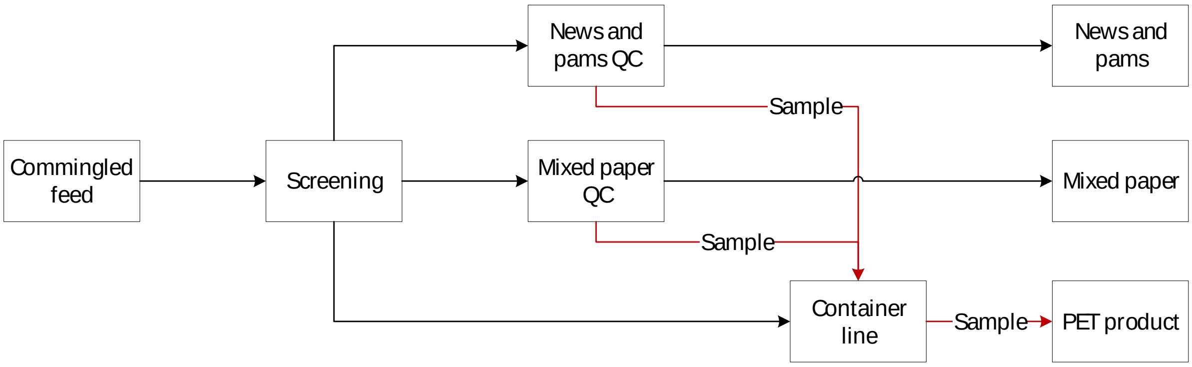

Figure 9 Section of process PET sample was taken from in C&I MRF

Figure 10 shows the distribution of thickness of bottles within each stream,

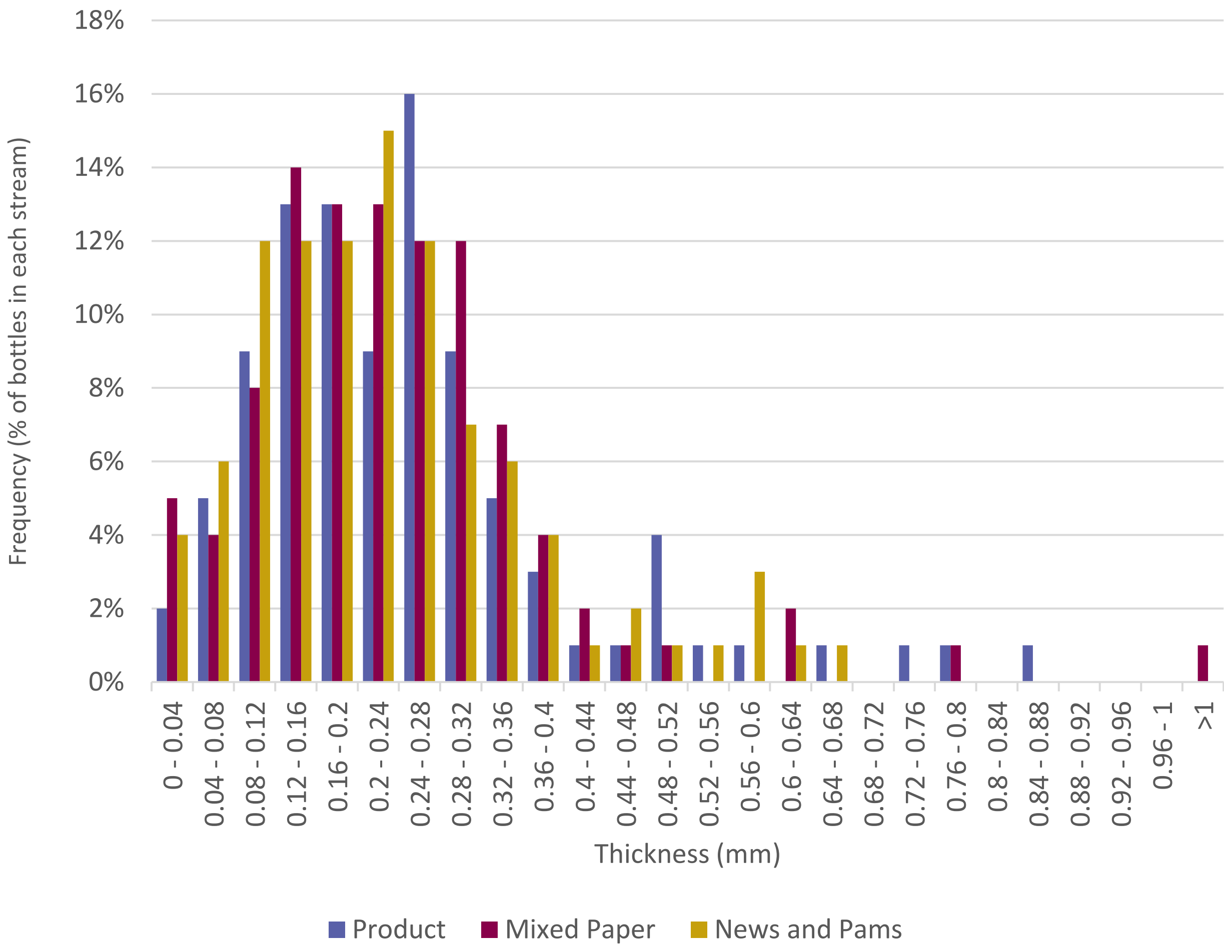

Figure 10 PET thickness distribution in each stream (C&I)

This analysis shows a very consistent thickness distribution across all three streams, showing no effect of the thickness on the sorting efficiency. When the mass balance is considered and the results are scaled, as shown in Figure 11, it can be seen that the majority of packaging is recovered to the correct stream.

