PlastiCircle
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Sorting requirements

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Abstract

One of the objectives of the Plasticircle project is to improve the sorting of post-consumer packaging. Near Infrared (NIR) sorting is used commonly in the waste industry to recover materials of value from mixed streams. A high level review of the waste composition in the three pilot cities has been carried out, along with specification of the sorted product requirements and an initial study into the sorting efficiency of the Picvisa NIR unit.

Abbreviations

HDPE	High density polyethylene
LDPE	Low density polyethylene
MRF	Materials recovery facility
NIR	Near Infrared
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride

Partners short names

1. ITENE: INSTITUTO TECNOLÓGICO DEL EMBALAJE, TRANSPORTE Y LOGÍSTICA
2. SINTEF: STIFTELSEN SINTEF
3. PICVISA: PICVISA OPTICAL SORTING
4. AXION : AXION RECYCLING
5. CRF : CENTRO RICERCHE FIAT
6. UTRECHT : GEMEENTE UTRECHT
7. INNDEA : FUNDACION DE LA COMUNITAT VALENCIANA PARA LA PROMOCION ESTRATEGICA EL DESARROLLO Y LA INNOVACION URBANA
8. ALBA: PRIMARIA MUNICIPIULUI ALBA IULIA
9. MOV: MESTNA OBCINA VELENJE
10. SAV: SOCIEDAD ANONIMA AGRICULTORES DE LAVEGA DE VALENCIA Spain
11. POLARIS: POLARIS M HOLDING
12. INTERVAL: INDUSTRIAS TERMOPLÁSTICAS VALENCIANAS
13. ARMACELL : ARMACELL Benelux S.A.
14. DERBIGUM : DERBIGUM N.V.
15. PROPLAST : CONSORZIO PER LA PROMOZIONE DELLA CULTURA PLASTICA PROPLAST
16. HAHN : HAHN PLASTICS Ltd.

17. ECOEMBES : ECOEMBALAJES ESPAÑA S.A.
18. KIMbcn : FUNDACIÓ KNOWLEDGE INNOVATION MARKET BARCELONA
19. PLAST-EU: PLASTICSEUROPE
20. ICLEI: ICLEI EUROPASEKRETARIAT GMBH

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Publishable summary

One of the objectives of the Plasticircle project is to improve the sorting of post-consumer packaging.

Near Infrared (NIR) sorting is used commonly in the waste industry to recover materials of value from mixed streams. The technology uses differences in the wavelengths of infrared light that is reflected by polymers with different chemical structures. The wavelengths of light that are reflected depend upon the covalent bonds in the polymer structure.

Using infrared spectroscopy mans that pure streams of different polymers can be sorted for recycling. NIR does have its limits however and is unable to detect low levels of contamination and very thin coatings.

In these early stages of the project, the requirements for the NIR sorting of post-consumer household packaging in order to maximise the value for the Plasticircle industrial partners has been established.

In addition, it has been demonstrated that the purity of pre-sorted material collected in Spain can be increased.

Further work will be required throughout the project to achieve the quality and recovery rates set out tin the Plasticircle project, however initial studies are very positive.

Introduction

One of the objectives of the Plasticircle project is to improve the sorting of post-consumer packaging.

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Using infrared spectroscopy mans that pure streams of different polymers can be sorted for recycling. NIR does have its limits however and is unable to detect low levels of contamination and very thin coatings.

The purpose of this deliverable was to:

- Obtain data on the characteristics of the waste streams from the three pilot cities; and
- Specify the requirements for sorting under the Plasticircle project; and
- Carry out an initial "base case" test with existing Picvisa sorting units

WP4 already has specifications to be achieved during sorting, which is >80% recovery and >95% purity.

1. Characteristics of waste

In order to develop and improve the sorting of post-consumer packaging, it is important to understand the composition of the material.

Characterising waste is very challenging and there are often significant errors in any sampling and analysis technique. In order to gain a true understanding of the waste composition form the three pilot cities, waste much be characterised during the pilots (as is planned in the project). However, to develop the sorting unit, some prior material has been analysed, along with using existing and published data. In this case analysing only material for the pilot city is not possible, and instead a view of the country the pilot city is in as a whole has been taken.

The level of information is therefore sufficient for the continued activities of WP4.

1.1 Waste in Spain

The first pilot city is Valencia, Spain. In order to characterise the material collected in Spain, a combination of existing data and analysis has been carried out.

Data for the percentage of different materials collected in Valencia have been provided by Ecoembes. Sampling was done from incoming vehicles which had collected material from the yellow bin and material sorted into various fractions. Data was obtained from between March and October 2017.

The results of the analysis are given below in Figure 1.

