Final report

Post-consumer film recycling

Summary report of a series of manufacturing trials using post-consumer comingle film, to identify a range of applications relevant to the retail sector environment

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**Date:** September 2011
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Executive summary

A series of manufacturing trials have successfully demonstrated the technical feasibility of using fully comingled post-consumer film packaging to manufacture products that the retail sector can adopt for use within their store networks and as part of their product ranges for customers. The rationale for this work has been to try and identify, and stimulate, closed loop applications for post-consumer plastic films. Plastic film packaging is significant in the UK’s waste stream, even outweighing some other plastic streams such as plastic bottles.

The main objectives of the project were to:

- Undertake collection and pre-processing trials to process comingled film into a usable form of LDPE for the manufacturing trials;
- Undertake trials with three manufacturing companies using post-consumer and retail waste film to make products which met an existing commercial specification; and
- Determine whether the products manufactured during the trials are suitable for adoption by the retail sector within their stores network and as products to be sold to their customers.

The overall project involved both recyclers and manufacturers as part of a large post-consumer comingled film recycling project commissioned by WRAP. This project demonstrated the potential to use comingled post-consumer recyclate collected in the UK, either from plastic collection systems operated by retailers themselves or from fully comingled household kerbside collections operated by local authorities. Several different manufacturing processes, including extrusion, film blowing and compression moulding were used during the trials.

From the list of potential end uses identified in the project, two uses of post-consumer film were selected for trialling:

- Production of refuse sacks with a recycled low density polyethylene (LDPE) content; and
- Production of rigid panels with a variety of end use applications including hoardings.

These two applications were chosen because until this project it had not been technically possible to manufacture any sort of film sacks from such feedstock. The second application (panels) was chosen because of the dexterity of uses that these could have in a retail environment, aside from basic hoardings.

Three manufacturing partners selected for the trials were:

- CeDo Limited: undertook refuse sack manufacturing trials from its manufacturing plant in Telford;
- Centriforce Products Limited: trialled the manufacture of a panel product by sheet extrusion at its Liverpool facility; and
- Protomax Plastics Limited: undertook panel manufacturing trials using compression moulding at its pilot scale facility in Swansea.

A series of pre-processing trials were undertaken in order to prepare the collected film for the manufacturing trials. The partners involved in these trials were:

- Biffa Waste Services: a post-consumer film separation trial was conducted at Biffa’s new state of the art Materials Recovery Facility (MRF) at Trafford Park, Greater Manchester, to provide feedstock material for the CeDo refuse sack manufacturing trial;
- Ecoplast: delivered a pre-processing trial in Austria for the CeDo manufacturing trial in order to produce a LDPE pellet suitable for refuse sack production; and
- Hanbury Recycling: undertook a pre-processing trial to produce a LDPE agglomerate for the Centriforce panel manufacturing trial.

Results from refuse sack manufacturing trial at CeDo

The manufacturing trial at CeDo involved two pre-processing stages; a film separation trial with Biffa at its MRF at Trafford Park and a cleaning and extrusion trial with Ecoplast in Austria. The Biffa trial separated film from kerbside sourced comingled recyclables using an optimised Near Infrared sorting regime. This provided film material for processing by Ecoplast in order to produce a suitable LDPE pellet for CeDo’s refuse sack production. Material was also sourced from Sainsbury’s front and back of store plastic film collections for processing at Ecoplast.
The post-consumer recyclate sourced from Sainsbury’s front and back of store waste and pre-processed at Ecoplast was successfully converted in to refuse sacks by CeDo without any significant processing problems.

The post-consumer recyclate sourced from Biffa was pre-processed on two different processing lines at Ecoplast (Line 1 and 3). The Line 1 material was successfully blown into refuse sacks. Whilst this material contained higher levels of polypropylene and gas than the Sainsbury’s material it was still low enough to be blown into refuse sacks which met CeDo’s normal commercial specification for refuse sacks for the retail sector. The Line 3 material required a further degassing stage at CeDo before it was successfully blown into refuse sacks. This additional degassing was carried out by reprocessing through an additional extrusion step before successful refuse sack blowing trials were completed.

The refuse sacks produced in all three manufacturing trials contained either 13.5% (single layer) or 27% (double layer) trial post-consumer recyclate. This replaced 50% and 100% respectively of the existing post-consumer recyclate used by CeDo, which until this project has needed to be sourced from Europe.

Sample refuse sacks from each trial run demonstrated that the material met the normal final production specification set by CeDo, with the exception of the tensile strength test for the 13.5% (single layer refuse sack) post-consumer recyclate Biffa material.

It is believed no modifications to the current CeDo production line would be required in order to allow full scale production using the recycled post-consumer film material sourced from Sainsbury’s. However, some minor modifications would need to be made to the perforation and bag rolling sections of the current CeDo production line at Telford for the material sourced from Biffa. This is due to particular complications arising in this area of the process during the trial. Nevertheless, the initial results are promising and the modifications should be relatively easy to implement. The refuse sacks manufactured during the trial were distributed to Sainsbury’s stores and no adverse comments from customers were received which is a very positive result.

The Co-operative segregates front and back of store materials, which reduces contamination of the higher quality back of store stream. This is achieved by the simple method of bagging front of store material prior to backhauling the materials together. The recycling contractor can easily identify the front of store material in the mixed load ensuring that the feedstock is a suitable.

**Results from panel board manufacturing trials at Centriforce**

The manufacturing trial at Centriforce used material sourced from Sainsbury’s front and back of store film collections. Comingled film sourced from Biffa’s normal operations (‘Class C’ film) from its Trafford Park MRF was also sourced but was not processed due to high levels of impurity within the feed material making it unsuitable for Centriforce. This Class C material was separated to a lower specification than the material produced for the CeDo refuse sack manufacturing trial.

The Sainsbury’s material was pre-processed at Hanbury Recycling, following two hand sorting approaches (thorough and minimal picks). The pre-processed material from both levels of hand sorting at Hanbury Recycling produced panels that met existing Centriforce standards for dimensions, edge curl and impact resistance.

However, the level of high melting point contaminants in the feedstock material led to rapid blinding of the screens. With the thorough pick material screen life was around 50% of Centriforce’s normal production performance. With the minimal pick material, screen life was reduced to less than 25% of normal production performance. However, it is not clear whether the frequency of screen changing found necessary during the trial is too high for a commercially viable process.

High melting point contaminants in the feedstock materials passing the screen led to an incidence of surface irregularities that was higher than normal. However, Centriforce technical staff judged the panels to be of sufficient quality for its typical hoarding applications.

Discussions have taken place with both Sainsbury’s and the Co-operative to determine ways to implement these products into their stores. Sainsbury’s has shown interest in the panel product and has a requirement for external hoardings as part of its store building and refurbishment programme.

The Co-operative team was also very positive and was particularly interested in using these panels for in-store display applications. Centriforce has supplied a number of trial panels to one of the Co-operative’s existing in-
store display contractors, who specialises in brand presentation. Initial results were promising and both parties believe a suitable panel made from the Co-operative's film waste can be manufactured for in-store display applications in the future.

**Results from panel board manufacturing trials at Protomax**

The trials at Protomax utilised a prototype P2 machine to demonstrate the feasibility of manufacturing panel boards from comingled film waste. The machine is capable of processing comingled waste streams to manufacture a range of panels that can be used in a number of applications.

The trial used material sourced from Sainsbury’s front and back of store collections, as well as comingled kerbside collected film sourced from Biffa’s Trafford Park MRF. For the Protomax trials, the film material from Biffa and Sainsbury’s was combined with rigid post-consumer plastic packaging sourced from Viridor. These were combined in a pre-set ratio to alter the density of the panels produced. Two ratios were trialled for the Biffa and Viridor material; 70:30 and 50:50. A third trial was also completed for the Sainsbury’s material with a 70:30 ratio mix with the Viridor rigid material.

All the panels manufactured were examined by Protomax staff and complied with the existing product specifications, in terms of dimensions and consistent skin layer distribution.

The panels produced are recommended to be suitable for use in a range of applications such as display panels, hoardings, security panels and shelving.

Discussions have taken place with Sainsbury’s and the Co-operative to determine ways to implement these products into their stores. Sainsbury’s was particularly interested in the Protomax panels, for external hoardings and a range of other opportunities. Discussions focused on applications such as shelving, point of sale displays, trolley bays, petrol station kiosks and toilet cubicles. The Protomax panels are potentially suitable for all these applications due to the combination of their lightweight nature and strength. The key issue for Sainsbury’s is to identify applications that can exchange a heavy, metal or virgin plastic material for the Protomax panels, in order to obtain the maximum carbon reduction benefit. Work is currently underway between Protomax and Sainsbury’s to produce samples of some of the key product applications and to trial these to evaluate their usage and performance.

The Co-operative team also focused on potential in-store applications for the Protomax panels. Discussions are ongoing between the Co-operative and Protomax to identify opportunities for trialling the panel product within its store network.

**Overall conclusions**

Overall, this set of manufacturing trials has been extremely successful in demonstrating the technical feasibility of manufacturing commercially useful products for the retail sector from fully comingled post-consumer film packaging. A range of products can be manufactured successfully from comingled film, including refuse sacks, external hoardings and in-store displays. The retail sector has shown real interest in these products.

