AN INVESTIGATION INTO THE

TECHNICAL AND MARKET FEASIBILITY OF RECYCLING POST-CONSUMER POLYPROPYLENE

Polysearch · basell Polyolefins · Qenos · Sealed Air CRYOVAC Food Packaging Systems · HUHTAMAKI

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PROJECT REPORT
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Project Management & Reporting By

Polysearch Pty. Ltd
PO Box 339
Northcote Vic 3070
Telephone (03) 9481-3940
Facsimile (03) 9489-3540
Mobile 0405 523 944

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PP Industry Recycling Group Members:

Packaging Industry Representatives	Michael Stewart (Sealed Air)
	Sam Padibjo (Huhtamaki)
Polypropylene Manufacturing Representatives	Con Stavropoulos (Basell)
	Rod Campbell (Qenos)
	Tracey Boseley (Qenos)
Project Management	Meredith Baker (Polysearch)

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DISCLAIMER

Attention is drawn to the fact that this report summarises a limited study undertaken within restricted time constraints. Although this report has been prepared with care and its recommendations made in good faith, it is a report of a study only and not produced with the intention that it be relied upon for commercial or other purposes. It is not advice. The author and Polysearch Pty Ltd do not accept any liability for any loss or damage resulting from reliance on information contained in this report.

GLOSSARY OF TERMS USED

HDPE – High Density Polyethylene

LDPE – Low Density Polyethylene

LLDPE – Linear Low Density Polyethylene

MRF – Materials Recovery Facility where kerbside materials are collected for sorting, baling and subsequent despatch to the market.

PET – Polyethylene Terephthalate

Post-Consumer Waste (PCW) – Those materials collected via the household kerbside collection system.

Positively Sort – To physically pick/sort the desired plastic bottle/container from the waste stream for baling.

PP – Polypropylene

PS - Polystyrene

PVC – Polyvinyl Chloride

Recyclate – Recycled plastic material ready to be used to make a new product.

Recycling – The process of collecting, sorting, reprocessing and re-using waste materials.

Reprocessing – The process by which a waste material is changed into a usable raw material.

Reprocessor – Defined in this study as a plastic recycler organisation with a wash plant, granulator and extruder system.

Sink-Float Method – Process used during recycling of waste plastics to separate different types of plastic based on the density of the individual plastics (heavier/denser plastic fragments sink and lighter plastic fragments float).

EXECUTIVE SUMMARY

To investigate the technical and market feasibility of recycling post-consumer Polypropylene, material was collected, sorted and audited from the kerbside waste stream at two independent MRF's in two different States. This material was reprocessed by two independent reprocessors in two different States. Material was then thoroughly analysed and the test results used to find six initial test market applications for this PP recyclate.

The entire post-consumer PP recycling process from households to end-markets is illustrated in Figure E1.

From the collection, sorting and auditing stage of the study, it was found that the PP recovery rate from the kerbside waste stream represented 3-9% of all plastics recovered. The higher % PP recovery rate was found with the MRF experienced in sorting PP. This MRF also had a comparatively larger variety of PP types present in its bales, improving its overall PP recovery rate. For the smaller MRFs, it may not be cost viable to have a dedicated PP employee sorting only PP due to the relatively low quantities of PP material found in the waste stream. This sorter would need to be involved in sorting other plastics, for example, coloured HDPE and/or PVC.

The most common PP products (by mass) found in the audited bales were cordial bottles, pot planters and ice-cream containers. The volume of ice-cream containers and margarine/butter containers found in the waste stream was not comparable to the known packaging volumes produced. This indicates that further education of the general population and sorters about what PP products are recyclable, may be required to improve recovery rates.

Sorters at both MRF's had difficulties distinguishing PVC from PP cordial bottles and PS yoghurt containers from PP margarine containers, with the PVC and PS contaminating the PP bales. This plastic contaminant was lost i.e. "sunk" during reprocessing and presented no technical problems to the manufacturers during moulding. During the reprocessor trials, it was noted that both plants were able to reprocess the PP bales provided with ease, although relatively high material losses of 20-30% over a 3 tonne run and a large number of screen changes on the extruder were observed. However, with larger production runs, this loss rate is expected to be significantly lower.

The bale content varied between MRF's in different geographical locations yet recyclate material properties were found to be very consistent across all samples. The quality of the PP recyclate was comparable from both MRF's indicating that an experienced capable employee can sort PP and other plastics at the same time without adversely affecting the PP recyclate quality.

The PP recyclate was found to be suitable for non-food grade injection-moulding type applications. All market moulding trials were technically successful and some of the potential end-markets for this recyclate are illustrated in Figure E1. For these identified markets, no modification of the recyclate was required to enhance material properties.

In summary, this project has demonstrated that the widespread recycling of post-consumer PP appears to be both technically feasible and desirable from the manufacturers viewpoint and further study to determine economic viability is warranted.

POST-CONSUMER POLYPROPYLENE (PP) RECYCLING PROCESS FROM HOUSEHOLDS TO MARKET

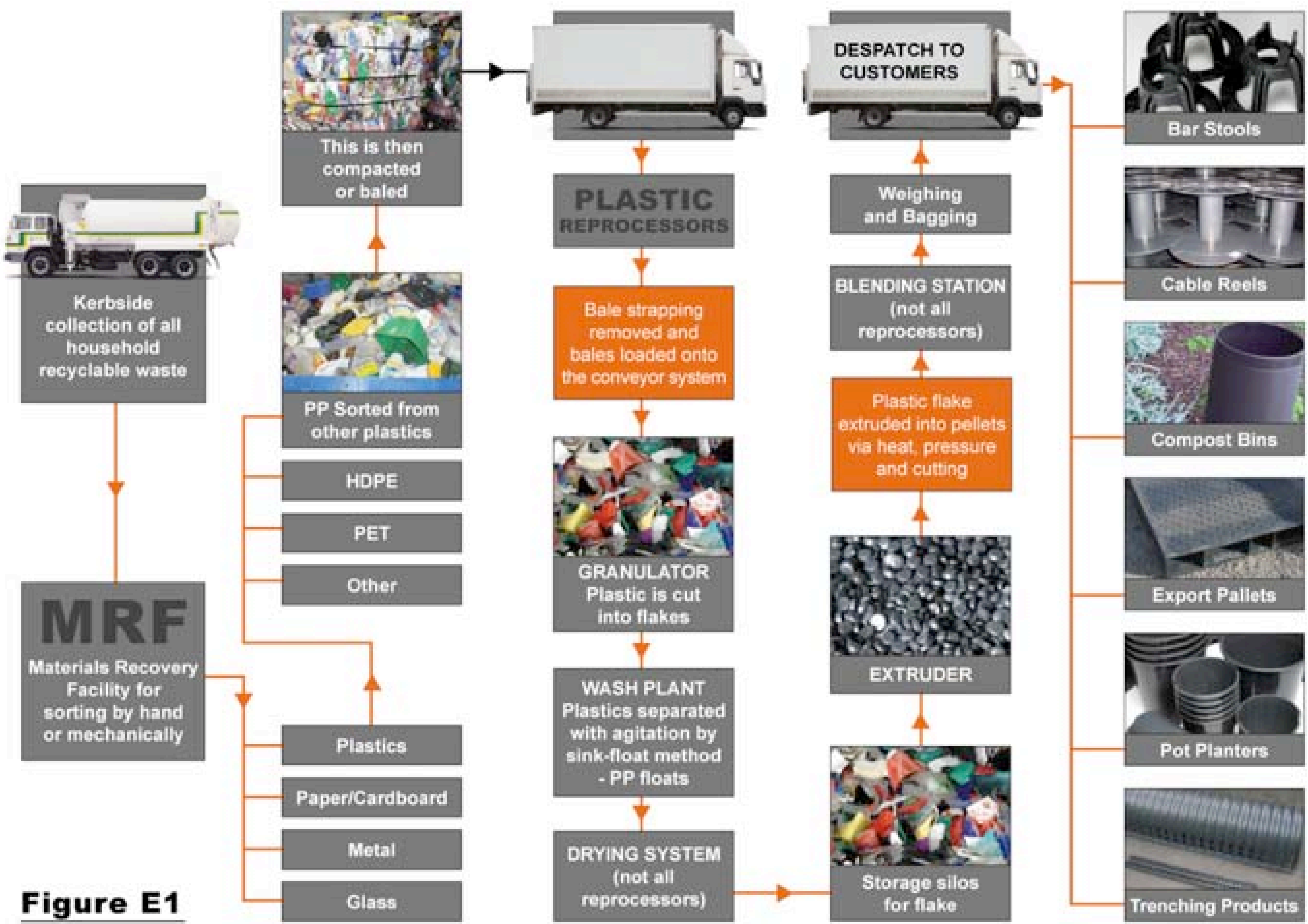


Figure E1

1. BACKGROUND

HISTORICAL COMMENTS

Plastics recycling has grown significantly over the past 15 years, principally driven by four major initiatives. Firstly, in 1979, was the development of a household collection system (a woven PP sack or crate system) for PET bottles. This collection system had been used for glass bottles for many years. In the early 1980's, ACI set up a PET recycling plant in Blacktown, NSW to recycle the PET bottles. Smorgons were also involved in recycling the black polyethylene cups at the base of the bottles. Ca. 1985, Smorgons established a company called Syntal which also purchased mixed post-consumer plastics for recycling into their lumber products. In 1991, the ACI Blacktown plant was replaced by a new PET recycling plant in Wodonga. The PET bottles collected were ground into flakes, washed and then extruded. The recyclate was used as a middle layer in PET bottles by a co-injection process. This PP sack collection system developed into the kerbside collection systems in use today.