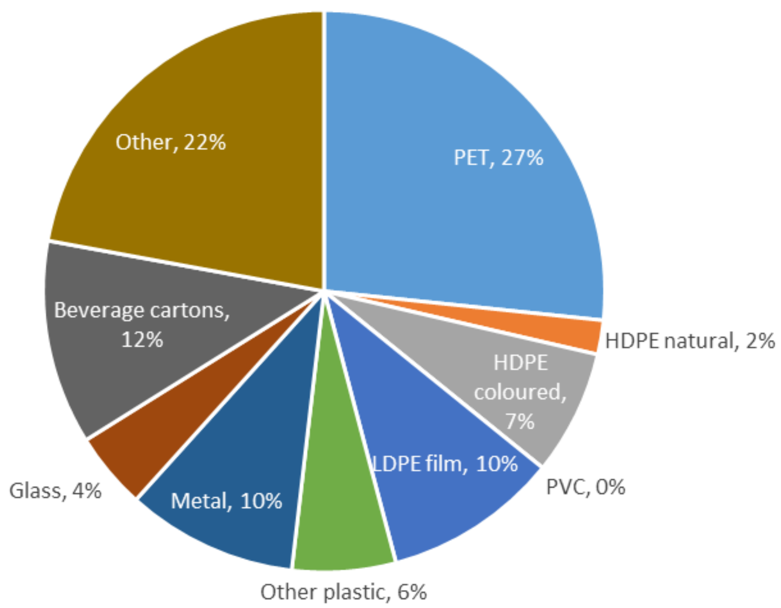


Figure 1 Compositon of yellow bin from Valencia

The analysis shows a large quantity of "other" material which is not targeted by the sorting facility. This should be reduced by the activities in WP2.

As expected PET makes up most of the plastic, with HDPE and LDPE contributing significantly also. The analysis did not separate PP packaging, and this will have been classed as "other plastic".

Since this data is limited, Axion and Picvisa carried out analysis of materials sorted by a Materials Recovery Facility (MRF) in the Barcelona area. Table 1gives the purity of the fractions produced by the MRF.

Table 1 Purity of sorted fractions from Barcelona MRF

Fraction	% purity
HDPE natural	77%
HDPE coloured	92%
PET	86%
Mixed plastics	51% (Polypropylene)
LDPE film	47%

Using this data it can be assumed that 50% of the "other plastics" would be PP.

Additional analysis was done on the PET fraction and is shown in Table 2

Table 2 Analysis of PET fraction from Barcelona MRF

Fraction	Composition (%)
PET bottle	70.2%
PET tray (mono-material)	8.3%
Contamination	21.5%
PET tray (multilayer) classed as contamination	7.1%

The level of PET trays in this material was quite low, and so in this case removing the trays from the bottles may not be vital for many existing applications such as the manufacture of sheet for new thermoforms.

This analysis shows there is sufficient material to be recovered for the Plasticircle project.

1.2 Waste in the Netherlands

The second pilot city that will be investigated is Utrecht. A very comprehensive report has been published on the composition of separately collected material from Dutch municipalities (rr. E.U. Thoden van Velzn, 2016). Figure 2 below shows some extracted data from the report, which is the composition of material collected from the city of Nijmegen in February 2016.

