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.

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Wash plant</th>
<th>Vacurema Line</th>
<th>ANCILLARIES</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>£1,053,649</td>
<td>£1,179,323</td>
<td>£780,633</td>
<td>£3,013,605</td>
</tr>
<tr>
<td>Floor Space m²</td>
<td>600</td>
<td>100</td>
<td>150</td>
<td>850</td>
</tr>
<tr>
<td>Water m³/hr</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Power kW</td>
<td>313</td>
<td>475</td>
<td>75</td>
<td>863</td>
</tr>
<tr>
<td>Output kg/hr</td>
<td>1000</td>
<td>1400-1000</td>
<td>NA</td>
<td>1000</td>
</tr>
<tr>
<td>Operators and staff</td>
<td>3x5 + 5 = 20</td>
<td>1</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

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%.

### Summary of capital costs and utilities for a shared plant.

<table>
<thead>
<tr>
<th>Summary</th>
<th>Wash plant</th>
<th>Vacurema Line</th>
<th>ANCILLARIES</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>£1,053,649</td>
<td>£1,179,323</td>
<td>£222,992</td>
<td>£2,455,964</td>
</tr>
<tr>
<td>Floor Space m²</td>
<td>600</td>
<td>100</td>
<td>50</td>
<td>750</td>
</tr>
<tr>
<td>Water m³/hr</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Power kW</td>
<td>313</td>
<td>475</td>
<td>75</td>
<td>863</td>
</tr>
<tr>
<td>Output kg/hr</td>
<td>1000</td>
<td>1400-1000</td>
<td>NA</td>
<td>1000</td>
</tr>
<tr>
<td>Operators and staff</td>
<td>3x5 + 1.65 = 16.65</td>
<td>1</td>
<td>0</td>
<td>16.65</td>
</tr>
</tbody>
</table>
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:

<table>
<thead>
<tr>
<th>Cost Description</th>
<th>Cost per kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct production cost</td>
<td>€0.41/kg</td>
</tr>
<tr>
<td>Overheads, personnel and infrastructure</td>
<td>€0.20/kg</td>
</tr>
<tr>
<td>Total</td>
<td>€0.61/kg</td>
</tr>
</tbody>
</table>
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 to 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

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

Table 1. Summary of MFR test results (For full results, refer to Appendices 2 and 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)](image)
The test results are summarised below in Table 2.

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

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.

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

Table 3 Major Equipment items for HDPE food grade plant
### Ancillaries

<table>
<thead>
<tr>
<th>Ancillaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical assembly and wiring</td>
</tr>
<tr>
<td>Low and High voltage Supply</td>
</tr>
<tr>
<td>Compressor</td>
</tr>
<tr>
<td>Laboratory equipment</td>
</tr>
<tr>
<td>Steam generator</td>
</tr>
</tbody>
</table>

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

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

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

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

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

| Plant Capital                     | £3,013,605                | £2,455,964                 |
| HDPE output t/yr                  | 6,121                     | 6,121                      |
| **Sales (equal to Virgin) £/t**   |                           |                            |
| Gross sales £/t                   | £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 i.e. 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 feedstock 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.
Effect of HDPE Sales Pricing on Plant Profit (EBIT %) at 25% Incoming Material Loss (Stand Alone HDPE Plant)

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)
Effect of Incoming Bale Purity (Material Loss Rate) on Plant Profit

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.

