Creating markets for recycled resources

WRAP Final Report

WRAP Food Grade HDPE Recycling Process: Commercial Feasibility Study

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WRAP Food Grade HDPE Recycling Process: Commercial Feasibility Study

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1 Executive Summary

1.1 Background

This project was initiated with the support of WRAP's Packaging Innovation Research program to develop innovative packaging that could reduce household packaging waste originating from the retail sector.

The technology developed by WRAP for the recycling HDPE milk bottles from kerbside and bring scheme collections in the United Kingdom contained the following key steps:

- Sorting of natural HDPE milk bottles to a purity greater than 99%.
- Grinding and hot washing of the bottles by a conventional plastic bottle recycling process.
- Super-clean decontamination by the EREMA process using high temperatures and vacuum.

This project has been initiated to assess the full commercial feasibility of a recycling plant based on the technology developed by WRAP in 2004/2005.

1.2 The Recycled HDPE

The results from the rheological tests, processing tests and the mechanical tests show that the recycled HDPE is technically very similar to the virgin resin used to make milk bottles.

The difference in colour was noticeable at 100% but was reported to be negligible at 30% rHDPE content.

The other differences that were noted were the presence of gels and black specks and the odour after processing, however these were not at a level that detracted from use as a commercially acceptable bottle.

1.3 Equipment

The equipment needed to deliver the technology for the manufacture of food grade HDPE resin must provide the following modules:

1. Bottle sorting to provide HDPE to at least 99% (food grade bottles and contents)
2. Bottle grinding and cleaning to remove external materials
3. Hot washing with surfactants at >90 °C
4. Sorting of flakes to remove coloured components
5. Decontamination (two stage Vacurema at 120 °C)
6. Extrusion into pellets
7. Packaging
8. Ancillaries to service the plant

1.4 Economic Analysis

The process of recycling HDPE can be conducted as a stand alone operation or as an integrated operation with an existing PET recycling plant. The analysis shows that there is significant synergy in integrating the operations mainly because it would reduce the fixed and overhead costs of the operation as shown on the tables below.

Item	Wash plant	Vacurema Line	ANCILLARIES	Total
Capital Cost	£1,053,649	£1,179,323	£780,633	**£3,013,605**
Floor Space m^2	600	100	150	**850**
Water m3/hr	3	0	0	**3**
Power kW	313	475	75	**863**
Output kg/hr	1000	1400-1000	NA	**1000**
Operators and staff	3x5 + 5= 20	1	0	**20**

Summary of capital costs and utilities for a stand alone plant.

Summary	Wash plant	Vacurema Line	ANCILLARIES	Total
Capital Cost	£1,053,649	£1,179,323	£222,992	**£2,455,964**
Floor Space m^2	600	100	50	**750**
Water m3/hr	3	0	0	**3**
Power kW	313	475	75	**863**
Output kg/hr	1000	1400-1000	NA	**1000**
Operators and staff	3x5 +1.65=16.65	1	0	**16.65**

Summary of capital costs and utilities for a shared plant.

The analysis of the economics of the food grade HDPE recycling process is based on the assumption that the sale price of the rHDPE will be £800/tonne (which is based on the sale price of virgin HDPE), the input price for the HDPE baled bottles is £265 per tonne and the loss of material form bales is 25%. This is effectively just over £360/tonne corrected for losses ie based on the output of the plant.

The data initially reveals that the direct processing costs are £296/tonne and the depreciation is £55/tonne giving a total cost of operating the plant, exclusive of materials of £341/tonne. This figure is encouragingly £81/tonne less than the cost predicted in the earlier work of €610/tonne or £422/tonne.

When the true cost of the HDPE material based on the output of HDPE (£359/tonne of output) is added to the cost of processing a final figure of £711/tonne is obtained. This provides a margin of £89/tonne if the resin can be sold at £800/tonne. This represents a profit on sales of 11%.

1.5 Resin Market

The price of virgin resin in the UK market place in 2006 has typically been in the range of £800/tonne.

Recycled HDPE made to food grade specifications could potentially reach this price point as well provided there were no obvious defects such as a shift in colour, odour and fine black specks. Potentially the price could be in the range £820 to £760/tonne depending on the demand for the resin.

For non-food grade HDPE then the price would depend on the purity of the colour and range from £600 to £550/tonne

The price of sorted baled HDPE bottles is currently £265–280/tonne and the bales have not been of high quality due to the export of these to Asia.

Mixed bales have approx. 20% HDPE and are being sold at up to £200/tonne.

The consistency in feed stock and hence quality would be higher when pre-sorted HDPE is used. However, the supply in UK is diminishing in deference to mixed plastics due to the lower capital and labour costs needed to reach this standard and the demand by exporters.

1.6 Business Opportunity

The variation in the profit on sales expressed as a percentage, as a function of sales price for the food grade HDPE and as a function of the cost of baled HDPE bottles shows the following significant trends:

- The profitability of the process is strongly dependant on the three factors investigated ie incoming bale cost, incoming bale quality and sales price.

- The margins may reduce and totally disappear in disadvantageous markets (low sales prices and high input prices). At a sales price of £750/tonne the maximum bale price that would give a 0% return is £290/tonne.

- In advantageous market conditions (high sales prices and low input prices), the profit can improve. At a sales price of £800/tonne and a bale price of £225/tonne would give an 18% return.

- The performance of the process is much more sensitive to changes in input HDPE prices than to changes in sales prices. A change of £50/tonne in the bale price changes profit by approx. 10% and a change of £50/tonne in the sales price changes profit by 5%.

- The quality of the incoming bales can strongly reduce the profitability of the operation. An 8% increase in material loss (from 25%) can shift a plant from a profit of 8% to a loss at a bale price of £275/tonne.

The sensitivity of the plant's profit on sales suggests that this is a process with a degree of risk that could perform well in good conditions and in poorer conditions, it may suffer lower margins and could easily pushed into a loss making position by reduction in input bale quality and increase in bale price.

1.7 Integration Into Existing Pet Plant

The financial performance of the process improves due to:

- Reduction in capital cost (£557,179) and depreciation (£55,700)
- Savings on rent
- Sharing of staff and equipment

The profit on sales in the model selected increases from a relatively unattractive 11% to a more interesting level of 21% provided all of the staffing and equipment savings can be achieved.

In key points are shown in the table below

Plant Capital	£3,013,605	£2,455,964
HDPE output t/yr	6,121	6,121
Sales (equal to Virgin) £/t	£800	£800
Gross sales £/yr	£4,896,681	£4,896,681
EBIT margin £/yr	**£89**	**£169**
Gross Margin £/yr	£546,010	£1,034,894
Profit on Sales%	**11%**	**21%**
Simple pay back (years)	5.519	2.373

Summary of operational factors for Stand-Alone and Integrated plants

In addition to the integration of the facilities and staff, a major advantage would arise from the ability to accept large quantities of mixed plastics bottles as in-feed and extract the maximum value from both the PET and HDPE components into food grade resins.

The seasonal nature of the supply of bottles would also be improved as the supply of HDPE bottles is less sensitive to the warm/cool weather patterns that can dramatically influence the PET beverage market.

1.8 Overall Assessment

This process is technically attractive due to its unique capabilities of recovering HDPE back to food grade. It could be an effective investment when integrated into an existing PET operation. There are risks associated with the operation of a stand-alone plant arising form price increases in the incoming baled bottles, the purity of the bales and the sale price of the food grade rHDPE.

2 **Project scope**

This project has been initiated to assess the full commercial feasibility of a recycling plant based on the technology developed by WRAP in 2004/2005. In this study (published by WRAP in June 2005 titled "Develop an food grade HDPE recycling process" by Dr Frank Welle) it was shown that HDPE milk bottles could be recycled into resin that met the EU food contact requirements and could be used to make production quality bottles at 30% without impact on bottle or milk quality. While this extensive study dealt very comprehensively with the issues, relating to the performance of the process further information was needed to fully assess the commercial feasibility of such a plant in UK.

This report seeks to provide information that will assist in a more detailed assessment of the commercial opportunities for this technology. The report investigates

- The type and cost of equipment required for an operational plant.
- The optimal plant layout and any overhead increases.
- The properties of the recycled HDPE compared to Virgin resin.
- The market situation for the resin.
- An assessment of the risks.
- The commercial implications for stand alone and integrated (with recycling of PET) plants

3 Introduction: HDPE recycling technology

The technology that was developed by WRAP (as referenced above) for the recycling HDPE milk bottles from kerbside and bring scheme collections in the United Kingdom contained the following key steps:

- Sorting of natural HDPE milk bottles to a purity greater than 99%.
- Grinding and washing of the bottles by a conventional plastic bottle recycling process.
- Super-clean decontamination by the EREMA process using high temperatures and vacuum.