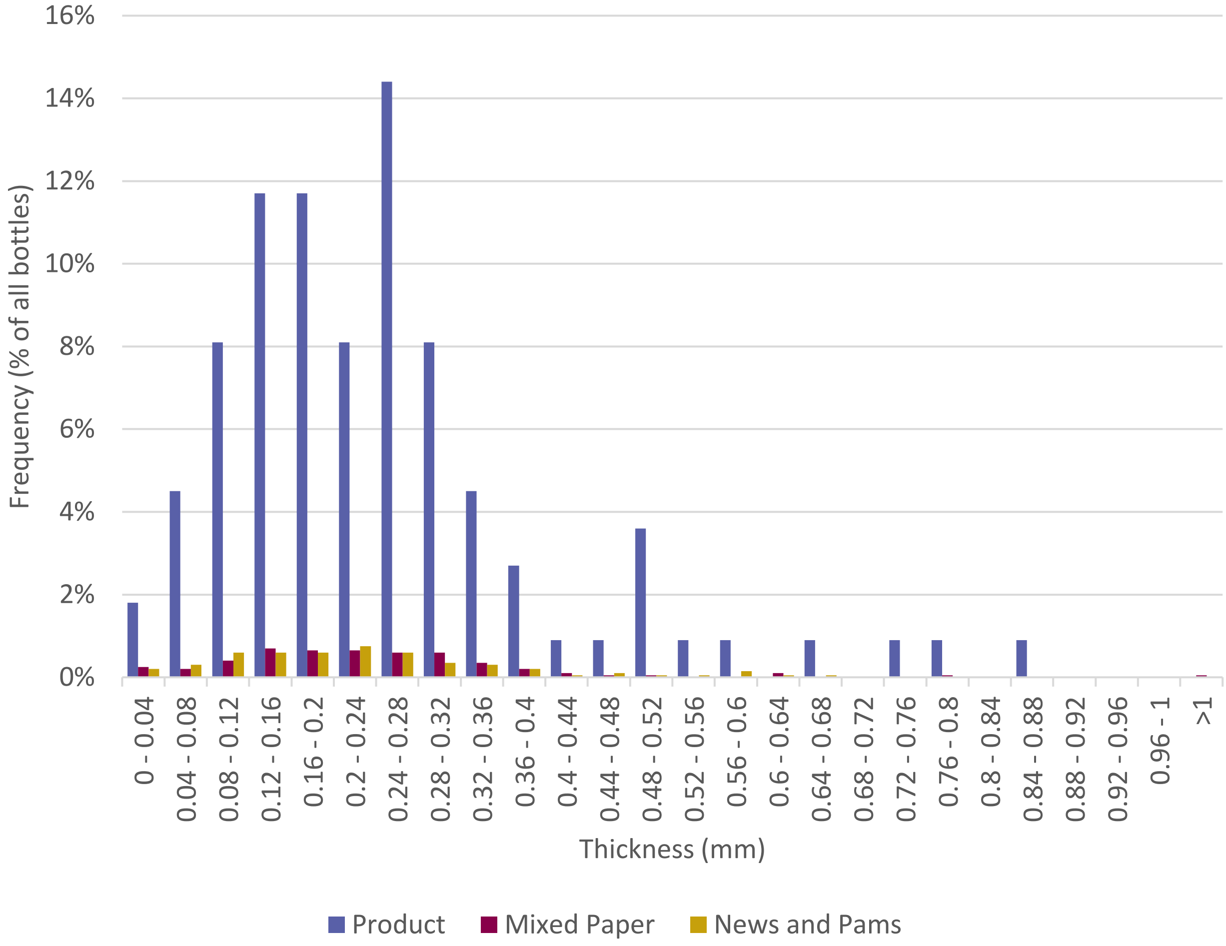

Figure 11 PET thickness distribution for all material scaled to the mass balance (C&I)

3.3.4 Summary on MRF sorting results

The results from the sampling, correlate with the feedback gained from the MRF surveys. The analysis carried out strongly indicates that sorting at the MRF is not affected by the thickness of packaging. MRFs are typically designed with NIR sorters on the fibre line as some carry over of plastic is inevitable. Therefore, plastic that is recovered with the fibre line into the 2D material stream will be recovered and sorted back into the correct stream.

3.4 PRF sampling results

Sampling took place at two UK PET recyclers. The recyclers have been labelled as “PRF A” and “PRF B”.

3.4.1 PRF A

Four samples were taken from various points of the process. These were:

- Floating fraction after washing which contains mostly cap material. This was sampled as thinner PET may be more likely to float;
- Filter cake from the washing process which may contain flakes that have broken up more;
- Lights removed between the drying steps using air. This step is designed to remove film; and
- The product

Figure 12 shows a simplified process flow diagram of where the samples were collected from.

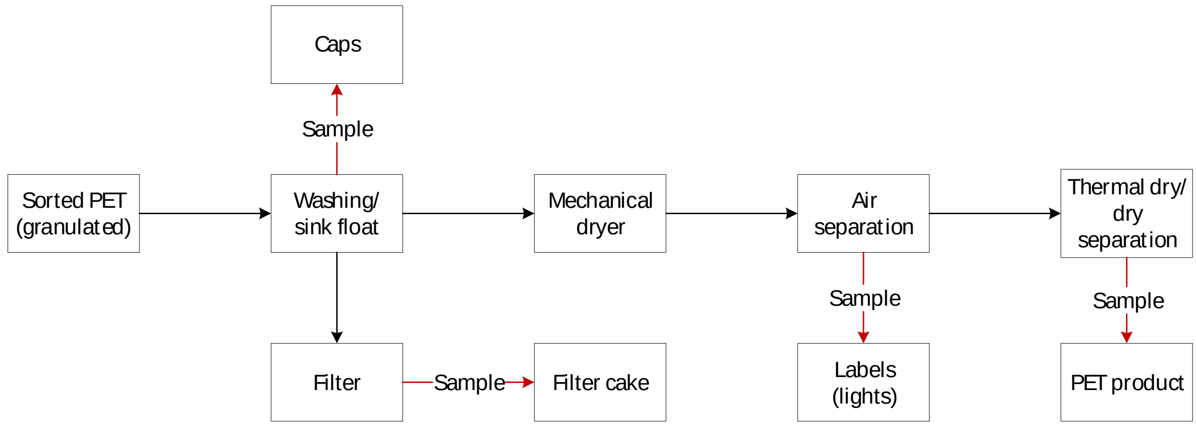

Figure 12 Basic PRF A flow diagram showing sample locations

It should be noted that all non-PET was excluded from the analysis. For example, in the caps fraction only the PET present in this fraction was analysed. Figure 13 shows the thickness distribution in each stream.