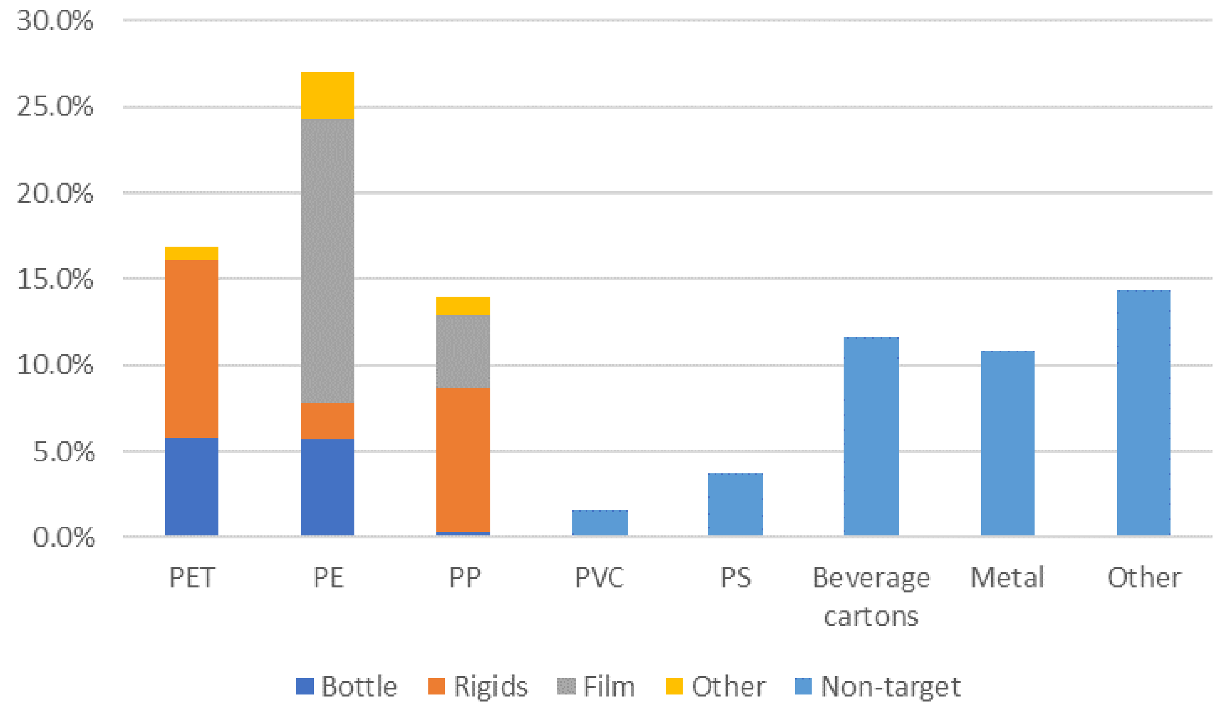


Figure 2 Composition of material collected from Nijmegen, Netherlands

The data is also given below in Table 3.

Table 3 Composition of material collected from Nijmegen

Polymer	Bottle	Rigids	Film	Other	Non-target	Total
PET	5.8%	10.3%	0.0%	0.8%		16.9%
PE	5.7%	2.2%	16.5%	2.7%		27.0%
PP	0.3%	8.4%	4.2%	1.1%		14.0%
PVC					1.6%	1.6%
PS					3.8%	3.8%
Beverage cartons					11.6%	11.6%
Metal					10.8%	10.8%
Other					14.3%	14.3%

The data suggest there will be a greater proportion of PP flexibles in the material collected in Utrecht. I addition, the quantity of PET trays is likely to be much greater than in Valencia, although the split between mono-material and multilayer tray is not yet known.

1.2 Waste in the Romania

The third pilot city is Alba Iulia, Romania. Of the three municipalities Alba Iulia has a less comprehensive collection of packaging materials for recycling. The city is in the earlier stages of establishing a robust recycling infrastructure. As a result there is little available information on the composition of this material.

Polaris, the current waste manager for Alba Iulia concentrate on recovering PET bottles only. The current estimation for the composition of this material is given in Table 4 below.

Table 4 Estimation of composition of material collected for recycling in Alba Iulia

Material	% in collection
PET bottle	45%
LDPE film	8%
HDPE	4%
Other plastic packaging	13%
Non-target material	30%

The pilot exercise in Albia Iulia will have a dramatic change on this composition if householders are encouraged to dispose of all their packaging instead of focusing only on PET bottles. In addition to this, the pilot will also look into more effective use of dedicated bags or containers.

2. Sorting requirements

The waste from all three cities will vary, however the sorting requirements will remain broadly the same. The criteria in terms of recovery and purity have been set by the project as 80% and 95% respectively.

The products to be recovered from the post-consumer packaging waste for the Plasticircle project are given in Table 5.

Table 5 Materials to be recovered in Plasticircle project

Sorted fractions	End user	Notes
PET bottles	Armacell CRF	Ideally PET thermoforms should be removed from the bottle fraction, even mono-PET thermoforms. If it is not possible to develop the Picvisa technology to identify PET thermoforms
Non-bottle mono-layer PET	CRF	Material not suitable for Armacell, validation for CRF is ongoing. May not be feasible to sort the non-bottle material using Picvisa sorters
HDPE	Derbigum Hahn	Rigid HDPE from bottles. Can increase material value outside of investigated applications by recovering the natural (clear) material
PP	Derbigum Hahn CRF	Can be rigid and flexible
LDPE film	Interval Hahn	Will be material that has been screened at 300 mm to ensure film is largely LDPE, although some HDPE will be present

In order to achieve the required purity and recovery set out in the project, material will first need to be pre-sorted to remove metals, glass and fines. Once sorted the material must be screened at 300 mm, as is common for this material. The >300 mm and <300 mm will then be sorted using NIR sorting. An example of how to do this with the end users identified is given in Figure 3 below.