The financial viability of each of the potential products needs to be explored further. Overall, these potential new applications will need to show an economic or environmental benefit over existing product solutions in order for the retail sector to adopt them.
Contents

1.0 Introduction ................................................................................................................. 7
  1.1 Background to the project ......................................................................................... 7
  1.2 Project aims and objectives ...................................................................................... 7
  1.3 Project partners ......................................................................................................... 7
  1.4 Sources of film .......................................................................................................... 8
    1.4.1 Biffa 'Class C' film bales .................................................................................... 8
    1.4.2 Biffa lower level contamination film bales ......................................................... 9
    1.4.3 Sainsbury's/Jayplas film bales ........................................................................... 10
  1.5 Trial procedure ......................................................................................................... 10

2.0 Manufacturing trials .................................................................................................... 12
  2.1 CeDo refuse sack manufacturing trial ....................................................................... 12
    2.1.1 Project partner .................................................................................................... 12
    2.1.2 Trial facility and equipment ................................................................................ 12
    2.1.3 Trial objectives ................................................................................................... 12
    2.1.4 Methodology ...................................................................................................... 13
    2.1.5 Results and discussion ....................................................................................... 17
    2.1.6 Conclusions and recommendations ................................................................... 22
  2.2 Centriforce panel manufacturing trial ........................................................................ 24
    2.2.1 Project partner .................................................................................................... 24
    2.2.2 Trial facility and equipment ................................................................................ 24
    2.2.3 Trial objectives ................................................................................................... 24
    2.2.4 Methodology ...................................................................................................... 24
    2.2.5 Results and discussion ....................................................................................... 27
    2.2.6 Conclusions and recommendations ................................................................... 32
  2.3 Protomax panel manufacturing trial ........................................................................... 32
    2.3.1 Project partner .................................................................................................... 32
    2.3.2 Trial facility and equipment ................................................................................ 32
    2.3.3 Trial objectives ................................................................................................... 33
    2.3.4 Methodology ...................................................................................................... 33
    2.3.5 Results and discussion ....................................................................................... 35
    2.3.6 Conclusions and recommendations ................................................................... 36

3.0 Product applications .................................................................................................... 37
  3.1 CeDo refuse sacks ..................................................................................................... 37
    3.1.1 Sainsbury's ......................................................................................................... 37
    3.1.2 The Co-operative ............................................................................................... 37
  3.2 Centriforce panels ..................................................................................................... 37
    3.2.1 Sainsbury's ......................................................................................................... 37
    3.2.2 The Co-operative ............................................................................................... 38
  3.3 Protomax panels ......................................................................................................... 39
    3.3.1 Sainsbury's ......................................................................................................... 40
    3.3.2 The Co-operative ............................................................................................... 40

4.0 Conclusions and recommendations ............................................................................ 41

List of figures

Figure 1 Biffa Class C film bale ............................................................................................ 9
Figure 2 Biffa lower level contamination film bales .............................................................. 9
Figure 3 Sainsbury's/Jayplas film bales ............................................................................. 10
Figure 4 Flow diagram of the overall trial process .............................................................. 11
Figure 5 Flow diagram of Ecoplast's film recycling process .............................................. 13
Figure 6 Biffa Line 1 PCR infeed ....................................................................................... 14
Figure 7 Biffa Line 3 PCR infeed ....................................................................................... 14
Figure 8 Sainsbury's/Jayplas Line 3 PCR infeed ................................................................. 15
Figure 9 Biffa Line 3 pellets after further de-gassing ........................................................ 15
List of tables

Table 1 CeDo infeed summary ........................................................................................................... 13
Table 2 Matrix of refuse sacks produced during CeDo trial .................................................................. 17
Table 3 Dimensional properties of trial products ................................................................................ 18
Table 4 Strength properties of trial products ....................................................................................... 18
Table 5 Evaluation of panels made from thorough picked material .................................................... 27
Table 6 Evaluation of panels made from minimal pick feed material ................................................... 30
Table 7 Weights of manufactured panels ............................................................................................. 35

Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE</td>
<td>High density polyethylene</td>
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<tr>
<td>LDPE</td>
<td>Low density polyethylene</td>
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<tr>
<td>MDPE</td>
<td>Medium density polyethylene</td>
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<tr>
<td>MRF</td>
<td>Materials recovery facility</td>
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<td>NIR</td>
<td>Near Infra-red</td>
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<td>PCR</td>
<td>Post consumer recycrate</td>
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<td>Polyethylene</td>
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<td>Polyethylene terephthalate</td>
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<td>Polypropylene</td>
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<td>PS</td>
<td>Polystyrene</td>
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<td>PVC</td>
<td>Polyvinyl chloride</td>
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Acknowledgements

Axion Consulting and WRAP would like to thank all the companies and individuals that have kindly participated in and given their time to this project. In particular Biffa Waste Services, CeDo, Centriforce, the Co-operative, Ecoplast, Hanbury Recycling, Jayplas, Novograf, Protomax, Sainsbury’s and Viridor Polymer Recycling.
1.0 Introduction

1.1 Background to the project

This project constituted the second phase of a large post-consumer comingled film recycling project commissioned by WRAP. The first phase of the project sought to:

- Identify carbon-beneficial opportunities for increased recycling of post-consumer comingled films in the UK; and
- Identify and secure potential UK-based partners for participating in any subsequent commercial-scale trials which WRAP may wish to commission.

The report detailed potential uses for post-consumer film including:

- New film applications;
- Street furniture;
- Drainage systems; and
- Panels and shelving.

Other options were investigated such as using the recyclate in the manufacture of plastic kerbs and in landscape applications but these end uses were rejected because they either:

- Used commercial and industrial film only and/or;
- Required a high degree of sortation for polymer purity in their processes; and/or
- Were outside the retail, comingled related scope of the project.

This second phase of the project was undertaken in order to assess the potential of using a UK derived comingled post-consumer recyclate (PCR) in several different manufacturing processes, including blown film and extrusion into panels. From the list of potential end uses identified in phase one, two uses of post-consumer film were selected for trialling during phase two:

- Production of refuse sacks with a recycled low density polyethylene (LDPE) content; and
- Production of rigid panels with a variety of end use applications including hoardings.

1.2 Project aims and objectives

The aims of this project were to:

- Undertake collection and pre-processing trials required to process comingled film into a usable form of LDPE for the manufacturing trials;
- Undertake trials with three manufacturing companies using post-consumer and retail waste film; and
- Determine whether the products manufactured during the trials are suitable for adoption by the retail sector within their stores network and as products to be sold to their customers.

Two types of end product have been manufactured during this project. The first product to be manufactured was refuse sacks using comingled post-consumer film. These sacks are currently produced using recycled LDPE from agricultural film and European sourced post-consumer film. The sacks are produced for a range of supermarket retailers in the UK. The second type of product used the comingled film in the production of rigid panels. These panels can be used in a variety of applications, including security hoardings and fencing (for further details see section 3).

1.3 Project partners

The trials were undertaken with a multiplicity of partners. The three manufacturing partners were:

- CeDo Limited – CeDo is a global organisation which manufactures a range of household products including refuse sacks, cling films, freezer bags and aluminium foil. It manufactures own-label products for major retail chains and has production facilities in the UK, Poland and China as well as a recycling facility in the Netherlands. Axion worked with the CeDo team in the UK on the refuse sack manufacturing trial from its Telford manufacturing plant;
- Centriforce Products Limited – Centriforce is a UK based established manufacturer of recycled plastic products, processing in the region of 20,000 tonnes per annum. It processes a range of plastic wastes including plastic bottles, carrier bags, agricultural film and transportation packaging and manufactures several different types of product including sheet products for the agricultural, civil engineering and land management markets, and underground utility protection. Axion worked closely with Centriforce to trial the manufacture of a panel product at its Liverpool facility for this project; and
Protopax Plastics Limited – Protopax is a plastics engineering company who has developed a prototype machine capable of processing comingled waste streams to produce a range of panel products. It is based in the UK, with machine building facilities in Austria. The panel products are suitable for a range of applications including hoardings, interiors, kitchens as well as military and protective uses. The trial Axion delivered with Protopax was a panel manufacturing trial from its pilot scale facility in Swansea.

In order to carry out the manufacturing trials, a number of pre-processing trials were undertaken along with a film collection trial. The partners involved in these trials were:

- Biffa Waste Services - Biffa is a leading company in the integrated waste management sector providing collection, treatment, recycling and energy generation services to its customers. Axion worked with Biffa's team at its new state of the art Materials Recovery Facility (MRF) at Trafford Park, Greater Manchester to deliver a post-consumer film collection trial to provide feedstock material for the CeDo refuse sack manufacturing trial;
- Ecoplast - Ecoplast is a leading European plastics recycler whose facility in Austria specialises in the processing of post use LDPE film. Axion worked with Ecoplast to deliver a pre-processing trial for the CeDo manufacturing trial in order to produce a LDPE pellet suitable for refuse sack production; and
- Hanbury Recycling – Hanbury Recycling, a UK based company, take medium to low grade plastic film, shred and agglomerate the material and sell to extrusion companies in the UK. Hanbury Recycling was involved in a pre-processing trial to produce a LDPE agglomerate for the Centriforce panel manufacturing trial.

This project has produced a number of individual trial reports to support this overall summary report:

- Material separation at Biffa Waste Services Limited;
- Processing of LDPE film at Ecoplast;
- CeDo manufacturing trial;
- Agglomeration trial at Hanbury Recycling;
- Centriforce manufacturing trial; and
- Protopax manufacturing trial.

1.4 Sources of film

Three different grades of comingled film were used in the series of manufacturing trials. Two of the film grades were collected from the Biffa MRF in Trafford Park, Greater Manchester, and the third grade was collected from Sainsbury’s stores from across the UK and supplied by Jayplas. A small amount of mixed rigid plastics were also used in the Protopax manufacturing trial, which was sourced from Viridor Polymer Recycling in Skelmersdale.