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

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

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

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.
Appendices

13.1 Appendix 1. Innovene Rigidex HD6007S Data

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

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
<th>Units</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (annealed)</td>
<td>962</td>
<td>kg/m³</td>
<td>ISO 1872</td>
</tr>
<tr>
<td>Melt Flow Rate (2.16 kg load)</td>
<td>0.6</td>
<td>g/10min</td>
<td>ISO 1133</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
<th>Units</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength at Yield (23°C Type 2 Speed D)</td>
<td>30.5</td>
<td>MPa</td>
<td>ISO 527</td>
</tr>
<tr>
<td>Elongation at Break (23°C Type 2 Speed D)</td>
<td>&gt;300</td>
<td>%</td>
<td>ISO 527</td>
</tr>
<tr>
<td>Flexural Modulus (23°C @ 100 mm/min)</td>
<td>1700</td>
<td>MPa</td>
<td>ISO 178</td>
</tr>
<tr>
<td>Charpy Impact Strength</td>
<td>8</td>
<td>kJ/m²</td>
<td>ISO 179</td>
</tr>
<tr>
<td>BTT stress crack resistance (F50 at 50°C, 100% concentration)</td>
<td>20</td>
<td>hours</td>
<td>ASTM D1693</td>
</tr>
<tr>
<td>Bottle stress crack resistance (60°C)</td>
<td>1</td>
<td>hours</td>
<td>Internal method</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>MFR (g/10min)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRAP sample 1a</td>
<td>0.57, 0.57, 0.58, 0.59, 0.60</td>
<td>0.58</td>
</tr>
<tr>
<td>WRAP sample 2a</td>
<td>0.57, 0.57, 0.57, 0.59, 0.60</td>
<td>0.58</td>
</tr>
<tr>
<td>WRAP sample 3a</td>
<td>0.55, 0.55, 0.56, 0.57, 0.57</td>
<td>0.56</td>
</tr>
<tr>
<td>WRAP sample 4a</td>
<td>0.59, 0.60, 0.60, 0.60, 0.61</td>
<td>0.60</td>
</tr>
<tr>
<td>WRAP sample 5a</td>
<td>0.60, 0.60, 0.60, 0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>WRAP sample 6a (virgin resin)</td>
<td>0.58, 0.58, 0.58</td>
<td>0.58</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Wrapp</th>
<th>HD6007S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1b</td>
<td>2b</td>
</tr>
<tr>
<td>MFR 2.19kg</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>MFR 2.1kg</td>
<td>48</td>
<td>47</td>
</tr>
<tr>
<td>MFR ratio (2.1/2.16)</td>
<td>80</td>
<td>78</td>
</tr>
<tr>
<td>Plastic recovery 2.19kg</td>
<td>%</td>
<td>69</td>
</tr>
<tr>
<td>Plastic recovery 2.1kg</td>
<td>%</td>
<td>67</td>
</tr>
<tr>
<td>Plastic recovery 2.1kg</td>
<td>%</td>
<td>165</td>
</tr>
<tr>
<td>Uniloy 2.8L production</td>
<td>g/mm</td>
<td>52.1</td>
</tr>
<tr>
<td>Bottle weight</td>
<td></td>
<td>154</td>
</tr>
<tr>
<td>Guts/bottle</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Spec/500g</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Colour</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>During production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>abortions after production</td>
<td></td>
<td>Low</td>
</tr>
</tbody>
</table>

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)

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

<table>
<thead>
<tr>
<th>Sorema 2t/hr Bottle recycling plant</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEEDING SECTION</td>
<td></td>
</tr>
<tr>
<td>DRY CLEANING AND METAL REMOVAL</td>
<td></td>
</tr>
<tr>
<td>BOTTLE SORTING</td>
<td></td>
</tr>
<tr>
<td>BUFFER STORAGE FOR WASHING PLANT</td>
<td></td>
</tr>
<tr>
<td>HOT PREWASHING SECTION</td>
<td></td>
</tr>
<tr>
<td>MANUAL SORTING SECTION</td>
<td></td>
</tr>
<tr>
<td>WET GRINDING SECTION item 22-25</td>
<td></td>
</tr>
<tr>
<td>IN-LINE WATER FILTRATION</td>
<td></td>
</tr>
<tr>
<td>SEPARATION, RINSING AND DRYING AREA</td>
<td></td>
</tr>
<tr>
<td>BUFFER STORAGE AND SIEVING</td>
<td></td>
</tr>
<tr>
<td>RINSING, DRYING, FINE AND METAL REMOVAL</td>
<td></td>
</tr>
<tr>
<td>BLENDING SILO SECTION item</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
</tbody>
</table>
### SECTION A) CRYSTALISATION DRYER