The second initiative was the establishment of HDPE milk bottle recycling ca. 1991 by Brickwood Holdings (the Vautin family) and Qenos (then Compol). They established Full Cycle Plastics in Cheltenham. This plant (capacity of 3500 tonnes per annum) was designed by Givoni Simbianca, and recycled milk bottles into pellets that were marketed by Compol. Brickwood were instrumental in having milk bottles included in the kerbside collection schemes and they also developed some of the initial products from the recycled HDPE, examples being pallets and wheelie bins. The plastics manufacturing market was slow to accept the remaining volume of recycled resin as being suitable for other applications, due to a number of limitations in the resin properties, and concern about product quality. The Full Cycle Plastics plant was sold to Visy Industries in 1997. It operated on that site until 1999 when it was shipped to Sydney to recycle milk bottles. This was done at the Waste Services site at Chullora until its closure in 2005.

The third initiative was the entry of Visy Industries into kerbside collection and recycling, in an effort to increase their feed stock of paper and cardboard, primarily to feed their paper mills. In the process of collecting all recyclables, Visy also collected plastics. In 1997, Visy decided to add value to the plastics stream by taking the further step of reprocessing the bottles to produce resin pellets. In 1998, Visy built a plastics bottle recycling plant at Reservoir that featured automatic sorting of co-mingled bottles into HDPE and PET streams. At this site, Visy developed a wide range of markets for PET (fibre, bottle and sheet applications) and HDPE (pipe, blow moulding, extruded sheet, and incorporation into some injection moulding applications).

The fourth initiative was the creation of a reliable and comprehensive kerbside collection and sorting system. This encouraged the establishment of a large number of local recyclers since there was now a reliable source of feedstock, and in turn this facilitated the development of market opportunities for plastic recyclate.

The market development phase for the recycled HDPE took over 5 years to mature. This was needed by the recycling industry to develop a consistent supply of uniform quality product. It was necessary to develop the processing capability to minimise contamination, provide uniform colour and batch-to-batch product consistency. This involved improvements in processing technology, redesign of product labelling and the development of appropriate quality assurance systems.

In the initial kerbside collection strategy, Polypropylene was generally considered to be excluded from the recycling stream due to the difficulty in separating it from HDPE, even though it was always technically recyclable.

When designing this investigation into Polypropylene recycling, we have been able to learn from and utilise the experience of HDPE developments, and in particular, to incorporate tests that should avoid many of the technical pitfalls that occurred with HDPE recycling.

2. INTRODUCTION

MARKET OVERVIEW

Polypropylene recycling is a broad term used to describe the reuse of Polypropylene plastic from previously manufactured PP products. This material is primarily either from post-industrial sources (i.e. scrap plastic from manufacturing plants/industry) or from post-consumer sources (i.e. household kerbside collection systems). Post-industrial recycling systems are well developed and reprocessor organisations, with or without wash plants, are able to process these materials. Examples of these materials include car bumper bars and batteries. It is the post-consumer PP material that is the focus of this study as it is predominantly this material that can end up in the landfill if not collected and recycled and it is also currently not already being recycled to the extent of its post-industrial counterpart.

It should also be noted that just because a plastic product bears the Plastics Identification Code (numbers 1 to 7), it does not mean that this product is readily recyclable. This is simply a plastic product identification system. In order for a plastic to be recycled, it must be technically and economically viable to reprocess this material into a product that can be utilised in the market place. This study has focussed on the technical and market feasibility of recycling post-consumer Polypropylene.

Recycling of post-consumer waste (PCW) plastics, such as soft drink bottles (PET Plastics Identification Code #1) and milk bottles (clear HDPE Plastics Identification Code #2), is now a well developed industry in terms of the collection, sorting and reprocessing of these materials. With strong end-market applications in both Australia and overseas for these plastics, these recycling markets appear to be sustainable in the longer term. However, there are very few MRF's currently actively collecting and sorting PP, the majority of MRF's are baling this PP material into a mixed or co-mingled bale after removal of milk bottles and soft drink bottles from the waste stream. These co-mingled bales are predominantly an export only product as local markets mostly require sorted bales of one type of plastic.

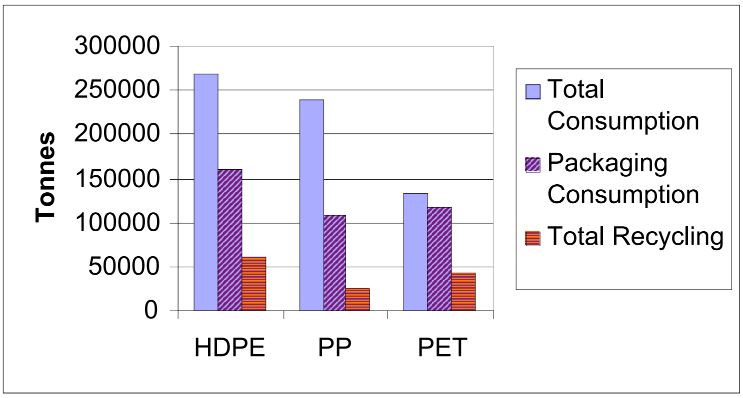
Polypropylene (PP) is a high volume plastic used in the packaging industry for products such as ice-cream containers, margarine/butter containers and cordial bottles, and yet this post-consumer plastic is not being recycled to the same extent as its counterparts. Table 2.1 below shows the tonnages of three key PP packaging products manufactured in 2004, and gives some indication of potential volumes that could be recycled per annum if actively collected and sorted.

Table 2.1: Retail Sales in 2004 for three key PP packaging products.
(Approximate data obtained from industry sources).

PRODUCT CATEGORY	ESTIMATED POTENTIAL MASS BY CATEGORY ENTERING THE PP WASTE STREAM (Kilotonnes)
BUTTER/MARGARINE TUBS and LIDS	4.6
ICE CREAM TUBS	3.8
CORDIAL BOTTLES	0.8
TOTAL POTENTIAL PP FOR RECYCLING	9.2

There was an estimated annual total consumption (packaging and non-packaging) of 240,068 tonnes of Polypropylene in Australia in 2003, with 23,721 tonnes recycled, representing a recycling rate of only 9.9%. In comparison, the recycling rate for PET is 31.5% and HDPE 23.1% (PACIA, Nolan ITU). This is illustrated in Figure 2.1.

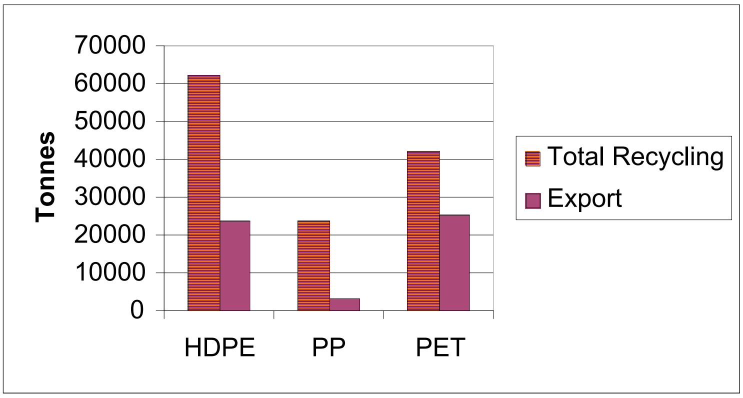
Figure 2.1: Total consumption and packaging consumption of HDPE, PP and PET plastics in 2003 and their respective recycling volumes



When comparing packaging recycling rates, the PACIA report found that only 5.6% of PP packaging was recycled during 2003 versus 35.3% of PET packaging and 32.3% of HDPE packaging.

It can also be noted from the PACIA report data, that of the total PP recycled, in 2003 only 12.4% was exported in comparison to 59.7% of total PET and 37.9% of total HDPE. This is illustrated in Figure 2.2 below.

Figure 2.2: HDPE, PP and PET usage in 2003, local versus export market



It can be seen from the above graph and from discussions with exporters, that the overseas markets prefer the non-pigmented plastics, such as milk bottle and soft drink bottle, to the pigmented plastics such as coloured packaging containers. With low export demand for the pigmented plastics, it seems imperative that strong local markets are developed for Polypropylene to drive the collecting, sorting and recycling of this post-consumer material.

3. PROJECT OBJECTIVES

During the course of this study, it was hoped that a better understanding could be gained of:

a) The technical properties of PP PCW recyclate.
b) Potential end markets for this recyclate.
c) Why recycling rates of PP are relatively low, and what constraints exist to its recycling.

Specific objectives of this project include:

1) Identifying key product handling and identification issues faced by the sorters in the Materials Recovery Facilities when sorting Polypropylene post-consumer waste (PP PCW).

2) Establishing the quality of PP recyclate produced from a typical waste sort and the technical feasibility of recycling PP PCW.

3) Identifying potential market opportunities for the PP recyclate produced in an unmodified form and whether product enhancement would be required to drive its market usage.

4) Within the limitations of this study, to identify factors that might make the widespread recycling of PP a more practical proposition.

5) To recommend any further investigations that appear desirable.

4. PROJECT STRUCTURE

The project was divided into four stages:

STAGE 1 Collecting and sorting of post-consumer Polypropylene .

STAGE 2 Reprocessing of the post-consumer Polypropylene.

STAGE 3 Technical evaluation of the Polypropylene recyclate.

STAGE 4 Market opportunity evaluation.

5. COLLECTING AND SORTING OF POST-CONSUMER PP

5.1 Selection of MRFs

Two independent plastic collection and sorting sites, Thiess Services and Sandhurst Enterprises Recycling, a division of Vatmi Industries, were chosen for this study. These organisations operate differently and are located in different states, allowing for some pertinent material comparison data to be included in this study. A third option was also considered, but was unable to be included due to timeframe constraints.

