

Avantium – Sortability of PEF bottles



Lieuwe Hendrik Lei

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Avantium – Sortability of PEF bottles

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Abstract

Avantium requested a sortability trial of 7 different PEF samples. PEF (Polyethylene Furanoate) is a 100% recyclable, bio-based polymer produced using renewable raw materials derived from plants. It shows similar characteristics as PET and could potentially be a replacer for PET. Three scenarios are considered: 1) the sortability of PEF in a current Dutch sorting facility, 2) the sortability of PEF when PEF is coupled with the PET spectrum and 3) the sortability when PEF is treated as a separated sorting stream.

In total 7 PEF samples have been assessed on their sortability behaviour. The main conclusions based on this test are:

- Samples PEF-2 up to PEF-6 are very well identified as PEF and can correctly be sorted. Therefore, it is essential that the PEF spectrum is added to a sorting program.
- In case the PEF spectrum is not added, samples PEF-2 up to PEF-6 are not identified meaning that these items end up in the residue stream. This stream goes to incineration.
- Adding the PEF spectrum to a sorting program does not lead to additional missorting of HDPE and PP rigid items.
- The PEF-spectrum can be combined with the PET stream or it can be treated as a separate PEF stream. Both options show similar sorting behaviour. The effect on recyclate levels and quality for both scenarios is not in scope for this research.
- Sample PEF-1 is a multilayer of PET and PEF. The optical sorter only penetrates the first PET layer and therefore is identified as PET.
- Sample PEF-1 up to PEF-6 are partly crushed after compression. PEF-7 is hard to compress and maintains its shape. Due to cylindrical shape, it easily rolls over the conveyer belt.
- This complicates the sortability of sample PEF-7. Only around 50% end up in the intended stream. Around a quarter go to the residue stream.
- Improving the sortability of PEF-7 can be realized by its compression characteristics. By making it a larger bottle, decrease the wall thickness such that it is easier to compress, or changing its shape; each change will minimize the rolling over the belt.

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1 Introduction

1.1 Avantium

Avantium develops and commercialises innovative chemistry technologies across industry value chains to produce chemicals and materials based on renewable feedstock instead of fossil resources. Avantium also provides R&D solutions in the field of sustainable chemistry and is the leading provider of advanced catalyst testing technology and services to accelerate catalyst R&D. Avantium is headquartered in Amsterdam with R&D laboratories and pilot plants in Geleen and Delfzijl.

1.2 NTCP

The National Test centre for Circular Plastics (NTCP) in Heerenveen (The Netherlands) was established in 2018 to facilitate the development of sorting and washing of the different plastic streams from municipal waste. A pilot scale sorting line, representative for European plastic sorting centers, fully customized for test- and research, is available to support the development of more efficient plastic recycling. This is done by facilitating the design process (support design for recyclability), facilitating technology development (real life testing of the process on pilot scale) and the development of data-driven decision models for sorting. Since November 2022 a pilot scale washing line including industrial size equipment for all relevant polymers out of MSW, fully developed for test- and research, is also operational.



Figure 1 Pilot scale sorting line at NTCP.

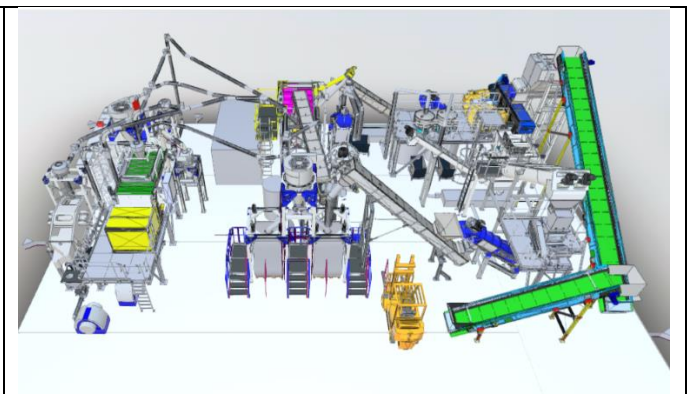


Figure 2 Washing facility for all relevant plastic types at NTCP

1.3 Background

PEF (Polyethylene Furanoate) is a 100% recyclable, bio-based polymer produced using renewable raw materials derived from plants. It shows similar characteristics as PET and could potentially be a replacer for PET. Avantium has an interest in the dynamic sortability of PEF. Avantium would like to test 7 different type of PEF samples, see **Error! Reference source not found.**

Sample	Sample type	Volume
PEF-1	Bottle – PET/10%PEF/PET	500 ml
PEF-2	Bottle – 100% PEF	237 ml
PEF-3	Cup – 100% PEF	
PEF-4	Bottle – 100% PEF – toned	237 ml
PEF- 5	Bottle – 100% PEF – toned	500 ml
PEF-6	Juice bottle – 100%PEF	330 ml
PEF-7	Wine bottle – 100% PEF green	187 ml

In this sortability trial, 3 situations are compared.

- 1) Check the sortability of PEF in the current situation.
- 2) Couple the NIR spectrum of PEF with the spectrum of PET. When sorting on PET, it results in a mixed stream of PEF and PET
- 3) Have a separate sorting program for PEF,

The mixed plastic stream is for situation 2 and 3 extended with the PEF spectrum. Those situations are considered for all 7 samples .

1.4 Objective(s)

The objective of this trial is:

- Evaluation of the sortability of multiple PEF SKUs following the RecyClass protocol including simulation of consumer use, collection, and transport. This evaluation should also include a detailed optical sorter analysis, where our optical sorter is extended with a specific program for PEF.
- Evaluation based on an optical sorter analysis on the sortability of HDPE and rigid PP when the PEF spectrum is added to the sorting program. This provides an insight in which extend the coupling of PEF to the PET spectrum could lead to additional contamination of other plastics/

During the trial, multiple persons representing Afvalfonds Verpakkingen and KIDV are attending the trials to be involved in the sortability of PEF.

2 Experimental approach

2.1 Sortability

For the sortability of the crisp bags, the following steps will be taken:

1. Detailed optical sorter analysis
2. Consumer usage simulation (e.g. product residue)
3. Collection and transport simulation (contamination and compression)
4. Sortability trial

2.2 Optical sorter analysis

The optical sorting process consist out of four elements as shown in Figure 2. For a packaging material to be sortable it needs to pass all four steps. During the optical sorter analysis, the first three steps of the optical sorter sorting process are evaluated. Moreover, Figure 3 provides a visual representation of the optical sorting process.

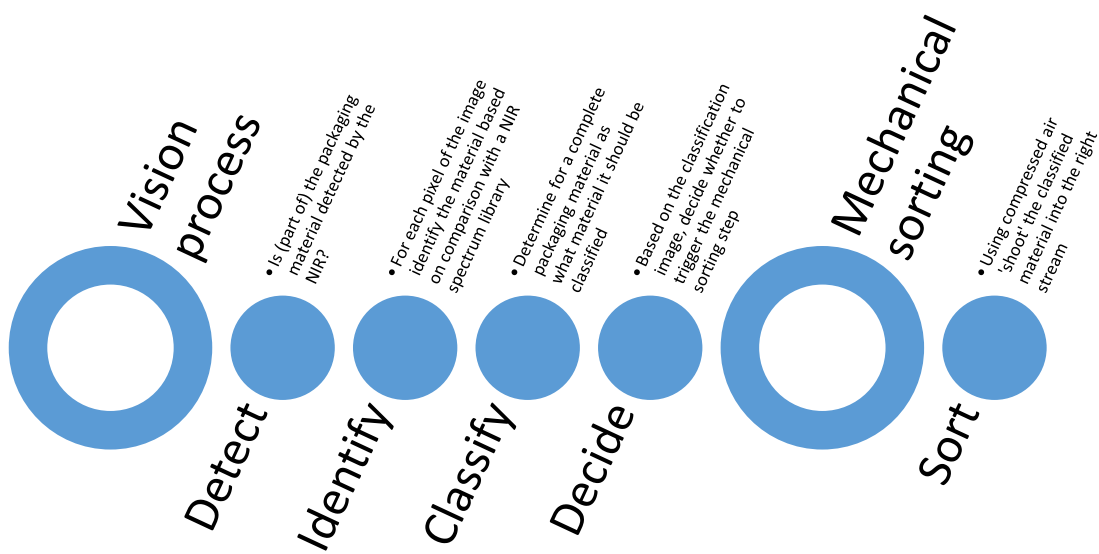


Figure 2 Elements of an industrial NIR optical sorting process.