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vacuum suction system</td>
<td>€31.845</td>
</tr>
<tr>
<td>2</td>
<td>All metal separator</td>
<td>€11.286</td>
</tr>
<tr>
<td>3</td>
<td>Double gate pneumatic slider with vacuum sluice</td>
<td>€40.453</td>
</tr>
<tr>
<td>4</td>
<td>High-performance vacuum system for KT £ 25 mbar</td>
<td>€51.241</td>
</tr>
<tr>
<td>5</td>
<td>Automatic backflush filter for dust elimination of evacuated air from vacuum KT</td>
<td>€31.174</td>
</tr>
<tr>
<td>6</td>
<td>Crystallisation dryer KT 1700/120</td>
<td>€237.645</td>
</tr>
</tbody>
</table>

Predryer power: frequency controlled 132 kW
Extractor power: frequency controlled 11 kW

### SECTION B) VACUREMA EXTRUSION SYSTEM

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Double gate pneumatic slider with vacuum sluice</td>
<td>€40.453</td>
</tr>
<tr>
<td>9</td>
<td>High-performance vacuum system for reactor £ 25 mbar</td>
<td>€51.241</td>
</tr>
<tr>
<td>10</td>
<td>Automatic backflush filter for dust elimination of evacuated air from vacuum reactor</td>
<td>€31.174</td>
</tr>
</tbody>
</table>

Item 11 | 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

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>High performance vacuum system for extruder</td>
<td>€27.712</td>
</tr>
<tr>
<td>13</td>
<td>Heat exchanger(s) for electrical control cabinet(s)</td>
<td>€5.072</td>
</tr>
<tr>
<td>14</td>
<td>Input slider – electrically driven</td>
<td>€11.191</td>
</tr>
<tr>
<td>15</td>
<td>Melt pressure indicator</td>
<td>€3.379</td>
</tr>
<tr>
<td>16</td>
<td>Melt temperature indicator</td>
<td>€2.016</td>
</tr>
</tbody>
</table>
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 frame  
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
13.7 Appendix 7. Financial Analysis Food Grade HDPE, Stand-Alone Plant

---

**Cost calculation WRAP Food Grade HDPE process**

<table>
<thead>
<tr>
<th>a) Products and prices</th>
<th>£/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>virgin HDPE Apr-06</td>
<td>800.000</td>
</tr>
<tr>
<td>Output of HDPE kg/hr</td>
<td>1000</td>
</tr>
<tr>
<td>average selling price</td>
<td>800.000</td>
</tr>
<tr>
<td>exchange rate</td>
<td>0.6922</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b) Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>annual hours</td>
</tr>
<tr>
<td>working days UK Mo - Fr</td>
</tr>
<tr>
<td>working days Sa/So</td>
</tr>
<tr>
<td>hours per shift</td>
</tr>
<tr>
<td>annual hours per shift</td>
</tr>
<tr>
<td>annual hours in 3 Shifts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>availability</td>
</tr>
<tr>
<td>efficiency</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c) input purchase and other costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK-Sorted HDPE Bottles 100%</td>
</tr>
<tr>
<td>Feb 140-170</td>
</tr>
<tr>
<td>sum input purchase</td>
</tr>
<tr>
<td>sum costs</td>
</tr>
<tr>
<td>revenue clean fines extrusion</td>
</tr>
<tr>
<td>revenue reject bottles</td>
</tr>
<tr>
<td>revenue polyolefin</td>
</tr>
<tr>
<td>waste costs</td>
</tr>
<tr>
<td>waste water 9%</td>
</tr>
<tr>
<td>sum costs/revenues by-products</td>
</tr>
<tr>
<td>disposal cost/t input £/t</td>
</tr>
</tbody>
</table>