The **Thiess Services** Facility (a MRF) in the ACT was chosen to perform the Polypropylene collection and sorting trial for the following reasons:-

a) They service an all-plastics collection (Council) area and it was important for the PP waste materials collected to be typical of the volume and type found in the general household waste stream.
b) They were currently not sorting Polypropylene into bales but rather removing the milk bottle and soft drink bottles and combining the
c) remaining plastic into bales (co-mingled bales). It was important as part of this study to assess any difficulties faced by sorters who are new to PP identification.
d) They had prior involvement in audit processes and experience in obtaining necessary and accurate audit information.

To add further accuracy to the study, a second MRF was involved. **Sandhurst Enterprises Recycling** in Bendigo Victoria was included for the following reasons:

a) The residents of the area had been educated that PP could be recycled and PP plastic was regularly placed in the recycling bin with other recyclables.
b) The MRF had been sorting Polypropylene into bales for several years and their sorters were already experienced in PP identification. This experience was important as we wanted to identify any other PP types of products found in the waste stream in high volume.
c) They had accumulated years of data of total PP recovery rates versus other post-consumer waste plastics. This would allow a comparison to the new Thiess PP sorting data.

5.2 Objectives

a) To test the technical feasibility of recovering specific post-consumer Polypropylene #5 products as a quality separated product from a recyclables stream, where the Council directive was that all plastic containers were recyclable.
b) To determine, through analysis of products recovered, the percentage of PP sorted from the total plastic waste stream and the percentage breakdown of different PP product types recovered.

5.3 THIESS SERVICES TRIAL

5.3.1 Background Information

Thiess Services operates the Hume Materials Recovery Facility (MRF) for ACT No Waste. This MRF receives recyclables from the ACT, Queanbeyan and other surrounding areas (Yass etc) collected through the household recycling system. The MRF also receives some recyclables from commercial businesses, primarily cardboard.

Rigid plastic containers are recycled through the ACT household recycling system and include rigid plastic containers #1 to #6. The processes used at the MRF for sorting of the recyclables are both mechanical (disk screens, magnets, air classifiers etc) and manual (hand-sorted). The recyclables initially arrive “fully co-mingled” (paper, glass, metals & plastics all mixed together). They pass over a disk screen that separates the paper from ‘containers’ (plastics, metals & glass). These then pass through a trommel (rotating drum with holes) that screens out the fine material (broken glass, rocks, dirt etc). A magnet is used to recover steel. An air classifier is used to separate the heavy (glass) & light (plastics & aluminium) fractions.

The rigid plastics are then manually recovered and sorted into three different products for sale:

1. Clear PET (#1)
2. Natural HDPE (#2)
3. Mixed (or co-mingled) plastics (consisting of coloured PET #1, coloured HDPE #2, PVC #3, LDPE #4, PP #5 and PS #6).

After sorting, plastic materials are stored in bunkers awaiting baling. Each bunker holds approximately 1 tonne (2 bales of plastic), providing for sufficient material to be recovered for efficient baling of products. The plastics are released individually from their storage bunkers when required for baling. The bunkers are controlled from the baler, which releases the product in a stream onto the baler in-feed conveyor. All recovered plastic, metals & fibre products are baled through a single high density, high capacity baler.

5.3.2 Methodology

The trial was conducted over a four week period in September 2004, with a full-time dedicated employee sorting only PP for 3 weeks.

The MRF plastics recovery process was altered for the trial to include the recovery of Polypropylene #5 as a fourth product to sort. This involved the employment of an additional sorter specifically for this product. The order of recovery was:

1. Clear PET (#1)
2. Natural HDPE (#2)
3. Polypropylene (#5) – specified products only
4. Mixed Plastics

Instructions were given as to the specific types of plastics to visually sort out and bale. These plastic products included those bearing the number 5 Plastics Identification Code:

ICE CREAM TUBS + LIDS

MARGARINE/BUTTER TUBS + LIDS

CORDIAL BOTTLES (NO PVC PLASTIC)

FLOWER POTS

TAKE-AWAY FOOD CONTAINERS

The PP was manually picked out by hand from the surrounding plastic products i.e. was positively sorted. Once the products were recovered, they were stored in bunkers. Due to the limited amount of Polypropylene (#5) in the plastics waste stream, approximately 1 weeks production was stored in the bunker prior to baling.

When a sufficient quantity of the plastic was recovered, the bunker door was opened releasing the product in a stream onto the Baler in-feed conveyor. This conveyor feeds the MRFs single high density, high capacity baler where the product was baled.

An audit sample (86.25kg) of this material was gained by passing some of the Polypropylene (#5) through the baler without compaction. This allowed a loose representative sample of the plastic to be collected for audit purposes. The audit was required to examine the contents of the PP bale in terms of types of Polypropylene products present in the waste stream. Each component was weighed and this weight used to provide a percentage composition calculation. This compositional breakdown was also confirmed from visual observations prior to baling. Observations on other types and volume of PP products found in the waste stream were recorded, any plastic contaminants present were noted, and the volume ratio of PP to total recoverable plastic was also established.

5.3.3 Results

Over the 4 week trial, the following approximate plastic volumes were recovered:

PET Clear	40 tonne
HDPE Natural	35 tonne
Polypropylene	3 tonne (items targeted for collecting & sorting)
Residual Mixed Plastics	30 tonne

The PP bale content from the audit was found to be the following:

Table 5.1: PP bale compositional breakdown by weight

PRODUCT	PERCENTAGE BREAKDOWN % w/w
Ice-cream containers	30
Cordial Bottles	30
Flower Pots	16
Margarine/Butter Containers/Lids	10
Take Away Food Containers	3
Other (Fruit tubs)	7
Contamination (PVC and Polystyrene)	4

Refer to Appendix 1 for full details of the bale audits.

5.3.4 Discussion

Polypropylene recovery was only approximately 3% of all plastics recovered. The Pine River Shire study supported these results showing that Polypropylene represented 3.62% of all the plastics collected from kerbside in the Domestic Waste Stream (EnviroCom Australia, July 2001). Contamination levels of 4% in the PP #5 product recovered could be attributed to the inexperienced PP sorters taking quite some time to become familiar with the vast range of products required to be sorted i.e. products that contained the “5” Plastics Identification Code. These Polypropylene products are very different visually in colour, size and shape and are more difficult to sort than milk bottles or soft drink bottles. The sorters also found it difficult to distinguish between margarine and 1 litre yoghurt containers which are Polystyrene (#6), and the latter contaminated the PP bales. They also found some products that looked like ice-cream containers (actually lunch boxes) and also some flowerpot-like products that were not Polypropylene either. The other main plastic contaminant apart from Polystyrene was PVC from cordial bottles.

Another potential source of contamination comes from the necessary rotation of sorters to meet OH&S requirements within the plant. It was found that all bales visually contained some plastic contamination. However, bale 1 contained the highest level of contamination, mainly as cordial bottles (PVC), confirming that the learning process directly impacts on contamination levels.

Some difficulties faced by the MRF in conducting the trial were linked to limited in-house resources for this PP sort i.e. it was a labour intensive process requiring one dedicated sorter. This sorter was required to recover other products in addition to the PP when labour was short at the MRF. Furthermore, the requirement for a dedicated storage hopper for the PP placed pressures on the MRFs total separate storage capacity.

5.4 SANDHURST ENTERPRISES RECYCLING TRIAL

5.4.1 Background Information

Sandhurst Enterprises Recycling receives recyclables from the City of Greater Bendigo and other surrounding areas collected through the household recycling system. The MRF also receives some recyclables from commercial/industrial businesses to supplement their kerbside intake. This is one of the few MRF’s actively collecting and sorting PP in Australia. This MRF has a policy to employ people with disabilities and has been sorting PP for several years.

Rigid plastic containers #1 to #5 are recycled through this MRF. Both mechanical (trommels, magnets, air classifiers etc) and manual (hand-sorted) processes are used for sorting recyclables. The recyclables initially arrive “fully co-mingled” (paper, glass, metals & plastics all mixed together). They pass over a trommel that separates the paper from ‘containers’ (plastics, metals & glass). These then pass through a secondary trommel that screens out the fine material (broken glass, rocks, dirt etc). A magnet is used to recover steel. An air classifier is used to separate the heavy (glass) & light (plastics & aluminium) fractions and an eddy-current is used to remove aluminium.

The rigid plastics are manually recovered, sorted and baled by plastic type for sale:

1. Clear PET (#1)
2. Coloured PET (#1)
3. Natural HDPE (#2)
4. Coloured HDPE (#2)
5. Polypropylene (#5)
6. LDPE (#4) – mostly film from industrial/commercial sources
7. PVC (#3)

5.4.2 Methodology

No training of staff was required with regards to PP identification and the sorter was involved in sorting both PP and coloured HDPE at the same time. The baled material (3.4T) had been positively hand-sorted by the employees and was sent in baled form to Waverley Industries for audit purposes in February 2005.

Figure 5.1: Baled Sandhurst Enterprises Recycling Material

Six bales (943kg) of this material was to be audited. Bales were broken apart and manually separated into bins based on types of PP product present. The content of each bin was weighed to determine the percentage composition of each type of PP product. Once again, observations on the presence of other "contaminating" plastics (non-PP types) was recorded and the weight of these and other PP product types was recorded.

Figure 5.2: Audit Process at Waverley Industries separating the PP by product type.

5.4.3 Results

The audit conducted at Waverley industries found the following in terms of compositional breakdown on their material:

Table 5.2: PP bale compositional breakdown by weight

PRODUCT	PERCENTAGE BREAKDOWN % w/w
Ice-cream containers	15
Cordial Bottles	13
Flower Pots/Seedling Trays	10
Tomato Sauce Bottles	2
Laundry Tubs/Buckets	28
Margarine/Butter containers/lids	2
Food Containers	5
Yoghurt Large 5kg	16
Yoghurt Large 20L	1
Other – Video Cases	2
Contamination	6

Some material loss (200kg) was observed during the audit process, when bales were broken apart for content analysis. 3.2T remained for the reprocessing trial.