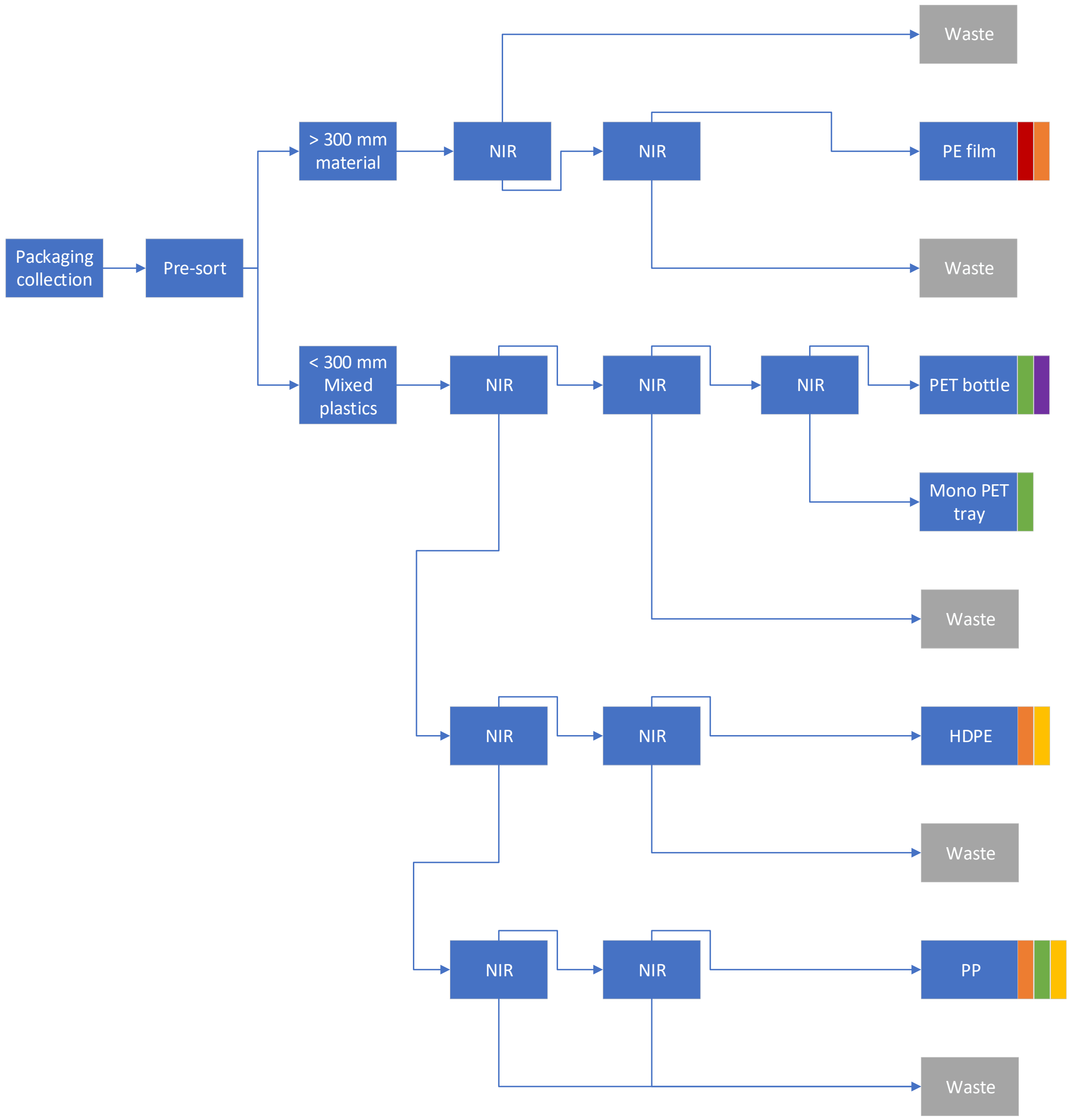


Figure 3 Separation flow diagram

Colour	End user
Red	Interval
Orange	Hahn
Yellow	Derbigum
Green	CRF
Purple	Armacell

3. Sorting trials

In order to qualify a starting point for the development of the Picvisa NIR sorting unit, an initial small-scale trial was carried out using material produced from a MRF in the Barcelona area of Spain.

Figure 4 shows a basic schematic of an NIR sorter.

