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Final Report

Recovery of laminated packaging from black bag waste

Feasibility study into the separation and recycling of laminated packaging from residual local authority-collected waste

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URS

Front cover photography: Laminated packaging from residual household waste

Executive summary

Laminated packaging is widely used as a packaging material for a range of food and non-food products. There are a range of different laminated materials in use, and this project uses the term "laminated packaging" to refer to plastic/aluminium laminates of the type commonly used for applications such as pet food and drinks pouches, toothpaste tubes and cosmetics.

WRAP has published a trial of the Enval pyrolysis process for recycling high value laminated packaging. The current project considers feedstock availability from residual "black bag" waste (residual Local Authority-collected waste (LACW)) and looks in more detail at the practical feasibility of including the Enval process into the waste recycling infrastructure.

Five operational MBTs were visited, all of which accepted residual LACW in various parts of the country. In all cases, the majority of laminated packaging was reported to be sorted into the non-ferrous metal stream. Operators expressed potential interest in separating laminated packaging from non-ferrous material, but only if it was financially viable.

The quantities of laminated packaging in the residual LACW were estimated. Data from Alupro (the Aluminium Packaging Recycling Organisation) suggests that approximately 41,000 tpa of laminated packaging may enter the LACW waste stream per year. The proportion of laminated packaging in the residual LACW stream is estimated to be around 0.17% by mass.

The following technologies have the potential to separate laminated packaging from various feedstocks:
- hand picking;
- eddy current separation;
- optical sorting; and
- air separation.

There are no insurmountable technical obstacles to separating laminated packaging from residual LACW using one or more of the separation technologies identified. The technical feasibility will depend on site-specific factors such as available space, existing plant design and layout. The lowest cost option is likely to be air separation, although the output will likely be lower quality than other more costly options.

The net revenue from recycling laminated packaging is subject to considerable uncertainty, but currently appears to be lower than the cost of separation. This suggests that, at the present time, separating laminated packaging from residual LACW is unlikely to be financially viable considered as a stand-alone activity; and the financial driver for separation is more likely to be to enhance the value of the non-ferrous stream by removing contamination.

A number of uncertainties were identified which may affect the overall feasibility of a separation and recycling scheme. The status of the pyrolysis facility with regard to the Waste Incineration Directive requires clarification; and there is uncertainty regarding the revenue which could be obtained from sale or use of the hydrocarbons produced by the process, both pyrolysis oil and gas.

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Glossary

2D	2 Dimensional Material
3D	3 Dimensional Material
CLO	Compost-Like Output
ECS	Eddy Current Separator
RDF	Refuse Derived Fuel
LACW	Local Authority Collected Waste
MBT	Mechanical Biological Treatment
MRF	Material Recovery Facility
tpa	Tonnes per annum
UBC	Used Beverage Cans

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1.0 Introduction

1.1 Background

Laminated packaging is widely used as a packaging material for a range of products. There are a range of different laminated materials in use, and this study uses the term "laminated packaging" to refer to plastic/aluminium laminates of the type commonly used for applications such as pet food and drinks pouches, toothpaste tubes and cosmetics. Other laminated materials (including paper/aluminium laminates such as aseptic beverage cartons, and metallised plastic film such as crisp packets) were specifically excluded from consideration under the scope of this project.

Laminated packaging is not currently recycled in the UK. A UK company, Enval Limited, has developed a process for recycling laminated packing using microwave pyrolysis. This process generates aluminium scrap and hydrocarbons in the form of both condensable (liquid) and non-condensable (gaseous) products.

WRAP has previously commissioned a project to undertake a trial of the Enval process (available on the WRAP website, search for laminated packaging) and assess its viability, which included technical assessment of the properties of laminated packaging and the recycling process. The current project considers feedstock availability from residual "black bag" waste and looks in more detail at the practical feasibility of including the Enval process into the waste recycling infrastructure.

URS was appointed by WRAP to study the potential options for capturing and recycling laminated packaging from residual ("black bag") local authority collected waste (LACW). The laminated packaging that would be the target material for the pyrolysis process is currently not targeted by kerbside collection schemes, and hence at present is likely to be found in residual LACW. Whilst a proportion of residual LACW currently goes to landfill disposal, increasing quantities are processed to remove recyclates and recover value from the waste. This takes place either in a Mechanical Biological Treatment (MBT) or a residual waste Material Recovery Facility (MRF), not to be confused with a "dry" MRF which treats source-separated recyclables. A large number of local authorities have invested or are investing in MBTs or residual waste MRFs, to the extent that a high proportion of residual waste is expected to be subject to some form of mechanical treatment.

1.2 Objectives

The objectives of this project are to:

- identify the streams into which laminated packaging is sorted in existing MBTs and wet MRFs;
- estimate the quantity of laminated packaging in the incoming waste and various output streams;
- identify options for the separation of laminated packaging for subsequent recycling;
- consider the economic and technical feasibility of separating and recycling laminated packaging; and
- estimating the potential viability of such schemes.

1.3 Methodology

Work was carried out between January and March 2012 and consisted of the following tasks:

- site visits to a number of operational MBTs and interviews with site managers in order to understand how laminated packaging is handled within each facility;
- discussions with suppliers of waste sorting technology and other stakeholders such as aluminium recyclers to understand the technical and operational constraints for separation of laminated packaging;
- review of available sorting technologies and techniques, to identify potentially suitable options for separation;
- assessment of the likely capital and operational costs for implementing the preferred options; and
- consideration of the likely overall viability of a system comprising separation and recycling of laminated packaging.

Sampling and compositional analysis of waste streams does not form part of the scope of this project.

2.0 Management of laminated packaging in MBT facilities

2.1 Introduction

MBTs are increasingly becoming a key part of the UK's waste management infrastructure. Many local authorities have invested or are investing in such facilities to treat their residual waste, i.e. waste other than kerbside-collected recyclables.

An MBT comprises:
- a mechanical treatment process to remove recyclates from the waste stream, using a range of sorting technologies such as screens, magnets, eddy current separators and optical sorters; and
- a biological treatment process which stabilises the organic fraction of the waste either aerobically (composting/biodrying) or anaerobically (digestion) to produce a solid product (digestate, refuse-derived fuel (RDF) or compost-like output (CLO)) and, in the case of anaerobic digestion, a biogas for power generation.

These two elements can be carried out in either order, although the most common configuration is for front-end mechanical treatment with subsequent biological treatment of the some or all of the residuals from this process. There are alternative configurations in which the incoming waste is biologically treated and the resultant stabilised waste is then mechanically treated.