Refer to Appendix 1 for full details of the bale audits.

5.4.4 Discussion

The material from these experienced sorters was found to contain a greater variety of household PP items, not just limited to food packaging items. Contamination levels were also slightly higher, probably due to the increased PP product types being sorted. For example, by including tomato sauce bottles in the bales, this introduced smaller sized HDPE sauce bottles.

It was found that at both the MRF sort level and the audit at Waverley Industries, the sorters had difficulties distinguishing between the small yoghurt (PS) and the margarine containers (PP).

It can be seen that ice-cream containers, cordial bottles and flower pots still make up a large % of the PP bale weight content, yet their effect is diluted somewhat by the addition of other household PP items, such as laundry baskets/buckets. (These laundry products appeared in relatively large quantities by mass in these bales but this figure may have been influenced by their sorting process. During this process, larger items are placed in a bin from the incoming waste steam and once the bin is full, they are added to the bales). Food containers are the next most prevalent (5%) with fruit containers and pasta food containers appearing frequently in the mix. It should be noted that this MRF receives the large yoghurt containers from a commercial site to add to their bales but the remainder of the material comes through in the kerbside collection waste stream. Margarine content levels were also lower at approximately 2% versus 10% with the Thiess audit. This may be explained by both the dilution effect of all the other items present in the bale but also because they have only recently begun including this margarine material into their bales and the sorters are probably still getting used to the sorting of these items.

Polypropylene recovery rates based on annual tonnages sold are in the order of 9% of total plastics for this MRF, versus 3% with the Thiess MRF. This could be partially explained by the greater variety of PP products identified and sorted using experienced sorters. It is also due to some post-industrial product additions i.e. large yoghurt tubs. It is interesting to have data from both of these MRFs because it gives some insight to volume recoveries that could be achieved by using experienced sorters. It also allows a comparison of recyclate materials formed from bales varying in composition.

5.5 Key Observations

a) **Bale Content Variance** - the contents of PP PCW were found to vary between MRF operations. Differences between MRF operational set up, geographical location and experience with PP identification contributed to the variations seen. Churchward, G et al. (1999), also found that the constituents of PP PCW varied with the geographical location of the MRF.

b) **Bale Compositional Breakdown** - ice-cream containers, cordial bottles and flower pots are the predominant PP products by weight in the waste stream. Table 2.1 shows that retails sales and potential PP volume in the waste stream from margarine/butter containers should be greater than ice-cream containers yet this was not found from bale audits. It also shows that cordial bottles represent one third of the potential volume of ice-cream containers manufactured, yet this proportional relationship was not found in the waste stream. These variances may be due to awareness from residents about what is recyclable and/or it may be a sorter awareness issue.

c) **Contamination** - from analysis of the contamination in the bale, sorters at both sites had some difficulty in identifying between different PP products. The main difficulties were seen with cordial bottles (distinguishing between the PVC and PP bottle) and yoghurt containers and margarine containers (PS and PP). These items are seen as contaminants for the PP recycling process and for the recycling of PP to be cost effective, care will need to be taken to reduce the presence of these contaminants in the bales.

d) **Recovery Rates** - Polypropylene recovery rates were 9% of total plastics for Sandhurst Enterprises Recycling and only 3% for Thiess Services. Sandhurst Enterprises Recycling bales also contained a wider variety of PP products. This provides an indication of recovery rates that can be achieved from hand-sorting with staff experienced with PP products.

5.6 The MRFs Viewpoints

Five other MRFs currently not collecting and sorting polypropylene were interviewed for their thoughts on its collection and sorting. The reasons they were not currently sorting PP were resource based. They felt the incoming volumes of PP in the waste stream were too low to justify additional labour costs to sort, unless the price paid by the market was on par with milk or PET baled bottle pricing to make it viable. There was also some confusion by some as to exactly which products were PP, having never positively sorted these before and some concerns regarding possible end-markets for this baled PP.

6. REPROCESSING OF THE POST-CONSUMER PP

6.1 Selection of the Reprocessors

Two independent plastics reprocessors, Plastics Granulating Services and SIMS plastics, were chosen for this study. Each reprocessor differs in its recycling set up and we wanted to see if there were any problems encountered reprocessing the PP PCW at either site. It has also provided two sets of reprocessing data from which to draw a comparison and conclusions.

Once the audits had been completed on the Polypropylene, the Thiess Services baled material was sent to Plastic's Granulating Services (PGS) in Adelaide and the Sandhurst Enterprises Recycling baled material to SIMS Plastics in Melbourne for reprocessing. The involvement of two separate recycling plants in the study was to allow any differences in processing conditions to be observed, to see if any problems were encountered at either or both sites and to see if a marketable recyclate end-product could be manufactured from both plants.

6.2 PGS TRIAL

6.2.1 Methodology

The trial was conducted at Plastic's Granulating Services (PGS) premises in Adelaide SA in October 2004. The objective was to process six Polypropylene bales (3.1 tonnes) sourced from Thiess Services and record the findings. The six bales were weighed on arrival and given a PGS batch number. Each bale was processed separately. Processing involved granulating, washing and then extruding the material into pelletised form.

The initial operation was to granulate the bale using a 15mm granulator screen size. The flakes were then air transferred to the water settling tank where contaminants that sink (PS, PET and PVC) were removed. The flakes then entered the friction washer where they were cleaned. It should be noted that this was a cold wash with no chemical additives such as caustic soda added to assist the cleaning process. The final step is where the water on the flake is removed using a spin drying process. The flake is then air transferred to a loading station where it enters a bulk bag. Each bulk bag was then weighed to determine the percentage of the original bales lost to waste. A sample of the waste material from the wash process was taken to be analysed for content.

The flake was then extruded using a non-vented extruder. The extruder was purged and the flake was processed. Samples during each run were taken and machine running parameters were recorded.

6.2.2 Results

Screen changes were required approximately every 30 minutes due to higher melt plastic, wood, aluminium and other contaminant build up on the screens. This was higher than would normally be observed when running post-industrial sourced PP.

From the initial 3.1 tonnes of baled sorted PP approximately 1.8 tonnes of pellet was produced. Material losses on this small batch trial were relatively high. It must be noted that the screw on the back flush piston was worn and a continuous stream of back flush material was produced and lost as purgings, thus reducing the yield of final product.

Refer to Chapter 7 for a more detailed technical analysis of the PP recyclate.

6.3 SIMS TRIAL

6.3.1 Methodology

The trial was conducted at SIMS Plastics in Maribrynong Victoria and divided into two stages due to production demands on the plant. The objective was to process 20 Polypropylene bales (3.2 tonnes) sourced from Sandhurst Enterprises Recycling and record the findings. The first stage involved washing and granulating the baled PP material at the end of February 2005 and the second stage involved extruding the washed flake into pellet in early March 2005.

Firstly, bale strapping was removed and bales were loaded onto the conveyor belt (audit bales (1-6) were segregated as much as possible from the others and processed together into one bulk bag). The plastic was transferred to the granulator and cut into pieces (flakes) using a 12mm granulator screen size. The flakes were then transferred through the sink-float system and washing process. It should be noted that this was a cold wash with no chemical additives added to assist the cleaning process. A sample of the plastic waste from the wash process was removed for testing. The “wet” flake was then transferred into bulk bags ready to be extruded (approximately one week later in stage two of the trial). Each bulk bag was then weighed to determine the percentage of material lost to waste. A measure of the moisture content in this flake was taken.

Four bulk bags of flake were produced. Bags 1,2 and 4 were extruded using a vented extruder. Bag 3 was kept as flake for testing and subsequent customer trials. Pellet samples were taken approximately every 15 minutes during the run and machine running parameters were recorded.

A 50% post-consumer waste material, containing post-industrial PP and black masterbatch, was chosen to be run prior to ease the transition of processing conditions and to prevent cross-contamination.

6.3.2 Results

All temperatures appeared quite steady throughout the extrusion process. However, it was noted that there was considerably more screen changes required in processing the post-consumer material versus their own post-industrial blends. Over the course of the extrusion (3.5hours), there were 29 screen changes in comparison to 2 screen changes observed over 1.5 hours of watching their own material processed. Screens appeared to contain higher melt plastics and significant amounts of wood flakes.

Table 6.1: SIMS MFR readings during trial

In-house Melt Flow Rate (MFR) readings were taken from each of the three flake bags extruded as illustrated below.

Flake Bag Number	MFR Reading g/10min
1 (645kg)	9.45
2 (704kg)	9.6
4 (490kg)	14.1

Bag number 3 containing 432kg of washed flake was not extruded but left for customer trials as flake. Bag number 4 contained the audit bales. The higher MFR reading here may possibly be attributed to a higher level of yoghurt tubs present in this audited material.

Moisture content in bagged-off flake was found to be in the order of 1%.

Another important point to note from this trial was the high observed losses of material from baled to washed flake. These were in the order of 20-30%. The initial 3.2 tonnes yielding approximately 2 tonnes of flake. It is difficult to accurately quantify these losses on such small batch runs and some material may also be caught up in the system to come through later, but it does still highlight this as a potential economic consideration for reprocessors of post-consumer PP. Running all one type of product, for example all milk bottles or all soft drink bottles, does reduce this percentage loss significantly, down to the order of 5-10%, according to the reprocessor interviewed.

Refer to Chapter 7 for a more detailed technical analysis of the PP recyclate.