The ability of this recycling process to produce material suitable for use in food contact applications was checked by means of a challenge test using artificial contaminants and by comparing the levels of contamination in the output material from the recycling process both with the input post-consumer HDPE milk bottles and with virgin polymer.

The analytical work demonstrated that the process is capable of producing high-grade polymer suitable for use in food contact applications from post-consumer HDPE bottles.

Compounds found in the recycled HDPE flake samples but rarely in the virgin polymer samples included:

- The flavour compound limonene.
- A degradation product of the antioxidant additive di-tert-butylphenol.
- Small amounts of saturated oligomers.

However, the total concentration of all contaminants in the post-consumer recycled samples was similar to or lower than found in virgin HDPE.

Contamination with other compounds that would not normally be found in virgin HDPE was rare and in most cases related to compounds originating from normal use of HDPE bottles in non-milk applications, for example shampoo. Non-milk containers comprised less than 2.1% of the input material to the recycling process.

The analytical and test work concluded that HDPE milk bottles containing up to 100% recyclate from the super-clean recycling process tested and validated during this project can be used safely for direct food contact applications.

The costs per kg for recycled HDPE (excluding the cost of baled input bottles to the sorting process) were estimated as follows:

Direct production cost	€0.41/kg
Overheads, personnel and infrastructure	€0.20/kg
Total	€0.61/kg

The overall production cost of €0.61/kg was compared to an average price for virgin HDPE of around €1.2 kg indicating that there was potential for the process the be commercially attractive.

An environmental impact comparison of the full super-clean recycling process including sorting, washing and EREMA super-clean treatment demonstrated that the HDPE recycling process had a lower environmental impact across all impact categories than the alternative of landfill.

The project concluded that three main quality assurance elements are essential for safe and successful recycling of post-consumer HDPE milk bottles:

- Careful source control
- Tight production control
- Regular analytical checks of input and output materials

In summary, the assessment of the technology showed that HDPE milk bottles may be recycled in closed loop on a commercially viable and environmentally sound basis. The recycled product would be comparable to, or even indistinguishable from, that made from virgin polymer.

4 Technical Scope: Additional information.

This report seeks to provide information that will assist in a more detailed assessment of the commercial opportunities for this technology. The report seeks to provide:

- A comparison of the physical and rheological properties of the recycled HDPE compared to Virgin resin.
- The full specification list and cost of equipment required for an operational plant as a stand-alone facility and as a facility integrated into an existing operation that is recycling PET bottles.
- The optimal plant layout and any overhead implications.
- A financial model for the operation of a HDPE recycling process.
- The market situation for the resin including a study of the sensitivity to price movements on the economic attractiveness of the process.
- An assessment of the risks.
- The commercial implications for stand alone and integrated (with recycling of PET) plants

The outcome of this additional data will be an improved capacity to assess the commercial attractiveness of the WRAP HDPE recycling technology in UK based on the commercial and market factors existing in the polymer and recycling industries in 2006.

5 Recycled HDPE Properties

5.1 Melt Flow Rate and Processing Analysis

The processing behaviour of polymers can be characterised by a number of flow tests that provide data on the viscosity of that material under controlled conditions. One such test is the Melt Flow Rate (MFR) test which measure the grams extruded in 10 minutes under a constant temperature and pressure. This test is used to compare the processing behaviour of the recycled resin against virgin HDPE.

Milk bottles in UK are made from HDPE homopolymer resins that are specifically made for this purpose. In UK, one such grade, Rigidex HD6007S, is made by Innovene. A data sheet for this resin is shown in Appendix 1. This shows that the MFR for the virgin resin is 0.6 g/10 min at 190 °C.

Melt Flow Rate analysis of r-HDPE material properties in direct comparison to Innovene HD6007S virgin HDPE was carried out on 5 polymer samples at two testing laboratories; the London Metropolitan University and Innovene (suppliers of HD6007S) at the Works Laboratory in Lillo, Belgium. The results are shown below

MFR Tests (g/10min)	WRAP Samples 1	2	3	4	5	Ave. of 1 -5	Innovene HD6007S
MFR 2.16 (London Met Uni Tests)	0.58	0.58	0.56	0.60	0.60	**0.58**	**0.58**
MFR 2.16 (Innovene Lab in Lillo)	0.6	0.6	0.6	0.63	0.64	**0.62**	**0.60**
MFR 21.6kg (Innovene Lab in Lillo)	48	47	44	44	46	**46.8**	**52**
MFR Ratio (21.6/2.16) (Lillo)	80	78	73	70	72	**76.7**	**87**

Table 1. Summary of MFR test results (For full results, refer to Appendices 2and 3).

The results from the two different laboratories show that the MFR at 2.16 kg and 190 °C are essentially the same for the virgin resin and the rHDPE. ie all of the MFR results were within the range of 0.60 ± 0.02 g/10min

The tests at Innovene's laboratories at 21.6 kg did show that the rHDPE was slightly less shear thinning as shown by the lower MFR results. This would be consistent with the longer heat history that would slightly crosslink the HDPE and the extraction of lower molecular species during the decontamination process. These changes did not affect the blow moulding process and could be easily compensated by the use of higher extruder screw speeds during blow moulding of bottles.

The tests at Innovene also included the blow moulding of a 30% rHDPE blend with virgin HD6007S and also virgin resin. The bottles were processed on a Uniloy 2016 Blow Moulder which make bottles comparable to those made in production.

The bottles processed normally and made good bottles with no failures. The bottles were noted to have a higher incidence of gels and small black specks than virgin bottles.

These slight variations in quality were not noted to be unacceptable to production quality. Also the technician commented on the difference in odour which significantly diminished over 24 hours.

5.2 The conclusion of the Innovene report was that the rHDPE was of excellent quality.

These results show that the recycling process does not greatly change the flow behaviour of the HDPE and it means that at 30% addition rate only small adjustments to the blow moulding process would be needed to produce bottles at the same rate and quality as virgin resin.

5.3 Tensile Test Results

The mechanical behaviour of the milk bottle resins can be characterised by tensile tests that readily measure the tensile stiffness (modulus) and deformation behaviour (yield behaviour) of a material.

The tensile testing was conducted at London Metropolitan University. Granules of rHDPE and virgin resins were moulded into tensile test bars shown in Figure 1 below. It is noticeable that at 100% concentration there is a noticeable difference in colour of the rHDPE test bars compared to the virgin HDPE test bars. The colour is a result of the residual (100 ppm) coloured HDPE closures left in the HDPE flake during the sorting process.

Test Conditions & Specimen Specifications:

Test Speed: 50mm/min Gauge Length: 75mm

Specimen (6 off) Dimensions (Width =12mm Thickness =1.7mm

Test method based on ISO 527 Tensile testing of Plastics

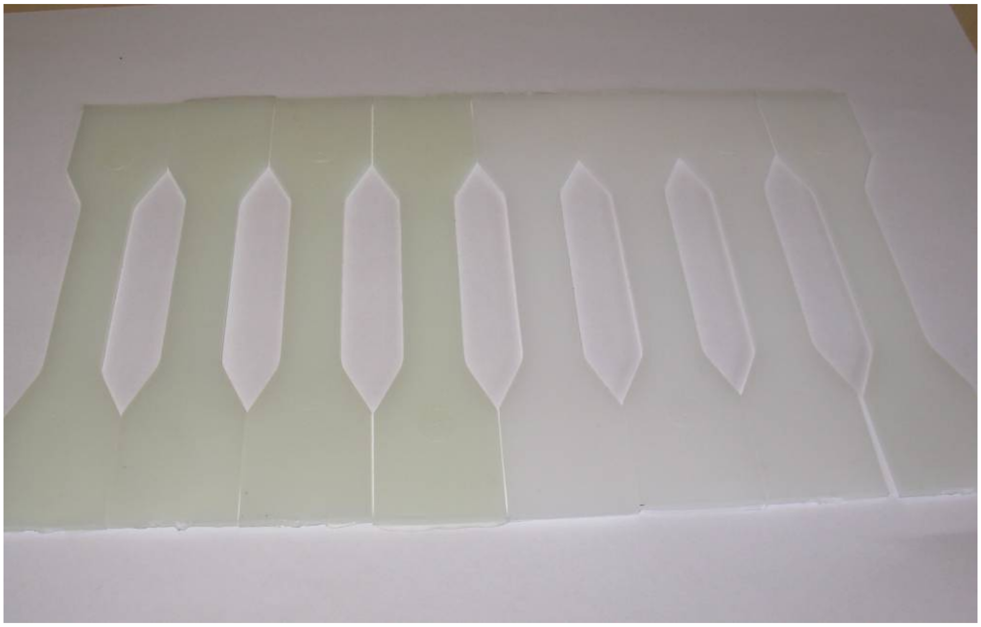

Figure 1 Tensile test bars (4x rHDPE on the left and 4x virgin HDPE on the right)

The test results are summarised below in Table 2.