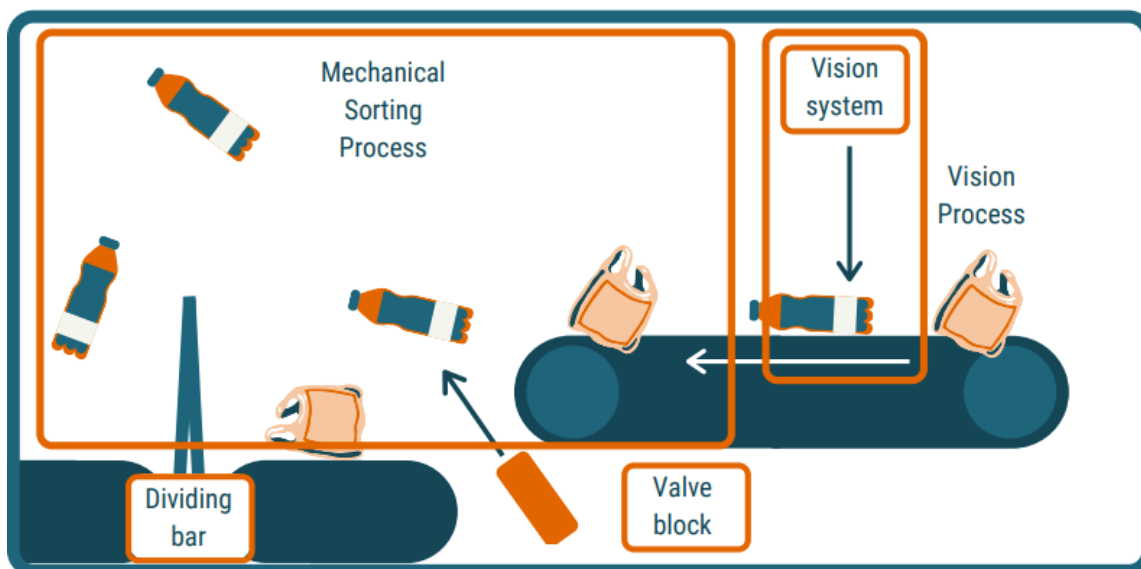


Figure 3 Visual representation of an industrial NIR optical sorting process

Each individual SKU is analysed with respect to detection, identification, classification and sorting in an industrial optical sorter. The used optical sorter is the Steinert Unisort PCM1000RF. It is equipped with a NIR (Near-Infrared) hyperspectral camera and an RGB camera.

With the use of our custom developed software, we perform sequencing scans of the SKUs. These scans result in a classification image, a colour image, and a decision image. Additionally, the optical sorter gives the possibility to extract the NIR spectra of the selected area (Figure 4).

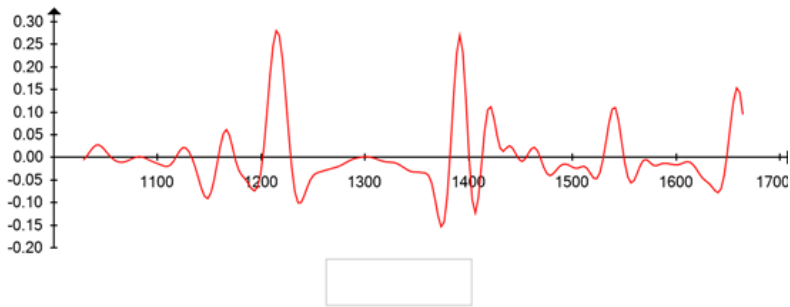


Figure 4 Example of an optical sorter NIR spectrum (intensity vs. wavelength in nm).

The classification image, the colour image and decision image are explained below:

- **Classification image:** visual representation of the identification of each pixel from the scanned product. Figure 5 shows the colour assignment for the detected material for standard program.
- **Colour image:** Picture taken by the RGB camera.
- **Decision image:** The programme shows the spectra of a selected area. Each colour represents a specific material category. The image is the result of the classification image after data processing. For example, the optical sorter recognizes that an individual product is made of PP when a 70% of the pixels in the classification image is identified as PP.

 PP-3D	 Paper/card
 PP-2D	 Cellulose
 PE-3D	 PVC
 PE-2D	 EPS
 PET-bottle	 Other plastics
 PET-tray	 Textiles
 PS	 NI
 TETRA	 Metall

Figure 5 Colour assignment for material categories as used by the NIR optical sorter on the standard programme

New or different spectra can be added to the library of the optical sorter in order to identify different (new) materials as well. Furthermore, the acceptance criteria can be set separately. For instance, instead of using a limit of 70% PP to consider the material as PP we can increase this value to get a purer stream.

Note, that these decision-making processes can have further conditions than the ones mentioned above. The development of such processes is dependent on the sorting goals and outside the scope of this project.

In this study we used a standard program for the sorting task:

- Plastics sorting program (belt speed 3 m/s).

It should be noted that the final decision on triggering the sorting step is programmed by the optical sorter manufacturer in such a way that the required stream quality is reached and intended objects for that stream are as much as possible sorted in that stream. Therefore, the translation from classification image to decision image is not just looking at the material percentages. The detailed calculation is proprietary to the optical sorter manufacturer.

2.3 Consumer usage simulation

For each SKU, we make an estimate of how the SKU is used by the consumer before disposal. This can be different for each SKU. For the SKU's in this study, we make the following assumptions:

- The SKU's will not contain residual product. They will be thrown away without cap.

2.4 Collection and transport simulation

This step mimics the contamination and compression of the packaging that would normally occur during collection transport, and storage. Pictures before contamination, after contamination, and after compression will provide an indication of the effect of collection and transport on the appearance of the packaging.

1. 50 pieces of the SKU were compressed, together with PMD waste, in a baling press with a compression rate of 1/5;
2. the SKU was contaminated with fines (manly organic material) in a concrete mixer to simulate friction and contamination;
3. the SKU was compressed again in the baling press with a compression rate of 1/5;

Steps 1 and 2 simulate the compression and contamination in a dumpster truck that picks up the waste. Step 3 simulates the dumping and the transport to the sorting installation.

2.5 Sortability trial

During a sorting test, 50 pieces of each SKUs are exposed to all sorting steps that are typical in an industrial sorting facility. To mimic a real sorting line, the SKUs are added to a real PMD waste stream. Figure 6 shows an overview of the steps in the sorting process, based on a Dutch sorting facility. The ballistic separator divides the streams into 2D and 3D, the 3D fraction moves on to the optical sorter cascade. Note, that sorting efficiency is determined for each step separately for at least 50 objects (they may pass multiple times) which enable the simulation of different sorting plants. In addition to the current process the situation the situation is shown when PEF is sorted together with PET (Figure 7) and where PEF is sorted separately (Figure 8).

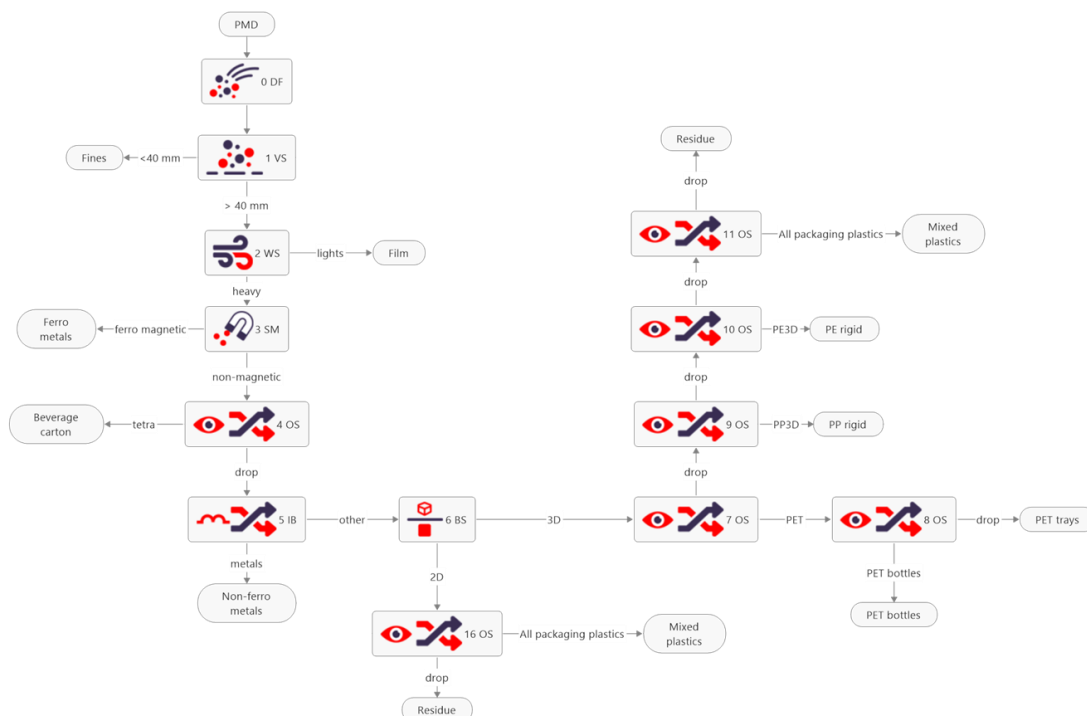


Figure 6 Schematics of a typical sorting process of a Dutch sorting facility; the actual categories may differ per country or location.