6.4 Key Observations

a) **Product Quality** - neither reprocessor used a hot wash or caustic soda to reprocess this material to achieve desired product quality levels.
b) **Material Losses** - both showed high losses of material during reprocessing, in the order of 20-30%. The main losses occurring during the bale to washed flake stage. This could be important from an economic viewpoint, and may require further study. However, It should also be noted that losses over a 3 tonne run would be higher than over a 20 tonne run and in practice, reprocessors would not process only 3 tonnes of material at a time.
c) **Moisture Content** - One reprocessor dried their flake prior to extrusion then used a non-vented extruder. The other didn't dry the flake prior to extrusion but used a vented extruder. This is relevant from a product quality perspective, specifically with regards to moisture content of the recyclate.
d) **Frequency of Screen Changes** - a large number of screen changes were observed using the same screens normally used to process their own in-house materials. Contamination levels of this PP PCW material appeared higher than found with post-industrial sourced materials. From an economic and practical viewpoint, this matter requires further investigation.
e) **Margarine Container Content** - the levels of margarine containers found in the PP PCW caused no problems to the reprocessors during this reprocessing trial. However, this would have to be proven over larger runs and with bales of higher margarine content.

6.5 The Reprocessors Viewpoints

Three reprocessors were interviewed regarding their thoughts on the use of post-consumer polypropylene if it was readily available in larger volumes to recycle. All were in agreement that it could be reprocessed if available. One reprocessor was comfortable that sizeable volumes could be reprocessed as 100% post-consumer PP, as long as the bale in-feed was relatively free of HDPE contamination i.e. less than 5%. However, this reprocessor felt that applications using 100% post-consumer PP were limited. The remaining volume would be blended with other post-industrial sourced PP as is currently done to a small degree. The belief is that blending reduces material losses, evens out any variations in material properties and is performed due to a lack of availability of any one type of material. The difficulty with blending the post-consumer PP is finding enough post-industrial material to blend with it when needed. Pricing paid per tonne of material may be an issue if PP material losses are in the order of 20-30% compared to milk bottle bale losses being only about 5%. It is highly likely that during larger production runs losses will decrease significantly but this would need to be explored further. Greater confidence in the use of 100% post-consumer PP by reprocessors could be achieved in future, now that initial trial work has shown promising results for this material in several different markets. These market applications would most likely grow in time, as has been the case with the HDPE milk bottle market , driving the usage of post-consumer PP still further upwards.

7. TECHNICAL EVALUATION OF THE PP RECYCLATE

7.1 Test Results

7.1.1 PGS TRIAL (TRIAL 1)

6 bales of PP post-consumer waste were reprocessed at PGS. Each bale was treated as a distinct lot of material and samples were taken during the start, middle and end of the reprocessing step. This then yielded a total of 18 pellet samples for physical property testing.

The detailed results of the testing are shown in Appendix 2.

From the results obtained it appeared there was little variation in the properties tested for the 18 samples. This would suggest that the bales of PP post-consumer waste collected over the 4 week period of time were similar in terms of content and therefore the waste mix of PP packaging collected was consistent over the collection timeframe.

Analysis of the reprocessed pellets by DSC (Differential Scanning Calorimetry) and FTIR (Infrared Spectroscopy) indicated the presence of polyethylene. The level of polyethylene present was not quantified, but would appear to be small. Other possible cross contaminants (eg PVC or PS) were not detected, indicating that the washing process appears to be effective in removing the denser non-PP materials (PET, PVC and PS) contaminating the sorted PP bales. These plastic fragments sink to the bottom of the water tank allowing physical separation from the PP which floats. Analysis of the sunken plastic waste from the wash step also confirms this as PET, PVC and Styrene based polymers were detected here.

The pellets obtained were dark grey in colour and did not show any evidence of gas entrapment. The presence of gas would be indicative of trapped moisture (water) but none was found to be present. Pressing films of the pellet samples did not show any evidence of foreign contamination being present (e.g. paper, wood etc.).

7.1.2 SIMS TRIAL (TRIAL 2)

Based on the results and findings of the first reprocessing trial, a further trial was undertaken utilising a second source of PP post-consumer waste and a second reprocessor. The intention was to see whether there was a difference in the material properties obtained on the reprocessed material by utilising PP post-consumer waste obtained from a different municipality, and reprocessed using a different reprocessing set-up.

3.4 tonnes of PP post-consumer waste was obtained in 20 bales. The bales were reprocessed and approximately 2kg of the pellet material was sampled approximately every 15 minutes. 15 samples in total were collected and sent for analysis as per the previous trial.

The detailed results of the physical property testing are shown in Appendix 3.

As for the first trial, the results obtained showed little variation in properties tested. The MFR's conducted on all 15 samples displayed similar consistency to the first trial. Having ascertained this, samples were combined into three groups for the remainder of the testing protocol.

The results obtained were in line with the previous trial findings. This was a welcome outcome in that both sets of trials yielded products with similar end properties. It would tend to indicate that the waste stream for PP post - consumer articles can yield a reasonably consistent end-product. Further extensive trials would need to be undertaken to confirm this finding.

DSC and FTIR analysis indicated that PE was present in the reprocessed material. The level of PE present was not quantified, but would appear to be small. FTIR analysis of the material removed during the washing phase of this trial revealed it to be composed of PET, PVC and PS materials. Once again the washing process appeared effective in removing possible cross contamination products from the PP.

As before, the pellets obtained were "grey/black" in colour and did not show any evidence of gas entrapment. Pressing films of the pellet samples did not show any evidence of foreign contamination being present (e.g. paper, wood etc.).

7.2 Definition of Properties

a) *MFR (or MFI)* – Melt Flow Rate or Melt Flow Index, is a measure of the flow characteristics of a material and is important when considering the types of applications to which a material can be used. The higher the MFR, the easier it is for a material to fill a certain mould and also assist with reducing cycle times. In this case, the MFR's obtained were typical of what we would term a medium flow material (approximately 12 g/10 minutes), that could be considered for use in injection moulding applications.

b) *FM* – Flexural Modulus (FM) is a measure of the stiffness or rigidity of a material. The higher the FM, the stiffer the material. In this instance, the FM observed in the reprocessed materials would indicate a rigidity that is close to a standard PP impact copolymer of equivalent MFR.

c) *Tensile Stress at Yield* – On application of a tensile force (ie a stretching force), the tensile stress at yield is the strength at which permanent deformation occurs in a material. In this situation the tensile yield stress of the reprocessed material was similar to a standard PP impact copolymer of equivalent MFR.

d) *Notched Izod Impact Strength* – Is a measure of the impact performance of a material when a rapid stress is applied. This specific impact test gives an indication as to the notch sensitivity of a given material. This is useful information for parts which have many ribs and/or incorporate many directional changes. The notched izod impact performance at both 23 and 0 degrees celsius for the reprocessed materials was similar to a PP impact copolymer of equivalent MFR.

e) *HDT* – Heat Distortion Temperature (HDT) is a relative measure of a materials ability to resist deformation at elevated temperatures whilst subjected to an applied load.

7.3 Comparison of PP Recyclate with Primary PP

The following table compares the project test results for PP recyclate with the properties of three commercially available grades of primary/virgin PP.

Table 7.1: A comparison of primary PP to PP recyclate

TYPICAL PROPERTIES (ex Product Data Sheets)	MOPLEN RP241P (random copolymer)	MOPLEN EP201N (impact copolymer)	MOPLEN HP400N (homopolymer)	Trial 1 Material (PGS)	Trial 2 Material (SIMS)
Melt Flow Rate 230°C;2.16kg (g/10min)	15	13	11	10.6-15.3 av 12.6	8.1-12.8 av 10.0
Flexural modulus (Mpa)	1050	1000	1400	1000-1050 av 1030	1000-1040 av 1027
Tensile Yield (Mpa)	26	23	32	23.5-24.6 av 24.0	22.8-24 av 23.5
Notched Izod Impact Strength at 23°C (kJ/m^2)	6.0	5	2.5	3.6-5.1 av 4.2	5.3-5.6 av 5.4
Notched Izod Impact Strength at 0°C(kJ/m^2)	-	3.5	-	2.5-3.1 av 2.8	3.3-3.6 av 3.4
HDT at 0.45 Mpa (ISO) 0°C	-	-	-	77-88 av 81.4	85-86 av 85.3

The results would indicate that the material obtained from the reprocessing trials of the PP post-consumer waste, had properties which were close, or at least within the limits of those evident in the three primary forms of PP (homopolymer, impact copolymer and random copolymer). This is not unexpected, as the articles used in this trial (obtained from the waste stream), are comprised of all three types of PP, with varying MFR's. The observation that the material properties were similar amongst all bales is a key finding as it would indicate a relatively consistent product could be made available for use. This finding though needs to be further tested.

The properties of the materials obtained indicates that they could be considered for a range of injection moulding applications – either alone or as a component in a blend with virgin material.

8. MARKET OPPORTUNITY EVALUATION

Based on the initial material property test results, it was identified that non-food-grade injection moulding type applications were suitable targets for this recyclate material. One customer trial per market segment was performed. The chosen markets were:

1. Bar Stools (Reinforcing Steel Supports)
2. Cable Reels
3. Compost Bins
4. Export Pallets
5. Pot Planters
6. Trenching Products (Drain Trenching and Surface Water Drainage Channel Grate)

The materials sent for trials were the following:

1. PP Pellet 1st Trial (Thiess material reprocessed by PGS) denoted **PPT1**
2. PP Pellet 2nd Trial (Sandhurst Enterprises Recycling material reprocessed by SIMS) denoted **PPT2**
3. PP Flake 2nd Trial (Sandhurst Enterprises Recycling material reprocessed by SIMS) denoted **PPFT2**.

The aim of these customer trials was to determine how the post-consumer Polypropylene samples compared to each other in terms of ease of processing, and how these samples compared to material normally used to make these end-products. The end-product produced was also tested to see if it passed the normal routine tests performed prior to release of the product to customers.