2.2 Site visits

Site visits were carried out during February 2012 to the following MBT facilities:
- Byker, Newcastle (operated by Sita)
- Canford, Dorset (operated by New Earth)
- Cotesbach, Leicestershire (operated by New Earth)
- Longley Lane, Manchester (operated by Viridor)
- Waterbeach, Cambridgeshire (operated by AmeyCespa)

The operations manager at each site was interviewed, and URS staff visited the mechanical processing hall in order to visually identify how laminated packaging is managed within the mechanical treatment process. The various material output streams were also visually inspected.

Each site operates the same general process: front-end mechanical treatment which removes various materials for recycling, followed by biological treatment (on-site, expect in the case of Byker) of some or all of the residual material after mechanical processing. Appendix A includes descriptions of the specific processes at each facility and the throughputs handled.

Each facility includes at least one eddy current separator (ECS) within the mechanical treatment process to remove non-ferrous metals. This metal (predominantly consisting of aluminium) is of high value and has a consistent demand from specialist metal recyclers. Even during the low points of recyclate demand in 2008 when markets dried up for many materials, metal recyclers were still willing to buy most grades of non-ferrous metals.

The results of the site visits are summarised in Appendix A.

A consistent finding for all facilities was that ECSs are effective at separating a significant proportion of laminated packaging from the waste stream, alongside other non-ferrous materials such as used beverage cans (UBC) and aluminium foil. The non-ferrous stream includes varying amounts of other non-metallic contaminants including entrained material (such as plastic bags wrapped around aluminium cans). Operators generally expressed the views that the primary destination of laminated packaging entering the facility was the non-ferrous metals stream. The actual proportion of laminated packaging present in the non-ferrous stream could not be accurately established. The destination of the remaining laminated packaging was uncertain, but visual observations and discussion with operators indicated that it was likely to end up mainly in the residual material (RDF or CLO), with small quantities in other outputs such as plastic film (for those facilities which separate this material).

The site at Longley Lane also includes a dry MRF whose outputs include non-ferrous metals which are extracted from co-mingled dry recyclates. The quality of final non-ferrous output (i.e. the proportion of used beverage cans) was noticeably higher quality than that from the MBT facility, and largely free of contaminants.

Operators reported that the relatively low quality of non-ferrous outputs from MBTs was reflected in the lower prices obtained from metal recyclers. Whilst exact prices are commercially sensitive, a general view was that non-ferrous metal from an MBT would typically command a price of between £200 and £300 per tonne, whereas non-ferrous metal from a dry MRF may command a price between £700 and £800 per tonne, a differential of up to £600 per tonne. Operators also commented that the market for clean material was more stable, since if metals recyclers reduce their purchasing requirements due to falls in end-user demand, it would inevitably be the lower quality materials which were rejected first.

Each MBT has a different arrangement of separation equipment, resulting in a range of different processes and outputs, which is assumed to be typical for the wider sector. In three of the five facilities visited, the bulk of input waste (except for organic fines) passes through an ECS at some point of the treatment process. For the other two facilities, only 3D material passes through an ECS, in which case it is possible that some laminated packaging may be separated by ballistic separation into the 2D fraction along with plastic films and paper, and may hence be incorporated into either the plastic film stream or shredded and returned to the residual material for biological treatment. Based on visual inspection, the proportion of laminated packaging in output streams other than non-ferrous metals was extremely low, with only occasional items identified.

2.3 Material quantities

Quantitative analysis of waste streams by means of composition surveys does not form part of the current project. Quantities were therefore estimated based on visual inspection and the results of any composition surveys made available by operators.

Clearly any visual inspection will produce only qualitative estimates, and this is particularly difficult in the case of materials with low density such as laminated packaging – they are of relatively high visibility being usually brightly coloured but are very light weight.

When designing an MBT, the designer will take account of a waste flow model which will indicate the quantities of various waste types that are expected in the waste inputs. This may either be provided by the waste generator (ultimately local authorities in the case of residual LACW facilities) or based on the operator's experience.

The MBTs visited as part of this project are typically designed around non-ferrous metal composition of approximately 1% of the input waste. Thus a 100,000 tonnes per annum (tpa) MBT facility will produce around 1,000 tonnes per year of non-ferrous metal. For each of the MBTs visited, the local authority also collects source-separated non-ferrous packaging at the kerbside and hence the non-ferrous material in the residual LACW is that fraction not separated by householders.

Based on visual inspection, laminated packaging formed a very small proportion of the overall input waste to each facility. Only within the non-ferrous metal stream could laminated packaging be clearly identified as a significant component of the waste stream. In these cases, it appeared to represent somewhere between 1% and 10% of the non-ferrous stream – i.e. between 0.01% and 0.1% of the total input waste.

Only one MBT current carries out extraction of contaminants (including laminated packaging) from the non-ferrous stream, using an extraction fan which removes laminated packaging and other light materials such as plastic film. There is no composition data on the efficiency of this system; and since the extracted/shredded material is blown directly into the RDF output there are no measurements of weight available. Site management indicated that initially this material was collected in a 40yd skip which was filled approximately weekly: assuming un-compacted bulk density of 0.1 t/m3 (similar to that for plastic film) this amounts to approximately 160 tpa of extracted material, or 0.19% of total waste inputs. The proportion of laminated packaging in this material is not known.

Further estimates of the amounts of laminated packaging in residual LACW are provided in Section 3.0 of this report.

2.4 Potential for separation of laminated packaging

The operators generally expressed interest in separating laminated packaging from the waste stream, but stressed that this would need to be supported by a sound business case.

The drivers for improving the recycling performance of an MBT are typically one or more of the following:

- reducing the cost for disposal of reject waste to landfill;
- reducing the quantity and hence cost for other outputs for which the operator has to pay a disposal cost, such as refuse-derived fuel or compost-like output;
- improving the landfill diversion rate or recycling rate so as to meet contract targets; and

- improving the value or marketability of the recyclates produced.

Laminated packaging is currently present as a contaminant in a stream that is already sent for recycling (non-ferrous metal), and hence further separation of laminated packaging for recycling would not improve the landfill diversion or recycling rate of the MBT, nor would it reduce the cost of disposing of reject waste to landfill.

The drivers for separating and recycling laminated packaging are likely to be primarily to enhance the marketability and hence price paid for the non-ferrous metal outputs and also to recover value from the actual recycling of the laminated packaging itself, but only if this was commercially viable (i.e. if the net revenues exceed the cost of separation and transport).

Operators suggested that laminated packaging could be removed from the non-ferrous stream by hand-picking, or alternatively using separation technology such as an optical sorter (near-infra red, NIR).

Only one of the sites surveyed currently removes contaminants from the non-ferrous stream, using a chopper fan.

Whether or not, having separated laminated packaging, operators would be interested in recycling it themselves on site would be entirely dependent on the economics of the recycling process, and whether it offers reasonable returns on investment having regard to regulatory and commercial risks.