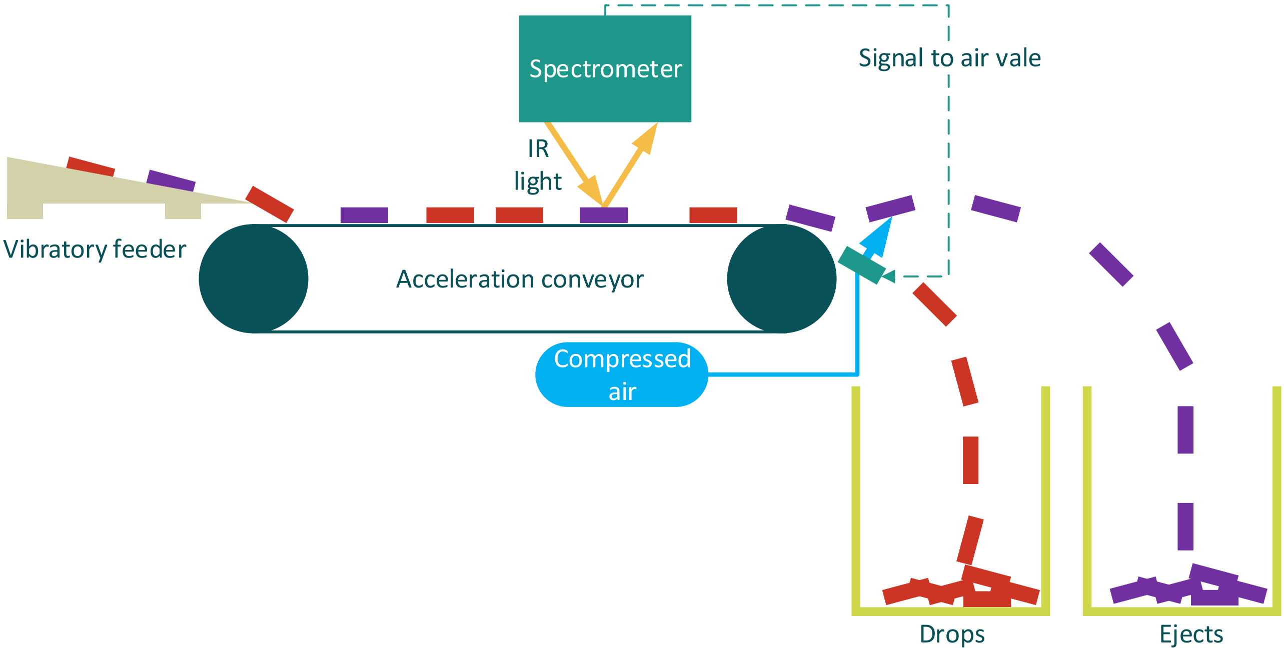


Figure 4 Scematic of NIR sorter

Material is fed onto the acceleration conveyor using a vibratory feeder to give an even distribution of material. The conveyor travels at between 2.5 and 3 m/s to ensure material is not overlapping.

The material travels along the conveyor where it is passed under Infrared (IR) light and a spectrometer that detects the reflected wavelengths of light. Using this data the unit is able to identify the polymer passing under the spectrometer.

IF the sorting unit has been programmed to eject the material passing under the spectrometer, a signal will be sent to the air vales at the end of the belt for the valves to open once the material has reached them. The result is the material is hit by a jet of air and is pushed away from the belt to the "ejects" fraction.

If the NIR sorter is programmed to not eject the material passing under the spectrometer, then the valves will remain closed and the material will pass through to the "drops" fraction.

For the trial, five different products were analysed and sorted. These were:

- PET – including bottles, mono-layer thermoforms, and multilayer thermoforms
- Natural HDPE
- Coloured HDPE
- Mixed plastics
- LDPE films

The tests were carried out for each material using the following methodology:

1. A 10 - 20 kg sample was taken from the bale of material
2. NIR was set to eject either the target material, or eject the non-target material
3. Material was passed through the test NIR sorter at a steady rate
4. The ejects and rejects from the sorter were manually separated and then weighed
5. The yield and the purity were then calculated

The calculation for yield is given as:

$$\frac{Mass\ of\ target\ material\ in\ the\ product}{Mass\ of\ target\ material\ in\ the\ feed} \times 100\% = Yield$$

The calculation for purity is given as

$$\frac{Mass\ of\ target\ material\ in\ the\ product}{Total\ mass\ of\ material\ in\ the\ sample} \times 100\% = Purity$$

When using NIR sorting, there are some limitations. These are:

- Plastic with carbon black pigment cannot be identified and will always report to the drops fraction;
- If material is overlapping on the belt it will create an unclear signal and may result in incorrect sorting
- If material is compounded together (i.e. one type of plastic crushed around another type of plastic), the unit will not separate the two materials, so it will be sorted as a single item
- If material is too dirty it can prevent a clear signal
- It material is too heavy (i.e. because of product residue or liquids) then the power of the air may not be enough to eject the material