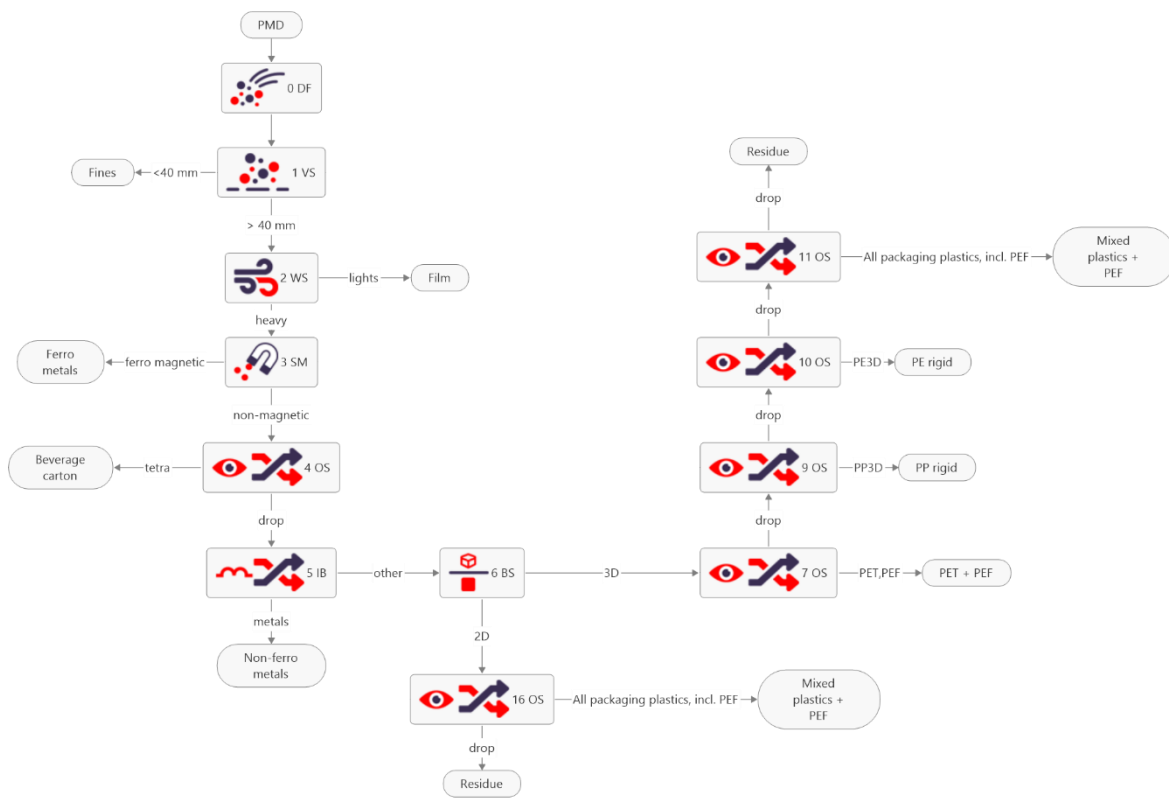


Figure 7 Schematics of a typical sorting process of a Dutch sorting facility when PEF is sorted together with PET. Additional sorting in trays and bottles is not displayed here.

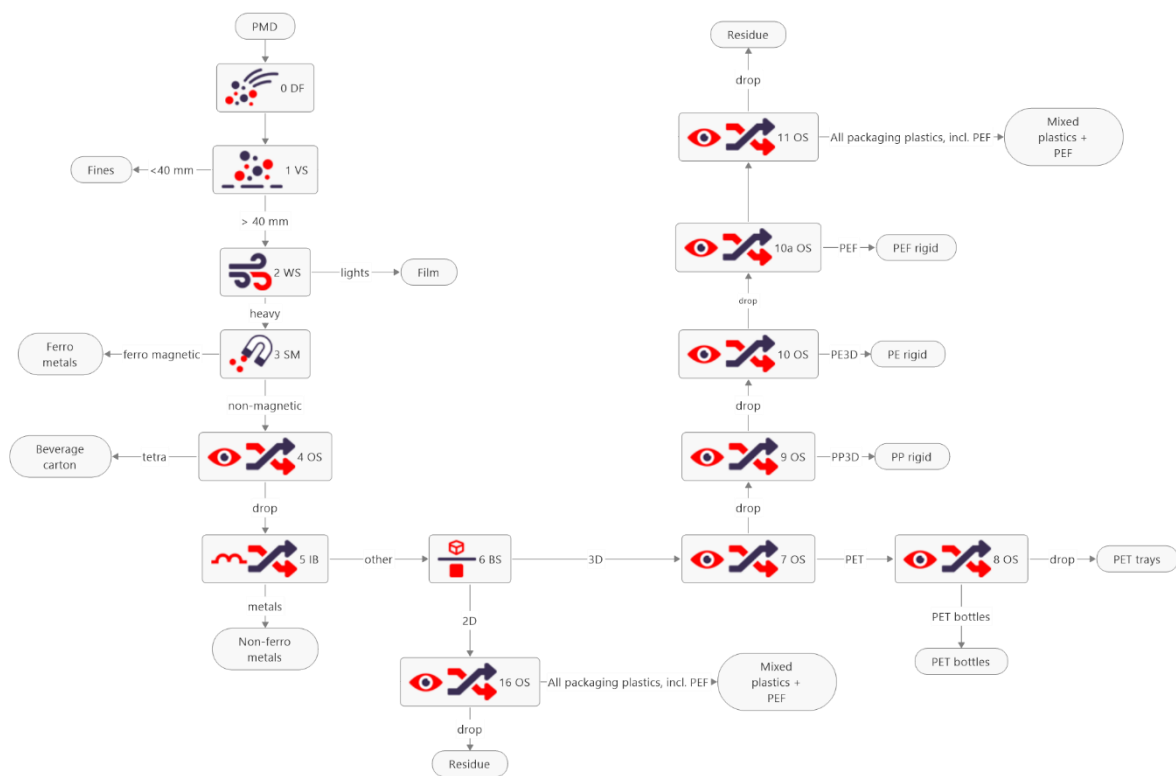



Figure 8 Schematics of a typical sorting process of a Dutch sorting facility when PEF is sorted separately.


3 Results


3.1 Sortability assessment


3.1.1 SKU description


In the tables below the SKUs are described:


500 ml bottle multilayer PET/10%PEF/PET		
Producer: Avantium		
Brand:		
EAN: N/A		
Material	Multilayer PET/10%PEF/PET	
Mass (g)		
Colour	Transparent clear	
Use	Bottle	
Remarks	PEF-1	


237ml bottle 100% PEF bottle		
Producer: Avantium		
Brand:		
EAN: N/A		
Material	PEF	
Mass (g)		
Colour	Transparent clear	
Use	Bottle	
Remarks	PEF-2	

PEF cup		
Producer: Avantium		
Brand:		
EAN: N/A		
Material	PEF	
Mass (g)		
Colour	Transparent clear	
Use	Cup	
Remarks	PEF-3	

237ml bottle toned 100% PEF		
Producer: Avantium		
Brand:		
EAN: N/A		
Material	PEF	
Mass (g)		
Colour	Transparent clear	
Use	Bottle	
Remarks	PEF-4	

500ml bottle toned 100% PEF		
Producer: Avantium		
Brand:		
EAN: N/A		
Material	PEF	
Mass (g)		
Colour	Transparent clear	
Use	Bottle	
Remarks	PEF-5	

330 ml juice bottle 100% PEF		
Producer: Avantium		
Brand:		
EAN: N/A		
Material	PEF	
Mass (g)		
Colour	Transparent clear	
Use	Juice bottle	
Remarks	PEF-6	

187 ml green wine bottle 100% PEF		
Producer: Avantium		
Brand:		
EAN: N/A		
Material	PEF	
Mass (g)		
Colour	Transparent green	
Use	Wine bottle	
Remarks	PEF-7	

3.1.2 Optical sorter program

To be able to sort on PEF, our optical sorter is extended with a sorting program including the PEF spectrum. Together with Steinert, scans have been made of SKU-2 (237ml bottle 100% PEF bottle) and are used to set-up a separate sorting program. Figure 9 shows the NIR-spectrum of PEF.

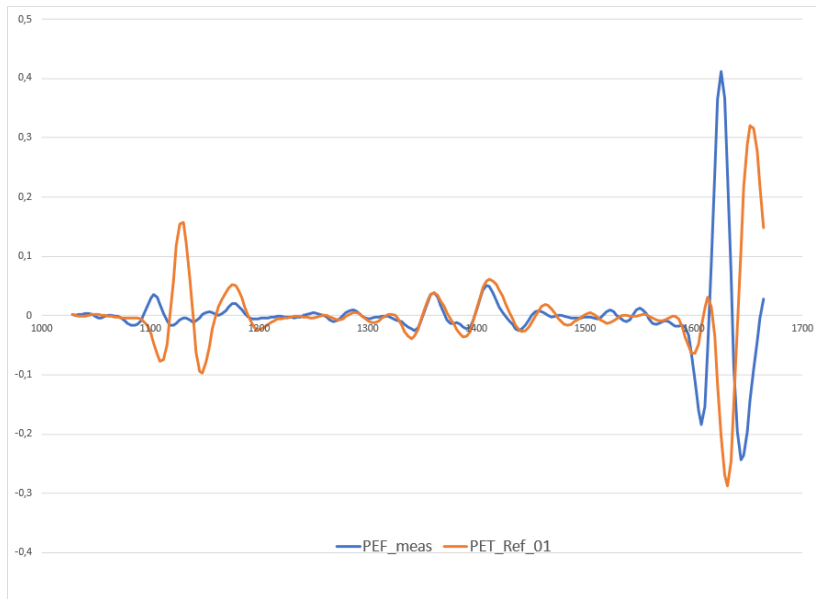


Figure 9 NIR spectrum of PEF (intensity vs. wavelength in nm) where the PET spectrum is included as a comparison.

3.1.3 Optical sorter analysis

During the optical sorter analyses, each sample was scanned using the new developed sorting program that includes PEF. It also contains PET colour sorting. This is typically used in Belgian sorting facilities where PET bottles are sorted on colour. Translating this to Dutch sorting facilities, it is seen as a PET-bottle. Table 1 up to Table 7 displays the results of the optical sorter analysis of each SKU.