1.4.1 Biffa ‘Class C’ film bales

One source of film used in the manufacturing trials was initially produced by the Biffa MRF at Trafford Park, Greater Manchester. The facility accepts mixed dry recyclables from household kerbside collections, as well as some commercial and industrial waste, and separates the recyclables into different product streams. These are in turn sold for reprocessing by others. The infeed material to the MRF contains a wide array of recyclables including plastics (film and rigid), ferrous and non-ferrous metals (cans and tins), paper, cardboard and glass.

The MRF uses several separation technologies and techniques including magnets, eddy current separators and ballistic separators to separate and recover different materials. LDPE film is relatively difficult to remove from other types of plastics and paper and so the Biffa MRF is equipped with several Near Infrared (NIR) optical sorters. The current setup of the plant and operation of the sorters results in a film stream with relatively high levels of contamination in order to produce a paper stream of a high purity. The film stream is classified as ‘Class C’ film by Biffa and is baled into 750kg bales.

The relatively high levels of contamination in the Class C film include principally polypropylene (PP) film and rigid packaging, polyethylene terephthalate (PET) packaging, metallised films such as crisp packets and paper. An example Class C film bale is shown in Figure 1.

This film was used in the Protopax panel manufacturing trial. It was also intended to be used in the Centriforce panel manufacturing trial but was not of sufficient quality to allow Centriforce to use it in its production.
1.4.2 Biffa lower level contamination film bales

A quantity of higher purity/lower level contamination film product was also generated at Biffa for use in the refuse sack manufacturing trials at CeDo to ensure the refuse sacks could be manufactured successfully. This was possible by altering the settings on the NIR sorter at Biffa which handles all the film waste prior to baling. This optimisation allowed for a purer film product to be produced with a significant reduction in the level of paper and non-LDPE polymer contamination.

Although the level of contamination was reduced compared to the Class C bales there was some contamination still present in the feedstock material. The processed film was baled into 750kg bales. An example of the bales is shown in Figure 2.

This film with a lower level of contamination was processed at Ecoplast before being used in the CeDo manufacturing trial.

Figure 2 Biffa lower level contamination film bales
1.4.3 Sainsbury’s/Jayplas film bales

The third feed material used was film collected from Sainsbury’s stores from across the UK by Jayplas, a plastics recycling company. The film was a combination of front of store collections and back of store film waste. The front of store collection material was predominantly carrier bags returned by customers and the back of store waste was film from bulk packaging from deliveries.

As with the Biffa material relatively high levels of contamination were present within the film bales, with approximately 50% of the bales constituting contamination. The majority of contamination was rigid plastic trays and pallet protectors made from polyethylene terephthalate (PET), polystyrene (PS) and polyvinyl chloride (PVC). The remainder of contamination was made up of paper and card.

The contamination in the bales was typically large pieces of material as opposed to the Biffa material where the contamination was typically smaller in size. As with the Biffa material, the Sainsbury’s/Jayplas material was in 750kg bales and is shown in Figure 3.

Figure 3 Sainsbury’s/Jayplas film bales

1.5 Trial procedure

Aside from the Protomax trial the infeed material for the CeDo and Centriforce manufacturing trials required pre-processing in order to produce a suitable LDPE recyclate for production. Figure 4 shows a flow diagram of the trial process and the steps undertaken in order to carry out the series of manufacturing trials.

The trials carried out in order to generate the LDPE recyclate and/or final products are shown in blue boxes. The red arrow signifies where attempts were made to process the feed material but were unsuccessful. The purple cells signify the three different infeed materials as described above. In total six trials were carried out and ten individual product types were manufactured.
Figure 4 Flow diagram of the overall trial process

Sainsbury’s front of store and back of store film waste

Collection and baling by Jayplas

Rigid non-bottle plastic packaging waste from Viridor

Pre-processing at Hanbury Recycling to produce LDPE agglomerate

Sainsbury’s minimal pick

Sainsbury’s thorough pick

Panel manufacturing trial at Centriforce

Sainsbury’s Jayplas film bales

Biffa standard Class C bales

Biffa high purity bales

Biffa Line 1 PCR

Biffa Line 3 PCR

Sainsbury’s Line 3 PCR

Pre-processing at Ecoplast to produce LDPE pellets

Panel manufacturing trial at Protomax

Refuse sack manufacturing trial at CeDo

70:30 Biffa Viridor panels

50:50 Biffa Viridor panels

70:30 Sainsbury’s Viridor panels

13.5% Biffa Line 1 PCR sacks

27% Biffa Line 1 PCR sacks

13.5% Biffa Line 3 PCR sacks

13.5% Sainsbury’s Line 3 PCR sacks

27% Sainsbury’s Line 3 PCR sacks

Kerbside collected dry household recyclables

Standard sorting at Biffa MRF

Sorting trial at Biffa

Infeed film for manufacturing trials

Trials carried out in order to complete project

Intermediate products

Final manufactured products

Non-film infeed

Route unable to be taken due to high contamination

Minimal pick panels

Thorough pick panels

Material change for a better environment

Post-consumer film recycling
2.0 Manufacturing trials

2.1 CeDo refuse sack manufacturing trial

The purpose of this trial was to use PCR to manufacture refuse sacks at CeDo’s production facility in Telford. The aim was to manufacture refuse sacks to meet the existing product specification for CeDo’s retail customers. CeDo currently uses PCR sourced from outside the UK in the production of refuse sacks. The aim of this trial was to determine the suitability of UK sourced LDPE PCR from fully commingled waste film for the production of refuse sacks.

2.1.1 Project partner

CeDo is a market leader in the supply of a range of household products sold primarily as retailers own branded products. The company has a number of manufacturing facilities around Europe including the plant in Telford, UK.

The portfolio of CeDo polyethylene (PE) products manufactured at the UK site includes refuse sacks, bin liners and cling film. Some of the products, including refuse sacks, are currently made using LDPE PCR sourced from outside the UK. The level of recycled material within each product varies depending on the final specification. The specification of each product is agreed with the customer and the products are manufactured to this specification by CeDo. CeDo perform comprehensive quality control checks to ensure the product manufactured is within the established specification.

2.1.2 Trial facility and equipment

The process used by CeDo to make refuse sacks is known as ‘blowing’. To blow refuse sacks, pellets of LDPE and other material used in their production such as chalk powder are weighed and mixed to conform to a standard composition. The pellets are fed into an extruder which melts and mixes the infeed components. The melted polymer mix is then fed through a ring shaped die. Air is blown into the extruded material to form a bubble. The bubble is fed through a collapsing frame a few metres above the die, where it brings the sides of the bubble together. The material is then in the form of a sheet and is passed over several rollers to cool it. The cooled sheet is passed through a series of machines to perforate and cut the film material into the shape and size of the desired refuse sacks. Once cut the sacks are rolled up and set for packaging.

The CeDo facility is equipped with numerous film production lines. The different lines are able to produce film of different sizes as well as films with multiple layers. The extruder used during the trial produced double layer refuse sacks with an inner and outer layer. These are produced by two separately fed extruders pushing material through the same die. The material from one extruder forms the outer layer and the other extruder produces the inner layer. This allows different infeed compositions to be used for the outer and inner layers or the same infeed can be used so the two layers are identical.

2.1.3 Trial objectives

The objectives of this manufacturing trial were to:

- Produce refuse sacks where the standard European sourced PCR is replaced by UK material in the outer layer of the sack, while still using the standard European sourced PCR in the inside layer for each of the three trial infeeds. This would create a sack containing 13.5% trial PCR, accounting for 50% of the total PCR used in the production of the sacks;
- Produce refuse sacks where the standard European sourced PCR had been replaced in both layers of the sack for each of the three trial infeeds of post-consumer feedstock. This would create a sack containing 27% trial PCR, accounting for 100% of the total PCR used in the production of the sacks; and
- Determine from laboratory and visual analysis if the quality of the refuse sacks produced is suitable for sale in a UK supermarket.
2.1.4 Methodology

Feedstock pre-processing trials

The trial infeeds were the products of trials undertaken at a Biffa MRF and Ecoplast, Austria. See Figure 4 for an overview of the individual trials. Separate detailed trial reports have been written for Biffa¹ and Ecoplast². The trial materials were taken from two sources.

The first source of material was bales of comingled post-consumer film sorted from household dry mixed recyclable kerbside materials, collected from different locations across the UK. The comingled film material was separated during a trial at the Biffa MRF. The Biffa MRF currently produces a film stream from the household waste which is typically relatively heavily contaminated with paper, PP film, metallised film and PET packaging. In order to purify this stream to ensure a suitable feedstock would be available for the CeDo manufacturing trial, the settings of an NIR sorting device was altered to give a higher purity of film at the sacrifice of yield. Details of this trial are covered in the separate trial report.

The second source of material was a mixture of back of store retail waste (predominantly shrink wrap) and front of store film material deposited by Sainsbury’s customers, primarily carrier bags. This material was collected from Sainsbury’s stores across the UK by Jayplas.

Both feedstock sources required processing at the Ecoplast film recycling facility in Austria. This was done in order to process the film bales into pellets of LDPE, which is the required form for the blown film process. The film bales contained high levels of contamination and dirt which would make it impossible to be directly blown into new film, and therefore cleaning and separation was also an important feature of the processing. Figure 5 shows the process undertaken during the Ecoplast processing trial.

![Flow diagram of Ecoplast's film recycling process](image)

The Ecoplast facility is equipped with two processing lines, Line 1 and Line 3. Line 1 has been recently modified to improve the separation and de-gassing of the LDPE and is believed to give a higher quality PCR. The film is separated, cleaned and extruded to produce an LDPE pellet which can be used in film blowing.

The Biffa material was processed on Line 1 and Line 3; however the Sainsbury’s/Jayplas material was only processed on Line 3 due to time constraints during delivery of the trial.

Table 1 shows a summary of the quality of the LDPE pellet products made at Ecoplast for use in the subsequent CeDo film manufacturing trial. More detail of the properties of the recycled LDPE pellets made at Ecoplast can be found in the Ecoplast trial report.