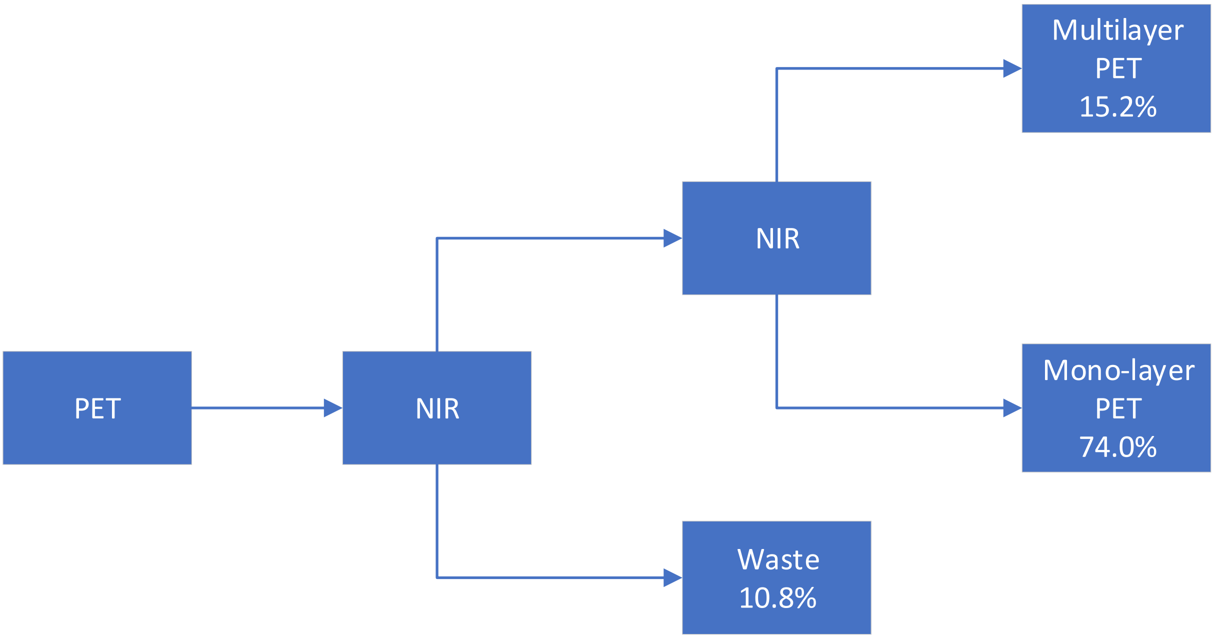
As a result, when analysing the results from the sorting trial, some material is classed as an "exception" meaning the NIR sorter would not be able to either identify it or sort it. This material is excluded from the yield and purity calculations.

3.1 Sorting trial results

In total five different sorting trials were carried out. They are discussed in the below section.

3.1.1 PET

The PET product from the MRF located outside Barcelona was subjected to a "two pass" sort. This was because there is potentially the need to remove multi-layer PET trays. The first step was to eject all PET, and then to eject the multilayer trays. In Plasticircle multilayer trays are considered a contamination, although there may be processes that can treat this material which could be investigated further. The results are given in Figure 5 below



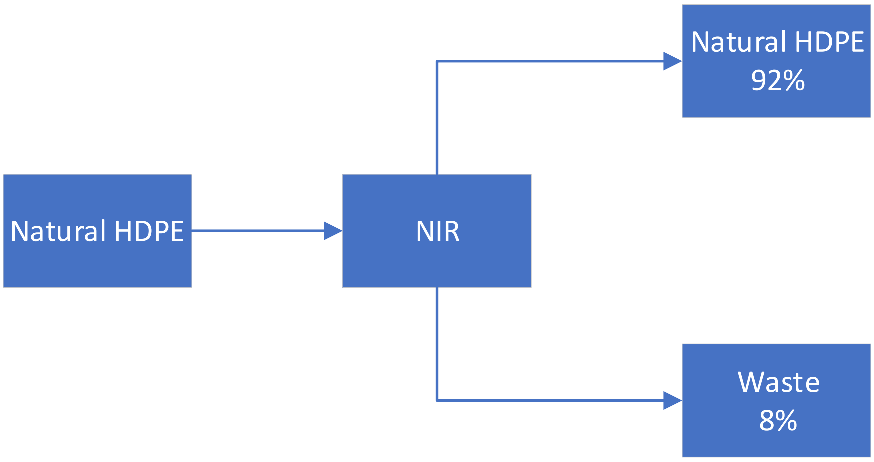
Yield	87%
Purity of feed	79%
Purity of product	92%
Increase in purity	+14%

Figure 5 Results for PET sorting

The two pass sorting achieved >80% recovery and increased the purity by 14% from 87%. The target purity of >95% was not reached in this instance, but this should be achievable with further optimisation.