2.5 Laminated packaging in dry MRFs

The project scope is limited to separation of laminated packaging from MBT facilities. However, at one of the facilities a dry MRF is located alongside the MBT and the process includes removal of laminated packaging from the MRF's non-ferrous output. The details of this operation are presented below as a useful comparison with operations at the MBTs.

The dry MRF processes kerbside-collected co-mingled household waste, which includes non-ferrous metals. The non-ferrous metals are separated using an eddy current separator and a hand-picking station is then used to remove contaminants. Laminated packaging is a significant (probably the major) contaminant, certainly by volume if not by mass.

An approximate estimate of the amount of laminated packaging was made based on the following assumptions:

- the operative fills a plastic box (estimated volume around 50L of laminated packaging, ignoring other components) 8 times per day;
- the facility operates 6 days per week (312 days per annum); and
- the bulk density of laminated packaging in the bin is 0.1 t/m3 (i.e. similar to the bulk density of plastic film).

This would equate to approximately 12.5 tpa of laminated packaging, and would represent approximately 0.5% of the 2,700 tpa of non-ferrous outputs from the MRF. It should be noted that in collection area for this facility, householders are not encouraged to put laminated packaging in their co-mingled recyclable collections, so this figure represents background contamination levels rather than active recycling.

2.6 Householder behaviour

The presence or otherwise of laminated packaging in the residual LACW stream is dependent on the extent to which householders dispose of this material to their residual bin or to one of their recyclables bins. A review of instructions to householders was carried out for a selection of those local authorities served by the MBT facilities visited.

Discussions with MBT operators and the metals recycling industry confirm that laminated packaging is currently viewed as a contaminant and is not wanted in the source-separated waste stream. Some local authorities specifically instruct residents not to dispose of laminated packaging in their source-separated recycling bins. Others give either ambiguous or no information. This is not helped by the fact that the nomenclature can be confusing – it is likely that most of the public are not familiar with the term "laminated packaging" and could consider the items in question to be either plastic food containers, plastic bags or foil packets. The clearest instructions are those where authorities (e.g. Cambridge City Council) refer to the material directly give examples of common product types – e.g. "laminated packaging, such as pet food pouches and drink pouches". This makes it clear to the public which materials are being discussed.

Each facility receives residual LACW from a range of different Waste Collection Authorities, each of which may give different instructions to householders. A selection of these instructions are summarised below, mainly to highlight the discrepancies and ambiguity in the information provided to householders and the ease with which the householder could be confused as to whether laminated packaging should counted as plastic or foil or as a separate category of packaging. In the absence of compositional analysis of waste streams, it is not possible to identify any direct correlations between the advice given to householders and the quantities of laminated packaging which end up in the residual LACW received at the MBT facilities.

Table 1: Selection of instructions to householders on separation of recyclables

Waste collection authority	Extracts from instructions to householders	Comments
Manchester City Council (served by Longley Lane MBT)	*Brown recycling bin* *…* *What you can put in you brown bin or box* ■ *glass bottles and jars (any colour);* ■ *tins and cans;* ■ *aerosol cans;* ■ *aluminum foil, foil trays and takeaway trays;* ■ *chocolate and biscuit tins; and* ■ *all plastic bottles e.g. milk bottles, soft drinks bottles, washing-up liquid bottles, shampoo bottles etc.* *…* *Plastics: only include plastic bottles, the processing plant that our plastic gets sent to only recognises plastic bottles so it's*	Potentially ambiguous – householders could class laminated packaging as "foil" and hence suitable for recycling.

	important not to include any other plastics for recycling such as, butter / margarine tubs, yogurt pots, plastic bags, food trays and plastic egg boxes.	
Bournemouth Borough Council (served by Canford MBT)	*In the Big Bin (recycling bin), you can recycle:* ■ *Paper (including newspaper, office paper, catalogues, phone directories, windowed envelopes)* ■ *Cans (including drinks cans and household aerosols)* ■ *Glass (including bottles of all colours)* ■ *Cardboard (including packaging, toilet roll tubes)* ■ *Plastic bottles (including milk containers, fizzy drinks bottles, shampoo, cleaning products and also the bottle tops)* ■ *Food and drink cartons (including fruit juice containers, fresh soup cartons, milk products etc.)* ■ *No foil or foil trays* ■ *No plastic film or plastic bags*	Potentially ambiguous if householders classify laminated packaging as being "food cartons" or "plastic bottles" and hence suitable for recycling, rather than as "foil" or "plastic bags" and hence unsuitable.
Newcastle City Council (served by Byker MBT)	*Use the main part of the blue bin for:* ■ *Plastic bottles (please rinse and squash)* ■ *Cardboard (please flatten)* ■ *Newspaper, yellow pages, magazines and paper including letters, flyers, leaflets, white and brown envelopes (no plastic coated paper or bound files).* ■ *Telephone directories* ■ *Food and drink cans (please rinse)* ■ *Foil and foil trays (please rinse)* ■ *Empty Aerosol Cans* ■ *Textiles (put in plastic carrier bag)* *Use the black caddy for:* ■ *Glass bottles and jars (please rinse)* ■ *Batteries (please put in a clear plastic bag on top of the glass*	Potentially ambiguous if householders view laminated packaging as "foil".

Cambridge City Council (served by Waterbeach MBT[1])	*Blue bin* *This information also applies to recycling boxes of any colour if you do not have a blue bin.* ■ *Yes please* *- all paper and card (except when shredded – put this in the green bin) envelopes, including window envelopes)* *- Cardboard* *- phone books and catalogues* *- food tins and drink cans* *- sweet or biscuit tins* *- aerosol cans* *- clean foil and foil trays* *- metal lids from jars (please remove from jars)* *- glass bottles and jars* *- plastic bottles, including drinks, shampoo and detergent bottles – no lids please drink or soup cartons, e.g. Tetra Pak)* ■ *No thanks* *- any plastic items that are not bottles, e.g. tubs, pots, trays, bags and wrappers* *- envelopes containing bubble wrap, e.g. Jiffy bags* *- shredded paper* *- wood, plasterboard, sand and other - building materials* *- food or garden waste* *- lids from plastic bottles* *- Pyrex, plate glass, glass dishes or light bulbs* *- saucepans and other metal items not listed under 'Yes please'* ***- foil-lined plastic pouches, e.g. pet food sachets*** *- crisp packets* *- clothes and textiles* *- motor-oil and pesticide containers* *- sanitary items and nappies* *- sacks of mixed rubbish*	Clear instructions provided on not including laminated packaging in recyclable collections, together with clear identification of typical products (i.e. pet food pouches)
Harborough District Council (served by Cotesbach MBT)	*The green box is for glass bottles and jars, drink cans and food tins, empty aerosols and clean foil trays.* *The blue box is for newspapers, magazines, junk mail (with the plastic wrappers removed) and stationery and*	Potentially ambiguous if householders views laminated packaging as "foil", although no plastics are collected at the kerbside so householders are most

[1] *Residual waste from Cambridge City Council is processed at Waterbeach MBT. Dry recyclates (blue bin contents) are received at Waterbeach, but transported for processing to Peterborough MRF.*

	computer paper. *Phone directories, paper backs, catalogues and yellow pages can also be put in here.* *The black bin is for non-recyclable rubbish only.* *NB Plastic bottles can be recycled at one of the many bring sites across the district plus there are 5 sites for recycling wax and foiled lined cartons.*	likely to put laminated packaging into residual black bin.