---
### Cost calculation WRAP Food Grade HDPE process p2

#### d) cost dayshift personnel

<table>
<thead>
<tr>
<th>Position</th>
<th>Amount</th>
<th>£/Mon</th>
<th>£/Yr</th>
<th>£/kg Recylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Manager</td>
<td>1</td>
<td>4,845</td>
<td>58,145</td>
<td>0.009</td>
</tr>
<tr>
<td>Laboratory</td>
<td>1</td>
<td>2,215</td>
<td>26,580</td>
<td>0.004</td>
</tr>
<tr>
<td>Admin Assistant</td>
<td>1</td>
<td>1,938</td>
<td>23,258</td>
<td>0.004</td>
</tr>
<tr>
<td>Forklift Driver</td>
<td>1</td>
<td>1,523</td>
<td>18,274</td>
<td>0.003</td>
</tr>
<tr>
<td>Craftsman</td>
<td>1</td>
<td>2,146</td>
<td>25,750</td>
<td>0.004</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>5</strong></td>
<td><strong>152,007</strong></td>
<td><strong>0.025</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### e) cost shift personnel

<table>
<thead>
<tr>
<th>Position</th>
<th>Amount</th>
<th>£/Mon</th>
<th>£/Yr</th>
<th>£/kg Recylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forklift Driver</td>
<td>0</td>
<td>1,523</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Shift Leader</td>
<td>1</td>
<td>3,115</td>
<td>186,894</td>
<td>0.031</td>
</tr>
<tr>
<td>Sorter</td>
<td>1</td>
<td>1,384</td>
<td>83,064</td>
<td>0.014</td>
</tr>
<tr>
<td>Operator</td>
<td>1</td>
<td>2,215</td>
<td>132,902</td>
<td>0.022</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>15</strong></td>
<td><strong>402,860</strong></td>
<td><strong>0.066</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### f) gas and electricity

<table>
<thead>
<tr>
<th>Description</th>
<th>Rate (£/kWh)</th>
<th>£/kWh/yr</th>
<th>£/a</th>
<th>£/kg Recylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working price</td>
<td>0.080</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Installation price</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total electricity</td>
<td>630 kW</td>
<td>0.08 £/kWh</td>
<td>0.087</td>
<td>0.067</td>
</tr>
<tr>
<td>Annual consumption</td>
<td>3,872,564.64 kWh</td>
<td>0.02870 £/kWh</td>
<td>0.02870</td>
<td>0.018</td>
</tr>
</tbody>
</table>

#### g) water and chemicals

<table>
<thead>
<tr>
<th>Description</th>
<th>Rate (£/m³)</th>
<th>£/t</th>
<th>£/kg Recylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water consumption washplant</td>
<td>3.00</td>
<td>31,024</td>
<td>0.005</td>
</tr>
<tr>
<td>Water consumption extrusion</td>
<td>-</td>
<td>125</td>
<td>0.010</td>
</tr>
<tr>
<td>NaOH-consumption (net)</td>
<td>1.00%</td>
<td>110.06</td>
<td>0.002</td>
</tr>
<tr>
<td>NaOH-concentration</td>
<td>50%</td>
<td>14,363</td>
<td>0.002</td>
</tr>
<tr>
<td>NaOH-consumption (gross)</td>
<td>2.0%</td>
<td>61,426</td>
<td>0.010</td>
</tr>
<tr>
<td>Defoamer</td>
<td>0.2% v. Input Hybridprozeß</td>
<td>0.002</td>
<td>0.002</td>
</tr>
</tbody>
</table>

#### h) other direct costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Rate (£/y)</th>
<th>£ / kg Recylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>~ 5% of invest</td>
<td>150,680</td>
</tr>
<tr>
<td>Quality inspection</td>
<td>0.02 £/kg</td>
<td>91,813</td>
</tr>
<tr>
<td>Package</td>
<td>7.78725 £/EA</td>
<td>47,965</td>
</tr>
<tr>
<td>Transport input</td>
<td>£/kg</td>
<td>-</td>
</tr>
<tr>
<td>Transport output</td>
<td>£/kg</td>
<td>-</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>290,158</td>
<td>0.047</td>
</tr>
</tbody>
</table>