3.1.2 Natural HDPE

A single sort was used to purify the natural HDPE product and the results are shown in below



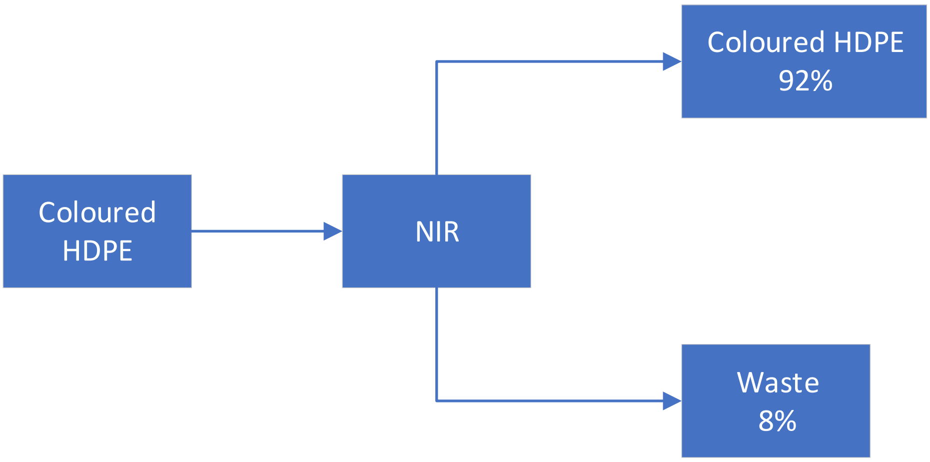
Yield	100%
Purity of feed	77%
Purity of product	84%
Increase in purity	+7%

Figure 6 Results from natural HDPE sorting

The yield achieved was very high with no significant loss of material. As with the PET the purity was increased, but only to 84%, so some additional work would be required to increase this, although this could likely be achieved by increasing the sensitivity and sacrificing some yield to improve the purity.

3.1.3 Coloured HDPE

The results for the sorting of the coloured HDPE fraction are given in Figure 7 below. As with the natural HDPE, a single pass was used and the target material was ejected



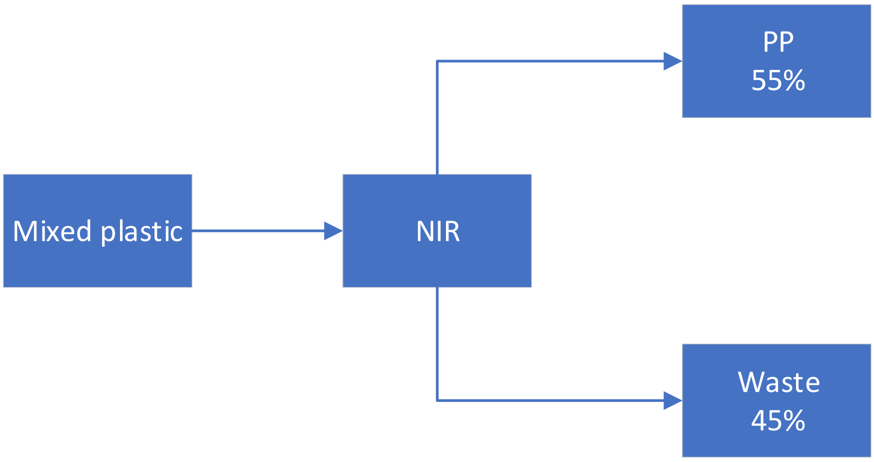
Yield	94%
Purity of feed	92%
Purity of product	95%
Increase in purity	+3%

Figure 7 results from coloured HDPE sorting

The quality of the coloured HDPE was already high at 92% pure, however the purity was increased to the target of 95% with only a small loss of material, achieving a 94% yield. No issues are seen therefore in sorting this material

3.1.4 Mixed plastic

The "mixed plastics" produced from MRF across Europe is typically very low grade. The polymer of interest in this fraction is the PP. A test was therefore carried out to recover the PP from the mixed plastics. All other material present was too contaminated to be of interest. Figure 8 shows the results from the mixed plastics sorting.