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<tr>
<th>Table 1 CeDo infeed summary</th>
<th>PP content (%)</th>
<th>% pellets containing gas</th>
<th>Bulk density (g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biffa Line 1</td>
<td>3.7</td>
<td>100</td>
<td>477</td>
</tr>
<tr>
<td>Biffa Line 3</td>
<td>7</td>
<td>100</td>
<td>316</td>
</tr>
<tr>
<td>Jayplas/Sainsbury’s Line 3</td>
<td>1.1</td>
<td>1</td>
<td>520</td>
</tr>
</tbody>
</table>

¹ Post-consumer film recycling: Material separation at Biffa Waste Services Limited – Trial report

² Post-consumer film recycling: Processing of LDPE film at Ecoplast – Trial report
The presence of PP can make any resulting film made from the pellets brittle and the gas content can prevent the pellets from being blown. It can be seen that the Biffa material processed on Line 3 had the highest PP content and the Sainsbury’s/Jayplas material the lowest.

Although both the Biffa materials produced LDPE pellets which contained gas, the higher bulk density of the Biffa Line 1 pellets suggests that the actual gas content was lower in this material. This, coupled with the appearance of the Biffa Line 1 pellets (relatively uniformed with few surface defects), reinforces the view that the gas content was higher in the Biffa Line 3 pellets (un-uniformed shape and many surface defects). It is likely that the gas content is higher in the Biffa pellets than in the Sainsbury’s/Jayplas pellets because the gases arise from the vaporising of fats which cannot readily be washed off. The Biffa material is likely to contain more of these fats as it was sourced from a comingled kerbside recyclable stream where it will have come in to contact with these types of contaminants, whereas the Sainsbury’s/Jayplas material was relatively clean.

**Figure 6** shows a picture of the Biffa Line 1 PCR pellets and **Figure 7** shows a picture of the Biffa Line 3 PCR pellets. From these pictures it is easy to see the difference in appearance, indicating the high gas content of the Line 3 pellets. **Figure 8** shows the Sainsbury’s/Jayplas Line 3 PCR pellets which had the lowest gas content. This is clear from their appearance, with the pellets being the most uniform of the three. It must be noted that the difference in colour in the photographs is due to the lighting conditions used. All the pellets appeared to be the same colour in daylight.

---

**Figure 6** Biffa Line 1 PCR infeed

![Biffa Line 1 PCR infeed](image1)

**Figure 7** Biffa Line 3 PCR infeed

![Biffa Line 3 PCR infeed](image2)
CeDo manufacturing trial

Before the refuse sack manufacturing trial took place the Biffa Line 1 material was reprocessed through CeDo’s in-house extruder with further vacuum extraction in order to reduce the gas content to a suitable level. The gas content was reduced from ‘high’ to ‘medium’, although no exact figures were given. The difference in pellet uniformity and lack of surface defects can be seen in Figure 9.

The bags which were to be produced during the manufacturing trial were double layer sacks. The refuse sacks currently produced by CeDo contain 27% LDPE PCR sourced from outside the UK. The LDPE is mixed with chalk, a ‘pre-mix’ material which largely contains CeDo’s in-house reground waste and a small amount of virgin Medium Density Polyethylene (MDPE). Both the inner and outer layers are the same on the standard refuse sack product.

Since the sacks are double layered it enabled two products from each infeed to be made. The first was a sack in which the standard PCR was replaced with the trial PCR in the outside layer only of the sack. The inner layer remained as standard PCR. This resulted in a refuse sack of which 13.5% was trial PCR, which is 50% of the total PCR used.

The second product was a sack in which the PCR in both layers was replaced with the trial PCR. This meant that the resulting sack would contain 27% trial PCR, which is 100% of the total PCR content used to produce the standard refuse sacks.

To perform the trial, the single layer trial refuse sacks were produced first. Production was allowed to run for approximately 30 minutes and at the end of this time five samples of 20 bag rolls were taken. The bags were produced at a rate of 64m/minute. After the first set of samples were obtained, the sacks with both layers of trial material were produced and the same sampling method repeated. In total approximately 20kg of trial material...
was used throughout the trial hour and approximately 100kg of sacks were made. **Figure 10** CeDo trial stage gate diagram shows a stage gate diagram of the process undertaken during the CeDo trial.

Throughout production the whole process was monitored by CeDo’s technical staff. Samples of the film produced underwent initial visual analysis to determine the levels of dirt and gels within the sack film. Samples also underwent CeDo’s quality control checks to determine if the properties were within the specification set by their retail customers.
2.1.5 Results and discussion

Table 2 shows a matrix of the products which were manufactured during the trial at CeDo.

<table>
<thead>
<tr>
<th>Refuse sacks with the outer layer made with trial PCR and one layer made with standard PCR. Total trial PCR in product = 13.5%</th>
<th>Sainsbury’s/Jayplas infeed material processed on Ecoplast Line 3</th>
<th>Biffa MRF infeed material processed on Ecoplast Line 1</th>
<th>Biffa MRF infeed material processed on Ecoplast Line 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produced</td>
<td>Produced</td>
<td>Produced</td>
<td></td>
</tr>
</tbody>
</table>

Refuse sacks with the inner and outer layers made using trial PCR. Total trial PCR in product = 27%

Produced

Produced

Unable to produce within trial

Due to time constraints during delivery of the trial it was not possible to produce refuse sacks with both layers containing the Biffa Line 3 PCR.

Table 3 and Table 4 show the average results of the quality control checks performed by CeDo. The physical properties were tested and compared to that of the standard refuse sack product. The aesthetics of the film were also visually analysed and compared to the standard product, which is shown in Figure 11. Further information on these tests and subsequent results can be found in the CeDo trial report⁴.

Figure 11 Standard CeDo refuse sack

---

⁴ Post-consumer film recycling: Post-consumer film recycling - Trial Report
### Table 3 Dimensional properties of trial products

<table>
<thead>
<tr>
<th>Specification (minimum)</th>
<th>Standard</th>
<th>Sainsbury’s/Jayplas 13.5% UK PCR refuse sacks</th>
<th>Sainsbury’s/Jayplas 27% UK PCR refuse sacks</th>
<th>Biffa Line 1 13.5% UK PCR refuse sacks</th>
<th>Biffa Line 1 27% UK PCR refuse sacks</th>
<th>Biffa Line 3 13.5% UK PCR refuse sacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lay flat width (mm)</td>
<td>720</td>
<td>725</td>
<td>730</td>
<td>728</td>
<td>725</td>
<td>720</td>
</tr>
<tr>
<td>Gauge by weight (µm)</td>
<td>N/A</td>
<td>22.13</td>
<td>21.98</td>
<td>22.40</td>
<td>22.68</td>
<td>21.91</td>
</tr>
<tr>
<td>Gauge by micrometer (µm)</td>
<td>Average</td>
<td>21.6</td>
<td>26.15</td>
<td>26.35</td>
<td>26.59</td>
<td>26.78</td>
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<tr>
<td>Minimum</td>
<td>19.2</td>
<td>23.00</td>
<td>21.00</td>
<td>24.00</td>
<td>24.00</td>
<td>24.00</td>
</tr>
</tbody>
</table>

### Table 4 Strength properties of trial products

<table>
<thead>
<tr>
<th>Specification (minimum)</th>
<th>Standard</th>
<th>Sainsbury’s/Jayplas 13.5% UK PCR refuse sacks</th>
<th>Sainsbury’s/Jayplas 27% UK PCR refuse sacks</th>
<th>Biffa Line 1 13.5% PCR refuse sacks</th>
<th>Biffa Line 1 27% PCR refuse sacks</th>
<th>Biffa Line 3 13.5% PCR refuse sacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dart D50 (g)</td>
<td>80</td>
<td>100</td>
<td>90</td>
<td>110</td>
<td>110</td>
<td>100</td>
</tr>
<tr>
<td>Tensile transverse direction</td>
<td>Average (N)</td>
<td>6</td>
<td>7.30</td>
<td>8.82</td>
<td>7.33</td>
<td>7.38</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>250</td>
<td>380.80</td>
<td>420.80</td>
<td>371.20</td>
<td>393.60</td>
</tr>
<tr>
<td>Tensile machine direction</td>
<td>Average (N)</td>
<td>8</td>
<td>10.80</td>
<td>10.15</td>
<td>11.02</td>
<td>7.89*</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>100</td>
<td>194.60</td>
<td>199.40</td>
<td>210.40</td>
<td>170.20</td>
</tr>
</tbody>
</table>

*Note the figures in red indicate this measurement was below specification.*
**Sainsbury’s/Jayplas refuse sacks**

The Jayplas/Sainsbury’s PCR was successfully used to manufacture refuse sacks where the outer layer contained the trial material (13.5% trial PCR within the refuse sack) and refuse sacks where both layers contained the trial material (27% trial PCR within the refuse sack).

The blowing process was straightforward and the bubble remained inflated throughout the processing for the refuse sacks, both with only the outer layer made with the trial material and with both layers made from trial material. The material went through the perforation and bag rolling stage without any problems. This demonstrated that no modifications would need to be made to the production line if the current CeDo PCR content were to be replaced with the Jayplas/Sainsbury’s PCR.

The cosmetic appearance of the film was similar to the standard film material produced by CeDo, however the degree of gelation was higher than usual. Gels are particles of LDPE which have bonded together during heating and extrusion. The gels appear as small black dots in the film. However, the gelation did not appear to have a detrimental effect on the physical properties of the refuse sack. **Figure 12** shows a refuse sack made with a single layer of trial material and **Figure 13** shows a refuse sack where both layers have been made using the trial material. The black dots in the film are the gels and it can be seen that the amount of gelation is higher within the bags where both the layers are made from the trial material.