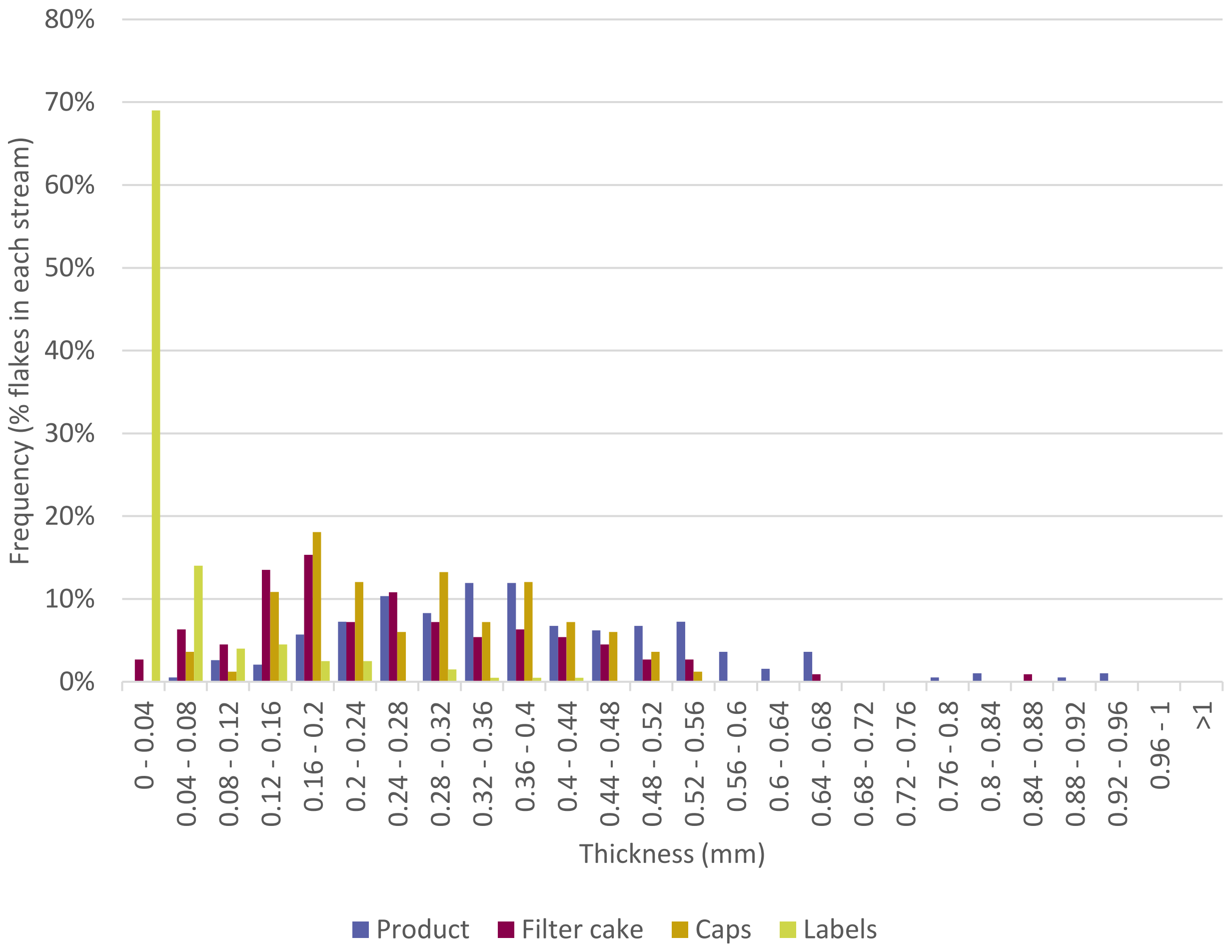

Figure 13 PET flake thickness distribution in each stream (PRF A)

The analysis of the individual streams shows that the reject streams are comprised mainly of thinner flakes. This is especially the case for the lights fraction which contains film. Figure 14 shows the data once it has been scaled to consider the mass balance. These reject streams only represent a small amount of the target PET flake, and as a result the actual loss of material in these streams is very low.

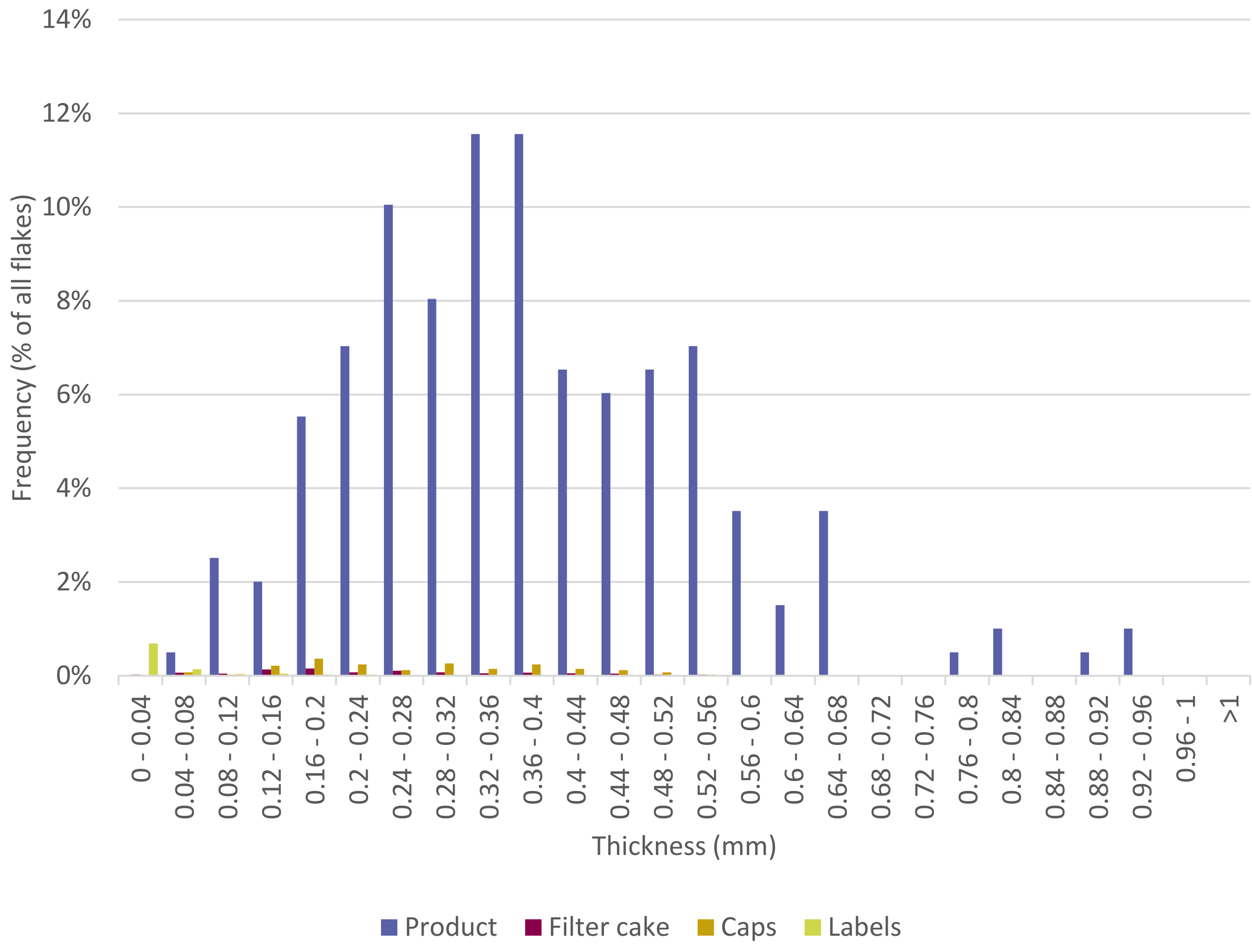

Figure 14 Distribution of flake thickness for all material scaled to the mass balance (PRF A)

Figure 15 shows the same data as above but focused only on the 0 – 0.15 mm flakes.