Table 1 Optical sorter analysis of PEF-1 (500 ml bottle multilayer PET/10%PEF/PET)



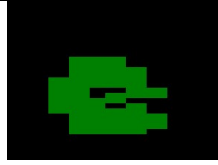
Scan #	Description	RGB	Identification	Decision	Classified as																																																					
1	Scan in color program inc. PEF				PET-Bottle (light blue)																																																					
	Material distribution classification image in scan	<table border="1"> <thead> <tr> <th colspan="2">Materialverteilung</th> <th colspan="2">Reflektion</th> <th colspan="2">PET-opak</th> </tr> </thead> <tbody> <tr> <td>PEF</td> <td>0 px 0.0 %</td> <td>Reflektion</td> <td>0 px 0.0 %</td> <td>PET-opaque</td> <td>19 px 5.2 %</td> </tr> <tr> <td>PS</td> <td>0 px 0.0 %</td> <td>Windel</td> <td>0 px 0.0 %</td> <td>PET-T-color</td> <td>1 px 0.3 %</td> </tr> <tr> <td>TETRA</td> <td>0 px 0.0 %</td> <td>Textile</td> <td>45 px 12.2 %</td> <td>PET-T-clear</td> <td>2 px 0.5 %</td> </tr> <tr> <td>PPK</td> <td>0 px 0.0 %</td> <td>EPS</td> <td>0 px 0.0 %</td> <td>PET-B-blue</td> <td>13 px 3.5 %</td> </tr> <tr> <td>Cellulose</td> <td>0 px 0.0 %</td> <td>PP_3D</td> <td>0 px 0.0 %</td> <td>PET-B-color</td> <td>0 px 0.0 %</td> </tr> <tr> <td>PVC</td> <td>0 px 0.0 %</td> <td>PP_2D</td> <td>0 px 0.0 %</td> <td>PET-B-clear</td> <td>123 px 33.4 %</td> </tr> <tr> <td>Andere KS</td> <td>10 px 2.7 %</td> <td>PE_3D</td> <td>0 px 0.0 %</td> <td>PET-B-light blue</td> <td>122 px 33.2 %</td> </tr> <tr> <td>NI</td> <td>2 px 0.5 %</td> <td>PE_2D</td> <td>0 px 0.0 %</td> <td>PET-B-light green</td> <td>31 px 8.4 %</td> </tr> </tbody> </table>				Materialverteilung		Reflektion		PET-opak		PEF	0 px 0.0 %	Reflektion	0 px 0.0 %	PET-opaque	19 px 5.2 %	PS	0 px 0.0 %	Windel	0 px 0.0 %	PET-T-color	1 px 0.3 %	TETRA	0 px 0.0 %	Textile	45 px 12.2 %	PET-T-clear	2 px 0.5 %	PPK	0 px 0.0 %	EPS	0 px 0.0 %	PET-B-blue	13 px 3.5 %	Cellulose	0 px 0.0 %	PP_3D	0 px 0.0 %	PET-B-color	0 px 0.0 %	PVC	0 px 0.0 %	PP_2D	0 px 0.0 %	PET-B-clear	123 px 33.4 %	Andere KS	10 px 2.7 %	PE_3D	0 px 0.0 %	PET-B-light blue	122 px 33.2 %	NI	2 px 0.5 %	PE_2D	0 px 0.0 %	PET-B-light green
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Observations:

- The sample is detected and recognized as PET-bottle (light-blue). Translating this to a Dutch sorting facility, it is classified as a PET-bottle. There is no identification of PEF, which means that the optical sorter does not penetrate through the first PET layer. In case of a thinner outer PET-layer, it could be possible that PEF is identified. In that case, the identification is a mix of PEF and PET.

Table 2 Optical sorter analysis of PEF-2 (237ml bottle toned 100% PEF)

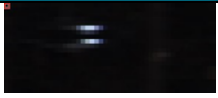


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	NI	1 px	0.6 %		PE_2D	0 px	0.0 %		PET-B-light green	0 px	0.0 %																																																																																															

Observations:

- The sample is detected and recognized as PEF. No further observations can be made.

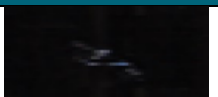


Table 3 Optical sorter analysis of PEF-3 (PEF cup)

Scan #	Description	RGB	Identification	Decision	Classified as																																																																																																					
1	Scan in color program inc. PEF				PEF																																																																																																					
	Material distribution classification image in scan	<table border="0"> <tr> <td colspan="6">Materialverteilung</td> </tr> <tr> <td></td> <td>PEF</td> <td>116 px</td> <td>97.5 %</td> <td></td> <td>Reflektion</td> <td>3 px</td> <td>2.5 %</td> <td></td> <td>PET-opaque</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>PS</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>Windel</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-T-color</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>TETRA</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>Textile</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-T-clear</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>PPK</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>EPS</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-blue</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>Cellulose</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PP_3D</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-color</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>PVC</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PP_2D</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-clear</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>Andere KS</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PE_3D</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-light blue</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>NI</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PE_2D</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-light green</td> <td>0 px</td> <td>0.0 %</td> </tr> </table>				Materialverteilung							PEF	116 px	97.5 %		Reflektion	3 px	2.5 %		PET-opaque	0 px	0.0 %		PS	0 px	0.0 %		Windel	0 px	0.0 %		PET-T-color	0 px	0.0 %		TETRA	0 px	0.0 %		Textile	0 px	0.0 %		PET-T-clear	0 px	0.0 %		PPK	0 px	0.0 %		EPS	0 px	0.0 %		PET-B-blue	0 px	0.0 %		Cellulose	0 px	0.0 %		PP_3D	0 px	0.0 %		PET-B-color	0 px	0.0 %		PVC	0 px	0.0 %		PP_2D	0 px	0.0 %		PET-B-clear	0 px	0.0 %		Andere KS	0 px	0.0 %		PE_3D	0 px	0.0 %		PET-B-light blue	0 px	0.0 %		NI	0 px	0.0 %		PE_2D	0 px	0.0 %		PET-B-light green	0 px
Materialverteilung																																																																																																										
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	PS	0 px	0.0 %		Windel	0 px	0.0 %		PET-T-color	0 px	0.0 %																																																																																															
	TETRA	0 px	0.0 %		Textile	0 px	0.0 %		PET-T-clear	0 px	0.0 %																																																																																															
	PPK	0 px	0.0 %		EPS	0 px	0.0 %		PET-B-blue	0 px	0.0 %																																																																																															
	Cellulose	0 px	0.0 %		PP_3D	0 px	0.0 %		PET-B-color	0 px	0.0 %																																																																																															
	PVC	0 px	0.0 %		PP_2D	0 px	0.0 %		PET-B-clear	0 px	0.0 %																																																																																															
	Andere KS	0 px	0.0 %		PE_3D	0 px	0.0 %		PET-B-light blue	0 px	0.0 %																																																																																															
	NI	0 px	0.0 %		PE_2D	0 px	0.0 %		PET-B-light green	0 px	0.0 %																																																																																															

Observations:

- The sample is detected and recognized as PEF. No further observations can be made.

Table 4 Optical sorter analysis of PEF-4 (237ml bottle toned 100% PEF)

Scan #	Description	RGB	Identification	Decision	Classified as																																																																																																					
1	Scan in color program inc. PEF				PEF																																																																																																					
	Material distribution classification image in scan	<table border="0"> <tr> <td colspan="6">Materialverteilung</td> </tr> <tr> <td></td> <td>PEF</td> <td>172 px</td> <td>98.3 %</td> <td></td> <td>Reflektion</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-opaque</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>PS</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>Windel</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-T-color</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>TETRA</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>Textile</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-T-clear</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>PPK</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>EPS</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-blue</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>Cellulose</td> <td>2 px</td> <td>1.1 %</td> <td></td> <td>PP_3D</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-color</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>PVC</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PP_2D</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-clear</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>Andere KS</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PE_3D</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-light blue</td> <td>0 px</td> <td>0.0 %</td> </tr> <tr> <td></td> <td>NI</td> <td>1 px</td> <td>0.6 %</td> <td></td> <td>PE_2D</td> <td>0 px</td> <td>0.0 %</td> <td></td> <td>PET-B-light green</td> <td>0 px</td> <td>0.0 %</td> </tr> </table>				Materialverteilung							PEF	172 px	98.3 %		Reflektion	0 px	0.0 %		PET-opaque	0 px	0.0 %		PS	0 px	0.0 %		Windel	0 px	0.0 %		PET-T-color	0 px	0.0 %		TETRA	0 px	0.0 %		Textile	0 px	0.0 %		PET-T-clear	0 px	0.0 %		PPK	0 px	0.0 %		EPS	0 px	0.0 %		PET-B-blue	0 px	0.0 %		Cellulose	2 px	1.1 %		PP_3D	0 px	0.0 %		PET-B-color	0 px	0.0 %		PVC	0 px	0.0 %		PP_2D	0 px	0.0 %		PET-B-clear	0 px	0.0 %		Andere KS	0 px	0.0 %		PE_3D	0 px	0.0 %		PET-B-light blue	0 px	0.0 %		NI	1 px	0.6 %		PE_2D	0 px	0.0 %		PET-B-light green	0 px
Materialverteilung																																																																																																										
	PEF	172 px	98.3 %		Reflektion	0 px	0.0 %		PET-opaque	0 px	0.0 %																																																																																															
	PS	0 px	0.0 %		Windel	0 px	0.0 %		PET-T-color	0 px	0.0 %																																																																																															
	TETRA	0 px	0.0 %		Textile	0 px	0.0 %		PET-T-clear	0 px	0.0 %																																																																																															
	PPK	0 px	0.0 %		EPS	0 px	0.0 %		PET-B-blue	0 px	0.0 %																																																																																															
	Cellulose	2 px	1.1 %		PP_3D	0 px	0.0 %		PET-B-color	0 px	0.0 %																																																																																															
	PVC	0 px	0.0 %		PP_2D	0 px	0.0 %		PET-B-clear	0 px	0.0 %																																																																																															
	Andere KS	0 px	0.0 %		PE_3D	0 px	0.0 %		PET-B-light blue	0 px	0.0 %																																																																																															
	NI	1 px	0.6 %		PE_2D	0 px	0.0 %		PET-B-light green	0 px	0.0 %																																																																																															

Observations:

- The sample is detected and recognized as PEF. No further observations can be made.