**Figure 12** Sainsbury’s/Jayplas single trial material layer sack

![Figure 12](image1)

**Figure 13** Sainsbury’s/Jayplas sack with both layers of trial material

![Figure 13](image2)
Biffa Line 1 refuse sacks

The Biffa Line 1 PCR was successfully used to make refuse sacks where the outer layer contained the trial material (13.5% trial PCR within the refuse sack) and refuse sacks where both layers contained the trial material (27% trial PCR within the refuse sack).

The extrusion and blowing equipment performed well throughout the trial, aside from a temporary bubble size loss which occurred when initially producing the bags with both layers of the trial material. However this is often observed when changing between feedstocks and was a one-off occurrence, suggesting the trial PCR was not the cause of the deflation.

The refuse sacks produced from the Biffa Line 1 material were noticeably stiffer than the standard CeDo refuse sack product and complications arose during the perforation and rolling stages. Although the sack blowing continued uninterrupted and the bubble remained inflated, the way in which the downstream sack perforating and rolling equipment was set up was not suitable for the Biffa Line 1 PCR and the line of sacks continually broke. More breakages occurred during the production of the refuse sacks where both layers contained the trial PCR compared to the refuse sacks that only contained a single layer of trial material. This could be due to the PP present within the LDPE pellets causing the perforations to be weaker.

In order to run the material again modifications would need to be made to this section of the CeDo process to increase the perforation strength of the sacks, but it is anticipated that these modifications would not be a major or costly undertaking.

Both the single trial layer and double trial layer refuse sacks were reported by experienced CeDo staff to have a higher level of contamination with solids than the Sainsbury’s/Jayplas refuse sacks, as well as a higher level of gelation than standard.

Figure 14 shows a Biffa Line 1 refuse sack where one layer was made using the trial material and Figure 15 shows a Biffa Line 1 refuse sack where both layers were made using the trial material. Although it may appear from the photographs in the report that the Sainsbury’s/Jayplas refuse sacks had a higher level of contamination this was not the case, as the solid contamination was small and did not show up well on the images. Instead it can be seen that the Biffa Line 1 sacks have a greater number of light patches, which is a good indication of the level of dirt within the material. It is possible that the level of contaminants may cause the refuse sacks to be rejected by the retail customers on a cosmetic level; although this is a decision made by the retail buyers and can only be known for sure once they have appraised the product in the context of the positive message they offer to consumers.

Figure 14 Biffa Line 1 single trial material layer sack
All of the dimensional properties of both the outer trial layer only and double trial layer refuse sacks met the final product specification. All except one of the physical properties were also within specification for the outer trial layer refuse sacks; with the tensile machine direction property being below specification. It is unusual that the refuse sacks containing 13.5% trial PCR were below specification, whereas the refuse sacks containing 27% trial PCR were within specification. The standard deviation for the tensile machine direction tests performed on the outer trial layer refuse sacks was 3.07 N, whereas for the double trial layer refuse sacks it was 1.96 N. This indicates that the laboratory tensile test results for the single layer sacks were more variable than the double layer sacks. If the variability of the test results was a consequence of poor quality recyclate, then one would expect the variability of the test results for the double trial layer sacks to be higher than for the single layer trial sacks, as they contain twice the amount of trial recyclate. As the results for the single layer sacks are significantly more variable this suggests that anomalous results in the laboratory testing for the single layer sacks, rather than variation in the recycled polymer, may have led to an average value which was below specification. In order to assess whether or not this is the case a larger scale trial with further laboratory testing would be necessary.

Biffa Line 3 refuse sacks
The Biffa Line 3 PCR was successfully used to make refuse sacks where the outer layer contained the trial material (13.5% trial PCR within the refuse sack). However, due to unforeseen time constraints on the CeDo plant during the manufacturing trial, production of a refuse sack with both layers using the trial PCR was not possible.

The refuse sacks produced exhibited the same processing issues as the Biffa Line 1 material; however no problems occurred during the bubble blowing process. The same perforation problems were present and the production line would once again need modifications to accommodate this feedstock material.

Similarly to the Biffa Line 1 material, the Line 3 material contained a higher concentration of dirt than the Sainsbury's/Jayplas material and a higher concentration of gels than in standard film, which is likely to be a point for further consideration amongst retail customers. Figure 16 shows a sack where a single layer was made using the trial PCR.
Figure 16 Biffa Line 3 single trial material layer sack

As with the Biffa Line 1 outer layer trial refuse sacks, the tensile strength was below specification on the Biffa Line 3 outer layer trial sacks. The standard deviation of all the tests, however, was significantly lower than that of the Biffa Line 1 outer trial layer refuse sacks, at 1.46 N, suggesting that anomalous results were not the reason for this property being below specification. The cause of this could be the higher percentage of PP present in this PCR, or could also be due to some gas still being present in the LDPE pellets. This suggests that it is likely this material would exhibit the same properties in larger scale production.

2.1.6 Conclusions and recommendations

The following conclusions can be drawn from the refuse sack manufacturing trial carried out at CeDo.

Sainsbury’s/Jayplas Film
The separation and cleaning process at Ecoplast produced a good quality PCR from the Sainsbury’s/Jayplas material. It produced a pellet of recycled LDPE with low PP and low gas content.

PCR sourced from Sainsbury’s and processed on Line 3 of the Ecoplast facility was successfully blown into refuse sacks. This was a mixture of film collected front of store and back of store through the Sainsbury’s store network.

Refuse sacks were produced with the outer layer made with the trial PCR and sacks with both layers made with the trial PCR. The refuse sack products had an overall composition containing 13.5% and 27% trial PCR respectively, replacing half and 100% of the European sourced PCR currently used by CeDo.

Sample refuse sacks demonstrated material from this trial met the specification for normal production and it is believed no modifications to the current CeDo production line would be required in order to allow full scale production.

Biffa Line 1 Film
The separation and cleaning of the post-consumer film at Ecoplast was satisfactory for the Biffa material processed on Line 1, which contained higher levels of PP and gas than the Sainsbury’s/Jayplas material but were still low enough to allow it to be blown into refuse sacks.

PCR sourced from Biffa and processed on Line 1 of the Ecoplast facility was also successfully blown into refuse sacks. This post-consumer material was film collected through a mixed dry recyclables kerbside scheme.

Refuse sacks were produced with just the outer layer made with the trial PCR and with both layers made with the trial PCR. The refuse sack products had an overall composition containing 13.5% and 27% trial PCR respectively, replacing half and 100% of the European sourced PCR currently used by CeDo.
Samples of refuse sacks obtained from the trial which replaced 50% of the European PCR had a tensile strength below the current customer final product specification; however the properties of the refuse sacks made by replacing 100% of the European PCR were all within specification.

In order to carry out a larger scale production trial, modifications would need to be made to the perforation and bag rolling sections of the current CeDo film blowing line at Telford. This is due to particular complications arising in this area of the process during the trial. However the initial results are promising and the modifications should be relatively easy to implement.

**Biffa Line 3 Film**

The separation and cleaning of the post-consumer film at Ecoplast was unsatisfactory for the Biffa material processed on Line 3. The LDPE pellets produced at Ecoplast required reprocessing through a second extruder by CeDo in order to reduce the gas content. After reprocessing the material was suitable for blowing into refuse sacks.

PCR sourced from Biffa and processed on Line 3 of the Ecoplast facility was successfully blown into refuse sacks. This material was again comingled post-consumer film collected through a dry recyclable kerbside scheme. Sacks were produced with the outer layer made with the trial material. The product therefore had an overall composition containing 13.5% trial PCR, replacing half of the current European sourced PCR.

Whilst the tensile strength of the sacks was found to be just below specification, the samples obtained from this trial demonstrated that the product met the majority of the customer’s final product specification requirements.

**Recommendations**

CeDo should source additional feedstock material and run larger production scale trials (minimum 24 hours) on the Sainsbury’s/Jayplas material and the Biffa MRF material (processed on Line 1 at Ecoplast). This will enable a more comprehensive commercial evaluation to be made of the feedstock materials and ensure that customer final product specifications can be met when producing the refuse sacks on a larger scale.
2.2 Centriforce panel manufacturing trial

The purpose of the manufacturing trial undertaken at Centriforce was to determine whether film collected from front of store customer carrier bag collections and back of store retail film waste collected from Sainsbury’s stores in the UK was of a suitable quality to manufacture rigid panels. The panels were produced for a variety of end uses, including hoardings and in-store applications.

2.2.1 Project partner

Centriforce is an established plastics recycler, turning a range of plastic waste into rigid products. The principle materials they recycle are carrier bags, shrink wrap, bottles, crates and piping. Their product range includes:

- Protection products for underground cables;
- ‘Stokbord’, a board which can be welded and fabricated into a variety of products for the agricultural industry, including animal pens, grain stores, troughs and ground protection mats;
- A range of profiles and planks used to manufacture a variety of products including fencing, picnic tables, benches, decking, boardwalks, street signs and vegetable boxes;
- Industrial grade sheets for fabrication purposes; and
- Industrial boards, with white laminated film surfaces, that can be used as fence panels or security hoardings around construction sites as an alternative to plywood.

2.2.2 Trial facility and equipment

The trial took place at Centriforce’s production facility in Liverpool. An extrusion process is used to produce a sheet of polymer from an agglomerate material. The main components of the extrusion line are:

- A screw feeder, which converts the agglomerated particles into a molten and mobile material;
- A screen unit for removal of contaminant particles with higher melting points than the temperatures achieved in the screw feeder;
- A spreader for introducing the molten material into the roller mechanism in which the 12mm thick sheet is produced and a white plastic laminating film applied to the top and bottom surfaces;
- A conveyor which allows the sheet to cool;
- Trimming cutters which remove about 50mm of material from each edge of the sheet; and
- A guillotine which cuts the sheet to the sizes required for product panels, to remove sections of the sheet with major surface defects or to produce testing samples.