3.0 Quantities of laminated packaging waste

3.1 Waste composition analyses

There are a number of analyses of waste composition which provide useful information in estimating the amount of laminated packaging present in residual LACW.

3.1.1 Previous WRAP laminated packaging study

As part of the previous WRAP study (MDP037)[2], composition analysis was undertaken on a 330kg sample of the non-ferrous output from the Waterbeach MBT facility. Overall, laminated packaging (excluding laminated beverage cartons) accounted for 0.8% of the non-ferrous metal outputs.

3.1.2 SATURN project

The SATURN project (Sensor-sorting Automated Technology for Advanced Recovery of Non-Ferrous Metals) is a research project funded by the EU Eco Innovation programme (http://ec.europa.eu/environment/eco-innovation/).

As part of the SATURN project, waste composition analysis was undertaken of non-ferrous outputs from three UK plants in 2009: one glass recycling plant, one dry MRF and one MBT[3]. The graph (not included here) of compositional analysis for the combined samples does not quote a specific figure, but the mean composition of plastic foils (the category used for laminated packaging) is approximately 3% of the total non-ferrous metal stream.

3.1.3 Defra waste compositional assessment

The categorisation scheme adopted by Defra in the report "WR1002 Detailed Compositional Assessment for Municipal Residual Waste and Recycling Streams in England"[4] is shown in Table 2 below.

Table 2: Categories for detailed compositional assessment for municipal residual waste and recycling streams in England

1. Food waste	1.1 Food waste
2. Garden waste	2.1 Garden waste
3. Other organic	3.1 Organic pet bedding/litter
	3.2 Other organics
4. Paper	4.1 Newspapers
	4.2 Magazines
	4.3 Recyclable paper (excl News and Magazines)
	4.4 Other paper
5. Card	5.1 Card packaging
	5.2 Other card
6. Glass	6.1 Packaging glass
	6.1.1 Green bottles
	6.1.2 Clear bottles

[2] *http://www.wrap.org.uk/downloads/Recycling_of_laminated_packaging1.9d2376c8.11122.pdf*

[3] *http://www.saturn.rwth-aachen.de/downloads.php*

[4] *http://randd.defra.gov.uk/Document.aspx?Document=[WR1002]MSWcomposition2ndaryanalysisALLMSWFINAL08-09-11.pdf*

	6.1.3 Brown bottles
	6.1.4 Jars
	6.2 Non-packaging glass
7. Metals	7.1 Ferrous food and drink cans
	7.2 Other ferrous metal
	7.3 Non-ferrous drinks cans (excl non-ferrous food tins)
	7.4 Foil
	7.5 Other non-ferrous metal
8. Plastics	8.1 Plastic film
	8.1.1 Plastic bags
	8.1.2 Plastic film packaging
	8.1.3 Other plastic film (non-packaging)
	8.2 Dense plastic
	8.2.1 Dense plastic drinks bottles
	8.2.2 Dense plastic non-drinks bottles
	8.2.3 Other dense plastic packaging
	8.2.4 Other dense plastic (non-packaging)
9. Textiles	9.1 Artificial textiles, excluding shoes
	9.2 Natural textiles, excluding shoes
	9.3 Shoes
10. Wood	10.1 Treated and composite wood
	10.2 Untreated wood
11. WEEE	11.1 White goods
	11.2 Large electronic goods (excluding CRT TVs and monitors)
	11.3 CRT TVs and monitors
	11.4 Other WEEE
12. Hazardous	12.1 Batteries
	12.2 Clinical waste
	12.3 Paint/varnish
	12.4 Oil
	12.5 Garden herbicides & pesticides
13. Sanitary	13.1 Disposable nappies
	13.2 Other (sanpro and dressings)
14. Furniture	14.1 Furniture
15. Mattresses	15.1 Mattresses
16. Misc combustible	16.1 Carpet/underlay
	16.2 Other combustibles
17. Misc non-combustible	17.1 Bricks, blocks, plaster
	17.2 Other non-combustibles
18. Soil	18.1 Soil
19. Other wastes	19.1 Other wastes
20. Fines	20.1 Unspecified Fine material <10mm

There is no separate category for laminated packaging. It could be recorded as a sub-set of either 7 (metals) or 8 (plastic film).

The mean composition of residual LACW for England in 2006/07 as reported in WR1002 for relevant subsets of these categories are as follows:

- Category 7.4 "Foil" - 0.28% (Total non-ferrous metal (categories 7.3 – 7.5) - 0.9%)
- Category 8.1.2 "Plastic film packaging" - 2.42%
- Category 8.2.3 "Other dense plastic packaging" - 3.19%

In the absence of further breakdowns, it is not possible to estimate the fraction of laminated packaging present within these specific categories.

The lack of a clearly-defined category for laminated packaging in standard composition survey methodologies is a constraint on obtaining detailed information on the amount of this material in the waste stream. If this material increases in prevalence in the future (which packaging industry sources suggest is likely) then it may be beneficial to include it as a separate category or sub-category in standard composition survey methodologies.

3.2 Estimates of quantities from trade sources

The previous WRAP study (MDP037) estimated the total amount of laminated packaging used in the UK each year as 139,000 tpa. This was based on data from Alupro, the Aluminium Packaging Recycling Organisation, which indicated that 14,400 tonnes of aluminium were used in laminated packaging in the UK in 2008, and assumed that aluminium represents just under 10% of the total mass of a laminated package. The latest information from Alupro (2010)[5] indicates that the amount of aluminium used in laminated packaging has increased to 16,000 tonnes.

Further discussions were held with Alupro to clarify the source of this information. Alupro explained that the total of 16,000 tonnes was an estimate from industry sources covering several different types of aluminium laminates, and could be broken down as shown in Table 3 below.

Table 3: Breakdown of Alupro estimates for aluminium in composite packaging

Category	Quantity (2010 data)
Aluminium in composites and laminates	**16,000 tpa**
of which	
Aluminium lids for steel cans	5,000 tpa
Beverage cartons (e.g. Tetrapak)	4,500 tpa
Foil for pharmaceutical packaging	2,500 tpa
Plastic laminates	**4,000 tpa**
Average proportion of aluminium in laminated packaging	9.7%
Total amount of plastic/aluminium laminated packaging	**41,237 tpa**

Based on this revised data, the total amount of laminated packaging (of the type considered in this project) entering the waste stream in the UK is estimated at approximately 41,000 tpa.