Tensile Test Parameter	Virgin HDPE Innovene Rigidex HD6007S	Recycled HDPE blend of samples 1 to 5	Data Sheet RIGIDEX HD6007S
Yield Stress (MPa) Std. Dev.	**29.91** 0.084	**30.47** 0.425	**30.5**
Elongation at yield (%) Std. Dev.	**12.62** 0.303	**12.63** 0.069	Not stated
Stress at Break (MPa) Std. Dev.	**18.23** 0.595	**20.36** 1.655	Not stated
Elongation (%) Std. Dev.	**35.47** 1.620	**35.06** 3.133	Not applicable
Tensile Modulus (MPa) ***Data from experimental stress/strain curves**	**332**	**354**	Not applicable

Table 2. Summary of Tensile, Modulus and Elongation results.

The stress strain curves for the two types of resin are shown in figures 2 and 3.

Figure 2. Stress/Strain Curves for Virgin HDPE samples

Figure 3. Stress/Strain Curves for Recycled HDPE samples

The data shows that the yield stress for both the rHDPE and the virgin HD6007S is the nearly the same as the typical value shown on the data sheet for the Rigidex HD6007S ie 30.5 MPa.

The other values measured in this test show that the two resins are very similar in elongation at yield and failure as well as Stress at failure and Modulus. If the curves are superimposed they appear to belong the same material.

These results show that the mechanical properties of the rHDPE are very similar to virgin HDPE and it would be expected that when 30% rHDPE was blended with virgin resin that there would be no change in the mechanical properties of bottles made from this blend.

5.4 Conclusions: Resin differences

The results from the rheological tests, processing tests and the mechanical tests show that the recycled HDPE is technically very similar to the virgin resin used to make milk bottles. The differences that have been noted in flow behaviour and mechanical behaviour could be considered negligible. The difference in colour is noticeable at 100% but was reported (by Dairy Crest) to be negligible at 30% rHDPE content. The other differences that were noted were the presence of gels and black specks and the odour after processing, however these were not at a level that detracted from use as a commercially acceptable bottle.

6 Equipment Requirements

6.1 Major equipment items

The equipment needed to deliver the technology for the manufacture of food grade HDPE resin must provide the following modules:

1. Bottle sorting to provide HDPE to at least 99% (food grade bottles and contents)
2. Bottle grinding and cleaning to remove external materials
3. Hot washing with surfactants at >90 °C
4. Sorting of flakes to remove coloured components
5. Decontamination (two stage Vacurema at 120 °C)
6. Extrusion into pellets
7. Packaging
8. Ancillaries to service the plant

A more detailed list of the major items of equipment has been listed below in Tables 3 and 4.

Major items - Bottle Recycling Plant
Conveyor with bale reservoir
Bale breaker
Bottle sorting plant
Automatic Bottle Sorter
Conveyor into grinder with metal separation
Grinder
HDPE flake Pre Cleaner
Air classifier
Hot wash system
Rinsing system
Sink floatation tank
Mechanical dryer
Thermal drying
Multi-channel-metal separation system
Flake colour sorter
Waste water treatment
Control cabinet
Crystallisation Dryer
Vacurema Extrusion system
Hot die-face granulation system
Integrated silo-throughput measuring and sacking system

Table 3 Major Equipment items for HDPE food grade plant

Ancillaries
Electrical assembly and wiring
Low and High voltage Supply
Compressor
Laboratory equipment
Steam generator

Table 4 Ancillary Equipment items for HDPE food grade plant

6.2 Equipment quotations

In order to develop a more detailed financial model, quotations were obtained from machinery suppliers that could deliver the appropriate technologies.

The price estimates for the plant and equipment have been based on quotes from three suppliers, two for the sorting and hot washing plant (Sorema and B+B) and one for the decontamination and extrusion plant (Erema). The detailed quotations are given in Appendices 4, 5 and 6 and are the basis for the operational model for the economic analysis. Since the financial model for the plant will be based on an operation at 1 tonne per hour, the quotations for that rate have been used in the operational model.

6.3 Plant configurations: Stand-alone and Shared Plant

The main analysis in this study will be on a plant that has the full capability to process the bales of HDPE bottles into food grade rHDPE pellet. It is also likely that such an operation may well be undertaken in an existing bottle recycling plant that was set up to recycle PET bottles. This would be particularly advantageous if the in-feed bottles were from a commingled source and the bottles were being sorted into PET, HDPE and other plastics streams.

In a shared plant, a number of items would already exist and would allow savings on capital and especially savings on staffing and overheads.

The items that a shared plant would not need to purchase are shown in Table 5

Bottle sorting plant	£296,427.73
Auto Sorting bottles	£249,676.54
Laboratory equipment	£11,075.20
Total	£557,179.47

Table 5. Savings in capital equipment for a shared plant

This would generate depreciation savings of £55,718 /year.

It would be anticipated that the staff to supervise the combined plants (in supervision, office, laboratory and inwards goods) would be shared 1/3rd with the existing PET recycling operation, consequently using approximately 1.65 staff and reducing the PET overhead staff from 5 to 3.35 full time staff.

This would generate savings of £101,400 per annum compared to a stand-alone plant.

The total savings would add £157,000 to the bottom line of the shared plant.

In addition, there would be savings in floor space of approximately 100m^2 due to the savings on the ancillary equipment located within the PET plant. Further savings in staff accommodation would also be possible however, they have not been included here due to the small impact on the total space requirements.

The capital costs, power and space requirements for a stand-alone and shared plants are shown below in Tables 6 and 7

Item	Wash plant	Vacurema Line	ANCILLARIES	Total
Capital Cost	£1,053,649	£1,179,323	£780,633	**£3,013,605**
Floor Space m^2	600	100	150	**850**
Water m3/hr	3	0	0	**3**
Power kW	313	475	75	**863**
Output kg/hr	1000	1400-1000	NA	**1000**
Operators and staff	3x5 + 5= 20	1	0	**20**

Table 6. Summary of capital costs and utilities for a stand alone plant.

Summary	Wash plant	Vacurema Line	ANCILLARIES	Total
Capital Cost	£1,053,649	£1,179,323	£222,992	**£2,455,964**
Floor Space m^2	600	100	50	**750**
Water m3/hr	3	0	0	**3**
Power kW	313	475	75	**863**
Output kg/hr	1000	1400-1000	NA	**1000**
Operators and staff	3x5 +1.65=16.65	1	0	**16.65**

Table 7. Summary of capital costs and utilities for a shared plant.

In summary, the analysis shows that there is significant synergy in integrating the operations of recycling HDPE into an existing PET operation mainly because it would reduce the fixed and overhead costs of the operation. The financial benefits are quantified later in the economic analysis in section 8.

7 Plant Layout

The layout of a plant for food grade plastics can be configured in a number of ways however, there is always a need to separate the incoming baled feedstock from the finished food grade resin.

This means that the plant should have a linear progression from the inwards goods area to keep the contaminated bottles separated from clean flake and preferably, there should be a walled separation of the wet and more contaminated bottle sorting, grinding and washing activities from the clean and dry flake sorting, decontamination, extrusion and bagging operations. The use of a linear operation means that there is a separate inwards and outwards goods area which will eliminate contamination and pest infestations.

In an integrated PET plant, the washing equipment would be co-located with the PET equipment to simplify provision of services such as heating and water and water recycling.

In the integrated PET plant, the additional area required would be 750m^2 and this would be divided between the washing and the extrusion zones of the plant. The wash plant occupies most of the space at 600m^2 and the extrusion area 100m^2 and the additional ancillaries would use 50m^2.

In the stand-alone version of the plant the area required for the factory would slightly higher at 800m^2, however additional external space would be needed for storage of the baled HDPE and for administrative offices and traffic space. This would mean a substantially higher rent as shown for the stand-alone operation of £272,284 against an allocation of £90,761 for the shared operation.

8 Recycling Process Economic Analysis

The financial model of the HDPE plant is based on a number of production assumptions some of which are given below.

Production hours/yr	= 6904 hrs/yr
Input of HDPE baled bottles	= 8300 tonnes/yr
Loss of input materials	= 25%
Output of food grade HDPE	= 6121 tonnes/yr
Electrical energy costs	= 0.08 £/kWhr
Gas energy costs	= 0.0287 £/kWhr
Water consumption	= 3 m^3/hr
Staff for stand alone plant	= 20
Staff for integrated plant	= 16.65
Depreciation rate	= 10%

Positive revenue is obtained for waste polyolefin.
Bale prices for HDPE are quoted on input basis
Final process costs are calculated on output of product rHDPE
PRN income have not been included.