Table 5 Optical sorter analysis of PEF-5 (500ml bottle toned 100% PEF)

Scan #	Description	RGB	Identification	Decision	Classified as																																																																																																						
1	Scan in color program inc. PEF				PEF																																																																																																						
	Material distribution classification image in scan	<table border="1"> <thead> <tr> <th colspan="2">Materialverteilung</th> <th></th> <th></th> <th></th> <th></th> </tr> </thead> <tbody> <tr> <td>PEF</td> <td>194 px</td> <td>97,5 %</td> <td>Reflektion</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>PS</td> <td>0 px</td> <td>0,0 %</td> <td>Windel</td> <td>2 px</td> <td>1,0 %</td> </tr> <tr> <td>TETRA</td> <td>0 px</td> <td>0,0 %</td> <td>Textile</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>PPK</td> <td>0 px</td> <td>0,0 %</td> <td>EPS</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>Cellulose</td> <td>0 px</td> <td>0,0 %</td> <td>PP_3D</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>PVC</td> <td>0 px</td> <td>0,0 %</td> <td>PP_2D</td> <td>1 px</td> <td>0,5 %</td> </tr> <tr> <td>Andere KS</td> <td>0 px</td> <td>0,0 %</td> <td>PE_3D</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>NI</td> <td>2 px</td> <td>1,0 %</td> <td>PE_2D</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-opaque</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-T-color</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-T-clear</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-blue</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-color</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-clear</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-light blue</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-light green</td> <td>0 px</td> <td>0,0 %</td> </tr> </tbody> </table>				Materialverteilung						PEF	194 px	97,5 %	Reflektion	0 px	0,0 %	PS	0 px	0,0 %	Windel	2 px	1,0 %	TETRA	0 px	0,0 %	Textile	0 px	0,0 %	PPK	0 px	0,0 %	EPS	0 px	0,0 %	Cellulose	0 px	0,0 %	PP_3D	0 px	0,0 %	PVC	0 px	0,0 %	PP_2D	1 px	0,5 %	Andere KS	0 px	0,0 %	PE_3D	0 px	0,0 %	NI	2 px	1,0 %	PE_2D	0 px	0,0 %				PET-opaque	0 px	0,0 %				PET-T-color	0 px	0,0 %				PET-T-clear	0 px	0,0 %				PET-B-blue	0 px	0,0 %				PET-B-color	0 px	0,0 %				PET-B-clear	0 px	0,0 %				PET-B-light blue	0 px	0,0 %				PET-B-light green	0 px	0,0 %
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TETRA	0 px	0,0 %	Textile	0 px	0,0 %																																																																																																						
PPK	0 px	0,0 %	EPS	0 px	0,0 %																																																																																																						
Cellulose	0 px	0,0 %	PP_3D	0 px	0,0 %																																																																																																						
PVC	0 px	0,0 %	PP_2D	1 px	0,5 %																																																																																																						
Andere KS	0 px	0,0 %	PE_3D	0 px	0,0 %																																																																																																						
NI	2 px	1,0 %	PE_2D	0 px	0,0 %																																																																																																						
			PET-opaque	0 px	0,0 %																																																																																																						
			PET-T-color	0 px	0,0 %																																																																																																						
			PET-T-clear	0 px	0,0 %																																																																																																						
			PET-B-blue	0 px	0,0 %																																																																																																						
			PET-B-color	0 px	0,0 %																																																																																																						
			PET-B-clear	0 px	0,0 %																																																																																																						
			PET-B-light blue	0 px	0,0 %																																																																																																						
			PET-B-light green	0 px	0,0 %																																																																																																						

Observations:

- The sample is detected and recognized as PEF. No further observations can be made.

Table 6 Optical sorter analysis of PEF-6 (330 ml juice bottle 100% PEF)

Scan #	Description	RGB	Identification	Decision	Classified as																																																																																																						
1	Scan in color program inc. PEF				PEF																																																																																																						
	Material distribution classification image in scan	<table border="1"> <thead> <tr> <th colspan="2">Materialverteilung</th> <th></th> <th></th> <th></th> <th></th> </tr> </thead> <tbody> <tr> <td>PEF</td> <td>188 px</td> <td>99,5 %</td> <td>Reflektion</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>PS</td> <td>0 px</td> <td>0,0 %</td> <td>Windel</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>TETRA</td> <td>0 px</td> <td>0,0 %</td> <td>Textile</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>PPK</td> <td>0 px</td> <td>0,0 %</td> <td>EPS</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>Cellulose</td> <td>0 px</td> <td>0,0 %</td> <td>PP_3D</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>PVC</td> <td>0 px</td> <td>0,0 %</td> <td>PP_2D</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>Andere KS</td> <td>0 px</td> <td>0,0 %</td> <td>PE_3D</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td>NI</td> <td>1 px</td> <td>0,5 %</td> <td>PE_2D</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-opaque</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-T-color</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-T-clear</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-blue</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-color</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-clear</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-light blue</td> <td>0 px</td> <td>0,0 %</td> </tr> <tr> <td></td> <td></td> <td></td> <td>PET-B-light green</td> <td>0 px</td> <td>0,0 %</td> </tr> </tbody> </table>				Materialverteilung						PEF	188 px	99,5 %	Reflektion	0 px	0,0 %	PS	0 px	0,0 %	Windel	0 px	0,0 %	TETRA	0 px	0,0 %	Textile	0 px	0,0 %	PPK	0 px	0,0 %	EPS	0 px	0,0 %	Cellulose	0 px	0,0 %	PP_3D	0 px	0,0 %	PVC	0 px	0,0 %	PP_2D	0 px	0,0 %	Andere KS	0 px	0,0 %	PE_3D	0 px	0,0 %	NI	1 px	0,5 %	PE_2D	0 px	0,0 %				PET-opaque	0 px	0,0 %				PET-T-color	0 px	0,0 %				PET-T-clear	0 px	0,0 %				PET-B-blue	0 px	0,0 %				PET-B-color	0 px	0,0 %				PET-B-clear	0 px	0,0 %				PET-B-light blue	0 px	0,0 %				PET-B-light green	0 px	0,0 %
Materialverteilung																																																																																																											
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PVC	0 px	0,0 %	PP_2D	0 px	0,0 %																																																																																																						
Andere KS	0 px	0,0 %	PE_3D	0 px	0,0 %																																																																																																						
NI	1 px	0,5 %	PE_2D	0 px	0,0 %																																																																																																						
			PET-opaque	0 px	0,0 %																																																																																																						
			PET-T-color	0 px	0,0 %																																																																																																						
			PET-T-clear	0 px	0,0 %																																																																																																						
			PET-B-blue	0 px	0,0 %																																																																																																						
			PET-B-color	0 px	0,0 %																																																																																																						
			PET-B-clear	0 px	0,0 %																																																																																																						
			PET-B-light blue	0 px	0,0 %																																																																																																						
			PET-B-light green	0 px	0,0 %																																																																																																						

Observations:

- The sample is detected and recognized as PEF. No further observations can be made.

Table 7 Optical sorter analysis of PEF-7 (187 ml green wine bottle 100% PEF)

Scan #	Description	RGB	Identification	Decision	Classified as																																																																																																						
1	Scan in color program inc. PEF				PEF																																																																																																						
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Observations:

- The sample is detected and recognized as PEF.
- High tendency of the sample rolling on the conveyor belt.

3.1.4 Optical sorter analysis: sensitivity on HDPE and PP Rigid

By adding the spectrum of PEF to a sorting program, it should be checked what the sensitivity of the PEF signal is on other sorted streams like HDPE and PP rigid. It should be avoided that adding the PEF spectrum leads missorting of HDPE and PP rigid. This is tested by running the new developed sorting program on HDPE and PP rigid items. Table 8 shows the results of a HDPE sample. It is fully identified as HDPE without any disturbance of PEF. A similar conclusion can be drawn for a PP sample, see Table 9. No missorting of HDPE and PP rigid is expected.

Table 8 Optical sorter analysis of a HDPE sample












































































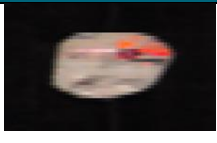










































































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Table 9 Optical sorter analysis of a PP rigid

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3.1.5 Consumer usage

The packaging material provided by Avantium is unused. During consumer usage, there could be some residual product left inside. However, this is in a very low amount and does not impact the sortability of the SKU. Consumer usage is therefore not considered.

3.1.6 Contamination and compression

The 7 SKU's were compressed and contaminated according to the contamination and compression protocol.

The following observations were made during contamination and compression:

- PEF-1 up to PEF-6 show similar compression behaviour. Most bottle and cups are partly crushed, where some sample shows cracks due to compression.

- PEF-7 (*green white bottle*) is hard to crush. The bottle maintains its shape and therefore it easily rolls over the belt.

3.1.7 Sortability test

For the test, 50 pieces of each SKUs were compressed and contaminated then added to a stream of PMD waste, and the sorting efficiency was determined by counting the SKU in each stream. Note, that the material is looped on the sorting line and hence 1 object can pass the optical sorter multiple times (in a different orientation). For the optical sorter, the following settings were used:










SKU	Settings
PEF-1 up to and including PEF-7	PET, PET+PEF, PEF, mixed plastics and mixed plastics +PEF

In the following sections, the results are shown per SKU. It shows the individual efficiencies per sorting step. From there on the sorting behaviour is derived for respectively the current sorting process, when PEF is included with PET and when PEF is sorted separately. Important to note is that it does not include confidence intervals and therefore the numbers can only be treated as a rough indication.