3.3 Summary of estimates

Data on total waste arisings in the UK are necessary in order to estimate the proportion of laminated packaging in the waste stream. Statistics on LACW are collected in Waste Data Flow and used by the UK and devolved national governments to prepare estimates of total and residual LACW. The figures for 2010/11 are shown in Table 4 below.

[5] *http://www.alupro.org.uk/aluminium-and-the-carbon-economy/aluminium-packaging-facts/*

Table 4: Total and residual LACW (000 tonnes per annum, 2010/11)

Waste Type	England[6]	Wales[7]	Scotland[8]	Total
LACW	26,199	1,621	3,141	30,961
Residual LACW	15,692	886	1,941	**18,519**

The total amount of LACW in the UK in 2010/11 was 30.9 Mtpa, of which residual LACW (i.e. the amount not separately collected for recycling, composting or reuse) was 18.5 Mtpa.

If it assumed that all laminated packaging ends up in the LACW stream (i.e. none is present in commercial and industrial waste (C&IW)), then laminated packaging therefore represents (0.041/30.9) x 100 = **0.13% of the total LACW stream**. This assumption may be an overestimate, in that a proportion of laminated packaging (e.g. that used in commercial premises) is likely to end up in the C&IW stream rather than LACW.

Assuming that 75%[9] of laminated packaging is disposed of in the residual LACW stream (with the remainder erroneously disposed of in the recyclables stream) then laminated packaging represents approximately **0.17% of residual LACW**. This assumption is an estimate only and there is no waste composition analysis to confirm this, since laminated packaging is not separately counted in standard compositional analysis.

If 75% of this laminated packaging in the residual LACW is captured in the non-ferrous output of an MBT, and if the non-ferrous output represents 1% of the MBT output, then the captured laminated packaging would represent 0.13% of the total facility throughput, and around 11% of the material in the non-ferrous output. It should be noted that the 75% capture rate in the non-ferrous stream is an estimate by the authors of this report, and there is no mass balance data to confirm this.

This estimate is broadly consistent with, although at the upper end of, visual estimates for laminated packaging in non-ferrous outputs actually observed at the MBT facilities (which were generally estimated as being in the range 1% - 10%). It should be noted however that these visual estimates cannot be confirmed without compositional analysis.

If it assumed that any separation technology used for extracting laminated packaging from the residual LACW stream has a capture rate of 75% (i.e. it will separate and remove 75% of the laminated packaging entering the MBT), the amount of available material will be equivalent to 1.3 kg of laminated packaging per tonne of residual LACW processed. A typical MBT with a throughput of 100,000 tpa equipped with suitable separation equipment which could capture 75% of the input of laminated packaging would therefore generate around 128 tpa of laminated packaging (just over 2 tonnes per week). Further assessment (including pilot trials of separation equipment) would be needed to confirm whether this capture rate could be achievable in practice – however, it is used as a realistic best-case estimate for the purposes of this project.

The pyrolysis process evaluated in the WRAP MDP037 project had an estimated throughput of 2,000 tpa of laminated packaging. If this material were to be sourced entirely from residual LACW, a single recycling facility may require the outputs of MBT facilities treating around 1.5M tpa of waste (around 8% of the UK's residual LACW).

[6] *http://www.defra.gov.uk/statistics/files/2011-12-Quarter-1-publication_WITHOUTLINKS_v2.xls*
[7] *http://www.statswales.wales.gov.uk/ReportFolders/reportFolders.aspx*
[8] *http://www.sepa.org.uk/waste/waste_data/waste_data_reports/landfill_allowance_scheme.aspx*
[9] *Working assumption for purposes of estimation – detailed composition analysis would be required to confirm the validity of this assumption*

4.0 Options for separation of laminated packaging

4.1 Identification of potential separation options

It may be possible for local authorities to request householders to include laminated packaging along with other non-ferrous metals (in particular UBCs and aerosols) in the recycling collection (either co-mingled or separate metals collections). This option was assessed in the previous report (MDP037) and may be feasible, but since the scope of this project is separation of laminated packaging from residual LACW, separation from co-mingled recyclables is not assessed further. It should be noted that dry MRFs (used for processing co-mingled recyclables) are likely to have significantly different configurations from MBTs and hence the methods for separating laminated packaging may be different (although ECS are commonly used in both MBT and MRF).

Table 5 below reviews the technologies that may be suitable for separating laminated packaging from residual LACW. Laminated packaging is not distinct from other materials in the residual LACW stream in terms of physical size or density, and hence it would not be feasible to separate it from residual waste by screening or ballistic separation alone, although these processes could be used as a pre-treatment stage to produce a waste stream better suited to subsequent separation technologies.

Table 5: Sorting technologies applicable to laminated packaging

Technology type	Possible application	Commentary
Screening (trommel, vibrating screen, star screen etc.)	Separation of laminated packaging by size from other waste types.	Screens in MBT are commonly used for separating fines for organic treatment (typically material less than 60 or 80mm). Laminated packaging is unlikely to be present in the fine fraction in significant quantities. Subsequent use of screening to separate laminated packaging is unlikely to be feasible since the material is very similar in size to a large proportion of residual LACW, including paper, plastic film, crisp packets, etc.
Ballistic separation	Separation of 2D "flat" material (which may include laminated packaging) from 3D "rolling" material such as UBC.	Ballistic separation may separate some (but not all) laminated packaging into the 2D stream whilst leaving UBC in the 3D stream, therefore allowing subsequent separation of laminated packaging from the 2D stream using ECS. However, it cannot selectively remove only laminated packaging from mixed waste. Site visits to facilities which include ballistic separators indicate that significant quantities of laminated packaging do still end up in the 3D stream.

Eddy current separation	Separation of laminated packaging along with other non-ferrous metals.	ECS are effective in removing laminated packaging along with other non-ferrous metals in existing MBTs. However, the resultant outputs would then need further processing to separate laminated packaging from UBC and contaminants in this output stream. A cascade of separate ECS operating in series could potentially achieve this.
Optical sorting	Use of Near-Infra Red (NIR) sensors and compressed air jets to identify and selectively eject laminated packaging.	NIR has the capacity to separate many different types of material, although there may be technical challenges in separating laminated packaging from non-laminated materials using the same polymers but not including aluminium.
Hand picking	Manual identification and removal of laminated packaging from a variety of waste streams.	Hand picking is feasible and proven, and is used in some dry MRFs to clean up the non-ferrous stream. The separation efficiency and output quality depends on number of pickers, input quality and belt speed. Hand picking from a non-ferrous stream from an ECS has the potential to produce a good quality output of laminated packaging.
Air separation	Use of fans or blowers to separate light material from heavy material. Includes wind sifters, air knives or fans.	One of the MBTs visited uses a chopper fan to remove light material from non-ferrous outputs. An air separation system will not distinguish between laminated packaging and other light materials such as plastic film and may not extract heavier weight laminated packaging (e.g. if contaminated with significant amounts of food residue).