The details of all of the plant operational assumptions such as water, energy and chemical consumption etc are shown in Appendices 7 and 8.

The analysis of the economics of the food grade HDPE recycling process is based on the assumption that the sale price of the rHDPE will be £800/tonne (which is based on the sale price of virgin HDPE) and the input price for the HDPE baled bottles is £265 per tonne. This is effectively just under £360/tonne corrected for losses ie based on the output of the plant.

The results of the financial modelling based on the above assumptions are shown in the Table 8 below.

The data initially reveals that the direct processing costs are £296/tonne and the depreciation is £55/tonne giving a total cost of operating the plant, exclusive of materials of £341/tonne. This figure is encouragingly £81/tonne less than the cost predicted in the earlier work reported in the introduction (Section 1) to this report of €610/tonne or £422/tonne.

When the true cost of the HDPE material based on the output of HDPE (£359/tonne of output) is added to the cost of processing a final figure of £711/tonne is obtained. This provides a margin of £89/tonne if the resin can be sold at £800/tonne. This represents a profit on sales of 11%.

COSTS	Stand alone £/t Recyclate	Shared Plant £/t Recyclate
Input purchase and other costs (1)		
HDPE bottles as purchased	265	265
HDPE bottles true cost based on output (1)	359.35	359.35
Process Costs (2)		
By product costs	-18.78	-18.78
Personnel	90.65	74.09
Energy	85.22	85.22
Water and chemicals	19.69	19.69
Maintenance	24.62	20.06
Inspection	15.00	15.00
Packaging	7.79	7.79
Overheads & rent	72.03	26.38
Sub-total Process Costs (2)	**296.22**	**229.46**
Depreciation (3)	55.23	42.12
Total Costs (1+2+3)	**711**	**631**

Plant Capital	£3,013,605	£2,455,964
HDPE output t/yr	6,121	6,121
Sales (equal to Virgin) £/t	£800	£800
Gross sales £/yr	£4,896,681	£4,896,681
EBIT margin £/yr	**£89**	**£169**
Gross Margin £/yr	£546,010	£1,034,894
Profit on Sales%	**11%**	**21%**
Simple pay back (years)	5.519	2.373

Table 8. Summary of financial performance of stand-alone and integrated rHDPE plants

For the integrated operation, the performance of the operation is significantly improved since the costs for personnel, overheads and rent is reduced by £46/tonne and the margin is improved to £169/tonne and the profit on sales increases to 21% based on the above assumptions.

While these numbers are helpful in starting to understand the economics of the process, the sensitivity of the process to market variations must be reviewed to fully characterise the commercial performance of this technology.

9 Market Analysis

9.1 End markets for food-grade and non food-grade HDPE

The HDPE used for milk bottles is a homopolymer resin ideally suited to the task of making thin walled lightweight bottles that do not have a long lifetime. This means that the resin is much more rigid and brittle than other blow moulding resins and lacks resistance to stress cracking.

The potential markets for milk bottle resin are relatively constrained due to the specialised nature of the resin when it is used in high concentrations ie over 50% to 100%. At lower levels of concentration, many more markets can be found as this grade of HDPE has a lower level of influence on the final properties.

If the resin is food grade quality then it can compete with virgin resin in the blow moulding of milk bottles. It can also be used at low concentrations in general blow moulded goods (e.g. up to 50%) however, its poor stress crack resistance will generally mean that the correct grade of virgin resin will be preferred unless there is a significant price incentive.

The typical price expectation for a recycled food grade resin would be 5 to 10% less than virgin resin to justify the costs associated with separate storage and final blending. The demand for such a novel resin may in some cases shift the expected price variation from a reduction to a price premium.

This resin can be used readily for sheet and film however, it is usually relatively brittle for these applications and would only be used at concentrations below 30% to minimise this behaviour.

There are not many other markets for such a grade in pipe extrusion, injection moulding or roto-moulding due to the mis-match in flow behaviour of this resin for those applications.

If the resin is non-food grade, then the price that can be asked usually falls to typically 70% of the virgin resin price. This lower price means that there is a significant incentive to blend this resin and to tolerate the changes to processability and properties. This resin has found markets as a blend in:

- Extruded sheets
- Extruded non pressure pipes such as drainage pipes
- Injection moulding of large products with large injection ports such as crates, wheelie bins and compost bins, and electrical pits for cable junctions.
- Blow moulding of non critical components such as coolers and bins

9.2 Prices of Resins in these markets

The price of virgin resin in the UK market place in 2006 has typically been in the range of £800/tonne.

Recycled HDPE made to food grade specifications could potentially reach this price point as well provided the quality was apparent and that there were no obvious defects such as a shift in colour, odour and fine black specks. Potentially the price could be in the range £820 to £760/tonne depending on the demand for the resin.

For non-food grade HDPE, the price would depend on the purity of the colour and the other quality attributes such as odour and any particulate matter present. Typically the price of the resin would be £600/tonne for resin that was very light in colour i.e. nearly natural. If the resin was more darkly coloured then the price would be in the region of £550/tonne

The price of sorted baled HDPE bottles is currently £265–280/tonne and the bales have not been of high quality due to the export of these to Asia.

Mixed bales that would have approx. 20% HDPE in them are being sold at up to £200/tonne, presuming that 25% of the contents would be lost due to contamination and inappropriate plastics and a further 15% is lost during processing, the effective price for the HDPE as output is £314/tonne.

The consistency in feed stock and hence quality would be higher when pre-sorted HDPE is used; however, the supply is diminishing in deference to mixed plastics due to the lower capital and labour costs needed to reach this standard and the demand by exporters.

9.3 Sensitivity to Price changes

The initial assumptions in the financial analysis in Section 8 selected the two important price points of £800/tonne as the sales price for the rHDPE and £265/tonne for baled HDPE. While these prices are in the proximity of the current market position for HDPE, it is important to examine the robustness of the process as these market prices fluctuate.

The variation in the profit on sales expressed as a percentage, is shown in Figures 4 and 5 respectively as a function of the cost of baled HDPE bottles and as a function of the purity of the incoming HDPE feed stock.

The two figures show the following significant trends:

- The profitability of the process is strongly dependant on the three factors investigated ie incoming bale cost, incoming bale quality and sales price.

- The margins may reduce and totally disappear in disadvantageous markets (low sales prices and high input prices). At a sales price of £750/tonne the maximum bale price that would give a 0% return is £290/tonne.

- In advantageous market conditions (high sales prices and low input prices), the profit can improve. At a sales price of £800/tonne and a bale price of £225/tonne would give an 18% return.

- The performance of the process is much more sensitive to changes in input HDPE prices than to changes in sales prices. A change of £50/tonne in the bale price changes profit by approx. 10% and a change of £50/tonne in the sales price changes profit by 5%.

- The quality of the incoming bales can strongly reduce the profitability of the operation. An 8% increase in material loss (from 25%) can shift a plant from a profit of 8% to a loss at a bale price of £275/tonne.

The sensitivity of the plant's profit on sales suggests that this is a process with a degree of risk that could perform well in good conditions and in poorer conditions, it may suffer lower margins and could easily pushed into a loss making position by reduction in input bale quality and increase in bale price. Neither of these factors are easily controlled by purchasing functions and require long-term supply contracts to be established to stabilise both a suitable quality and fair price.