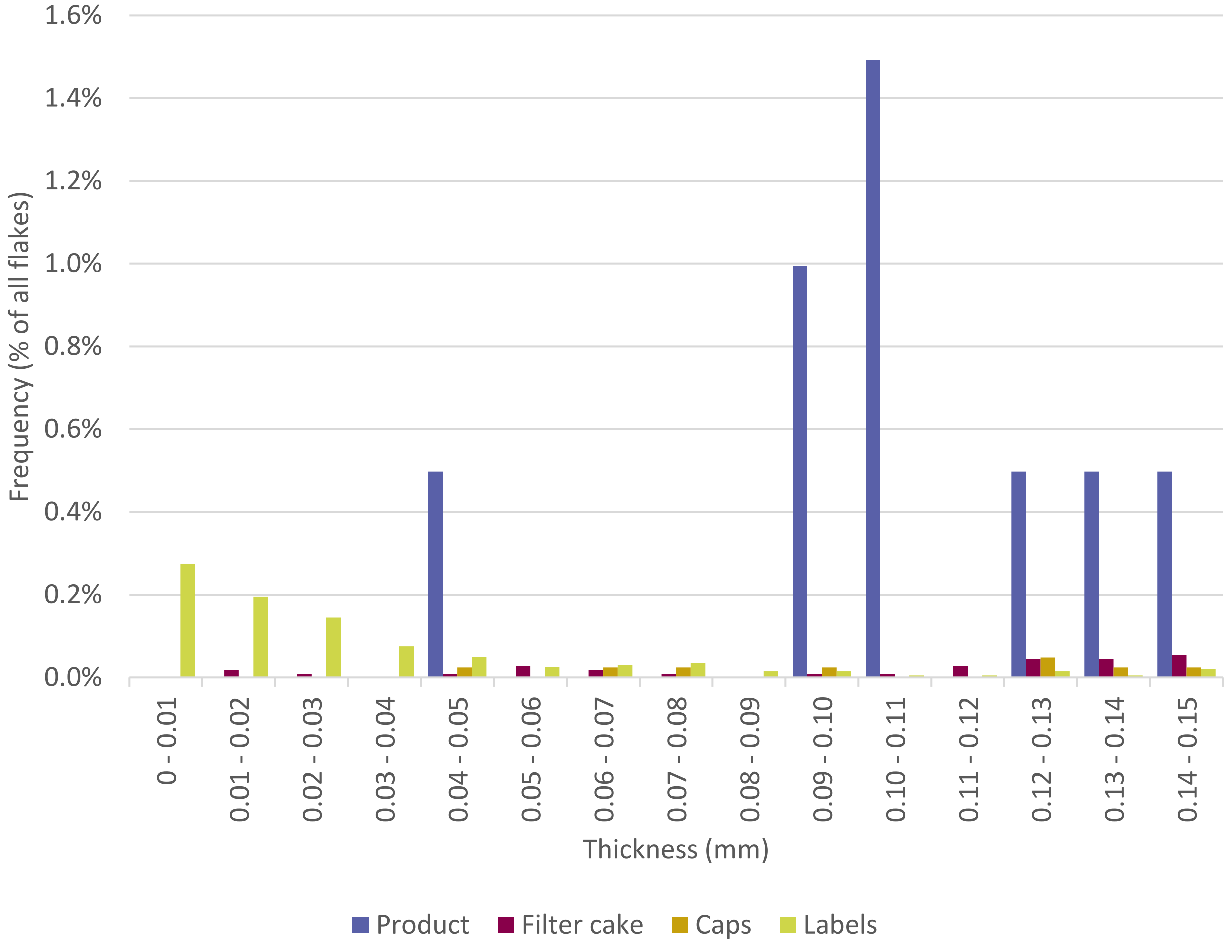

Figure 15 Distribution of flake thickness for all material scaled to the mass balance 0 - 0.15 mm only

The data shows that none of the flakes in the product were thinner than 0.05 mm, and the material that was <0.05 mm was recovered in the label stream. There were no significant number of flakes found between 0.05 mm and 0.09 mm in any stream. Above 0.09 mm the quantity of flakes in the product far exceeded that in the reject stream.

This data indicates that providing the thickness of the PET is above 0.05 mm, it will be recovered effectively. Below a thickness of 0.05 mm the flake will behave like film and will be recovered in the labels product which will not be recycled.

The quantity of material lost in this manner is very low, with fewer than 1% of all flakes having a thickness of <0.05 mm and reporting to the lights stream. This suggests that the yield loss being experienced by PET recycling facilities, is more likely resulting from brittle, low Intrinsic Viscosity (IV) material breaking up completely into dust or through the increased moisture/contamination levels per tonne of feed. The low IV material is used mostly in PET trays, which have been increasing in the PET recycling stream over the past years.

3.4.2 PRF B

PRF B uses significantly more separation stages than PRF A, however fewer of these streams were thought likely to contain PET flakes. Several of the by-product streams contained very fine material (<2mm) which could not be analysed to determine the thickness, however this material is still sold as a product by PRF B and is recycled into new applications.

Three streams were analysed to determine the thickness distribution of the flakes. These were:

- The clear PET product
- Labels removed during the drying process
- Light material removed using zig zag separators after the drying process.

Both the label material and Zig Zag material were rich in polyolefin films or flake. As with PRF A only the PET material was analysed

Figure 16 shows the thickness distribution of flakes in each of the three streams.