#### i) other indirect costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Rate (£/y)</th>
<th>£ / kg Recylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>~ 1% of Invest</td>
<td>440,880</td>
</tr>
<tr>
<td>Rent</td>
<td>22,690.32 £/Mon</td>
<td>138,440</td>
</tr>
<tr>
<td>Insurance</td>
<td>~ 1.9% of Invest</td>
<td>30,136</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>480,026</td>
<td>0.047</td>
</tr>
</tbody>
</table>

#### total operative costs (excl. Capital costs)

<table>
<thead>
<tr>
<th>Description</th>
<th>Rate (£/y)</th>
<th>£ / kg Recylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost</td>
<td>4,012,524</td>
<td>0.656</td>
</tr>
<tr>
<td>Excl. Input HDPE purchase</td>
<td>1,813,124</td>
<td>0.296</td>
</tr>
</tbody>
</table>
Invest:
- Hot Washing plant: £1,053,649
- Double Vacuum Decontamination extrude: £1,179,323
- Utilities stand alone plant: £780,633
- Environmental permit: £55,376
- Design and layout: £138,440
- Preliminary costs: £173,050
- Total investment: £3,380,471

<table>
<thead>
<tr>
<th>£/yr</th>
<th>£/kg Recyclate</th>
</tr>
</thead>
<tbody>
<tr>
<td>338,047</td>
<td>0.055</td>
</tr>
</tbody>
</table>

Depreciation duration: 10.00 years

Sales:
- £/kg: 0.800

Costs:
- Operation costs: £0.296
- Raw material: £0.359
- Depreciation: £0.055
- Total of Costs: £0.711

EBIT:
- £/kg: 0.089

Profit on Sales before Tax and Interest:
- 11%
### Cost calculation WRAP Food Grade HDPE process- Shared Plant

#### a) Products and prices

<table>
<thead>
<tr>
<th>Products and prices</th>
<th>£/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>virgin HDPE Apr-06</td>
<td>800.000</td>
</tr>
<tr>
<td>Output of HDPE kg/hr</td>
<td>1000</td>
</tr>
<tr>
<td>average selling price</td>
<td>800.000</td>
</tr>
<tr>
<td>£ EUR = 0.6922 cap</td>
<td>0.6922</td>
</tr>
</tbody>
</table>

#### b) Productivity

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>h / yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>annual hours</td>
<td>8,568</td>
</tr>
<tr>
<td>working days UK Mo - Fr</td>
<td>255 d</td>
</tr>
<tr>
<td>working days Sa/Su</td>
<td>102 d</td>
</tr>
<tr>
<td>hours per shift</td>
<td>8 h</td>
</tr>
<tr>
<td>annual hours per shift</td>
<td>2,856 h / yr / Shift</td>
</tr>
<tr>
<td>annual hours in 3 Shifts</td>
<td>8,568 h / yr / 3 Shift</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Productivity</th>
<th>h / yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>availability</td>
<td>90%</td>
</tr>
<tr>
<td>efficiency</td>
<td>90%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculation</th>
<th>£/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>input baled milk bottles 99% HDPE</td>
<td>8,300 t / yr</td>
</tr>
</tbody>
</table>

#### nominal capacity needed for wash plant

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>kg/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>yield washing plant</td>
<td>75.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Losses</th>
<th>(dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>label, closures</td>
<td>1.8%</td>
</tr>
<tr>
<td>reject bottles</td>
<td>11.0%</td>
</tr>
<tr>
<td>paper pulp + other waste</td>
<td>4.1%</td>
</tr>
<tr>
<td>liquid residues</td>
<td>5.0%</td>
</tr>
<tr>
<td>coloured flakes</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