8.1 Bar Stool Trial

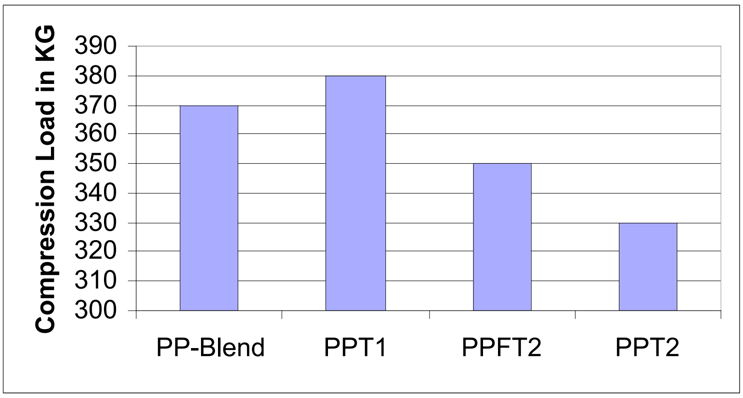
The trial was conducted in March, 2005. All three samples (PPT1, PPT2 & PPFT2) were supplied to the bar stool manufacturer for trial on an NR-550A injection moulding machine.

PPT1 and PPT2 were found to have very similar MFR and moulding conditions in relation to each other, but less stiff (or easier flow) than **PPFT2** and **PP-blend.** PP blend was the manufacturers own material from post-industrial not post-consumer sources. No masterbatch was required to be added to the end-product; the dark grey recyclate colour was acceptable.

The compression strength of each sample varied. It was observed that PP loses some of its compression strength after reprocessing (extrusion) since PPT2 had a lower compression strength than the PPFT2 material. It was also observed that the PPT2 produced a product with a lower compression strength than the PPT1 material, but all materials met the minimum required strength for the product.

PPFT2 exhibited inconsistent moulding conditions due to short and flash mouldings during the trial run. All other samples exhibited consistent moulding conditions. It should be noted that small pieces of wood were found in the gate section of one of the bar stool products moulded from the flake sample and that it is likely that on larger sample trials, this wood contaminant would cause problems during moulding. Wood floats in the water tank along with the PP during reprocessing. Extrusion into pellet would remove any wood present in this flake.

<u>Figure 8.1:</u> Comparative strength of PP trial samples



<u>Figure 8.2:</u> Bar stools successfully moulded using the PP recyclate.

8.2 Cable Reel Trial

The trial was conducted in July, 2005. Two samples (PPT1 & PPT2) were supplied to the cable reel manufacturer for trial on their injection moulding machine.

It was found that visually the trial mouldings were of a lighter colour than the post-industrial reprocessed PP normally used. The dark grey recyclate colour would have to have black masterbatch added prior to release to the market and to maintain consistency of their current product appearance in the market.

Other observations made were that a gas burn was found on one of the samples of the PPT1, which may be due to the easier flow and faster filling of the tool cavity. The flanges of the cable reels from the trial were also found to be more flexible and not quite as rigid. The manufacturer was able to run at lower injection pressures for both trial samples as they were easier to mould than their existing source of reprocessed PP.

Both trial materials appeared to perform equally and produced a product that passed both visual inspection and internal moulding requirements. Further market trials would need to be performed to ascertain if this product was acceptable to their customers.

Figure 8.3: Cable reels successfully moulded using the PP recyclate.

8.3 Compost Bin Trial

The trial was conducted in April, 2005. Two samples (PPT1 & PPT2) were supplied to the compost bin manufacturer for trial on their injection moulding machine.

It was found that both samples of pellet were able to be moulded successfully into the compost bin. It was observed that injection pressures on the machine were increased from 140 Bar to 145 Bar when changing from their existing post-industrial black source of material to the post-consumer recyclate. This was to overcome some initial short shots upon material changeover.

Both end-products produced from the two trial materials passed their in-house impact testing.

The dark grey recyclate colour would have to have 1-2% black masterbatch added prior to release to the market and to maintain consistency of their current product appearance in the market. Also, some “shark skinning” effects were observed on the compost bins from the PPT2 material where possibly melt flow variations were observed. Due to the nature of the application for this product, the manufacturer said that either of the materials would be acceptable for use in this application. This product has a wide processing window meaning that it can cope with Melt Flow Rate variation from anywhere between 3 – 15g/10 min and is ideally suited for this type of material.

Figure 8.4: Compost bins successfully moulded using the PP recyclate.

8.4 Export Pallet Trial

The trial was conducted in March, 2005. Three samples (PPT1, PPT2 & PPFT2) were supplied to the pallet manufacturer for trial in their modified compression moulding process.

It was found that all three samples moulded well, both flake and pellet samples could be used to make this product. The material was of a much higher MFR (9-15) than the material normally used (MFR less than 1) but the manufacturer believes it could still be used if available. A "medicinal" smell was observed from the PPT2 material during processing that had not been observed with the PPT1 material. Material they normally use is from post-industrial and post-consumer sources.

No masterbatch was required to be added to the end-product, the dark grey recyclate colour was acceptable.

Modification of the existing tooling to produce a lighter weight pallet for export would be necessary from an economic perspective. However, based on the intended one way application of these products, this material would be deemed to be appropriate for use from initial trial results.

Figure 8.5: Pallet successfully moulded using the PP recyclate.

8.5 Pot Planter Trial

The trial was conducted in April, 2005. Three samples (PPT1, PPT2 & PPFT2) were supplied to the pot planter manufacturer for trial in 4 different pot sizes (4, 6, 10 and 12 inch diameter pots) on their injection moulding machines.

It was found that all three samples moulded well, both flake and pellet samples could be used to make this product. The pellet could be used for all four pot sizes but the flake could only be used for the larger 12 inch diameter size pot due to material feeding restrictions. It was found that the flake size (approximately 12mm) was too large for efficient and higher volume usage and would need to be passed through a smaller diameter granulator screen (8 or 10mm).

The material normally used for the pot planters is a blend of mainly post-industrial sourced plastics and overall it was found that the post-consumer trial material was of a higher standard. At comparable temperatures, the trial material showed improved processability to current materials used, with only the post-consumer PP being able to be used successfully to mould the smaller 4 inch pots. The pot planter end-products passed all tests and were found to be satisfactory in structure, setup and resistance to crushing.

Black masterbatch (approximately 1%) would be required to be added to the end-product, the dark grey recyclate colour would not be acceptable in their established markets.

Based on initial trial results, this recyclate material would be appropriate for use in pot planters.

Figure 8.6: Pot planters successfully moulded using the PP recyclate.

8.6 Trenching Products Trial

The trial was conducted in March 2005. Two samples (PPT1 & PPT2) were supplied to the trenching product manufacturer for trial on their 2000T and 550T injection moulding machines. Both materials were trialled in a traditional thin wall moulding (2.5mm) and also in a thick walled structurally foamed part (8 – 10mm).

Both batches of material moulded successfully in both styles of products i.e. the drain trenching and the surface water drainage channel grate. No changes were required to be made to the moulding conditions that the tools were currently operating at prior to or during the trial.

Material normally used by this manufacturer is from post-industrial sources, a small amount of post-consumer is used but it needs to have black masterbatch added. This grey recyclate would also need to be coloured black.

Both batches of materials displayed higher flow rates than the traditional Polypropylene materials used but the cavity fill and pack process presented no problems. Both batches of materials also displayed a higher longitudinal shrinkage rate of 0.4% in thick wall section products (ie 8-10 mm). Extension of the cycle time would be expected to resolve this issue. Neither trial material displayed shrinkage variation in thin wall section parts (2.5mm). The recyclate pellets were clean, regular shaped and the material showed no obvious signs of contamination. The components were assessed under the usual quality system tests and both products in both batches achieved suitable performance.

Based on the initial trial results, this manufacturer believes they could utilise these post-consumer recyclate materials if commercially available in larger volumes.

Figure 8.7: Trenching products successfully moulded using the PP recyclate.

8.7 Key Observations

a) **Contamination by Polyethylene** - the low level presence of Polyethylene in the PP recyclate trialled has not had a detrimental effect on the end-product performance for the chosen market applications. These Polyethylene levels were not quantified and it may be that at higher levels there could be some problems. Minimising the level of polyethylene cross contamination in the sorted PP bales would have to be the responsibility of the MRF.
b) **Other Contamination** - contaminants such as wood, high melt plastics and aluminium are effectively screened out of the recyclate during the extrusion phase. The resultant recyclate pellet produced posed no problems to the manufacturers during moulding trials.
c) **Product Quality** - the fact that neither a hot wash nor caustic soda were employed during the wash stage at either reprocessor, appears to have had no detrimental effect on these end-product trials.
d) **Moisture** - use of a non-vented extruder when the material has been previously dried, or using a vented extruder with previously ‘wet” material, did not appear to have a detrimental effect on the end-products moulded via the injection or compression moulding processes.
e) **Chemical Modification** – the PP recyclate could be successfully used in an unmodified form, no product enhancements were required for use in these trial market applications.
f) **Acceptance by Manufacturers** – at the end of the trials, many manufacturers asked when they could purchase this material and it had to be explained that the PP recyclate was still not commercially available in large volumes. With technical product requirements met, the decision to use this PP recyclate material by the manufacturers will be influenced by material price and availability.

9. FURTHER MARKETING CONSIDERATIONS

The cost factors that need to be taken into account, when investigating the overall viability of recycling post-consumer PP, include:

- costs to collect and sort PP
- costs to reprocess i.e. (wash, granulate and extrude) PP material
- transport costs of baled PP material (from the MRF to the reprocessor) and processed material in flake or pellet form (from the reprocessor to the manufacturer)
- market prices paid for the recyclate.