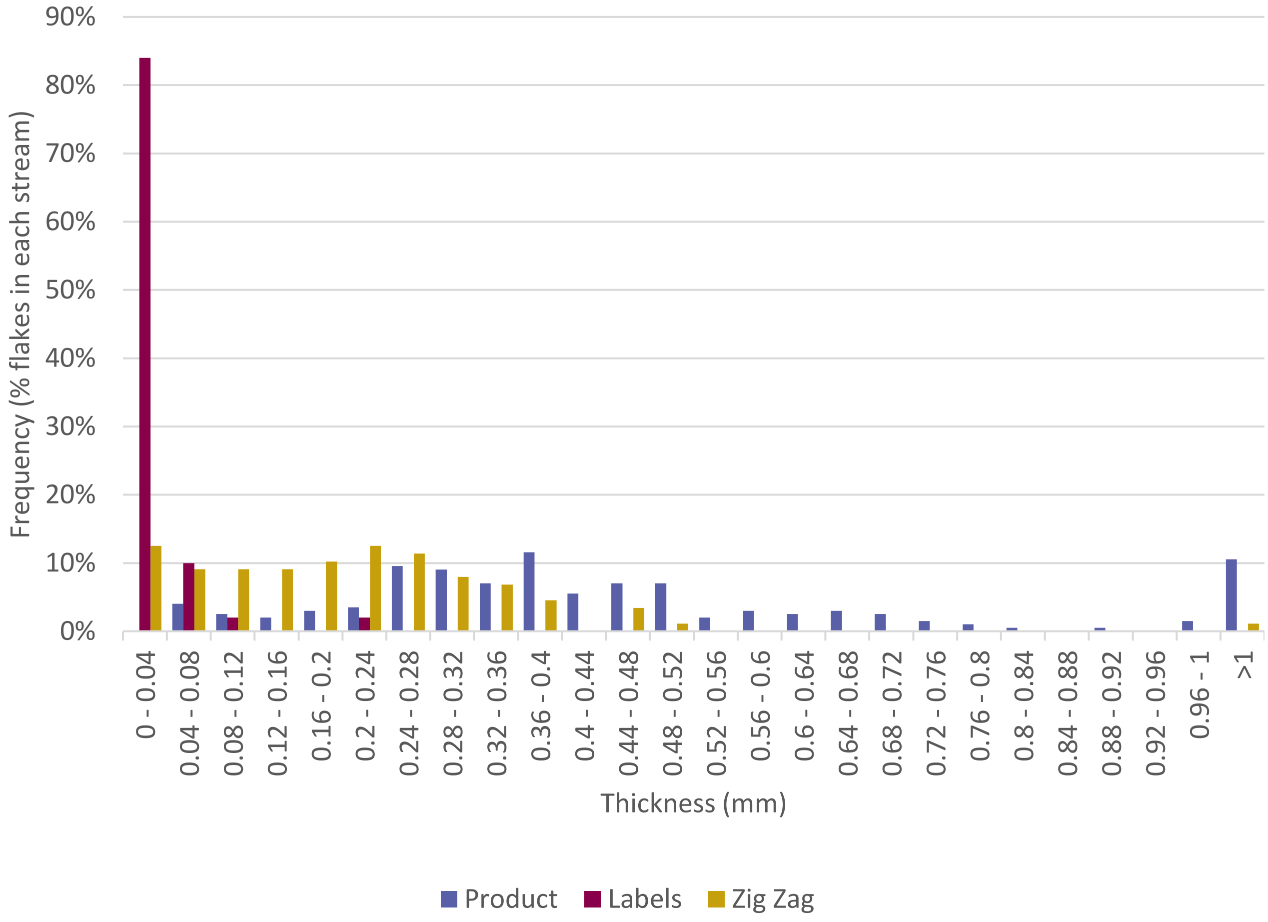

Figure 16 PET flake thickness distribution in each stream (PRF B)

As with PRF A, the label stream contained only very thin flakes, which is to be expected as the unit is designed to remove film. The material removed from the zig-zag however, had a much wider distribution of thickness. spread almost equally between 0 and 0.4 mm thick.

When the mass balance is considered, as has been seen previously, the actual loss of material is very low. Figure 17 shows the scaled thickness distribution for all flakes and Figure 18 shows the distribution between 0 and 0.15 mm.

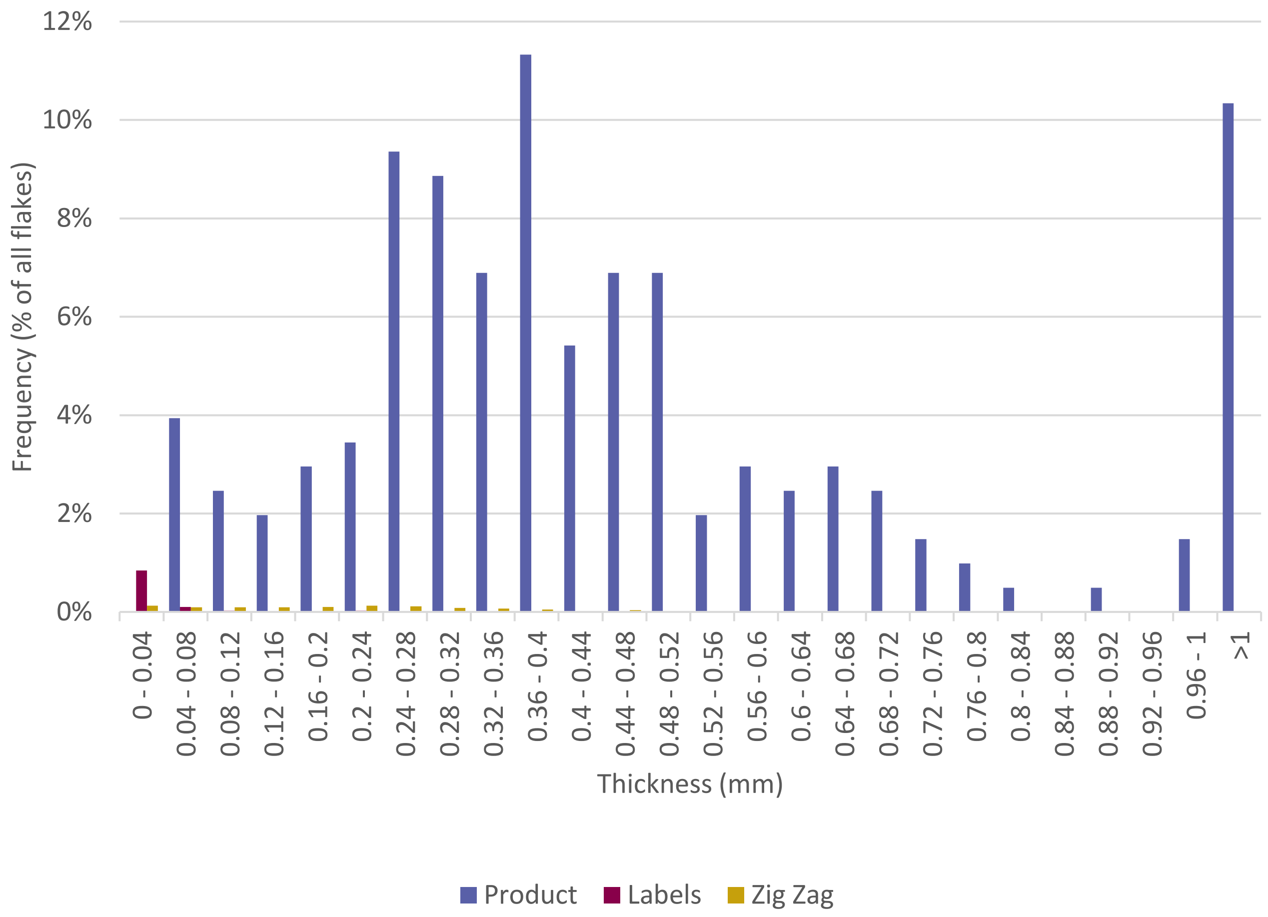

Figure 17 Distribution of flake thickness for all material scaled to the mass balance (PRF B)