#### input extrusion

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>t / yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>extrusion capacity required</td>
<td>688 kg/h</td>
</tr>
<tr>
<td>moisture from wash plant</td>
<td>1.0%</td>
</tr>
<tr>
<td>extruder production</td>
<td>98.0%</td>
</tr>
<tr>
<td>moisture final product</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HDPE fines</th>
<th>2.0%</th>
<th>125 t / yr incl. 40 % moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>yield</td>
<td>73.7%</td>
<td>6,121 t / yr</td>
</tr>
</tbody>
</table>

#### c) input purchase and other costs

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>t/a (net)</th>
<th>£/tonne</th>
<th>£/yr</th>
<th>£/kg Recyclate</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK-Sorted HDPE Bottles</td>
<td>100%</td>
<td>8,300</td>
<td>265.00</td>
<td>2,199,500</td>
</tr>
<tr>
<td>Feb 140-170</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>£/tonne</th>
<th>£/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>revenue clean fines extrusion</td>
<td>-200.00</td>
<td>-29,920</td>
</tr>
<tr>
<td>revenue reject bottles</td>
<td>-100.00</td>
<td>-90,387</td>
</tr>
<tr>
<td>revenue polyolefine</td>
<td>-250.00</td>
<td>-57,146</td>
</tr>
<tr>
<td>waste costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper, pulp, …</td>
<td>60.00</td>
<td>29,402</td>
</tr>
<tr>
<td>waste water</td>
<td>1.40</td>
<td>23,655</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>£/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>sum costs/revenues by-products</td>
<td>-114,933</td>
</tr>
<tr>
<td>disposal cost/t input</td>
<td>-13.85</td>
</tr>
</tbody>
</table>
d) cost dayshift personnel

<table>
<thead>
<tr>
<th></th>
<th>amount</th>
<th>£/mon</th>
<th>£/yr</th>
<th>£/kg Recyclate</th>
</tr>
</thead>
<tbody>
<tr>
<td>plant manager</td>
<td>0.333</td>
<td>4,845</td>
<td>19,362</td>
<td>0.003</td>
</tr>
<tr>
<td>laboratory</td>
<td>0.333</td>
<td>2,215</td>
<td>8,851</td>
<td>0.001</td>
</tr>
<tr>
<td>admin assistant</td>
<td>0.333</td>
<td>1,938</td>
<td>7,745</td>
<td>0.001</td>
</tr>
<tr>
<td>forklift driver</td>
<td>0.333</td>
<td>1,523</td>
<td>6,085</td>
<td>0.001</td>
</tr>
<tr>
<td>craftsman</td>
<td>0.333</td>
<td>2,146</td>
<td>8,575</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>sum</strong></td>
<td>1.665</td>
<td>50,618</td>
<td>0.008</td>
<td></td>
</tr>
</tbody>
</table>

e) cost shift personnel

<table>
<thead>
<tr>
<th></th>
<th>amount</th>
<th>£/mon</th>
<th>£/yr</th>
<th>£/kg Recyclate</th>
</tr>
</thead>
<tbody>
<tr>
<td>forklift driver</td>
<td>0</td>
<td>1,523</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>shift leader</td>
<td>1</td>
<td>3,115</td>
<td>186,694</td>
<td>0.031</td>
</tr>
<tr>
<td>sorter</td>
<td>1</td>
<td>1,384</td>
<td>83,064</td>
<td>0.014</td>
</tr>
<tr>
<td>operator</td>
<td>1</td>
<td>2,215</td>
<td>132,902</td>
<td>0.022</td>
</tr>
<tr>
<td><strong>sum</strong></td>
<td>15</td>
<td>402,860</td>
<td>0.066</td>
<td></td>
</tr>
</tbody>
</table>

f) gas and electricity

<table>
<thead>
<tr>
<th></th>
<th>£/kWh</th>
<th>£/kWh/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>working price</strong></td>
<td>0.080</td>
<td></td>
</tr>
<tr>
<td><strong>installation price</strong></td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

| total electricity     | 630   | kW       |
| Annual consumption    | 5,131,204 | kWh/yr |