9.1 Costs to Collect and Sort

From discussions with the two MRF's involved with this trial, it was noted that the labour costs per sorter vary significantly due to the following factors:

a) Whether the sorter is classified as "disabled" or "non-disabled". With the disabled sorters, a further classification system determines their salary. This productivity award based wage system was determined by each individuals competency at their assigned task.
b) The State in which the MRF operates (because of the different tax regimes), and the Awards under which the employees are paid.
c) Whether the employee is only sorting PP or can also sort other plastics at the same time. The experience level and ability of the sorter and the size of the MRF, plays an important role here. For the smaller MRF's, because of the smaller volumes processed, it probably is not possible for an experienced sorter to be dedicated full-time to just PP sorting. This employee will need to sort several plastic types to achieve an economy of labour.

It was found that the costs per sorter ranged from $700-1000 per week. This figure is inclusive of salary, employee benefits and relevant MRF overheads. Costs to the MRF were on the lower end of the scale when disability workers were involved.

From the Thiess trial, it was found that approximately 1T of PP per week was sorted by a dedicated sorter. This medium to large-sized MRF sorts approximately 15-20T/hour. They felt it was safer and better that the inexperienced sorter did not sort other plastic products at the same time during this trial period. With labour costs as quoted above, this would mean PP could cost up to $1000/T to sort. The cost of sorting PP in the medium-term at the MRF, could possibly be reduced if the sorter was utilised for other duties and not 100% occupied on PP sorting. Larger throughput MRF's (for example, processing 20T/hour or more) could also expect this cost/tonne to decrease.

From the Sandhurst Enterprises Recycling sort data, approximately 1T every week of PP is sorted on a routine basis. This MRF has now been sorting PP for years, using disabled sorters. This MRF would be classified as a small to medium-sized MRF, sorting approximately 5-10T/hour. The experienced PP sorters can sort PP and coloured HDPE and/or PVC at the same time. This brings the costs per tonne of PP down to approximately $200-$300/T. Current market pricing on PP baled stock is in the order of $300-450/T, making this a potentially viable exercise for them when factoring it into the business as a whole.

The PP sorting exercise appears to become viable when a dedicated well-trained sorter can be utilised to sort PP in conjunction with other lower volume products, or if the MRF throughput is large enough to allow several tonne of PP to be sorted per week by a dedicated sorter. Optical sorting may help to reduce these labour costs/tonne of sorted material still further, but the high cost of this specialised equipment would probably exclude its use by smaller MRF's.

9.2 Costs to Reprocess

Currently, a plastics reprocessor with plants in VIC, NSW and QLD, is offering to toll-process baled plastic stock to pellet for $460/tonne. With material loss rates factored in at 5-10%, this would equate to a reprocessing cost of approximately $500/tonne. For reprocessing to flake stage only, further cost reductions can apply. Early indications from other reprocessors in different States would suggest that they would require $500-600/tonne to reprocess baled PP, but this information should only be used as a guide.

9.3 Transport Costs

In an effort to keep costs to a minimum, baled PP and reprocessed PP would best be transported within the same State. Transport costs for a full truck load of baled or reprocessed material in bulk bags can range from $20-35/tonne depending on whether it is a metropolitan or regional area delivery. With reprocessors in every State, the majority of these materials should be able to stay within their respective States. There may be certain cases where it is economically viable to transport materials between States.

9.4 Market Prices Paid for the Recyclate

The market price paid for PP recyclate is affected mainly by the availability of other PP post-industrial type materials, the end application for the recyclate and (to a small extent) by the current virgin PP material prices. From this trial, prices paid for existing post-industrial PP pellet ranged from $700-$1200/tonne. At the higher end of this range, utilisation of post-consumer PP recyclate would appear to be economically viable in the current market. At the lower end of this range, reduced processing of the PP only to flake (instead of pellet) or direct utilisation of baled stock by the manufacturer may have to be explored further. It should also be noted that over time, higher-priced applications may develop allowing for improved volume consumption of this material.

The purpose of this study was to focus on the technical and market feasibility of recycling post-consumer PP. The above costing information is only indicative at this stage and should not be relied upon. Further study is required to validate these initial findings. It should also be noted that the plastics market is subject to regular and unpredictable pricing fluctuations. This study is not advice and should not be relied upon for any commercial or other purposes.

10. CONCLUSIONS AND RECOMMENDATIONS

a) The positive results from this technical and market evaluation of PP recycling certainly suggests that further economic viability studies should be undertaken. The scope of our study did not include an in-depth economic viability analysis, but the results point to areas warranting further investigation. Furthermore, trial sample sizes of 3 tonne are not large enough to provide an accurate indication of material losses for the reprocessor during processing of material from baled form to pellet. It is difficult to process small batches on large equipment and draw conclusions on yield. More information would be required to calculate the cost to the manufacturer of using this baled PP material. Losses over the 3 tonne trial runs were found to be in the order of 20-30%, with the largest material losses occurring during the wash stage of the reprocessing. Perchard, D. (2005), found that after taking into account moisture, contamination and process losses, there may be a difference of 30% between material input and output volumes. However, these loss rates would be expected to drop over larger batch runs but may still be higher than processing of single source material (which has been quoted from reprocessors at around the 5% level).

b) Another limitation to this study was the small customer sample trial sizes of 25kg-200kg, dependant on product application. Larger material runs would need to be performed to test for the impact of any batch-to-batch variance in the recyclate. Possible variability between batches could not be tested during this study, although numerous readings were taken over the processing time and specification ranges identified. End-products with wide processing windows for Melt Flow Rate (MFR) specifically are the most suitable products for this material. Material would best be batch-blended, but this process is not possible currently with all reprocessors. As a minimum, MFR tests would need to be performed and results recorded on individual bulk bags. This will allow the customers to modify their machinery parameters to suit.

c) Furthermore, this study did not take into consideration the seasonal variation in the type and quantity of PP PCW in the waste stream. Although Thiess material was collected in September and Sandhurst Enterprises Recycling material in January (five months later), it does not represent a true Winter versus Summer relationship. However, analysis of the material properties showed very little differences between material collected at different times of the year and across different States. Churchward, G et al. (1999), found some seasonal variations were noted in PP bale content and that PP PCW contained a larger volume fraction of ice-cream in Summer than Winter. However, it is possible that there may be <u>no</u> noticeable difference in end-product material properties if the main compositional elements in the waste stream increase proportionally at the same time e.g. in Summer, if both cordial and ice-cream sales increase at similar rates.

d) Experience in hand-sorting PP at the MRF level may help to reduce cross-contamination and lead to reduction in the material loss rate at the reprocessor. The quality of the PP PCW bale in-feed is of paramount importance to the reprocessors. Optical sorting methods could possibly help improve PP recovery rates from the waste stream, reduce other plastics contaminating PP bales, improve product yields for the reprocessors, possibly improve end-product quality of the recyclate and reduce sorting costs. This machinery is expensive and may be limited to use by only the larger MRFs but further study to ascertain potential benefits would be required.

e) The main barrier to post-consumer PP recycling appears to be at the collection and sorting stage and is a result of economic considerations. The efficiency of manually recovering plastics appears to be reduced as the number of types of recovered products increases. This is due to both physical limitations of the sorters (a sorter can only typically throw into two different storage bunkers at one time) and their ability to accurately make multiple decisions. For best recovery and quality results, a dedicated well-trained PP sorter would often be preferred. However, this decision by the MRF to have an employee sorting only PP, would need to factor in labour costs relative to the PP volume recoverable from the waste stream and the market bale price. The desired end-product quality required is also important. For the smaller and medium sized MRFs, it may not be economically justifiable to have a dedicated PP employee sorting only PP due to the relatively low quantities of PP material found in the waste stream. In this study, the quality of the PP recyclate was comparable from both MRF's indicating that an experienced capable employee can sort PP and other plastics without adversely affecting the recyclate quality.

f) In order to drive the collection and sorting of this PP plastic, all councils need to advertise that PP can be collected via the kerbside collection system for recycling. They would need to educate the residents on the types of products that are made of PP in their household waste and thereby increase the volumes of these plastics passed through to the MRFs. This in turn, will help encourage the MRFs to invest in PP sorters or machinery to sort this plastic. PP recycling could be further fuelled with co-operation and support from various Government organisations, Greenpeace, Keep Australia Beautiful and other environmentally conscious organisations.

Overall Conclusion

This study has shown that it is technically feasible to recycle post-consumer PP, and that there are established markets capable of incorporating this PP recyclate into their products. If the collection and sorting of this post-consumer waste material can be implemented on a National scale, then recycling of PP should be viable and sustainable into the future.

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APPENDIX 1
WAVERLEY INDUSTRIES AUDIT

BALE NUMBER 1

Total Bale weight 165kg

PRODUCT	PRODUCT WEIGHT IN KGS	% of TOTAL WEIGHT
Ice-cream containers/lids	27	16.4
Cordial Bottles	39	23.6
Flower Pots/Seedling Trays	22	13.3
Tomato Sauce Bottles*	2	1.2
Laundry Tubs/Buckets	52	31.5
Margarine/Butter containers/lids	4	2.4
Food containers**	6	3.6
Yoghurt Large 5kg	3	1.8
Contaminant	10	6.0

Contaminant plastic was small 200g yoghurt containers (PS) 1.2%, coloured HDPE bottles (shampoo, pine o'cleen etc) 2.4% and other plastics in the form of toys, detergent bottles, low levels of PVC from cordial bottles, plastic bags and bottle lids (LDPE) 2.4%.