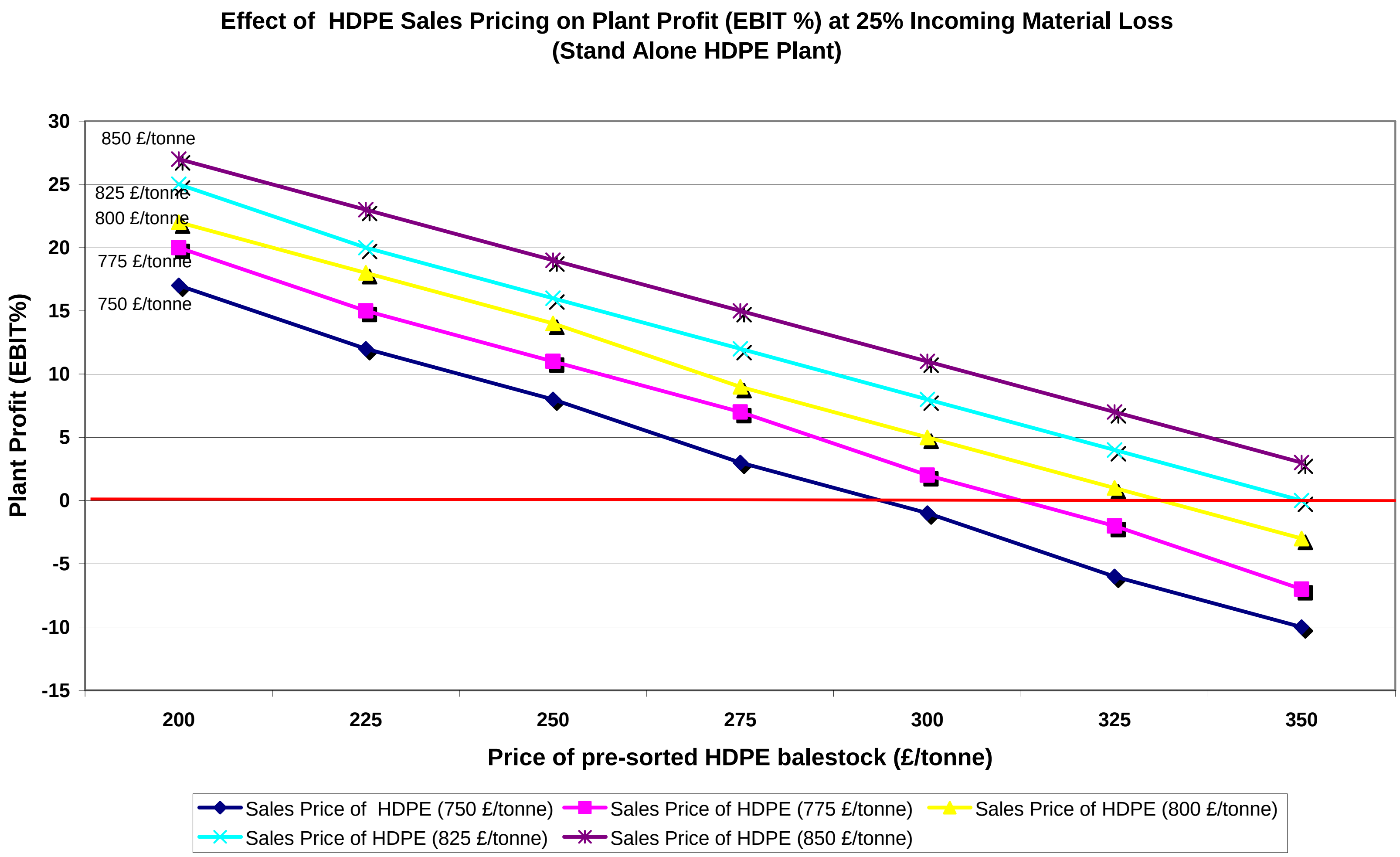

Figure 4 Plant profit (EBIT%) as a function of cost of baled in-feed bottles for a range of final sales prices (virgin resin price)

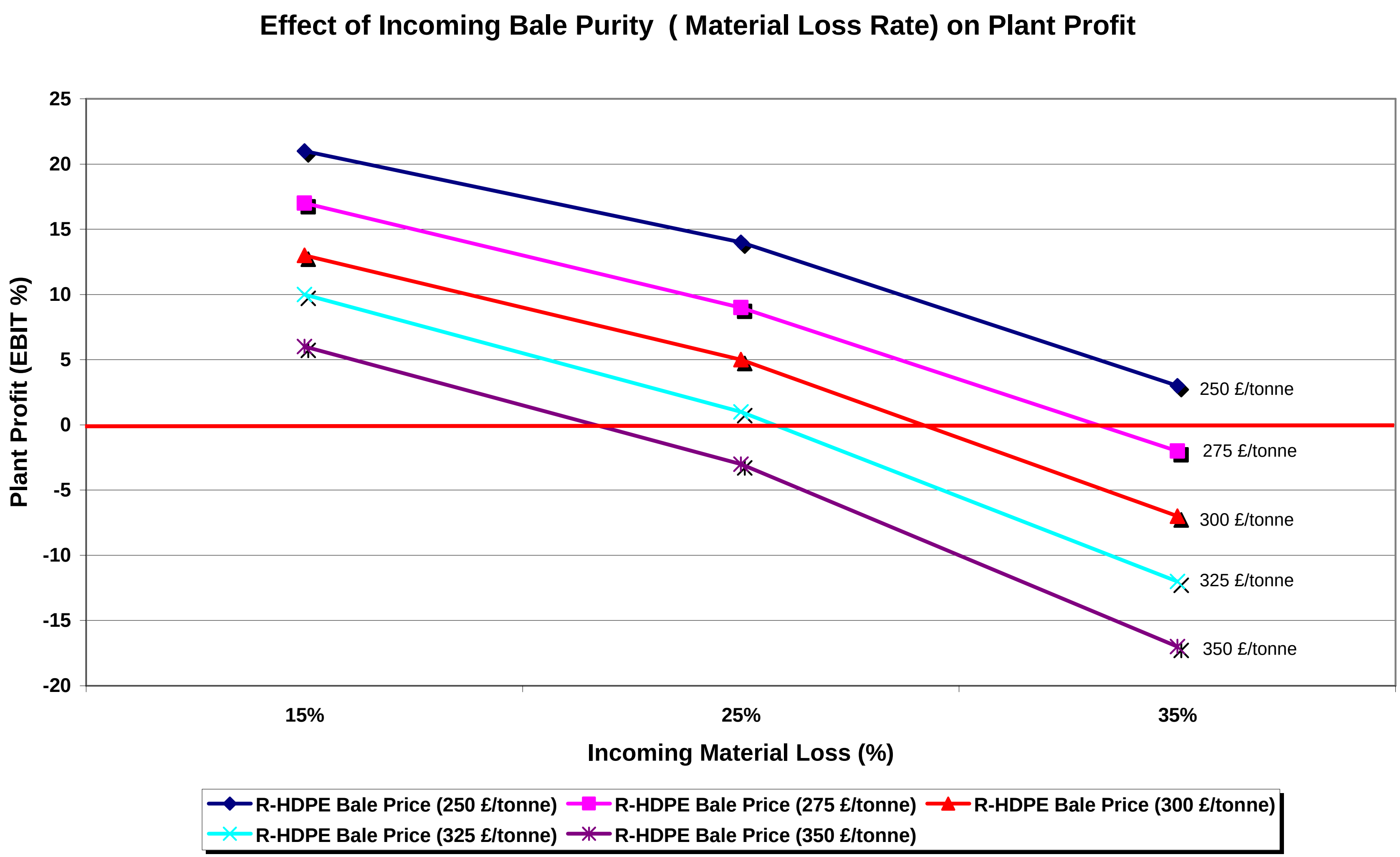

Figure 5 Plant profit (EBIT%) as a function of sorted baled HDPE bottles

10 **Risk analysis**

The recycling of post-use milk bottles into food grade HDPE resin is subject to a number of technical and commercial risks that should be evaluated for their impact on a potential business. The key issues are listed and discussed below

Nature of risk	**Probability**	**Potential result**	**Strategy**
Large scale contamination of in-feed material.	Very low	Reduction to sales	The process can decontaminate 100% contaminated input
High levels of opaque carbon black multilayer milk bottles in-feed.	medium	Reduction to output	Ensure that via calibration of flake sorters opaque flakes are removed.
Variations in cost of post-use baled bottles	medium	Reduction in margin	Purchase bottles under long term supply contracts to stabilise pricing
Alternative packages for milk	low	Reduction of input material	Approx 120,000 tonnes of bottles are used in UK. Supply of 8,000 t/yr of bottles will not dent supply
Virgin resin pricing reductions	low	Reduction in margin	Prices will tend to remain high in current environment. Lower prices usually reduce bottle prices.
Negative perception by virgin resin producers	medium	Reduction to sales	Co-operate with supply chain to share technical knowledge to support market position of HDPE bottles.

The most significant risk factors to the viability of the process are:

- The cost and quality of the incoming feedstock.

Both factors will tend to worsen while there is strong export activity of UK plastics bottles and both would improve when bottles find local markets under long-term supply agreements where quality standards could be established and reinforced over a period of time.

The other factors could be handled through public and corporate education programs to improve the quality and quantity of the feedstock that is available for recycling.

11 Implications of larger capital project on existing PET project

In the Economic Analysis section of this report (Chapter 8) it was demonstrated that by integrating the HDPE recycling process into an existing PET plant, the viability of the operation was greatly enhanced. This was mainly due to the:

- Reduction in capital cost (£557,179) and depreciation (£55,700)
- Savings on rent
- Sharing of staff and equipment

The profit on sales in the model selected increases from a relatively unattractive 11% to a more interesting level of 21% provided all of the staffing and equipment savings can be achieved.