3.1.7.1 Sortability test PEF-1

Table 10 shows the sorting results per sorting step for sample PEF-1.

Table 10. Individual sorting efficiencies for PEF-1

	Process	Streams	Efficiency	Items
	Vibrating screen	+ < 40 mm	0 %	0
		- > 40 mm	100 %	50
	Windshifter	+ Lights	0 %	0
		- Heavy	100 %	50
	Suspension magnet	+ Ferro metals	0 %	0
		- Other	100 %	50
	Ballistic separator	+ 2D	0 %	0
		- 3D	100 %	50
 PET-tray/bottle	Optical sorter	+ PET-tray/bottle	100 %	0
		- Other	0 %	50
 PET+PEF	Optical sorter	+ PET & PEF	98 %	50
		- Other	2 %	1
 PEF	Optical sorter	+ PEF	2 %	1
		- Other	98 %	50
 MIX	Optical sorter	+ Mixed plastics	98 %	51
		- Other	2 %	1
 MIX + PEF	Optical sorter	+ Mixed plastics + PEF	96 %	50
		- Other	4 %	2

Observations for sample PEF-1:

Summarizing the sorting behaviour of sample PEF-1, an overview is made shown in Figure 10. This represents the flow diagram based on the current process in sorting facility. Allmost all items end up in intended stream (PET bottle). In Figure 11 the behaviour is shown when PEF and PET is sorted collectively. As there is no detection of PEF, it will never end in a separate PEF stream and is therefore not shown.

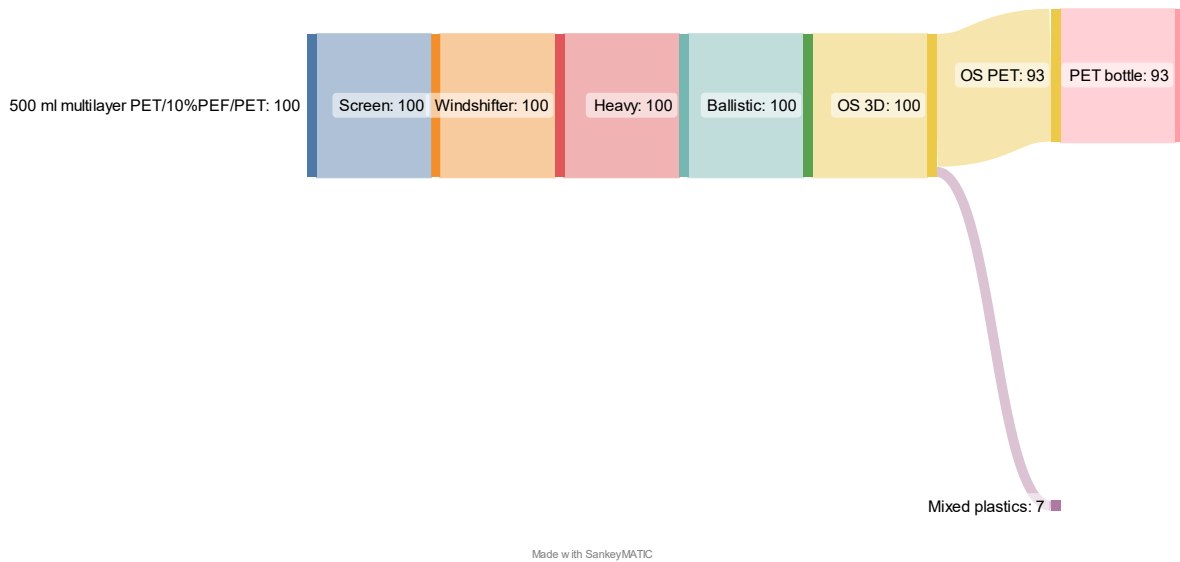


Figure 10. Sorting behaviour of PEF-1 based on a current Dutch sorting facility












Figure 11 Sorting behaviour of PEF-1 when PEF sorting together with the PET stream

3.1.7.2 Sortability test PEF-2

Table 11 shows the sorting results per sorting step for sample PEF-2.

Table 11 Individual sorting efficiencies for PEF-1

	Process	Streams	Efficiency	Items
	Vibrating screen	+ < 40 mm	0 %	0
		- > 40 mm	100 %	50
	Windshifter	+ Lights	0 %	0
		- Heavy	100%	50
	Suspension magnet	+ Ferro metals	0 %	0
		- Other	100 %	50
	Ballistic separator	+ 2D	0 %	0
		- 3D	100 %	50
 PET-tray/bottle	Optical sorter	+ PET-tray/bottle	0 %	0
		- Other	100 %	50
 PET+PEF	Optical sorter	+ PET & PEF	96 %	50
		- Other	4 %	2
 PEF	Optical sorter	+ PEF	84 %	52
		- Other	16 %	10
 MIX	Optical sorter	+ Mixed plastics	11 %	6
		- Other	89 %	50
 MIX + PEF	Optical sorter	+ Mixed plastics + PEF	93 %	50
		- Other	7 %	4

Observations for sample PEF-2:

Figure 12, Figure 13 and Figure 14 show the sorting behaviour for the three scenarios. When PEF is not included in the sorting strategy, it clearly shows that it all ends up in the residue stream which go to incineration. In case PEF is included, it is well sorted in the intended stream.

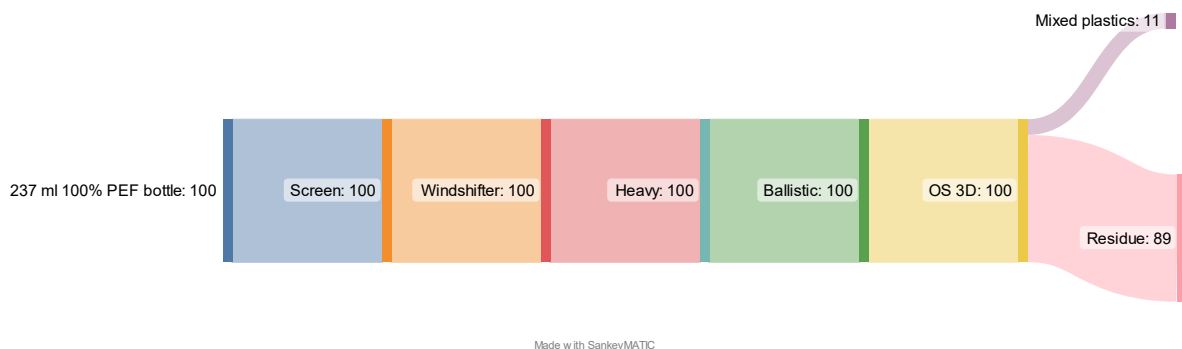


Figure 12 Sorting behaviour of PEF-2 based on a current Dutch sorting facility

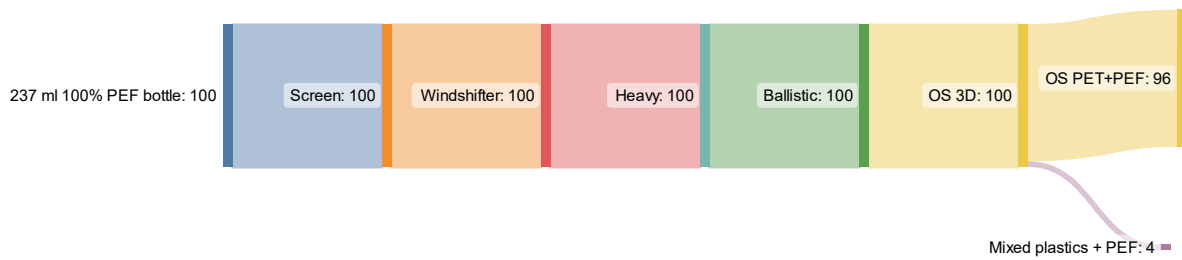


Figure 13 Sorting behaviour of PEF-2 when PEF is sorted together with a PET stream

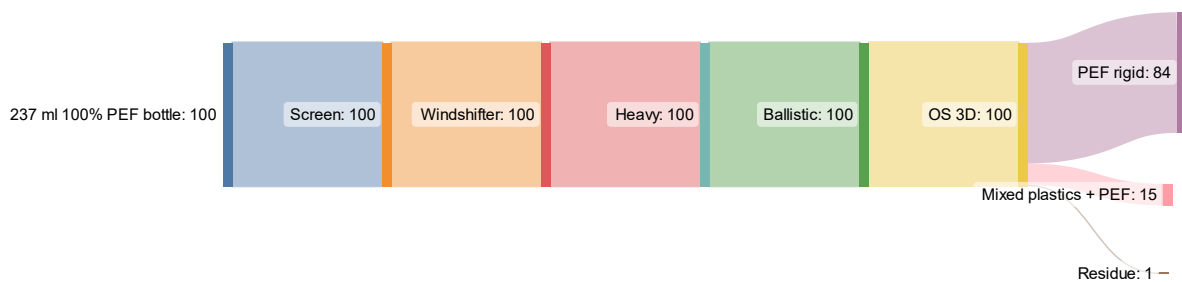




Figure 14 Sorting behaviour of PEF-2 when PEF is sorted as a separate stream

3.1.7.3 Sortability test PEF-3

Table 12 shows the sorting results per sorting step for sample PEF-3.