4.1.1 Discussion

A plant configuration could be designed which would optimise the separation of laminated packaging, but given the space and financial constraints for existing MBTs, any viable solution is more likely to entail a "bolt-on" addition which could separate laminated packaging from the relevant output stream.

The type of separation technology used would depend on a number of factors, including:

- Primary objective of separation – whether this is driven primarily by the need to separate laminated packaging to recover value from it directly; or by the need to remove laminated

packaging and other contaminants from a non-ferrous metal stream to enhance the value of the non-ferrous metal.
- Scale of operations – investment in sorting technology will be driven by the expected returns, and given the relatively low quantities of laminated packaging expected to be present in a typical MBT, the incentive for significant capital investment may be low.
- Existing plant configuration – unless the financial returns are very attractive, it is unlikely that existing MBT operators would want to carry out major reconfigurations of their plants to remove laminated packaging. As well as the direct costs involved, this may also have knock-on effects on their ability to meet their existing performance requirements under their contracts with local authorities.

Of the technologies discussed in the preceding section, not all would be practical as a means of producing a good quality laminated packaging output.

Neither ballistic separation nor screening alone will be capable of separating laminated packaging from a mixed waste stream, and the results of the site visits suggest that a large proportion of laminated packaging is not separated from other non-ferrous materials by screening. These two technologies are therefore not considered further.

The technologies capable of removing laminated packaging with an adequate degree of selectivity from an existing MBT facility such that it could form a suitable feedstock for a recycling process are therefore:
- Hand Picking.
- Eddy Current Separation.
- Optical Sorting.
- Air separation.

In terms of investment, there are two possible scenarios:
- a facility invests in new separation equipment specifically to separate laminated packaging; or
- a facility utilises their existing separation equipment outside of normal operating hours to separate laminated packaging.

The use of existing separation equipment is highly dependent on factors such as plant layout, mode of operation and working hours, and may be constrained by the need to empty hoppers, clean and re-programme equipment and employ staff during non-core hours. Whilst this option may merit further consideration on a site-by-site basis, it has not been assessed in further detail in this report and hence the evaluation focuses on investment in new plant.

4.2 Evaluation of potential separation options

In each case it is assumed that there will be no costs for structural modification of the existing buildings. It is assumed that MBT operators would be unlikely to carry out major structural or process modification to the existing mechanical separation plant, since these are typically optimised to produce outputs appropriate to the contract requirements and existing outlets; and hence any new separation plant would be a "bolt-on" to the process to treat a particular output.

Each of the cost estimates are based on an MBT facility with 100,000 tpa throughput, which consists of 0.17% by mass of laminated packaging, which is separated from the non-ferrous output stream with a recovery rate of 75% to give an output of 128 tpa of laminated packaging.

Although it may be technically feasible to recover some laminated packaging from other process streams, in reality it is present in much lower concentrations in these streams, and hence would require larger and more expensive equipment to separate smaller quantities of material, and would therefore be less commercially viable.

For all options, utility costs (electricity) are based on supplier information for installed load and utilisation factors for the equipment in question, multiplied by a nominal 2,000 hour working year (approximating to a single 8hr/5day shift operating year-round) and a unit cost of 7.5p/kWh (DECC Energy Price Statistics Q3 2011 – average electricity unit cost for medium industrial users). Maintenance costs are assumed to be 5% of the capital cost per year. Labour costs are based on labour employed specifically to operate the separation equipment. For automated separation equipment, it is assumed that there is no need for the facility to employ additional maintenance staff, managers, control room staff or general operatives, since the incremental increase in workload for these staff will be minimal when considering the facility as a whole.

For all options, capital expenditure is depreciated over the lifetime of the plant on a straight-line basis. The capital cost includes the cost of the separation equipment plus a nominal £20,000 for installation, additional conveyors, hoppers, supports and upgrades to the control systems. Capital costs have been based on estimates from technology providers. This approach does not take into account the cost of capital and hence is likely to underestimate costs.

The combined opex and capex per year is then divided by the number of tonnes of laminated packaging to give an estimate of the cost per tonne of separation. The costs of each option are presented in Table 6 below.

Table 6: Estimated cost of separation for laminated packaging at MBT

	Hand picking	**Eddy current separation**	**Optical sorting**	**Air separation**
Opex				
Labour	£70,000	0	0	0
Utilities & consumables	£750	£938	£915	£2,250
Maintenance	£3,250	£5,250	£13,500	£2,000
Annual opex	*£74,000*	*£6,188*	*£14,415*	*£4,250*
Capex				
Sorting equipment	*£45,000*	*£85,000*	*£250,000*	*£20,000*
Installation and ancillary works	*£20,000*	*£20,000*	*£20,000*	*£20,000*
Total capital cost	£65,000	£105,000	£270,000	£40,000
Life of Plant	15	15	15	15
Annualised capex	*£4,333*	*£7,000*	*£18,000*	*£2,667*
Capex + Opex (per tonne)	**£614**	**£103**	**£254**	**£54**
Sensitivity Analyses:				
Capex + 25%	*£625*	*£123*	*£311*	*£59*
Capex - 25%	*£604*	*£84*	*£197*	*£50*
Increase life of plant to 20 years	*£604*	*£84*	*£197*	*£50*

4.2.1 Hand picking

Hand picking could be effective at separating laminated packaging from a wide range of different waste streams, including non-ferrous material. The effectiveness of hand picking depends on the intensity of picking effort which in turn is influenced by width and speed of the picking line, the number of operatives and their efficiency in spotting and removing target material. To minimise cost and maximise separation efficiency, it would be preferable for laminated packaging to be picked from a material stream which has already received some pre-treatment to remove non-target materials and to concentrate the proportion of laminated packaging – experience from the site visits suggest that the non-ferrous stream would be the most obvious stream for hand picking.

A major advantage of hand picking is the ability to remove not only laminated packaging but also other contaminants from the non-ferrous stream, whilst simultaneously separating laminated packaging from the other contaminants. This could potentially produce both a higher quality of "clean" non-ferrous output, and also a high-grade output of laminated packaging for recycling, whilst other contaminants would be managed in other ways.

A significant cost of hand-picking will be labour. Assuming each operative is able to pick 30 items per minute and the average weight of each item is 10 g each full-time equivalent operative (40 hrs x 52 weeks) will be able to separate [(60 x 40 x 52) x 30 x 0.00001] = 36 tonnes per annum of laminated packaging. A facility removing 128 tpa of laminated packaging would therefore require approximately 3.5 full-time equivalent operatives, at an assumed total employment cost of £10/hr.