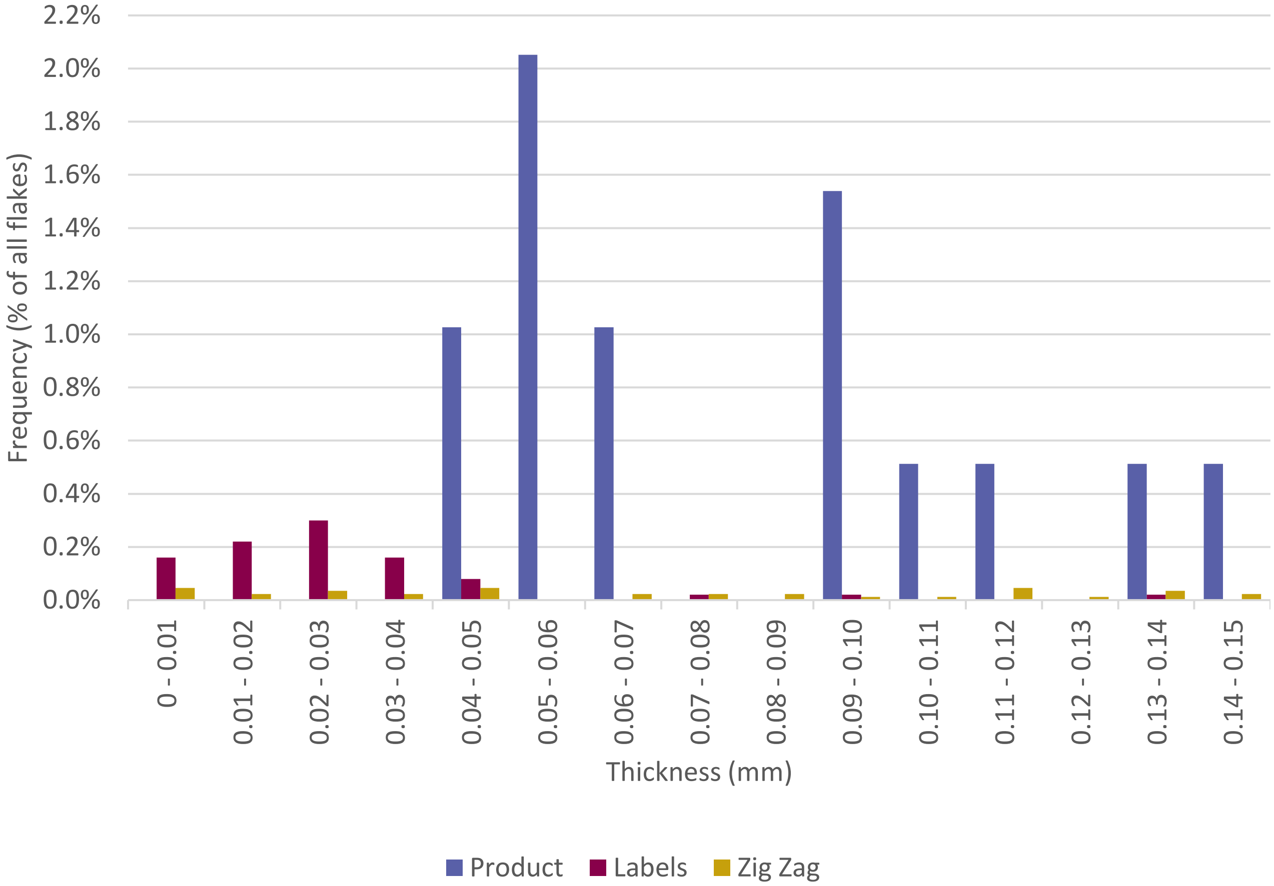

Figure 18 Distribution of flake thickness for all material scaled to the mass balance 0 - 0.15 mm only (PRF B)

As with PRF A, flake begins to appear in the product at a significant level at 0.05 mm. Below this, the material is recovered to the label fraction. Although the Zig Zag had a wide thickness distribution, because the mass flow is so low, the amount recovered to the product is far greater than the amount lost.

The data from PRF B correlates with the data from PRF A, and both suggest that providing the PET flakes are 0.05 mm or thicker they will report to the product stream.

The sampling and analysis at the PRF was limited to streams containing flakes (material >2mm). This means that if any material was broken down to below this size, it could not be analysed.

Analysis of material at the MRF showed that on average ≈2% of PET bottles had a thickness of <0.05 mm in the mid-section. The PRF analysis showed that on average ≈0.8% of flakes had a thickness of <0.05 mm. This difference is due to the fact that bottles do not have a uniform thickness. The top and bottom will be thicker than the mid-section. It is reasonable to assume that 60% of the bottle is >0.05 mm, and so the analysis suggests that all the lightweight material is recovered as a flake into one of the output streams rather than lost as dust.

3.5 Identification of minimum thickness for recycling

Using the qualitative and quantitative analyses, it appears that at the MRF sorting stage there is no requirement for a minimum thickness specification. Providing MRFs are designed with Near Infrared sorters on the 2D line, flat material should be recovered effectively.

From the surveys it appears, there is no issue for polyolefin recyclers in terms of material loss, and although the PET recyclers were confident there was no issue, sampling was still carried out as PET has seen light weighting to the lowest thickness.

At the PRF stage there does appear to be a point at which material is not recovered effectively, which is <0.05 mm. At this point, the flakes will behave more like a film and will be removed with the labels. However, only around 0.8% of flakes in the streams analysed were <0.05 mm, leading to a very low level of loss.

A thickness of 0.05 mm is very thin, and is very likely to be at the limits of current light weighting. It must also be kept in mind that the thickness of a bottle will vary along the profile, with thicker material at the top and bottom and thinner material in the middle. Therefore, even if a bottle has a midsection of < 0.05 mm thick, the top and bottom are likely to be >0.05 mm and will represent most of the mass of the packaging.

Therefore, a guidance for packaging specifiers would be to specify a PET bottle thickness of >0.05 mm to ensure the material is recovered effectively. For polyolefin packaging we recommend that the same minimum thickness should be used as guidance, as the PET plants have demonstrated this is the point at which flakes behave like a film.

The sampling focused on PET bottles. PET is also used in trays, however there is a known problem with the brittleness of trays leading to significant yield loss, and so this was excluded from the study. In the future when a PET tray recycling plant has been installed, it may be beneficial to repeat the analysis to determine if there is a minimum thickness requirement for PET trays that is different from bottles.

3.6 Feedback from European recyclers

Along with the UK based recyclers feedback was also gained from two large PET recyclers in Europe. The feedback was different from that given by the UK based recyclers. The main issues identified were:

- Difficulty in handling/feeding thin material leading to loss of productivity;
- Higher moisture levels in bales;
- Lower throughput due to lower bulk densities; and
- More fines generation from more brittle material

The issue of higher moisture levels was not one expressed by the UK recyclers. However, if material is thinner, it will still have the same surface area but a lower mass. Since moisture adheres to the surface, this means that the relative level of moisture will increase per kilogram of useful PET. In situations where there is more lightweight material, the moisture levels in a bale will likely be higher.

Although this does decrease the yield, it does not mean the PET is not getting recycled. It does however have a direct impact on the economics. One of the recyclers estimated that a decrease in 1% of yield could cost the recycler up to 15,000 Euros per month. This is therefore an economic argument rather than a technical argument.

The reduction of throughput also affects the economics rather than the technical recyclability of the material. All sorting and washing equipment works on a volumetric basis. Therefore, when bulk density is reduced through reducing the thickness of the material, the overall throughput will also be reduced. Since the operating cost will not have changed, the cost per tonne of product will have increased, reducing the potential profit margin.

Both this potential indirect reduction in yield and reduction in throughput lead to more challenging economics for the recyclers. However on a technical basis if the material is still being recycled, it would be hard to justify increasing material thickness, as this would lead to additional environmental impact.