2.2.3 Trial objectives

The objectives of the trial were:

- To determine the feasibility of producing 12mm thick PE panels from agglomerated UK post-consumer film waste; and
- Evaluate the panels to determine if they were of sufficient quality for Centriforce to consider them for use as security hoardings in their established markets for such products.

2.2.4 Methodology

Feedstock pre-processing trials

In order to carry out the manufacturing trial at Centriforce the film was first processed at Hanbury Recycling in Congleton to improve purity and produce a flowable agglomerate from the film bales. The trial intended to use both the material collected from Sainsbury’s and the Class C film material supplied by Biffa. On inspection of the Biffa sourced film, Centriforce technical staff decided it was not of sufficient quality to be used in its manufacturing process and therefore the material was not processed by Hanbury Recycling.

The process used by Hanbury Recycling is shown in Figure 17. The process relies on hand picking to remove any contamination and does not use any additional automated separation techniques. The handpicked film is shredded and agglomerated in order to significantly increase its bulk density and the processability of the film.
The material was divided into two streams, each subjected to a different level of sorting/picking:

- A thorough pick, in which care was taken to remove as much of the contaminants as possible; and
- A minimal pick, which was less thorough and removed only the largest items of contamination.

The minimal picking approach is considered by Centriforce to present a more commercially viable operation for sorting and agglomerating post-consumer film for panel production.

The resulting material batches were both agglomerated at Hanbury and then delivered to Centriforce at Liverpool in preparation for the manufacturing trial. Approximately 1.6t of each material was sent to Centriforce. A detailed report of the Hanbury Recycling trial is available separately4.

Figure 18 and Figure 19 respectively show the minimal picked and thorough picked material. It can be seen in Figure 18 the material still contains large pieces of contamination after only minimal picking.

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4 Post-consumer film recycling: Agglomeration trial at Hanbury Recycling – Trial report
Centriforce trial procedure

Each of the two feed materials (1.56t for the thorough pick material and 1.68t for the minimal pick material) was blended with 25kg of quicklime to ensure removal of any residual moisture from the agglomeration process. Centriforce would normally also include a black master batch to ensure consistent appearance of the final product. No master batch was used in the trial to ensure that the visual nature of the extruded waste would not be obscured.

The two blended feed materials were loaded into separate hoppers for feeding into the extrusion line at Centriforce. The coarsest screen available (5mm aperture size) was used on the screening unit in the extruder with the aim of reducing the screen change time.
The thorough pick material was fed into the extrusion line first. As the hopper was becoming empty, the feed of minimal pick material was started. Thus there was a continuous feed of material into the extrusion line throughout the trial. The line was not stopped or purged at the transition between the two feed materials.

Centriforce recorded the time at which each feed material started to enter the extrusion line, the finishing time for the complete trial and the throughput rates. The manufactured panels were stacked on pallets and weighed on completion of the trial. Scrap material, whether as pre-start up purge, production scrap or edge trim, was collected separately and weighed after the trial.

There were four areas in which the panels produced were tested to determine if they were within Centriforce’s current production standards and how they compared with their standard products. These were:
- A visual examination of the white plastic film surface;
- Measurement of each panel’s length, width and thickness. The trial panels were deliberately made oversize to allow them to be used by a range of end users. The panels were to have dimensions of around 2,490mm by 1,245mm, with an expectation of 5-7mm shrinkage as the panel cooled. Centriforce regard a thickness between 11mm and 12.5mm to be acceptable;
- Visual assessment of the degree of upward curl along the edges of the panels; and
- Impact testing using a Centriforce variant of a standard industry test. This test is more onerous than is required for a panel that is being used for a hoarding application. In order to pass the test any cracks or tears caused by the impact weight must be within a 75mm radius of the impact point.

### 2.2.5 Results and discussion

**Thorough picked material**

0.87t of panel product was manufactured from the thorough picked agglomerate giving a yield of 55%. The losses of material were through pre-start up purge (6%), start-up scrap (20%), production scrap (9%) and edge trim (8%). These losses are a necessary part of production; however the pre-start up purge and start-up scrap would be far lower if a normal production run was undertaken as these were only necessary to remove traces of previous material and to establish optimum operating conditions.

The throughput rate for the trial was 0.417t/hr, which was slightly slower than Centriforce’s normal production. However, due to the relatively small quantity of feed material available, Centriforce preferred to operate conservatively to be sure of producing panels of a sufficient quality for possible downstream trial applications.

Table 5 shows the results obtained from analysing the panels produced during the trial. The trial panels passed the necessary tests and all were within Centriforce’s existing final product specification for hoardings. An example of the finished panel is shown in Figure 20.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Centriforce standard</th>
<th>Trial panels</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (mm)</td>
<td>2,440-2,450</td>
<td>2,475-2,492</td>
<td>Deliberately made oversize</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>1,220-1,226</td>
<td>1,235-1,245</td>
<td>Deliberately made oversize</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>11-12.5</td>
<td>11.7-11.9</td>
<td>Pass</td>
</tr>
<tr>
<td>Edge curl (mm)</td>
<td>Less than 10</td>
<td>Less than 10</td>
<td>Pass</td>
</tr>
<tr>
<td>Impact test</td>
<td>Cracks/tears within a 75mm diameter circle</td>
<td>Cracks/tears within a 75mm diameter circle</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Figure 20 Finished panel produced from thoroughly picked material

Figure 21 shows an example of a panel after it has undergone an impact test. It should be noted that the cracks are well within the 75mm radius.

Figure 21 Result of impact test

Although the panels passed the above tests the issues of concern were the consequences of contamination in the feed material on the operation of the screen unit and on overall product quality. Screens lasted about 15 minutes before they needed to be changed as a result of them blinding with contaminants which did not melt, causing the pressure drop over the extruder to increase. This is significantly lower than the 25 to 30 minutes typically observed during normal operation at Centriforce. Figure 22 shows a typical screen and the thick layer of impurities which built up on it over the 15 minute operation period.
Although a large amount of impurities were removed by the screen, smaller contaminants were able to pass through the 5mm aperture and were therefore incorporated into the final panel product with the following effects:

- Some surface irregularity was apparent where a contaminant particle was trapped between the surface of the extruded feed and the applied white film. This is illustrated in Figure 23;
- Some particles became sufficiently hot within the roller bank to cause occasional local punctures of the applied film, illustrated in Figure 24; and
- The presence of particles was clearly visible on the trimmed edges of the product panels. Small voids were also visible in some places due, presumably, to particles having been dragged out by the trimming knives.

Figure 23 Surface irregularities due to trapped contaminant particles
Centriforce was clearly concerned about the manpower implications of frequent screen changes if they were processing this type of material on a regular basis. However Centriforce judged the overall quality of the finished boards to be good enough to be offered for potential downstream use in hoarding applications.

**Minimal picked material**

1.46t of panel product was produced from the minimal picked material, giving a yield of 86%. The yield is significantly higher than that of the thoroughly picked material as there was no start up or pre-start up waste, giving a more realistic achievable yield.

The throughput rate for the trial was 0.373t/hr. This was below the rate achieved with the thorough pick feed material and appreciably slower than normal Centriforce production. However it was dictated by the increased frequency of screen cleaning, as discussed below, and the problems this raised for the stability of the molten feed material in the roller bank.

**Table 6** shows the results obtained from analysing the panels produced during the trial. The trial panels once again passed the necessary tests and were all within the final product specification. An example of the finished panel is shown in **Figure 25**.

**Table 6 Evaluation of panels made from minimal pick feed material**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Centriforce standard</th>
<th>Trial panels</th>
<th>Comment</th>
</tr>
</thead>
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<tr>
<td>Length (mm)</td>
<td>2,440-2,450</td>
<td>2,475-2,492</td>
<td>Deliberately made oversize</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>1,220-1,226</td>
<td>1,235-1,245</td>
<td>Deliberately made oversize</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>11-12.5</td>
<td>11.1-11.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Edge Curl (mm)</td>
<td>Less than 10</td>
<td>Less than 10</td>
<td>Pass</td>
</tr>
<tr>
<td>Impact test</td>
<td>Cracks/tears within a 75mm diameter circle</td>
<td>Cracks/tears within a 75mm diameter circle</td>
<td>Pass</td>
</tr>
</tbody>
</table>
The issues of concern were once again with the level of contamination in the feed material. The impact on the operation of the screen unit and on product quality was more severe than with the thorough pick feed material, with screens lasting only about 6-7 minutes before they needed to be changed.

As well as requiring a higher frequency of screen changes the impurities also led to the same issues seen with the thorough picked material. These were contaminants passing through the screens causing imperfections on the surface of the panel and particles and voids present in the trimmed edge of the panels.

The contamination in the trimmed edges is more severe in the minimally picked material as can be seen in Figure 26.
Once again the overall quality of the finished panels was judged to be good enough to be offered for potential downstream use in hoarding applications. However Centriforce was more concerned about the manpower implications of frequent screen changes if they were processing this type of material on a regular basis.

2.2.6 Conclusions and recommendations

The key conclusions from the Centriforce manufacturing trial are:

- Both feed materials (thorough and minimal pick) produced panels that met existing Centriforce standards for dimensions, edge curl and impact resistance;
- The level of high melting point contaminants in the feedstock materials led to rapid blinding of the screens. With the thorough pick material, screen life was around 50% of Centriforce normal production performance. With the minimal pick material, screen life was reduced to less than 25% of normal production performance; and
- High melting-point contaminants in the feedstock materials passing the screen led to an incidence of surface irregularities that was higher than the normal Centriforce product but was judged to be acceptable for a hoarding application. The irregularities were more noticeable with the minimal pick feed material than with thorough pick material.