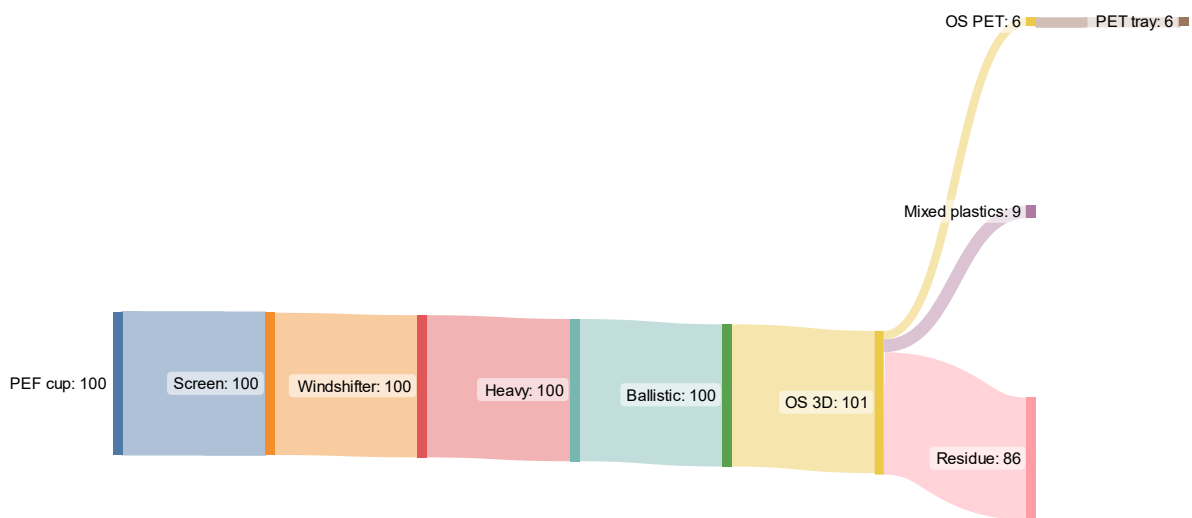
Table 12 Individual sorting efficiencies for PEF-3

	Process	Streams	Efficiency	Items
	Vibrating screen	+ < 40 mm	0 %	0
		- > 40 mm	100 %	50
	Windshifter	+ Lights	0 %	0
		- Heavy	100%	50
	Suspension magnet	+ Ferro metals	0 %	0
		- Other	100 %	50
	Ballistic separator	+ 2D	0 %	0
		- 3D	100 %	50
	Optical sorter	+ PET-tray/bottle	0 %	0
		- Other	100 %	50
	Optical sorter	+ PET & PEF	95 %	38
		- Other	5 %	2
	Optical sorter	+ PEF	93 %	50
		- Other	7 %	4

 MIX	Optical sorter	+	Mixed plastics	9 %	5
		-	Other	91 %	50
 MIX + PEF	Optical sorter	+	Mixed plastics + PEF	32 %	32
		-	Other	6 %	2

Observations for sample PEF-3:

Similar observations can be made as for PEF-2. Despite the cups are small, it is still well picked up by the air nozzles of the optical sorter. The three sorting scenarios are shown in Figure 15, Figure 16 and Figure 17.



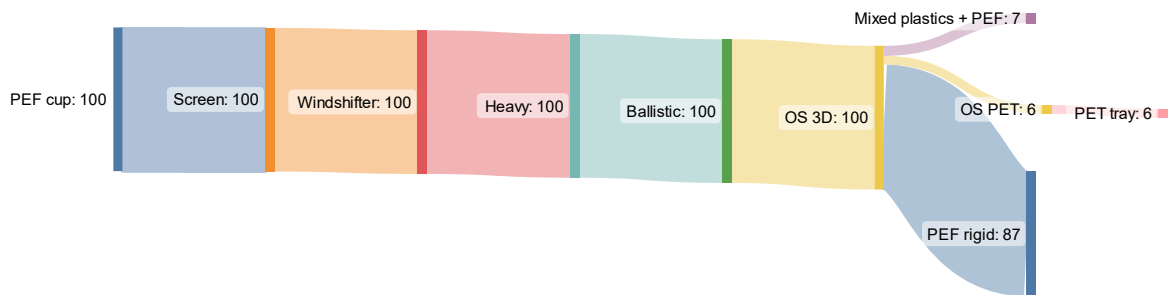
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Figure 15 Sorting behaviour of PEF-3 based on a current Dutch sorting facility



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Figure 16 Sorting behaviour of PEF-3 when PEF is sorted together with a PET stream



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Figure 17 Sorting behaviour of PEF-3 when PEF is sorted as a separate stream

3.1.7.4 Sortability test PEF-4

Table 13 shows the sorting results per sorting step for sample PEF-4.

Table 13 Individual sorting efficiencies for PEF-4

	Process	Streams	Efficiency	Items
	Vibrating screen	+ < 40 mm	0 %	0
		- > 40 mm	100 %	50
	Windshifter	+ Lights	0 %	0
		- Heavy	100%	50
	Suspension magnet	+ Ferro metals	0 %	0
		- Other	100 %	50
	Ballistic separator	+ 2D	0 %	0
		- 3D	100 %	50
 PET-tray/bottle	Optical sorter	+ PET-tray/bottle	2 %	1
		- Other	98 %	40
 PET+PEF	Optical sorter	+ PET & PEF	96 %	43
		- Other	4 %	2
 PEF	Optical sorter	+ PEF	93 %	40
		- Other	7 %	3
 MIX	Optical sorter	+ Mixed plastics	2 %	1
		- Other	98 %	40
 MIX + PEF	Optical sorter	+ Mixed plastics + PEF	84 %	41
		- Other	16 %	8

Main observation for sample PEF-4:

Results are given in Figure 18, Figure 19 and Figure 20. No additional observations can be made compared to the ones given for PEF-2

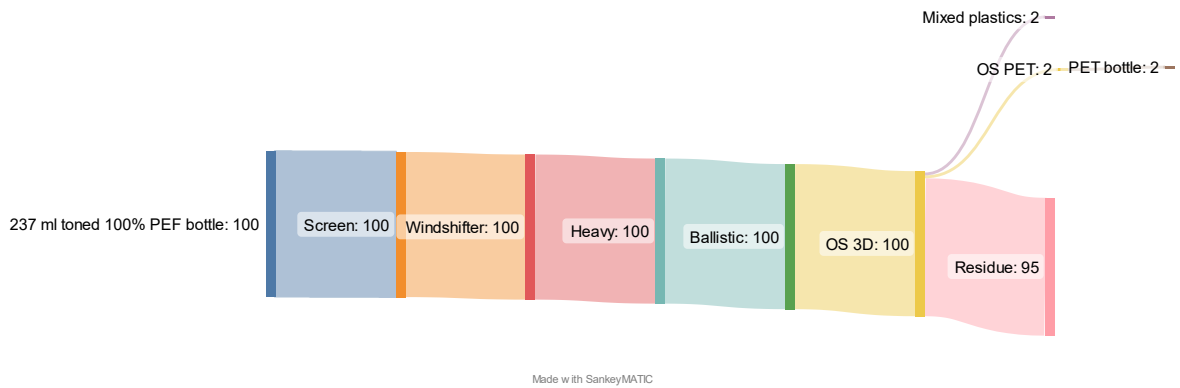


Figure 18 Sorting behaviour of PEF-4 based on a current Dutch sorting facility



Figure 19 Sorting behaviour of PEF-4 when PEF is sorted together with a PET stream

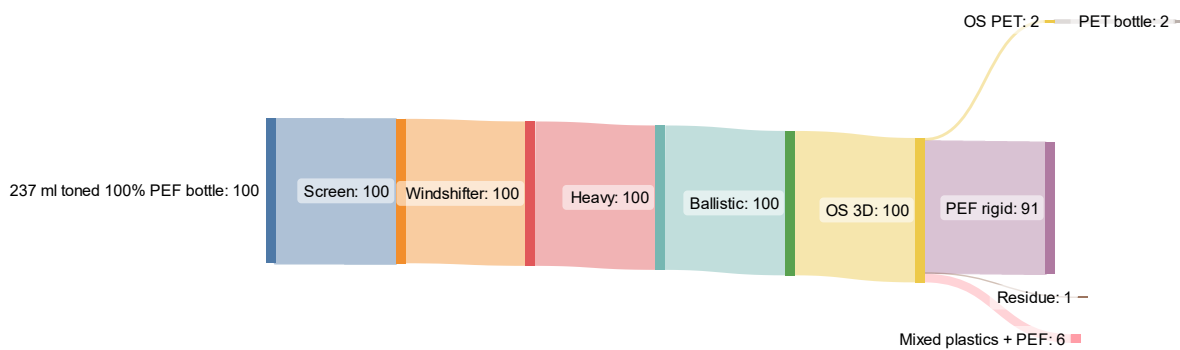











Figure 20 Sorting behaviour of PEF-4 when PEF is sorted as a separate stream

3.1.7.5 Sortability test PEF-5

Table 5 shows the sorting results per sorting step for sample PEF-5.