Accounting for this economic impact is not straightforward, and it should probably be included in wider discussions on Extended Producer Responsibility (EPR) and how a system could be designed to reflect the true cost of recycling.

3.7 Feedback from PET wash line providers

In addition to surveying existing recyclers, conversations were also held with two of the main providers of PET wash plants in Europe. These have been referred to as Provider A and Provider B.

The feedback from Provider A echoed the European recyclers in terms of reduced throughput due to lower bulk density. Provider A estimated if 100% of material was “thin” then the capacity could drop to 60 – 70% of design capacity. This would be a highly unlikely scenario however, as carbonated drinks will never be light weighted to the extent of water bottles, and many brands would not lightweight past a certain point as it may change the feel and function of the packaging.

Provider A also commented that some thin material has a lower IV than the thicker bottles. If this is the case the lower IV material will behave more like trays and will be broken up into very fine dust. The PET recyclers in this project both also have relatively high levels of PET tray, with PRF A accepting up to 12% tray and PRF B accepting between 15 and 20% tray. Due to the inclusion of tray it is impossible to determine if the fines generation is from the trays or thin bottles. In addition, the mass balance data suggests that the bottle flake is getting recovered as flake rather than being broken down into dust.

Provider B had similar views to Provider A especially concerning the volumetric throughput issue although they did not raise the issue of fines generation. They commented that any system should be designed with the feed material in mind and if this is known, then a suitable system can be installed.

The design of the process is therefore vital. Any modern PET recycling facility should account for lightweight and brittle material and use techniques such as wet granulation, less aggressive friction washing and a combination of gentle mechanical and then thermal drying.

4.0 High level carbon benefit review

The analysis carried out in this project has shown that material thinner than.05 mm is not recycled effectively. However, there is the argument that at a certain point, the benefit from reducing raw material usage will outweigh the benefit of recycling the material. At a certain point it would therefore be more advantageous form a Life Cycle Assessment (LCA) point of view to lightweight rather than recycle.

Conducting a full LCA is not within the scope of this project, and instead a high-level carbon footprint comparison has been done to determine the level of weight reduction that is needed to justify not recycling the material. The comparison is based on a PET bottle.

Due to the high-level nature of the study, the information and data should only be used in this comparison and is not suitable for use in other studies.

4.1 Methodology

The comparison will be carried out between:

- A 0.05 mm thick "recyclable" PET bottle with 20% recycled content (post-consumer recyclate (PCR)) PET
- A "non-recyclable" PET bottle with 20% PCR
- A "non-recyclable" PET bottle with 0% PCR

The following method has been used to determine the reduction of mass required to justify creating a non-recyclable bottle:

- Set variables and obtain carbon footprint data
- Carry out a mass balance to model the flow of material at end of life
- Calculate the carbon footprint for a 0.05 mm thick bottle with 20% recycled content
- Determine the weight of a bottle that is not recycled, which would give the same carbon footprint

Carry out the comparison on "non-recyclable" bottles with 20% recycled content and 0% recycled content.

4.2 Assumptions and data

The following assumptions have been made for the study:

- All "non-recyclable" bottles are rejected at the PRF stage
- Impact from transport is excluded as this will be equivalent in all scenarios

Table 1 shows the variables used in the comparison and Table 2 shows the carbon emission data used.

Table 1 Variables used in footprinting comparison

Thin walled bottle weight (0.05 mm)	12g
% of bottles collected for recycling	58%
% of bottles not collected going to landfill	50%
% of bottles not collected going to incineration	50%
MRF recovery efficiency	90%
% MRF reject going to incineration	100%
PRF recycling efficiency	90%
% of PRF reject going to landfill	50%
% PRF reject going to incineration	50%

Table 2 Carbon footprint data used in comparison

Material/process	Carbon emission (kg CO_2 eq/kg)	Source/comments
Virgin PET	2.19	Plastics Europe
rPET	0.45	Alpa (recycler)[3]
Incineration with energy recovery	1.12	Axion first principles estimate
Landfill	0	No breakdown of plastic in landfill and negligible impact from landfill operation

4.3 Results

Figure 19 shows the mass balance on which the comparison has been based.

[3] https://www.alpla.com/en/press-releases/08-2017/study-confirms-the-excellent-carbon-footprint-of-recycled-pet