The key recommendations from the trial are:

- Despite the effect of the high melting-point contaminants on surface appearance, Centriforce judged that the panels were of sufficient quality to be used in a hoarding application. It is therefore recommended that products from this trial be put forward to a prospective user for evaluation; and
- Screen changing should be investigated further to determine whether the frequency found necessary during the trial is too high for a commercially viable process and, if so, whether an automatic screen changer or a continuous screen cleaner would be appropriate.

2.3 Protomax panel manufacturing trial

The purpose of the trial undertaken at Protomax Plastics was to determine if cominged post-consumer film collected from a MRF and from retail front of store and back of store film waste could be processed into panels using a prototype machine developed by Protomax.

2.3.1 Project partner

Protomax Plastics is a plastic engineering company based in London, and Swansea, with machine building facilities in Piesendorf, Austria. Protomax has produced a prototype machine P2 capable of processing cominged waste streams to manufacture a range of panels, which can be used in a number of applications including:

- Display panels;
- Hoardings;
- Shutterings; and
- Security panels.

The company’s primary objective is to produce and sell P2 machines. For this reason it has a prototype P2 at its facility in Swansea which is used for demonstrations to potential new customers. To generate interest in the P2 machine, Protomax undertakes limited production runs for customers.

2.3.2 Trial facility and equipment

The P2 prototype produces a standard panel of 2,440mm x 1,220mm x 19mm, which has a smooth polymer skin of 2mm thickness and a rigid honeycomb core of 15mm. The time to produce a single panel is between 30 and 40 minutes.

By using different materials in the layers of the panels Protomax is able to produce application-specific panels, for example ballistic and blast protective panels, flame retardant panels and anti-bacterial panels. The panels can also be made in varying densities to suit their applications. In general, lower density panels with a higher degree of foaming in the core are stiffer per unit weight.
2.3.3 Trial objectives

The objectives of the trial were to:
- Produce panels containing 70% film waste and 30% rigid plastic waste from both Biffa and Sainsbury’s film feedstocks;
- Produce a 50% film waste and 50% rigid plastic waste panel using the Biffa film waste feedstock; and
- Evaluate the panels to determine if they were of sufficient quality to be used as display panels or in a hoarding application.

2.3.4 Methodology

Trial feedstock materials

The Biffa Class C film bales and Sainsbury’s/Jayplas film bales were used in the core layer of the manufactured panels.

The trial also involved the use of non-bottle rigid plastic post-consumer waste from Viridor’s plastic bottle recycling plant in Skelmersdale, also to be used in the core layer. This material included trays, tubs and pots and is likely to have been a mixture of polypropylene (PP), high density polyethylene (HDPE) and polystyrene. This was combined with the LDPE film in a specific ratio to alter the density, and therefore final application, of the panels produced. Figure 27 shows a photograph of the Viridor mixed non-bottle rigid material.

Figure 27 Viridor non-bottle rigid material

For use in the outer skin layer Protomax provided recycled wheelie bin material. This material is predominantly HDPE, potentially with small quantities of medium density polyethylene. For standard panels Protomax has found that a recycled PE is ideally suited for the skin material. However PP can also be used for the outer skin layer of panels requiring a harder surface.

The material did not require pre-processing at an additional facility as with the CeDo and Centriforce trials.

Trial procedure

Prior to the manufacturing of the panels all three infeeds (Biffa, Sainsbury’s/Jayplas and Viridor) underwent a pre-processing stage. Figure 28 shows a flow diagram of this.
Figure 28 Flow diagram of pre-processing stage

It was found that the Sainsbury's/Jayplas and Viridor infeeds required handpicking to remove large pieces of card from the Sainsbury's/Jayplas material and ferrous packaging from the Viridor material. The level of contamination removed from both was approximately 1%. Visual inspection of the Biffa material showed that it did not contain any undesirable contamination and therefore did not require hand sorting.

One of the main advantages of the process and machine developed by Protomax is that the final panel product can be a composite of many materials, including different polymers and paper. This means that only metal, which can damage the granulator, and large pieces of card had to be removed during the trial. This accounts for the low level of handpicking that was required in comparison to the other trials.

Once the material had been pre-processed laboratory scale trials were undertaken to determine the ratio of film waste to rigid waste required to give the desired density for the final panels of around 500 kg/m$^3$. It was found that a ratio of 70:30 film material to rigid material provided the required density for the finished panels.

After the optimum blend ratio had been found the materials were fed into the P2 process separately. The order of production was the Biffa/Viridor 70:30 material first, followed by the Sainsbury's/Viridor 70:30 material and finally the Biffa/Viridor 50:50 mix. Figure 29 shows a flow diagram of the production process.

Figure 29 P2 panel production process

The skin material has to be passed through a fine mesh in order to provide a smooth surface to the manufactured panel.
A nitrogen blowing agent is added to the feed during the blending stage. This addition of a blowing agent gives the core its honeycomb structure and makes it more lightweight. The exact quantity of nitrogen blowing agent is confidential to Protomax.

Ten full scale panels were produced from both the Biffa feed and Sainsbury's/Jayplas feed.

Once the 70:30 blend panels were produced a third formulation of 50:50 Biffa film waste and Viridor rigid waste was produced in the same manner, beginning with laboratory scale production followed by full scale production.

2.3.5 Results and discussion

Results applicable to all panels

Each panel took approximately 40 minutes to produce. However it is suggested that a more efficient operating procedure would be to have four P2 units running in parallel and it is claimed that this setup can yield 50 panels per 8 hour shift.

All panels were visually examined by the Protomax staff and were deemed to be satisfactory.

All the panels were measured and found to comply with the standard dimensions of 2,440mm x 1,220mm x 19mm after cooling and shrinking by 2% which is accounted for in the design of the P2 prototype equipment.

A cross section of the panels was inspected and showed a consistent distribution of the skin layer at 2mm totally encapsulating the core. The core layer was the desired thickness of 15 mm.

Table 7 Weights of manufactured panelsshow the maximum, minimum and average weights of the panels manufactured during the trial.

<table>
<thead>
<tr>
<th>Infeed</th>
<th>Weight</th>
<th>Minimum (kg)</th>
<th>Maximum (kg)</th>
<th>Average (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70:30 Biffa:Viridor</td>
<td></td>
<td>29.3</td>
<td>30.1</td>
<td>29.9</td>
</tr>
<tr>
<td>70:30 Sainsbury's/Jayplas:Viridor</td>
<td></td>
<td>30.0</td>
<td>30.5</td>
<td>30.2</td>
</tr>
<tr>
<td>50:50 Biffa:Viridor</td>
<td></td>
<td>27.8</td>
<td>28.3</td>
<td>28</td>
</tr>
</tbody>
</table>

70:30 Sainsbury’s/Jayplas film and Viridor rigids panels

Figure 30 70:30 Sainsbury’s/Jayplas film and Viridor rigids shows the cross section of a panel produced using 70% Sainsbury’s/Jayplas film and 30% Viridor rigids. The cross section shows relatively little contamination.

Figure 30 70:30 Sainsbury’s/Jayplas film and Viridor rigids panel

The weight of the panels was similar to that of the 70:30 Biffa Viridor panels and was higher than the 50:50 Biffa Viridor panels.

70:30 Biffa film and Viridor rigids panels

Figure 31 shows the cross section of a panel produced using 70% Biffa film and 30% Viridor rigids. The level of contamination appears to be higher in the core of the panels than for the panels manufactured using the
Sainsbury’s/Jayplas film; however the panel appearance was still satisfactory due to presence of the skin layer covering the core.

**Figure 31** 70:30 Biffa film and Viridor rigids panel

The weight of the panels was the highest of the three, although only slightly more than the panels produced using the Sainsbury’s/Jayplas film.

It was noted during processing that due to the levels of dirt and contamination in the Biffa infeed material a foul smelling odour was given off on heating. This however disappeared once the panel had cooled to ambient temperature.

**50:50 Biffa film and Viridor rigids panels**

**Figure 32** shows the cross section of a panel produced using 50% Biffa film and 50% Viridor rigids. The panel also shows more contamination than the ones manufactured using the Sainsbury’s/Jayplas film; however it was difficult to determine whether it showed more or less contamination than the panels made with 70% Biffa film. Once again the contamination was not an issue for panel appearance due to the skin layer.

**Figure 32** 50:50 Biffa film and Viridor rigids panel

The 50:50 Biffa:Viridor panels had a less dense core than the other two types of panels, due to the higher levels of the less dense rigid material used in the blend. This, however, was not deemed to be out of specification for the panels.

As with the previous Biffa panel a foul odour was also observed, but this disappeared on cooling.

**2.3.6 Conclusions and recommendations**

The P2 prototype machine was able to produce panels from both the Biffa Class C bales and Sainsbury’s/Jayplas film bales which met the existing final product specifications of Protomax.

The panels are recommended to be suitable for use in applications such as display panels or hoarding, as well as a number of other applications referred to in Section 3. It is therefore suggested that the products from the trials are put forward to prospective users for evaluation.
3.0 Product applications

The first phase of this project identified a number of end use applications for products manufactured from post-consumer films. Through discussions with the retail sector, WRAP selected two key applications for this second phase of work;

- Refuse sacks; and
- Panels for use in a variety of applications such as external hoardings and in-store displays.

Following the trials covered in Section 2.0 the next stage of the project was to present the trial products to the retail sector in order to obtain their feedback and to identify a route by which these products could be adopted for use in their store networks and/or sold as products to their customers.