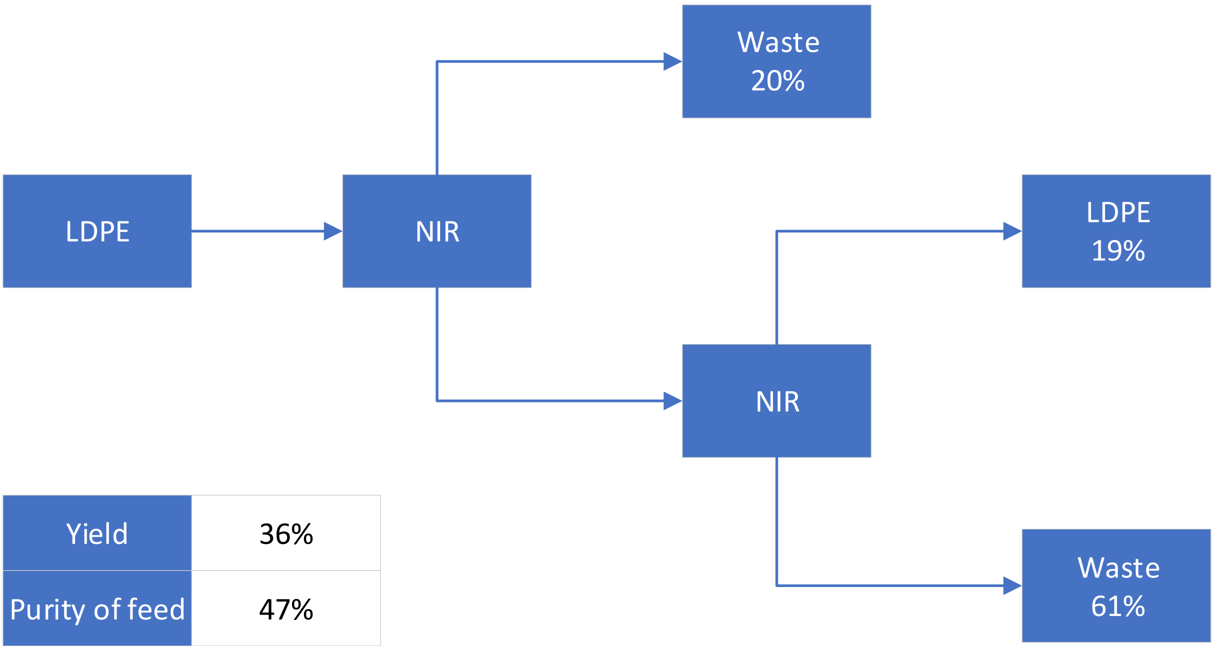
Yield	98%
Purity of feed	47%
Purity of product	84%
Increase in purity	+37%

Figure 8 Results from mixed plastics sorting

The sorting of the mixed plastics fraction to recover the PP was very successful. A yield of 98% was achieved, significantly greater than is required in the project. The purity was increased from 47% to 84%. Although this is not pure enough for the project, it is a huge increase in purity from a very contaminated starting material. In the project an additional sorting step may be required, or by reducing the yield a higher purity may be achieved.

3.1.5 LDPE film

The LDPE film fraction was heavily contaminated, and so it was decided two passes would be needed. In order to have a high purity film, first a negative sort (target material goes to the drops fraction) followed by a positive sort (target material is ejected) was used. The results are shown in Figure 9.



Yield	36%
Purity of feed	47%
Purity of product	87%
Increase in purity	+40%

Figure 9 Results from LDPE film sorting

Sorting film material is very challenging, both in achieving high yields and a high purity. Film, due to its lightweight nature, can move around easily on the sorting belt causing a reduction in sorting efficiently.

The purity of LDPE from the MRF was originally very low at 47%, however through two sorting steps this was increased by 40% to 87%. This is a significant increase in quality. The downside to this was the low yield, of only 36%, In order to improve the yield and quality further, more effective pre-sorting and a material stabilisation device on the NIR sorter could be developed.

4. Conclusions

4.1 Waste composition

The composition of waste will vary between the three pilot cites, although in general this will have no effect on the desired sorting reequipments. All three municipalities have similar waste composition in that:

- PET and HDPE bottles account for a significant amount of material
- LDPE film will be present in large quantities
- PP, both rigid and flexible will be present and must be recovered
- Non-target polymers such as PS, PVC, and PLA are present in small quantities and will not be recovered.

The main difference between the three cities is the large quantity of PET trays in the Dutch material. The development of the NIR sorter to detect these trays would be very beneficial.

4.2 Sorting requirements

The sorting requirements have been set by the project are:

- Sorting of five different plastic fractions
  - PET bottles;
  - Mono-layer PET trays;
  - HDPE bottles;
  - PP rigids and flexibles; and
  - LDPE film.
- Materal loss <20%; precision in sorting >95%
- PE film and PP film with rejects <5%
- Final reject fraction will present <7% PET, <6% rigid PE and < 8% PP-PE films
- Presence of biodegradables and PVC in sorted fractions <0.3%

Recovering these fractions will ensure all valuable material is recovered and it should be able to be used by the end users (Armacell, Derbigum, CRF, Hahn and Interval)

4.3 Sorting trials

The ability to increase the purity of pre-sorted material collected from a MRF in the Barcelona area was demonstrated. In all cases purity could be increased, however there is development work required to achieve the yield and purity requirements. In addition, the ability to sort PET trays from PET bottles should be investigated further by Picvisa.

References

rr. E.U. Thoden van Velzn, i. M. (2016). *Contributions of municipalities to the recycling of post-consumer packages* . Wageningan Food & Biobased Research .

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