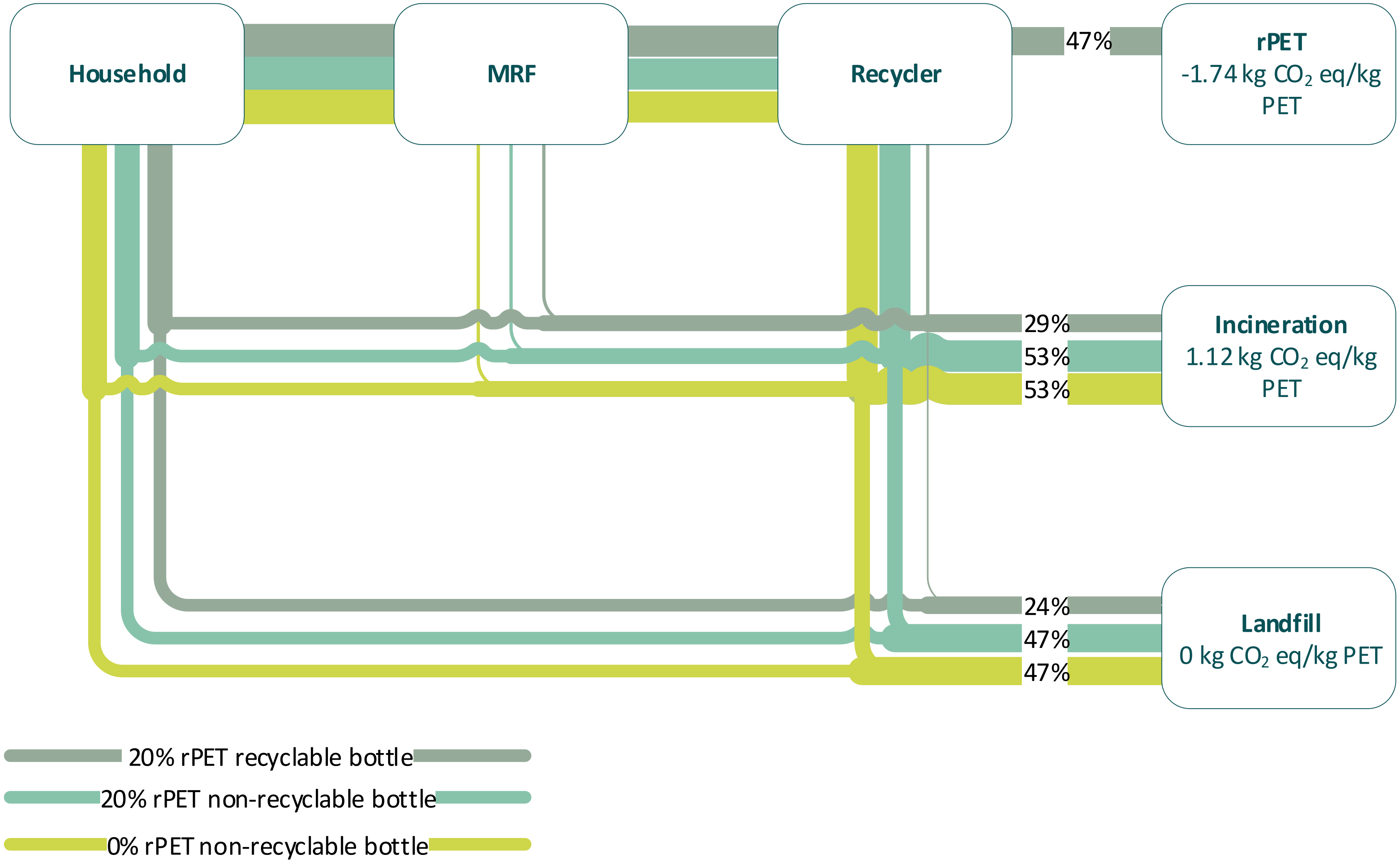

Figure 19 Mass flow of PET bottles at end of life

Using the assumptions and variables shown in Table 1 and Table 2, the carbon footprint for the 0.05 mm thick recyclable bottle with 20% PCR is 16.2 g CO_2 eq. In order for a "non-recyclable" bottle with 20% PCR to have the same footprint, the weight would have to be reduced by 44% to 6.7 g from 12 g. IF the non-recyclable bottle does not have any PCR, then the weight reduction would have to be greater at 51% in order to maintain the same impact.

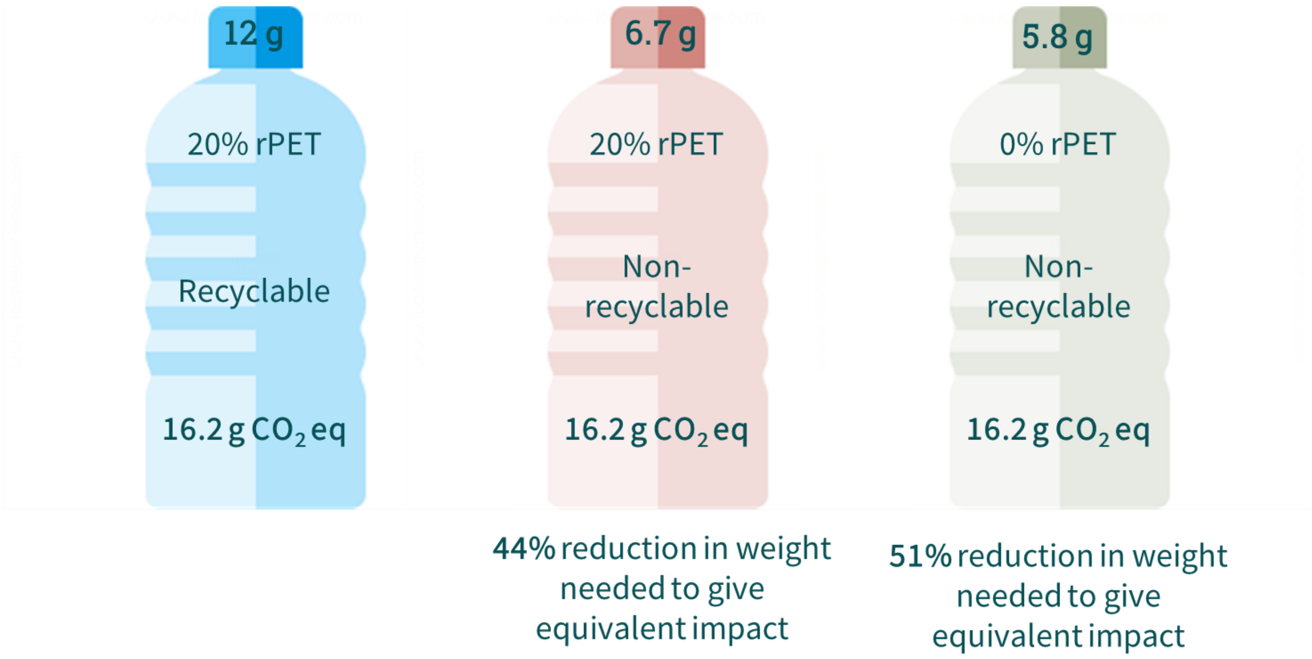

Figure 20 Graphic demonstrating bottle weight for the same carbon footprint

Therefore, in order to justify light weighting a bottle beyond 5 mm thick, the bottle must be 44 – 51% lighter than the same bottle would be at 5 mm thick. If this level of light weighting cannot be achieved, then it would be better from an LCA perspective to ensure the bottle meets the 0.05 mm thickness criteria, so it can be recycled.

This analysis depends on the variables and assumptions used, and would change if factors such as collection rate increased or decreased. If collection rate increases, it would mean more bottles would reach the MRF, and light weighting would have to be greater than already estimated, to maintain the same impact.

5.0 Conclusions

The study has shown that sorting at the MRF is not being negatively impacted by the light weighting of rigid packaging in the UK.

The quantitative analysis shows that recovery of PET flakes <0.05 mm is not effective, and in order to be recycled material should be 0.05 mm or thicker. Although there was no perceived issue for polyolefin recyclers, it is suggested the same minimum thickness be used as the evidence shows it is at this point that the material will be removed with films/labels.

Due to the lack of PET tray recycling infrastructure and the already known issues with the brittle nature of the material, the study has focused on bottles. Once a dedicated tray recycling facility has been established, the study could be repeated to determine if the minimum thickness for trays is different than for bottles.

Recyclers in Europe and wash line providers have expressed that the light weighting of packaging will lead to a reduction in throughput due to the fact the equipment works on a volumetric basis, and thinner, lighter material will have a lower bulk density. In addition to this, the thinner material will have a higher surface area to mass ratio, meaning overall levels of moisture and contamination may be higher in bales with thin material

This reduction in yield and throughput will have an effect on the economics of recycling thin and lightweight material. Although it does not prevent recycling on a technical level, it does increase the cost of recycling the material and reduces the margin for the recyclers. This is an economic challenge that is not straightforward to address and should be considered more widely in an improved Extended Producer Responsibility (EPR) system that reflects the true cost of recycling.

To recycle PET effectively and reduce loss in yield from fines generation, techniques such as wet granulation, less aggressive friction washing, and a combination of mechanical and thermal drying should be used to reduce the mechanical force acting on the polymer.

The high-level carbon footprint comparison showed that in order to justify reducing the thickness of a PET bottle beyond 0.05 mm, a weight reduction of 44% - 51%[4] is required.

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[4] 44% reduction in weight is required if 20% PCR is used in the bottle and 51% reduction is required is 0% PCR is included