In key points are shown in the Table 9 below

Plant Capital	£3,013,605	£2,455,964
HDPE output t/yr	6,121	6,121
Sales (equal to Virgin) £/t	£800	£800
Gross sales £/yr	£4,896,681	£4,896,681
EBIT margin £/yr	**£89**	**£169**
Gross Margin £/yr	£546,010	£1,034,894
Profit on Sales%	**11%**	**21%**
Simple pay back (years)	5.519	2.373

Table 9.Summary of operational factors for Stand-Alone and Integrated plants

In addition to the integration of the facilities and staff, a major advantage would arise from the ability to accept large quantities of mixed plastics bottles as in-feed and extract the maximum value from both the PET and HDPE components into food grade resins.

The seasonal nature of the supply of bottles would also be improved as the supply of HDPE bottles is less sensitive to the warm/cool weather patterns that can dramatically influence the PET beverage market. This would ensure greater overall stability in both supply, pricing and eventually quality as well, as suppliers better understand the quality standards and the mutual benefits to both sides of the business.

The additional cash flow of nearly £5 million would significantly improve the flexibility to meet financial commitments for the overall operations. The profitability of the two units of the plant i.e. rPET and rHDPE components are of a similar magnitude (approx 20%) however the capital investment for the HDPE plant (£2.5 million) is significantly less than that for the PET plant (£7 million) so it can be viewed as a lower investment risk component. This would improve the attractiveness of the investment to the financial backers of the project.

12 **Overall conclusions**

12.1 The technology

The WRAP process for recycling post-use HDPE milk bottles into food grade resin has been shown to be technically suited to the task of recovering HDPE for re-use into milk bottles. The process is capable of decontaminating HDPE milk bottles that have been exposed to high levels of contaminants back to food grade standards using tests that that conform to EU practices and also potentially USFDA requirements.

12.2 The equipment

The process depends on the provision of an efficient hot wash followed by Vacuum Decontamination prior to extrusion in to pellets.

The equipment is available from a restricted range of reliable suppliers in Europe and a plant could be set up for approximately £3 million.

12.3 The material

This process does not damage the HDPE and bottles made from a 30% rHDPE and virgin blend performed as well as virgin bottles in all tests for the bottle and the milk within the bottle.

12.4 The business opportunity

The process can be developed into a self supporting business provided that there are helpful conditions in the market including a suitable supply and prices for raw materials, suitable quality and sales prices that can reach virgin prices.

The business operation has a degree of risk associated with high prices for HDPE bales and the supply of low purity bales. The incidence of low sales prices is not considered to be a high risk in the current situation with rising hydrocarbon prices.

The integration of the operation with an existing PET bottle operation significantly enhances the attractiveness of the HDPE investment through the reduction of costs for staff, rent and equipment.

This operation in turn enhances the financial flexibility stability and success of the PET operation by increasing the cash flow, increasing the return on a higher fraction of the bottle stream (70% instead of just 50%), increasing the buying power for mixed bottles and reducing seasonal supply factors.

12.5 Overall Assessment

This process is technically attractive due to its unique capabilities of recovering HDPE back to food grade. It could be an effective investment when integrated into an existing PET operation.

13 **Appendices**

13.1 Appendix 1. Innovene Rigidex HD6007S Data

Issue: April 2005

innovene

Product Technical Information

RIGIDEX® HD6007S

Rigidex® HD6007S is a medium molecular weight homopolymer grade supplied in pellet form for use in a wide range of blow moulding and extrusion applications.

Characteristics

- very easy processing
- high rigidity
- good surface finish

Applications

- lightweight containers produced at high speeds, e.g. bottles for packaging powders, milk and chemical products which have a low environmental stress cracking activity

Properties

	Value	Units	Test Method
Physical			
Density (annealed)	962	kg/m^3	ISO 1872
Melt Flow Rate (2.16 kg load)	0.6	g/10min	ISO 1133
Mechanical			
Tensile Strength at Yield (23°C Type 2 Speed D)	30.5	MPa	ISO 527
Elongation at Break (23°C Type 2 Speed D)	>300	%	ISO 527
Flexural Modulus (23°C @ 100 mm/min)	1700	MPa	ISO 178
Charpy Impact Strength	8	kJ/m^2	ISO 179
BTT stress crack resistance (F50 at 50°C, 100% concentration)	20	hours	ASTM D1693
Bottle stress crack resistance (60°C)	1	hours	Internal method

The values given are typical values measured on the product. These values should not be considered as specifications.

13.2 Appendix 2. MFR Analysis - London Metropolitan University

Melt Flow Rate Analysis

WRAP Samples 1-6/a

Report No. 2014/MI/DW/06

Client:	Nextek Ltd 221, Westbourne Park Road London W11 1EA
Attention:	Edward Kosior
Reported by:	Marion Ingle

Date of report: 3rd February 2006

1. INTRODUCTION

At the request of Mr Edward Kosior of Nextek Ltd, the Melt Flow Rate was determined for 5 polymer samples. Samples for analysis were received in January 2006.

2. ANALYSIS AND RESULTS

Analysis was carried out in accordance with BS EN ISO 1133:2000 BS2782-7:Method 720A at 190°C, 2.16Kg.

Analysis was carried out by Mr Dave Westney.

Sample Identification	MFR (g/10min)	Mean
WRAP sample 1a	0.57 0.57 0.58 0.59 0.60	0.58
WRAP sample 2a	0.57 0.57 0.57 0.59 0.60	0.58
WRAP sample 3a	0.55 0.55 0.56 0.57 0.57	0.56
WRAP sample 4a	0.59 0.60 0.60 0.60 0.61	0.60
WRAP sample 5a	0.60 0.60 0.60 0.60 0.60	0.60
WRAP sample 6a (virgin resin)	0.58 0.58 0.58 0.58 0.58	0.58

Reported by

Marion Ingle

13.3 Appendix 3. MFR Analysis - Innovene Lillo

Assessment of Wrap PCR ex Nampak

Evaluation

5 samples of Wrap PCR supplied by Nampak have been evaluated in the Works Laboratory in Lillo. The testing involved a limited laboratory physical assessment and a bottle blowing evaluation on the Uniloy 2016. For the blow moulding exercise the PCR pellet was hand blended at a level of 30%w/w with virgin HD6007S.

Results

		Wrap					HD6007S
		1b	2b	3b	4b	5b	
MFR 2.16kg	g/600s	0.6	0.6	0.6	0.63	0.64	0.6
MFR 21.6kg	g/600s	48	47	44	44	46	52
MFR ratio (21.6/2.16)		80	78	73	70	72	87
Plastic recovery 2.16kg	%	60	59	59	58	55	58
Plastic recovery 5.0kg	%	67	70	66	59	64	72
Plastic recovery 21.6kg	%	105	104	102	98	96	115
Uniloy 2.5L production							
Bottle weight	g	52.1	52.1	54.2	53.1	52.7	50.6
Base scar	mm	154	153	155	154	153	152
Gels/bottle		1	4	3	1	1	0
Specks/bottle		2	4	4	0	2	0
Odour							
During production		High	High	High	High	High	Low
48hrs after production		Low	Low	Low	Low	Low	Zero

Comments / conclusions

From the MFRs and MFR ratios the samples appear to have been made from a high purity milk bottle stream. The Plastic Recoveries are generally lower than those of HD6007S suggesting a narrower molecular weight distribution. This may be a consequence of the feed for the PCR but is more likely to be a result of its thermal history.

All samples were readily processed on the Uniloy to make good quality milk bottles with no failures due to holes etc.

The die swell of the material, as measured by bottle weight and base scar, were noticeably higher than that normally expected with virgin resin. It should however be noted that the difference would generally not necessitate re-tooling.

Although the bottles were of a high standard, on close inspection they contained a comparatively high level of gels and black specks (especially samples 2b + 3b). It should also be noted that the bottles had a very strong "soapy" odour just after production though this did fade considerably after around 48 hours.

Whilst this PCR is undoubtedly of excellent quality, it is difficult to comment on its suitability for food packaging as no overall, nor specific, migration testing was performed nor was any taint transfer assessment made.

A.W.Sorrie
Technical Service and Development.
1/2/06.