Following a sector wide consultation, Sainsbury’s and the Co-operative came forward as being particularly keen to participate in the trials.

3.1 CeDo refuse sacks

The CeDo manufacturing trial produced refuse sacks with a post-consumer LDPE recycled content of up to 27% (the maximum polymer addition rate that CeDo normally use in its refuse sack formulation). CeDo manufactures a number of own-brand products for retail customers. For the purposes of the manufacturing trial a Sainsbury’s refuse sack product was selected from CeDo’s current production range.

3.1.1 Sainsbury’s

A meeting was held with key representatives of Sainsbury’s to present the findings and results of the manufacturing trial and to discuss the next stage of Sainsbury’s adopting the product into its existing product range.

The refuse sacks manufactured from the trial were distributed to Sainsbury’s stores and sold to customers. No adverse feedback from customers was received which is a very positive response.

3.1.2 The Co-operative

The Co-operative was very enthusiastic to include a product of this kind in its product range. Internal discussions are taking place to put in to action the necessary changes to the way that its front and back of store film is currently handled to enable a suitable feedstock to be provided to CeDo for manufacturing. The plan is to manufacture a post-consumer film recycled content own-brand refuse sack that can be part of its existing product range. The aim is to launch the product within the next 12 months.

3.2 Centriforce panels

The Centriforce manufacturing trial produced a LDPE panel suitable for external hoarding applications. This application was identified during the first phase of this project as one in which the retail sector was particularly interested. The panels manufactured by Centriforce are a standard 1,220 x 2,440 x 12mm size, with a recycled core and a thin virgin polymer skin.

3.2.1 Sainsbury’s

Sainsbury’s representatives have been shown the Centriforce panel product and discussions have been held on applications for the panels within Sainsbury’s stores.

Sainsbury’s was interested in the product and has a requirement for external hoardings as part of its store building and refurbishment programme. Centriforce can also provide hoardings through a fleet option, whereby Sainsbury’s could hire the panels as and when needed and this is an option which is being explored further.
Sainsbury’s has a site in central London for trialling new products and store fittings and infrastructure and there are plans to trial the Centriforce hoarding panels here so they can be fully evaluated.

Discussions were also held as to other potential panel applications. Centriforce provided an illustration, shown in Figure 33, of a variety of applications for the retail environment. Sainsbury’s was particularly interested in in-store applications, for example display panels. This is currently being followed up by Centriforce and Sainsbury’s through its existing store fit-out contractors.

Figure 33 Recycled plastic products in retail applications

3.2.2 The Co-operative

The Co-operative team was very positive and encouraging regarding in-store applications for these panel boards. The Co-operative was particularly interested in in-store displays. It has a high number of semi-permanent in-store displays as part of its store network, with ethical and environmental messages and information for customers. These are in place for approximately 18 months at a time before being updated.

Centriforce supplied a number of trial panels to one of the Co-operative’s existing contractors, Novograf, who produce and supply in-store displays to the Co-operatives store network. Novograf specialises in brand presentation and works with leading high street stores and brands. Its portfolio includes in-store displays, window graphics, signage, checkout and counter refurbishments.

Novograf ran some initial printing trials on the panels supplied by Centriforce, using both digital and screen printing techniques and solvent and UV cured inks. The results were promising and both parties believe a suitable panel made from the Co-operative’s film waste can be manufactured for in-store display applications. It should be recognised that the trial panels manufactured by Centriforce were produced to its product specification for external hoardings and therefore some further product development and testing is needed for this application, particularly in the area of ink adhesion to the panel. Work is ongoing in this area between Novograf and Centriforce.
3.3 Protomax panels

The Protomax manufacturing trial produced a panel made from comingled film waste suitable for a variety of applications, including external hoardings. The panels are a standard 1,220 x 2,440 x 19mm size, with a comingled recycled film core and a single recycled polymer outer layer.
3.3.1 Sainsbury’s

As with the Centriforce panels Sainsbury’s was very encouraging and showed a lot of interest in the Protomax panels. It was recognised that the panels would be suitable for external hoardings but Sainsbury’s already has a system that works well and there would need to be a clear benefit for Sainsbury’s to swap to the Protomax panels.

Discussions focused on applications such as shelving, point of sale displays, trolley bays, petrol station kiosks and toilet cubicles. The Protomax panels are potentially suitable for all these applications due to the combination of their lightweight nature and strength. The key issue for Sainsbury’s is to identify applications that can exchange a heavy, metal or virgin plastic material for the Protomax panels, in order to obtain the maximum carbon savings benefit.

Work is currently underway between Protomax and Sainsbury’s to produce samples of some of the key product applications and to trial these to evaluate their usage and performance.

3.3.2 The Co-operative

Again the Co-operative team has focused on potential in-store applications for the Protomax panels. These include store fittings (surfaces and counters) and shopping trolley bays. Discussions also identified potential opportunities earlier in the food supply chain for Protomax panels to be used within food production facilities that supply the Co-operative.

Discussions are ongoing between the Co-operative and Protomax to identify opportunities for trialling the panel product within its store network.
4.0 Conclusions and recommendations

Overall this project has delivered a series of successful manufacturing trials using comingled post-consumer film as a recyclate in a range of products.

**CeDo refuse sacks manufacturing trial**

The CeDo manufacturing trial utilised material sourced from both Sainsbury’s front and back of store film collections and kerbside collected comingled film from Biffa’s MRF at Trafford Park. The material was pre-processed to ensure it was suitable for the production processes at CeDo’s facility in Telford. This involved a film collection trial at Biffa whereby optimised NIR sorting enabled a higher quality film feedstock to be obtained. This material and the Sainsbury’s material were processed at Ecoplast in Austria in order to produce a LDPE pellet to be used in the CeDo production.

The Sainsbury’s film material produced good quality pellets, with a low level of PP and gas content. This material was successfully blown into refuse sacks, with both single (outer) layer sacks and double layer (outer and inner) sacks made from the trial PCR. The trial enabled 50% and 100% of the currently European sourced PCR to be replaced with the UK sourced comingled film. The sacks met the full specification currently in place and no modifications are thought to be needed on the CeDo production line to enable full scale production to be undertaken with the Sainsbury’s material.

The Biffa material was processed on two different lines at Ecoplast (Line 1 and 3); Line 1 is newer following recent modifications and thought to produce a better quality pellet. The Biffa material processed on Line 1 was satisfactory and made refuse sacks with both single (outer) layer sacks and double (inner and outer) layers from the trial PCR. This was despite having higher levels of PP and gas content than the Sainsbury’s material. The sacks with the double layer of trial PCR met the current end product specification, whilst the single layer trial PCR sacks was below specification for tensile strength. CeDo expects to need to make modifications to the perforation and bag rolling sections of their production line to enable the Biffa material to be used as a feedstock but the results from the trial are promising and the modifications are thought to be relatively straightforward to implement.

The Biffa material was processed on Line 3 at Ecoplast produced the lowest quality material. It needed to be reprocessed by CeDo to reduce the gas content in order for it to be suitable to produce refuse sacks. Refuse sacks were manufactured with an outer layer from the trial PCR. The tensile strength of these sacks was slightly below the current specification but the majority of the specification requirements were achieved.

The recommendation for CeDo is to source more comingled film and run larger scale production trials to enable a full commercial evaluation to be undertaken.

**Centriforce panel manufacturing trial**

A successful trial was delivered with Centriforce using film sourced from Sainsbury’s front and back of store collections. It was not possible to use material sourced from Biffa due to the presence of contaminants making it unsuitable for Centriforce’s production processes.

The Sainsbury’s material was pre-processed at Hanbury Recycling in order to remove contaminants and produce an agglomerate. The removal of contaminants was undertaken through hand sorting, following a thorough pick and minimal pick approach.

Both the thorough and minimal pick materials produced in specification panels and Centriforce considered them suitable for external hoarding applications. The key processing issue was the frequency of screen changing due to the presence of high melting point contaminants, which was much higher for the trial material compared to Centriforce’s typical production.

The recommendation is for Centriforce to investigate the screen changing issue further to ensure a commercially viable product can be manufactured.
**Protomax panel manufacturing trial**

A successful manufacturing trial was also delivered with Protomax Plastics. Material sourced from both Sainsbury’s and Biffa was utilised in the production of panels. The film material needed to be mixed with a proportion of non-bottle rigid plastics to ensure the required density was achieved for the panels. The feedstock material required a low level of pre-processing, primarily to remove metal packaging, to ensure the granulation equipment was not damaged.

The P2 machine was shown to be capable of handling comiled film material and in specification panels were produced from both feedstock film materials. The panels are thought to be suitable for a range of applications, including external hoardings and in-store displays.

**Retail sector involvement**

Sainsbury’s and the Co-operative were involved as retail partners in the project. Following the manufacturing trials discussions were held with both retailers to explore the opportunities for them to adopt these products as part of their product range and/or within their store networks.

Sainsbury’s showed interest in both the panel products (Centriforce and Protomax) and are investigating opportunities for the products to be used within their store network.

The Co-operative was also very enthusiastic in the products manufactured by the trial partners. The panels present a strong opportunity for the Co-operative; in particular the Centriforce panels could be used for in-store displays and work is underway with Novograf, one of the Co-operatives in-store display contractors, to trial these applications. Discussions are also taking place with CeDo to manufacture a refuse sack using film collected through Centriforce’s front and back of store network.

The overall conclusion is that the manufacturing trials have demonstrated that there are a number of technically feasible products that can be manufactured from UK sourced comiled post-consumer film. Both the film material collected through the retail network and from kerbside schemes can be made into quality recycled products that the retail sector have shown interest in. The next step is for the manufacturers and retailers to explore how these products can be developed further to be commercially viable and adopted for sale or use within their stores.