Pickers are generally housed in a picking cabin, which includes picking stations for operatives and allows a safe and effective working environment to be maintained. Outline cost estimates from suppliers suggest that a picking cabin to accommodate up to 4 operatives is likely to cost in the region of £45,000.

4.2.2 Eddy current separation

A variety of different types of eddy current separator are available, and can potentially be used to separate laminated packaging from other non-ferrous materials.

Material is separated in an ECS on the basis of eddy currents being generated in non-ferrous materials by rapidly rotating permanent magnets. These eddy currents in turn cause the material to be repulsed by the magnet field of the ECS, and the non-ferrous material is ejected from the flow of materials and is "thrown" into a separate hopper or conveyor.

Materials passing through an ECS exhibit different responses depending on the type and density of the metal component and the size of material. It is possible to tune an ECS such that certain materials (e.g. beverage cans) are thrown further from the belt than other materials, and guiding these different types of materials into different streams using a "long throw splitter".

Technology suppliers can also provide a cascade of ECS connected in series, each of which is tuned to separate specific material. For example, it may be possible to use a standard ECS to remove mixed non-ferrous material from a residual waste stream, followed by another ECS designed to specifically remove aluminium cans. The residual material following removal of cans would likely include a high proportion of laminated packaging, albeit along with other contaminants such as plastics and other metals.

Outline cost estimates from suppliers suggest that a standard ECS is likely to cost in the region £85,000; and an additional ECS to remove cans is likely to be less expensive, in the region of £35,000. For the purposes of this assessment, it is assumed that an additional standard ECS is added to provide further treatment to the non-ferrous stream arising from the MBT facility's existing ECS(s).

4.2.3 Optical sorting

Near infra-red (NIR) technology is commonly used in the waste sector for the segregation of components from within the waste stream. Discussions with suppliers of NIR technology have indicated that an NIR unit with combined metal detection could be used to separate laminated packaging from a MBT input an/or a mixed non-ferrous metal output. Use of NIR without metal detection would be less effective since the NIR sensors may not adequately distinguish between laminated packaging (including aluminium metal) and non-laminated material consisting of similar polymer types but without a metallic layer.

Metal detection is provided by an electromagnetic (EM) sensor. The combination of an EM sensor and a NIR spectrometry sensor delivers information to recognise materials based on their conductivity and unique spectral properties. The EM sensor is available in two resolutions (25mm and 12.5mm). The minimum particle size of metal objects, which the EM sensor can detect is 1-2mm. Unsorted material is spread out on the conveyor belt and fed through the EM sensor and NIR scanner unit. The unit then triggers air nozzles which separate the selected materials as programmed.

Polymer stream purities in the range of 80-95% are often achieved by NIR sorters. High performing and well configured systems can achieve in excess of 95% purity. Suppliers have indicated that similar purities could be achieved when sorting laminated packaging.

Outline cost estimates from suppliers suggest that a suitable NIR with EM sensor is likely to cost in the region of £250,000.

4.2.4 Air separation

An existing MBT visited during this project uses air separation (a chopper fan) to remove and shred light material from the non-ferrous output resulting from eddy current separation. No data is available on the selectivity or efficiency of this process although the operator reports an increase in the quality of the "cleaned" non-ferrous material.

Air separation is unlikely to be able to separate laminated packaging from other non-metallic contaminants (e.g. plastic bags) and may remove other relatively light material such as crisp packets and aseptic packaging. Whilst the output will likely have a relatively high proportion of laminated packaging, the presence of contamination will likely reduce the efficiency of the pyrolysis process (lower metal recovery) in the absence of any additional clean-up of the feedstock.

Outline cost estimates from suppliers suggest that suitable air separation equipment is likely to cost in the region of £20,000.

4.2.5 Quality of outputs

The pyrolysis process is capable of handling a degree of contamination within the laminated packaging feedstock, although contamination may reduce the proportion of aluminium that is recovered and also potentially its quality.

Hand picking can produce a relatively high quality output since (with correct training) operatives can be very selective in picking out laminated packaging.

Optical sorting could be used to selectively remove laminated packaging, particularly if combined with a metal detection system.

Eddy current separation and air separation are both likely to be less selective, since they rely on removing all light or non-can containers from the non-ferrous stream. The resulting output would likely include a high proportion of laminated packaging, but also other contaminants which may affect the efficiency or output quality of the pyrolysis process.

Further assessment including plant trials would be necessary in order to confirm the likely separation efficiency and output quality of these options.

It is notable that the least costly separation technique (air separation) is also likely to give the lowest quality of outputs, and further clean up may be required (e.g. by hand picking or additional ECS). Conversely, direct hand picking or optical sorting are both potentially highly selective, but have considerably higher costs.

4.2.6 Summary of Costs

The analysis shows that the least costly means of separating laminated packaging from non-ferrous material is likely to be air separation (£54/t). The next lowest cost method is additional eddy current separation (£103/t).

Hand picking and optical sorting are considerably more costly, due to the high cost of labour and the high cost of NIR separation plant respectively.

It should be noted that further eddy current separation will not be effective at removing other non-metallic contaminants from the non-ferrous stream (e.g. plastic bags); and hence may not add much value to the resulting "clean" non-ferrous stream when compared to more costly separation stages such as NIR and hand picking, which may result in a cleaner non-ferrous stream. This is of particular relevance since the main driver for separating laminated packaging from aluminium is unlikely to be the value recovered through recycling, but the value added to the resulting clean non-ferrous stream.

Air separation will produce a stream of "mixed lights" which will include laminated packaging but also other contaminants such as plastic film. Further upgrading (e.g. eddy current separation or hand picking) may be needed to produce a stream of laminated packaging of sufficient quality for recycling, which would add to the cost.

A typically-sized MBT (100,000 tpa throughput) is likely to produce around 128tpa of laminated packaging, i.e. around 2 tonnes per week. Depending on the size of vehicle used, haulage costs are likely to be from £0.2/t/km to £1.0/t/km. Assuming a distance of 50km from the MBT to the recycling facility, this equates to a transport cost of between £10/t and £50/t. Because of the relatively small quantities and low density of this material, it may not be practicable to use the cheaper large vehicles (44-tonne artics) since this would require the material to be bulked on site over an extended period. If more regular collection is required, then transport costs may be at the upper end of this range. The cost of transport could be paid by either the MBT operator or the recycler.

The analysis indicates that, based solely on the economics of separating and recycling laminated packaging (excluding the economics of the remaining non-ferrous stream), MBT operators are unlikely to see a commercial benefit from separating laminated packaging unless there is a return from recycling greater than the cost of separation i.e. more than around £54/tonne in the case of air separation, or £103/tonne in the case of ECS.