13.4 Appendix 4. Quotation for Hot Wash system (1 tonne/hr)

B&B HOT WASH LINE 1 tonne /hr for HDPE		
Pos. Nr.	**Description**	**Price EUR**
1	1 piece Conveyor with bale reservoir	
2	1 piece bale breaker	
3	1 piece sieve	
4	1 piece conveyor with balance	
5	1 piece sorting cabin	
6	1 piece conveyor into grinder + metal separation flap	
8	1 piece grinder	
8.1	1 piece electrohydraulical opening	
9	1 piece evacuation cyclone incl. Filter	
10	1 piece PE Pre Cleaner	
11	1 piece evacuation cyclone incl. Filter	
12	1 piece rotary valve	
13	1 piece air classifier ZZ 4/250	
14	1 piece evacuation cyclone incl. Filter	
15	1 piece hot wash system HWK 1000	
16	1 piece caustic regeneration unit	
17	1 piece rinsing system Type FA/Sch-60/120-25	
18	1 piece sink floatation tank TRB 4 US/32 2PW	
19	2 pieces mechanical dryer	
20	1 piece conveying system	
21	1 piece evacuation cyclone incl. Filter	
22	1 piece rotary valve	
23	1 piece multicanal-metall separation system	
24	1 piece flake sorter	
25	1 piece air classifier ZZ 4/250	
26	1 piece evacuation cyclone incl. Filter	
27	1 piece thermal drying	
28	1 piece waste water treatment	
29	Control cabinet + cable	
30	mechanical assembly by supervisor	
31	mechanical assembly turn-key	
32	electrical assembly by supervisor	
33	electrical assembly turn-key	
34	start up	
	TOTAL	

C O N F I D E N T I A L

13.5 Appendix 5. Quotation 2 for Hot Wash system (2 tonne/hr)

Sorema 2t/hr Bottle recycling plant	EU
FEEDING SECTION	C O N F I D E N T I A L
DRY CLEANING AND METAL REMOVAL	
BOTTLE SORTING	
BUFFER STORAGE FOR WASHING PLANT	
HOT PREWASHING SECTION	
MANUAL SORTING SECTION	
WET GRINDING SECTION item 22-25	
IN-LINE WATER FILTRATION	
SEPARATION, RINSING AND DRYING AREA	
BUFFER STORAGE AND SIEVING	
RINSING, DRYING, FINE AND METAL REMOVAL	
BLENDING SILO SECTION item	
Total	

13.6 Appendix 6. Quotation for Decontamination system (1 tonne/hr)

SECTION A) CRYSTALISATION DRYER €

Item 1 **1 Vacuum suction system**
Item 2 **1 All metal separator**
Item 3 **1 Double gate pneumatic slider with vacuum sluice**
Item 4 **1 High-performance vacuum system for KT £ 25 mbar**
Item 5 **1 Automatic backflush filter for dust elimination of evacuated air from vacuum KT**
Item 6 **1 Crystallisation dryer KT 1700/120**
Predryer power **frequency controlled** 132 kW
Extractor power **frequency controlled** 11 kW
Item 7 **1 Surcharge for all sealings for vacuum KT**
Option: **1 Surcharge for steel construction**
(Vacuum KT on first floor)
Is required, but could be supplied by customer.

SECTION B) VACUREMA EXTRUSTION SYSTEM

Item 8 **1 Double gate pneumatic slider with vacuum sluice**
Item 9 **1 High-performance vacuum system for reactor £ 25 mbar**
Item 10 **1 Automatic backflush filter for dust elimination of evacuated air from vacuum reactor**

Item 11 **1 VACUREMA Extrusion System 1716 TE VSV**
Reactor / pre-drier - extruder combination with vacuum operated reactor and with double vented extruder cylinder
Patented design in its execution.
Vacuum reactor / pre-drier power, **frequency controlled** 132 kW
Extruder power – **frequency controlled** 200 kW
Reinforced **vacuum-pump VH 300**
Item 12 **1 High performance vacuum system for extruder**
Item 13 **1 Heat exchanger(s) for electrical control cabinet(s)**
Item 14 **1 Input slider – electrically driven**
Item 15 **1 Melt pressure indicator**
Item 16 **1 Melt temperature indicator**

C O F I D E N T I A L

Item 17 **1 Touch screen control system**
Alternative: **1 Touch screen Control System - Office**

Option: **1 Closed circuit for operating water of**

vacuum pump incl. PH-measurement

Item 18 **1 Screen changer SW 8/170 RTF with fully automatic self cleaning system.**
Reduces screen cost and increases productivity of plant. Patented design in its execution. Hydraulically operated eightfold filter with fully automatic, pressure controlled partial backflush system

SECTION C) HOT DIE FACE GRANULATION

Item 19 **1 Hot die face cutting granulator HG 242 P**
Advanced design with knife adjustment during operation. Results in elongated pelletizer function.

Item 20 **1 Auto knife pressure adjustment – pneumatic**

Option: **1 Adjustment device for pelletizer speed**

Item 21 **1 Pellet dewatering screen GS 2000/160**
Item 22 **1 Heat exchanger external**
Item 23 **1 Water temperature control valve**
Item 24 **1 Pellets centrifugal dryer GZ 500**
Item 25 **1 Injector type pneumatic conveyor IFG 40**
Item 26 **1 Cyclone with shut off valve and support fram**
Item 27 **1 Integrated silo-throughput measuring and sacking system TMS 2500**

SUBTOTAL EXW ANSFELDEN
Supervision for installation 4 man weeks
Start-up of plant/ training/ acceptance test run through Erema technician (6 man weeks)

TOTAL PRICE, without options

C O F I D E N T I A L

13.7 Appendix 7. Financial Analysis Food Grade HDPE, Stand-Alone Plant

Cost calculation WRAP Food Grade HDPE process

a) Products and prices						£/tonne	
virgin HDPE		Apr-06				800.000	
Output of HDPE	kg/hr	1000					
average selling price						800.000	
1 EUR = 0.6922 GBP	0.6922						
b) Productivity							
annual hours						8,568	h /yr
working days UK Mo - Fr		255	d				
working days Sa/So		102	d				
hours per shift		8	h				
annual hours per shift		2,856	h / yr / Shift				
annual hours in 3 Shifts		8,568	h / yr / 3 Shift				
production hours							h /yr
availibility		90%				7,711	
efficiency		90%				**6,940.08**	h /yr
input baled milk bottles 99% HDPE						**8,300**	t / yr
nominal capacity needed for wash plant			1,076	kg/h			
yield washing plant			75.1%			6,233	t / yr
losses			(dry)				
	label, closures		1.8%		19 kg/h	137	t / yr incl. 2 % moisture
	reject bottles		11.0%		118 kg/h	904	t / yr incl. 10 % moisture
	paper pulp + other waste		4.1%		44 kg/h	490	t / yr incl. 60 % moisture
	liquid residues		5.0%		54 kg/h	415	t / yr
	coloured flakes		3.0%		32 kg/h	229	t / yr
input extrusion			**75.1%**			**6,233**	**t / yr**
extrusion capacity required			898	kg/h			
moisture from wash plant			1.0%		9 kg/h	62	t / yr
extruder production			98.0%		880 kg/h	6,109	t / yr
moisture final product			0.2%		2 kg/h	12	t / yr
HDPE fines			2.0%			125	t / yr
						150	t / yr incl. 40 % moisture
yield			**73.7%**		882 kg/h	**6,121**	t / yr

c) input purchase and other costs

input purchase		t/a (nett)		£/tonne	£/yr	£/kg Recyclate
UK-Sorted HDPE Bottles		100%	8,300	265.00	2,199,500	0.359
Feb	140-170					
sum input purchase			8,300		2,199,500	0.359
revenue clean fines extrusion			150	-200.00	- 29,920	- 0.005
revenue reject bottles			904	-100.00	- 90,387	- 0.015
revenue polyolefin			229	-250.00	- 57,146	- 0.009
waste costs						
paper, pulp, ...			490	60.00	29,402	0.005
waste water	95%		23,655	1.400	33,117	0.005
sum costs/revenues by-products					- 114,933	- 0.019
disposal cost/t input	£/t				- 13.85	