Table 14 Individual sorting efficiencies for PEF-5

	Process	Streams	Efficiency	Items
	Vibrating screen	+ < 40 mm	0 %	0
		- > 40 mm	100 %	50
	Windshifter	+ Lights	0 %	0
		- Heavy	100%	50
	Suspension magnet	+ Ferro metals	0 %	0
		- Other	100 %	50
	Ballistic separator	+ 2D	0 %	0
		- 3D	100 %	50
	Optical sorter PET-tray/bottle	+ PET-tray/bottle	0 %	0
		- Other	100 %	40
	Optical sorter PET+PEF	+ PET & PEF	93 %	40
		- Other	7 %	3
	Optical sorter PEF	+ PEF	98 %	40
		- Other	2 %	1
	Optical sorter MIX	+ Mixed plastics	0 %	0
		- Other	100 %	40
	Optical sorter MIX + PEF	+ Mixed plastics + PEF	91 %	40
		- Other	9 %	4

Main observation for sample PEF-5:

Results can be found in Figure 21, Figure 22 and Figure 23. No additional observations can be made compared to the ones given for PEF-2

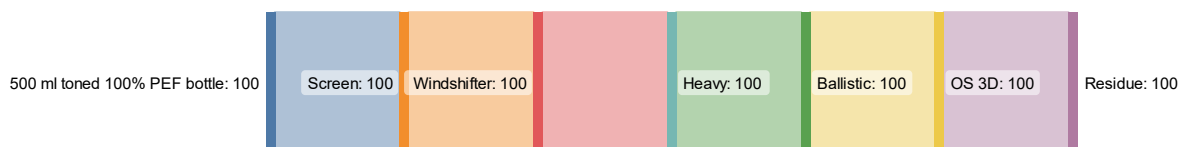


Figure 21 Sorting behaviour of PEF-5 based on a current Dutch sorting facility



Figure 22 Sorting behaviour of PEF-5 when PEF is sorted together with a PET stream












Figure 23 Sorting behaviour of PEF-5 when PEF is sorted as a separate stream

3.1.7.6 Sortability test PEF-6

Table 15 shows the shows the sorting results per sorting for sample PEF-6.

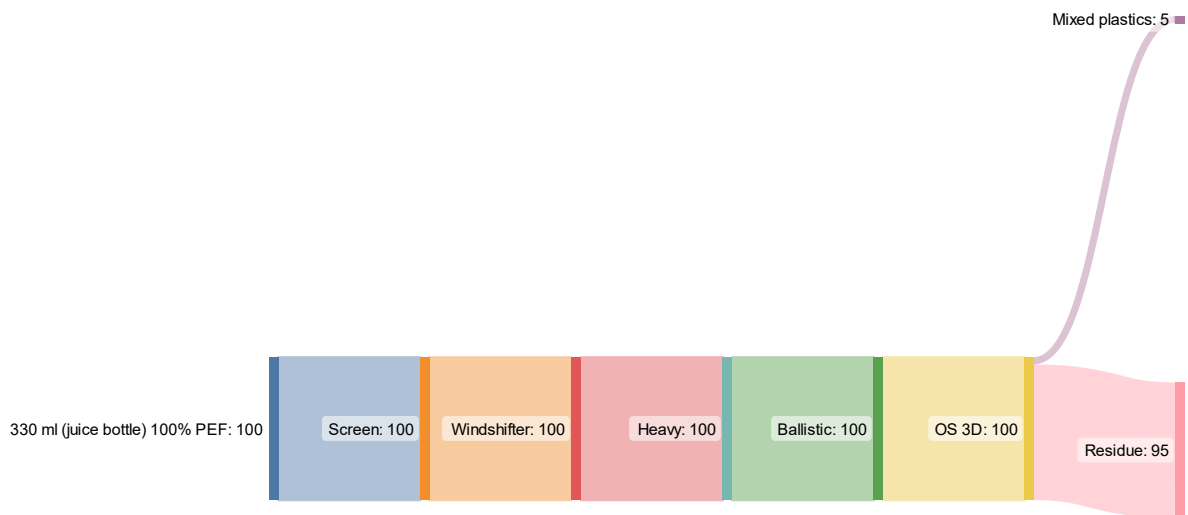
Table 15 Individual sorting efficiencies for PEF-6

	Process	Streams	Efficiency	Items
	Vibrating screen	+ < 40 mm	0 %	0
		- > 40 mm	100 %	50
	Windshifter	+ Lights	0 %	0
		- Heavy	100%	50
	Suspension magnet	+ Ferro metals	0 %	0
		- Other	100 %	50
	Ballistic separator	+ 2D	0 %	0
		- 3D	100 %	50
 PET-tray/bottle	Optical sorter	+ PET-tray/bottle	0 %	0
		- Other	100 %	40
 PET+PEF	Optical sorter	+ PET & PEF	100 %	40
		- Other	0 %	0

 PEF	Optical sorter	+	PEF	100 %	40
		-	Other	0 %	0
 MIX	Optical sorter	+	Mixed plastics	5 %	2
		-	Other	95 %	40
 MIX + PEF	Optical sorter	+	Mixed plastics + PEF	93 %	40
		-	Other	7 %	3

Main observation for sample PEF-6:

Results can be found in Figure 24, Figure 25 and Figure 26. No additional observations can be made compared to the ones given for PEF-2



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Figure 24 Sorting behaviour of PEF-6 based on a current Dutch sorting facility

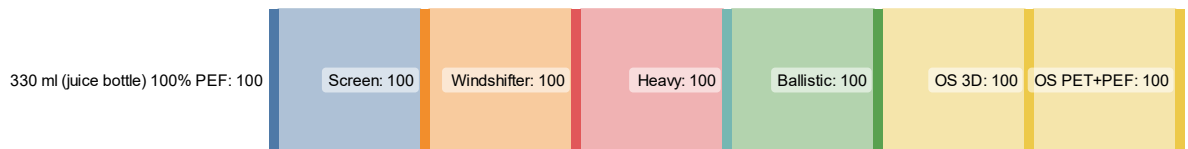


Figure 25 Sorting behaviour of PEF-6 when PEF is sorted together with a PET stream

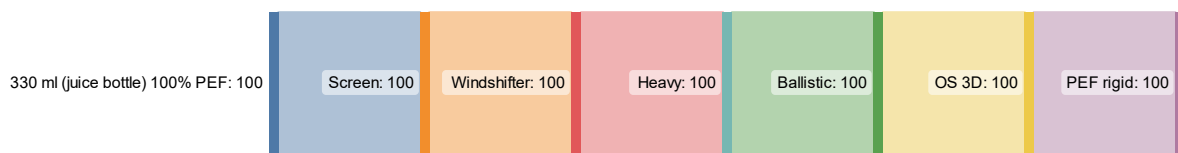











Figure 26 Sorting behaviour of PEF-6 when PEF is sorted as a separate stream

3.1.7.7 Sortability test PEF-7

Table 16 shows the sorting results per sorting for sample PEF-7.

Table 16 Individual sorting efficiencies for PEF-7

	Process	Streams	Efficiency	Items
	Vibrating screen	+ < 40 mm	0 %	0
		- > 40 mm	100 %	50
	Windshifter	+ Lights	0 %	0
		- Heavy	100%	50
	Suspension magnet	+ Ferro metals	0 %	0
		- Other	100 %	50
	Ballistic separator	+ 2D	0 %	0
		- 3D	100 %	50
 PET-tray/bottle	Optical sorter	+ PET-tray/bottle	0 %	0
		- Other	100 %	40
 PET+PEF	Optical sorter	+ PET & PEF	51 %	40
		- Other	49 %	39
 PEF	Optical sorter	+ PEF	53 %	40
		- Other	47 %	35
 MIX	Optical sorter	+ Mixed plastics	0 %	0
		- Other	100 %	40
 MIX + PEF	Optical sorter	+ Mixed plastics + PEF	51 %	40
		- Other	49 %	38

Main observation for sample PEF-7:

The wine bottles are very well classified as PEF. However, as the wine bottle maintain its shape it has a high tendency to roll over the conveyer belt. That make it challenging to correctly shoot on these items, which is clearly visible in the results. Around 50% of the bottle go to the correct stream. 25% end in the lower valuable mixed plastic stream and the remaining 25% go to residue.

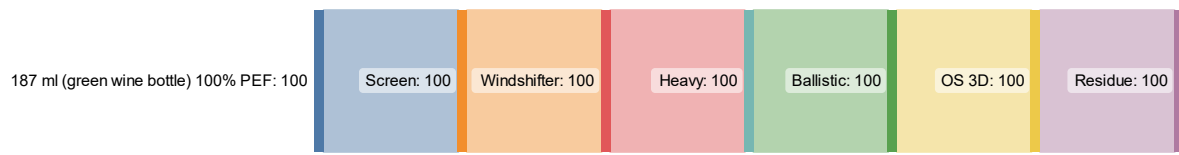


Figure 27 Sorting behaviour of PEF-7 based on a current Dutch sorting facility



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Figure 28 Sorting behaviour of PEF-7 when PEF is sorted together with a PET stream



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Figure 29 Sorting behaviour of PEF-7 when PEF is sorted as a separate stream

4 Conclusions & recommendations

In total 7 PEF samples have been assessed on their sortability behaviour. The main conclusions based on this test are:

- Samples PEF-2 up to PEF-6 are very well identified as PEF and can correctly be sorted. Therefore, it is essential that the PEF spectrum is added to a sorting program.
- In case the PEF spectrum is not added, samples PEF-2 up to PEF-6 are not identified meaning that these items end up in the residue stream. This stream goes to incineration.
- Adding the PEF spectrum to a sorting program does not lead to additional missorting of HDPE and PP rigid items.
- The PEF-spectrum can be combined with the PET stream or it can be treated as a separate PEF stream. Both options show similar sorting behaviour. The effect on recyclate levels and quality for both scenarios is not in scope for this research.
- Sample PEF-1 is a multilayer of PET and PEF. The optical sorter only penetrates the first PET layer and therefore is identified as PET.
- Sample PEF-1 up to PEF-6 are partly crushed after compression. PEF-7 is hard to compress and maintains its shape. Due to cylindrical shape, it easily rolls over the conveyer belt.
- This complicates the sortability of sample PEF-7. Only around 50% end up in the intended stream. Around a quarter go to the residue stream.
- Improving the sortability of PEF-7 can be realized by its compression characteristics. By making it a larger bottle, decrease the wall thickness such that it is easier to compress, or changing its shape; each change will minimize the rolling over the belt.