BALE NUMBER 2

Total Bale weight 162kg

PRODUCT	PRODUCT WEIGHT IN KGS	% of TOTAL WEIGHT
Ice-cream containers/lids	23	14.2
Cordial Bottles	15.5	9.6
Flower Pots/Seedling Trays	9	5.6
Tomato Sauce Bottles*	5.5	3.4
Laundry Tubs/Buckets	53	32.7
Margarine/Butter containers/lids	2	1.2
Food containers**	6	3.7
Yoghurt Large 5kg	40	24.7
Contaminant	8	4.9

Contaminant plastic was small 200g yoghurt containers (PS) 1.2%, coloured HDPE bottles 3.1% and other plastics 0.6% in the form of toys and bottle lids.

BALE NUMBER 3

Total Bale weight 160kg

PRODUCT	PRODUCT WEIGHT IN KGS	% of TOTAL WEIGHT
Ice-cream containers/lids	23	14.4
Cordial Bottles	14	8.8
Flower Pots/Seedling Trays	12	7.5
Tomato Sauce Bottles*	2	1.3
Laundry Tubs/Buckets	53	33.1
Margarine/Butter containers/lids	3	1.9
Food containers**	3	1.9
Yoghurt Large 5kg	43	26.9
Contaminant	7	4.4

Contaminant plastic was small 200g yoghurt containers (PS) 1.9%, coloured HDPE bottles 1.9% and other plastics 0.6% in the form of toys and bottle lids.

BALE NUMBER 4

Total Bale weight 156kg

PRODUCT	PRODUCT WEIGHT IN KGS	% of TOTAL WEIGHT
Ice-cream containers/lids	10	6.4
Cordial Bottles	4	2.6
Flower Pots/Seedling Trays	19	12.2
Tomato Sauce Bottles*	3	1.9
Laundry Tubs/Buckets	56	35.9
Margarine/Butter containers/lids	2	1.3
Food containers**	4	2.6
Yoghurt Large 5kg***	50	32.1
Contaminant	8	5.1

Contaminant plastic was small 200g yoghurt containers (PS) 1%, coloured HDPE bottles 1% and other plastics 3.1% in the form of toys, bottle lids and plastic bags (LDPE), cordial bottles (PVC).

BALE NUMBER 5

Total Bale weight 161.5kg

PRODUCT	PRODUCT WEIGHT IN KGS	% of TOTAL WEIGHT
Ice-cream containers/lids	32	19.8
Cordial Bottles	17	10.5
Flower Pots/Seedling Trays	15	9.3
Tomato Sauce Bottles*	5	3.1
Laundry Tubs/Buckets	22	13.6
Margarine/Butter containers/lids	3	1.9
Food containers**	16	9.9
Yoghurt Large 5kg	10	6.2
Yoghurt Large 20L***	5	3.1
Other – Video cases	20	12.4
Contaminant	16.5	10.2

Contaminant plastic was small 200g yoghurt containers (PS) 1.2%, coloured HDPE bottles 2.5% and other plastics 6.5% in the form of toys, bottle lids and plastic bags (LDPE), cordial bottles (PVC).

BALE NUMBER 6

Total Bale weight 138.5kg

PRODUCT	PRODUCT WEIGHT IN KGS	% of TOTAL WEIGHT
Ice-cream containers/lids	27	19.5
Cordial Bottles	32	23.1
Flower Pots/Seedling Trays	15	10.8
Tomato Sauce Bottles*	6	4.3
Laundry Tubs/Buckets	26	18.8
Margarine/Butter containers/lids	3.5	2.5
Food containers**	9	6.5
Yoghurt Large 5kg	11	7.9
Contaminant	9	6.5

Contaminant plastic was small 200g yoghurt containers (PS) 1.4%, coloured HDPE bottles, toys, bottle lids and plastic bags (LDPE), cordial bottles (PVC) made up other 5.1% contamination.

NOTE

No paper, cans or PET soft drink bottles or milk bottles found in any audited bales.

*Includes small HDPE tomato sauce bottles primarily together with the larger PP tomato sauce bottles.
** Food containers were mostly pasta containers and clear fruit containers.
*** Large Yoghurt tubs from an industrial source in the area, not household waste.

APPENDIX 2
PGS REPROCESSING TRIAL (TRIAL 1)

PROPERTY	Bale 1 Start	Bale 2 Start	Bale 3 Start	Bale 4 Start	Bale 5 Start	Bale 6 Start
MFR (230°C/2.16kg) g/10min	12.1	13.7	10.6	12.3	14.9	15.3
FM (Chord Modulus, ISO, 2mm/min) MPa	1000	1020	1030	1030	1020	1030
Tensile Stress at Yield (ISO, 50mm/min) Mpa	23.5	24.1	24.5	24.5	24.1	24.1
Tensile Strain at Yield (ISO, 50mm/min) %	9.5	8.8	9.4	9.2	8.8	8.6
Notched Izod Impact at 23°C (ISO) kJ/m^2	4.9	4.3	4.5	4.3	4.2	4.1
Notched Izod Impact at 0°C (ISO) kJ/m^2	3	2.9	3	2.8	2.9	3.1
HDT at 0.45 Mpa (ISO) °C	83	82	81	79	81	79

PROPERTY	Bale 1 Middle	Bale 2 Middle	Bale 3 Middle	Bale 4 Middle	Bale 5 Middle	Bale 6 Middle
MFR (230°C/2.16kg) g/10min	11.9	11.8	11.8	12.1	13	11.8
FM (Chord Modulus, ISO, 2mm/min) MPa	1000	1020	1030	1050	1050	1050
Tensile Stress at Yield (ISO, 50mm/min) Mpa	23.6	24.2	24.1	24.6	24.4	23.5
Tensile Strain at Yield (ISO, 50mm/min) %	9.4	9.6	8.9	9.1	8.2	9.3
Notched Izod Impact at 23°C (ISO) kJ/m^2	5.1	4.5	4.5	4.4	4.2	3.9
Notched Izod Impact at 0°C (ISO) kJ/m^2	3	2.9	2.5	2.7	3	2.5
HDT at 0.45 Mpa (ISO) °C	81	78	78	84	88	77

TRIAL 1 continued

PROPERTY	Bale 1 End	Bale 2 End	Bale 3 End	Bale 4 End	Bale 5 End	Bale 6 End
MFR (230°C/2.16kg) g/10min	11.7	11.4	11.8	12.5	14.9	12.6
FM (Chord Modulus, ISO, 2mm/min) MPa	1030	1050	1030	1040	1030	1030
Tensile Stress at Yield (ISO, 50mm/min) Mpa	23.6	23.9	23.9	23.8	23.5	23.7
Tensile Strain at Yield (ISO, 50mm/min) %	9	9.7	9.1	8.9	8.8	9.2
Notched Izod Impact at 23°C (ISO) kJ/m^2	4	3.7	3.7	3.6	3.7	4
Notched Izod Impact at 0°C (ISO) kJ/m^2	2.9	2.7	2.5	2.5	2.5	2.5
HDT at 0.45 Mpa (ISO) °C	78	81	79	86	85	85

Points to note:

- PE detected in pellet samples
- No other plastic materials, such as PS, PET or PVC detected
- The pellet samples displayed evidence of being nucleated
- During moulding, the recycled materials emitted some odour but there was no excessive fuming from melt. The moulded specimens appeared normal and there were no voids in the cross sections.

APPENDIX 3
SIMS REPROCESSING TRIAL (TRIAL 2)

PROPERTY	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
MFR (230°C/2.16kg) g/10min	9.5	8.8	8.8	9.1	8.9	8.2
FM (Chord Modulus, ISO, 2mm/min) MPa	→	→	→	→	1040	→
Tensile Stress at Yield (ISO, 50mm/min) Mpa	→	→	→	→	23.8	→
Tensile Strain at Yield (ISO, 50mm/min) %	→	→	→	→	10.8	→
Notched Izod Impact at 23°C (ISO) kJ/m^2	→	→	→	→	5.3	→
Notched Izod Impact at 0°C (ISO) kJ/m^2	→	→	→	→	3.3	→
HDT at 0.45 Mpa (ISO) °C	→	→	→	→	86	→

PROPERTY	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
MFR (230°C/2.16kg) g/10min	8.6	9.8	8.1	12.8	11.9	11.5
FM (Chord Modulus, ISO, 2mm/min) MPa	→	→	→	1040	→	→
Tensile Stress at Yield (ISO, 50mm/min) Mpa	→	→	→	24	→	→
Tensile Strain at Yield (ISO, 50mm/min) %	→	→	→	11	→	→
Notched Izod Impact at 23°C (ISO) kJ/m^2	→	→	→	5.4	→	→
Notched Izod Impact at 0°C (ISO) kJ/m^2	→	→	→	3.3	→	→
HDT at 0.45 Mpa (ISO) °C	→	→	→	85	→	→

TRIAL 2 continued

PROPERTY	Sample 13	Sample 14	Sample 15
MFR (230°C/2.16kg) g/10min	11.2	11.4	11.8
FM (Chord Modulus, ISO, 2mm/min) MPa	→	→	1000
Tensile Stress at Yield (ISO, 50mm/min) Mpa	→	→	22.8
Tensile Strain at Yield (ISO, 50mm/min) %	→	→	8.7
Notched Izod Impact at 23°C (ISO) kJ/m^2	→	→	5.6
Notched Izod Impact at 0°C (ISO) kJ/m^2	→	→	3.6
HDT at 0.45 Mpa (ISO) °C	→	→	85

Points to note:

- PE detected in pellet samples
- No other plastic materials detected in pellet or flake samples ie no PS PET or PVC detected
- All pellet samples displayed evidence of being nucleated
- During moulding, the recycled materials emitted some odour but there was no excessive fuming from melt. The moulded specimens appeared normal and there were no voids in the cross sections.
- Waste from washing step found to contain PET, PVC and Styrene based polymers
- Samples 1→5, 6→10, 11→15 were pooled together to give 3 lots for the physical testing.