Cost calculation WRAP Food Grade HDPE process p2

d) cost dayshift personnel

	amount	£/mon	£/yr	£kg Recyclat
plant manager	1	4,845	58,145	0.009
laboratory	1	2,215	26,580	0.004
admin assistant	1	1,938	23,258	0.004
forklift driver	1	1,523	18,274	0.003
craftsman	1	2,146	25,750	0.004
sum	5		152,007	0.025

e) cost shift personnel

shift factor:	5.00	amount	£/mon	£/yr	£kg Recyclat
forkliftdriver		0	1,523	-	-
shift leader		1	3,115	186,894	0.031
sorter		1	1,384	83,064	0.014
operator		1	2,215	132,902	0.022
sum		15		402,860	0.066

f) gas and electrcity

working price	0.080	£/kWh	0.08	£/kWh	
installation price	-	£/kWh/yr			
total electricity	630	kW			
Annual consumption	5,131,204	kWh/yr			
			kW	£ / yr	£/kg Recyclate
total electricity costs variable			630	410,496	0.067
total electricity costs fix			788	-	-
gas price	0.02870	£/kWh	0.02870	£/kWh	
Gas Energy (kJ/ kg)	334.8				
annual gas consumption	3,872,564.64	kWh		£ / a	£/kg Recyclate
efficiency factor	0.5000			111,143	0.018

g) water and chemicals

water consumption washplant			3.00	m3 / t		
water consumption extrusion			-	m3 / t		
NaOH-consumption (nett)		1.00%				
NaOH-concentration		50%	62	t / a		
NaOH-consumption (gross)		2.0%				
			125	t / a		
defoamer		0.2%	v. Input Hybridprozeß			
price freshwater			1.246	£ / m³	31,024	0.005
diesel	0.0 l/h	0 l/a	1.00	€ / l	-	-
NaOH; 50%			110.06	£/t	13,721	0.002
other lubricants			1.73	£/l	14,363	0.002
defoamer			4.15	£/l	61,426	0.010
sum					120,534	0.020

h) other direct costs

					£ / yr	£/kg Recyclate
maintanance		~	5%	of invest	150,680	0.025
quality inspection			0.02	£/kg	91,813	0.015
package	7.78725 £/EA		1.00	t	47,665	0.008
transport input				£/kg	-	-
transport output				£/kg	-	-
sum					290,158	0.047

i) other indirect costs

					£ / yr	£/kg Recyclate
overhead					138,440	0.023
rent	building + land,….		22,690.32	£/Mon	272,284	0.044
insurance		~	1.0%	of invest	30,136	0.005
sum					440,860	0.072

total operative costs (excl. Capital costs)

	£ / yr	£/kg Recyclate
incl. Input HDPE purchase	4,012,624	0.656
excl. Input HDPE purchase	1,813,124	0.296

Cost calculation WRAP Food Grade HDPE process p3

invest

Hot Washing plant	~	1,053,649	£
Double Vacuum Decontamination extrude	~	1,179,323	£
utilities stand alone plant	~	780,633	£
		3,013,605	£

enviromental permit	~	55,376	£
design and layout	~	138,440	£
preliminary costs	~	173,050	£
total investment		3,380,471	£

				£ / yr	£/kg Recyclate
depreciation	duration	10.00	years	338,047	0.055

	£/kg	€/kg
sales	**0.800**	1.16
costs		
operation costs	0.296	0.43
raw material	0.359	0.52
depreciation	0.055	0.08
Total of Costs	**0.711**	**1.03**
		-
EBIT	**0.089**	**0.13**
Profit on Sales before Tax and Interest	**11%**	**11%**

13.8 Appendix 8. Financial Analysis: Food Grade HDPE, Shared Plant

Cost calculation WRAP Food Grade HDPE process- Shared Plant

a) Products and prices			£/tonne
virgin HDPE		Apr-06	800.000
Output of HDPE	**kg/hr**	1000	
average selling price			800.000
1 EUR = 0.6922 GBP	0.6922		

b) Productivity

annual hours			8,568	h /yr
working days UK Mo - Fr	255	d		
working days Sa/So	102	d		
hours per shift	8	h		
annual hours per shift	2,856	h / yr / Shift		
annual hours in 3 Shifts	8,568	h / yr / 3 Shift		
production hours				h /yr
availibility	90%		7,711	
efficiency	90%		**6,940.08**	h /yr
input baled milk bottles 99% HDPE			**8,300**	t / yr
nominal capacity needed for wash plant	1,076	kg/h		

yield washing plant		75.1%		6,233	t / yr
losses		(dry)			
	label, closures	1.8%	19 kg/h	137	t / yr incl. 2 % moisture
	reject bottles	11.0%	118 kg/h	904	t / yr incl. 10 % moisture
	paper pulp + other waste	4.1%	44 kg/h	490	t / yr incl. 60 % moisture
	liquid residues	5.0%	54 kg/h	415	t / yr
	coloured flakes	3.0%	32 kg/h	229	t / yr
input extrusion		**75.1%**		**6,233**	**t / yr**
extrusion capacity required			898 kg/h		
moisture from wash plant		1.0%	9 kg/h	62	t / yr
extruder production		98.0%	880 kg/h	6,109	t / yr
moisture final product		0.2%	2 kg/h	12	t / yr
HDPE fines		2.0%		125	t / yr
				150	t / yr incl. 40 % moisture
yield		**73.7%**	882 kg/h	**6,121**	t / yr

c) input purchase and other costs

input purchase			t/a (nett)	£/tonne		£/yr		£/kg Recyclate
UK-Sorted HDPE Bottles		100%	8,300	265.00		2,199,500		0.359
Feb	140-170							
sum input purchase			8,300			2,199,500		0.359
revenue clean fines extrusion			150	-200.00	-	29,920	-	0.005
revenue reject bottles			904	-100.00	-	90,387	-	0.015
revenue polyolefine			229	-250.00	-	57,146	-	0.009
waste costs								
paper, pulp, …			490	60.00		29,402		0.005
waste water		95%	23,655	1.400		33,117		0.005
sum costs/revenues by-products					-	114,933	-	0.019
disposal cost/t input	£/t				-	13.85		

Cost calculation WRAP Food Grade HDPE process- Shared Plant p2

d) cost dayshift personnel

	amount	£/mon	£/yr	£kg Recyclat
plant manager	0.333	4,845	19,362	0.003
laboratory	0.333	2,215	8,851	0.001
admin assistant	0.333	1,938	7,745	0.001
forklift driver	0.333	1,523	6,085	0.001
craftsman	0.333	2,146	8,575	0.001
sum	1.665		50,618	0.008

e) cost shift personnel

shift factor:	5.00	amount	£/mon	£/yr	£kg Recyclat
forkliftdriver		0	1,523	-	-
shift leader		1	3,115	186,894	0.031
sorter		1	1,384	83,064	0.014
operator		1	2,215	132,902	0.022
sum		15		402,860	0.066

f) gas and electrcity

working price	0.080	£/kWh	0.08 £/kWh		
installation price	-	£/kWh/yr			
total electricity	630	kW			
Annual consumption	5,131,204	kWh/yr			
			kW	£ / yr	£/kg Recyclate
total electricity costs variable			630	410,496	0.067
total electricity costs fix			788	-	-
gas price	0.02870	£/kWh	0.02870	£/kWh	
Gas Energy (kJ/kg)	334.8				
gas consumption	3,872,564.64	kWh		£ / a	£/kg Recyclate
Efficiency Factor	0.5000			111,143	0.018

g) water and chemicals

water consumption washplant		3.00	m3 / t		
water consumption extrusion		-	m3 / t		
NaOH-consumption (nett)	1.00%				
NaOH-concentration	50%	62	t / a		
NaOH-consumption (gross)	2.0%				
		125	t / a		
defoamer	0.2% v. Input Hybridprozeß				
price freshwater		1.246	£ / m³	31,024	0.005
				-	-
NaOH; 50%		110.06	£/t	13,721	0.002
other lubricants		1.73	£/l	14,363	0.002
defoamer		4.15	£/l	61,426	0.010
sum				120,534	0.020

h) other direct costs

					£ / yr	£/kg Recyclate
maintanance		~	5%	of invest	122,798	0.020
quality inspection			0.02	£/kg	91,813	0.015
package	7.78725 £/EA		1.00	t	47,665	0.008
transport input				£/kg	-	-
transport output				£/kg	-	-
sum					262,276	0.043

i) other indirect costs

					£ / yr	£/kg Recyclate
overhead					46,147	0.008
rent	building + land,….		22,690.32	£/Mon	90,761	0.015
insurance		~	1.0%	of invest	24,560	0.004
sum					161,468	0.026

total operative costs (excl. Capital costs)

	£ / yr	£/kg Recyclate
incl. Input HDPE purchase	3,603,961	0.589
excl. Input HDPE purchase	1,404,461	0.229

Cost calculation WRAP Food Grade HDPE process- Shared Plant p3

invest			
Hot Washing plant	~	1,053,649	£
Double Vacuum Decontamination extrude	~	1,179,323	£
utilities shared plant	~	222,992	£
		2,455,964	£
enviromental permit	~	18,459	£
design and layout	~	46,147	£
preliminary costs	~	57,683	£
total investment		2,578,253	£

				£ / yr	£/kg Recyclate
depreciation	duration	10.00	years	257,825	0.042

	£/kg	€/kg
sales	**0.800**	1.16
costs		
operation costs	0.229	0.33
raw material	0.359	0.52
depreciation	0.042	0.06
Total of Costs	**0.631**	**0.91**
		-
EBIT	**0.169**	**0.24**
Profit in Sales before Tax and Interest	**21%**	**21%**