<table>
<thead>
<tr>
<th></th>
<th>£ / a</th>
<th>£/kg Recyclate</th>
</tr>
</thead>
<tbody>
<tr>
<td>total electricity costs variable</td>
<td>630</td>
<td>410,496</td>
</tr>
</tbody>
</table>

| gas price             | 0.02870| £/kWh |
| gas consumption       | 3,872,564.64 | kWh/yr |
| Efficiency Factor     | 0.5000 |        |

<table>
<thead>
<tr>
<th>g) water and chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>water consumption washplant</td>
</tr>
<tr>
<td>water consumption extrusion</td>
</tr>
<tr>
<td>NaOH-consumption (nett)</td>
</tr>
<tr>
<td>NaOH-concentration</td>
</tr>
<tr>
<td>NaOH-consumption (gross)</td>
</tr>
<tr>
<td><strong>defoamer</strong></td>
</tr>
<tr>
<td>price freshwater</td>
</tr>
<tr>
<td>NaOH: 50%</td>
</tr>
<tr>
<td>other lubricants</td>
</tr>
<tr>
<td>defoamer</td>
</tr>
<tr>
<td><strong>sum</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>h) other direct costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>maintenance</td>
</tr>
<tr>
<td>quality inspection</td>
</tr>
<tr>
<td>package</td>
</tr>
<tr>
<td>transport input</td>
</tr>
<tr>
<td>transport output</td>
</tr>
<tr>
<td><strong>sum</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>i) other indirect costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>overhead</td>
</tr>
<tr>
<td>rent</td>
</tr>
<tr>
<td>insurance</td>
</tr>
<tr>
<td><strong>sum</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>total operative costs</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>incl. Input HDPE purchase</strong></td>
</tr>
<tr>
<td><strong>excl. Input HDPE purchase</strong></td>
</tr>
</tbody>
</table>
### Cost calculation WRAP Food Grade HDPE process- Shared Plant p3

<table>
<thead>
<tr>
<th>Investment</th>
<th>Amount</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Washing plant</td>
<td>~ 1,053,649</td>
<td>£</td>
</tr>
<tr>
<td>Double Vacuum Decontamination extrude</td>
<td>~ 1,179,323</td>
<td>£</td>
</tr>
<tr>
<td>Utilities shared plant</td>
<td>~ 222,992</td>
<td>£</td>
</tr>
<tr>
<td>Environmental permit</td>
<td>~ 18,459</td>
<td>£</td>
</tr>
<tr>
<td>Design and layout</td>
<td>~ 46,147</td>
<td>£</td>
</tr>
<tr>
<td>Preliminary costs</td>
<td>~ 57,683</td>
<td>£</td>
</tr>
<tr>
<td>Total investment</td>
<td>~ 2,578,253</td>
<td>£</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depreciation</th>
<th>Duration</th>
<th>£/yr</th>
<th>£/kg Recyclate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.00</td>
<td>257,825</td>
<td>0.042</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sales</th>
<th>£/kg</th>
<th>€/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.800</td>
<td>1.16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs</th>
<th>£/kg</th>
<th>€/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation costs</td>
<td>0.229</td>
<td>0.33</td>
</tr>
<tr>
<td>Raw material</td>
<td>0.359</td>
<td>0.52</td>
</tr>
<tr>
<td>Depreciation</td>
<td>0.042</td>
<td>0.06</td>
</tr>
<tr>
<td>Total of Costs</td>
<td>0.631</td>
<td>0.91</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EBIT</th>
<th>£/kg</th>
<th>€/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.169</td>
<td>0.24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Profit in Sales before Tax and Interest</th>
<th>Percentage</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21%</td>
<td>21%</td>
</tr>
</tbody>
</table>

WRAP Food Grade HDPE Recycling Process: Commercial Feasibility Study