If each tonne of laminated packaging yields 90kg (0.09t) of aluminium with a value of £800/t (i.e. £72 worth of aluminium per tonne of laminated packaging) and 200kg (0.2t) of pyrolysis oil with upper estimate of value of £150/t (i.e. £30 worth of pyrolysis oil per tonne of laminated packaging) then the gross revenue would be £102 per tonne of laminated packaging processed.

There are considerable uncertainties associated with the value of the pyrolysis oil which may reduce total revenue. Conversely, the use of gas from the pyrolysis process to generate electricity could increase the total revenue; but this would require additional investment in electricity generation plant (i.e. gas engines and generators) as well as suitable grid connections and supply agreements. These potential revenues have therefore not been taken into account at present, but could be significant.

The net revenue from recycling will be considerably lower than the gross revenue, since the capex and opex of the recycling facility must be taken into account. Based on information in the WRAP MDP037 report, the opex for a 2,000 tpa pyrolysis facility is estimated to be 154,100/2,000 = £77 per tonne, which would reduce the net revenue to around £25/t, before accounting for capex.

This estimate of likely net revenue excluding capex (£25/t) is lower than the lowest estimated cost of separation (£53/t), and hence separation of laminated packaging from residual LACW is unlikely to be financially viable based solely on the value obtained from the recycling process itself.

If operators are able to significantly reduce the cost of separation (e.g. by using existing plant at low cost) then it is possible that separation may be viable, but this would be based on site-specific factors. Similarly, the recycler may be able to increase the revenue by recovering additional value from the hydrocarbon products.

However, this does not necessarily mean that MBT operators would not be willing to separate laminated packaging from non-ferrous material, since there are other financial incentives over and above those from recycling of laminated packaging.

4.3 Incentives for separation of contaminants from non-ferrous metals

At present MBT operators do not directly pay for disposal of laminated packaging, since it is present primarily in the non-ferrous output for which the operator is paid a price. However, there can be considered to be an indirect cost, to the extent that the price obtained for the non-ferrous output is much lower than the price obtained for clean non-ferrous metal.

The price obtainable for non-ferrous metals varies from £200 - £300 per tonne for mixed non-ferrous materials from an MBT to £700 - £800 per tonne for clean aluminium cans from a dry MRF. Laminated packaging appears (from visual inspection of output streams) to be one of the major contaminants in the non-ferrous metal outputs from MBT facilities.

There would appear to be a strong case for MBT operators to upgrade non-ferrous materials in order to command a higher price. Whilst the quality of materials may never match that from a dry MRF, it may be possible to increase the quality of the material such that it commands a price higher than £300 per tonne and closer to the price for “clean” non-ferrous material from a dry MRF, and also reduce the risk of returned loads (a situation where the metal recycler returns the material as being of inadequate quality, which is costly to the MBT and may jeopardise their ability to meet contractual targets).

If such separation were to be carried out, then the outputs would be:

- a "clean" stream of upgraded non-ferrous metal, predominantly aluminium cans; and
- a "residual" stream of contaminants, which would include laminated packaging as a significant component.

The clean non-ferrous metal would be sent for recycling where it would command a higher price. The residual stream would be either landfilled or (more likely in the case of an MBT) shredded and incorporated into the plastic film, CLO or RDF fractions.

The disposal cost for the residual stream would be equivalent to the marginal cost for disposal of the CLO or RDF. This figure will vary depending on the outlet and material quantities, but experience of similar projects suggests that the gate fee for disposal of RDF is in the region of £65/tonne, plus transport cost.

The driver for separating laminated packaging from the non-ferrous waste stream is likely to be the increased revenue from sale of the clean non-ferrous stream rather than the revenues from a recycling process.

If such separation is carried out by MBT operators, then a stream of relatively clean laminated packaging may be available to the operators of an Enval process. It is possible that the operators of the process may be able to charge a gate fee equivalent to the marginal cost to the operator of disposing of this material through the MBT process, i.e. in the region of £65/tonne, although this would be subject to commercial negotiations.

4.4 Alternative approaches to separation

It is understood that metal processors who receive non-ferrous materials from MBTs and MRFs carry out upgrading and separation in order to produce metal outputs that are suitable for their ultimate end markets (e.g. metal smelters). Techniques and believed to include air separation (for removing "lights", which may include plastic film and laminated packaging) as well as dense media separation to separate aluminium from other denser non-ferrous metals such as copper. Given that these facilities will typically aggregate non-ferrous metals from a wide area and will likely have a higher throughput, it is possible that separation of laminated packaging at a metal processor may be more cost effective than separation at an MBT. Further assessment would be required to confirm the technical and financial viability of such operations.

4.5 Conclusion

The incentives for MBT operators to separate laminated packaging from other waste streams (most likely non-ferrous material) are likely to be driven primarily by the value added to the remaining "clean" non-ferrous material, rather than the value obtained from recycling the laminated packaging.

If MBT operators do separated laminated packaging, then the marginal costs for them to dispose of it in their RDF output (the most likely outlet) could be in the region of £65/t (which may vary subject to market conditions in the RDF sector).

5.0 Risks and uncertainties

5.1 Overview

In assessing the viability of separating and recycling laminated packaging from residual LACW using a microwave pyrolysis process, there are several areas of uncertainties which may need to be resolved before commercialisation of any such scheme.

5.2 The Waste Incineration Directive

The aim of the WID is to prevent or limit, as far as practicable, negative effects on the environment, in particular pollution by emissions into air, soil, surface and groundwater, and the resulting risks to human health, from the incineration and co-incineration of waste. The WID seeks to achieve this high level of environmental and human health protection by requiring the setting and maintaining of stringent operational and technical requirements and through the setting of emission limit values for plants incinerating and co-incinerating waste throughout the European Community.

The WID applies to the incineration and co-incineration of both hazardous and non-hazardous waste. The definition of the three terms 'waste', 'incineration plant' and 'co-incineration plant' determine the scope of the WID.

Article 3 of the WID defines 'incineration plant' as follows:

'Incineration plant means any stationary or mobile technical unit and equipment dedicated to the thermal treatment of waste with or without recovery of the combustion heat generated. This includes the incineration by oxidation of waste as well as other thermal treatment processes such as pyrolysis, gasification or plasma processes insofar as the substances resulting from the treatment are subsequently incinerated.'

The key element of the definition is that the activity must involve 'thermal treatment of waste'.

Defra's publication "Environmental Permitting Guidance - The Waste Incineration Directive For the Environmental Permitting (England and Wales) Regulations 2010" states that:

'Thermal treatment' includes both incineration/combustion and other treatments, such as gasification and pyrolysis. However, if the activity involves only thermal treatment in this broader sense (as distinct from incineration/combustion), then it will be subject to the WID only 'insofar as the substances resulting from the treatment are subsequently incinerated' [emphasis added]. This ensures that the WID covers processes such as pyrolysis and gasification, unless their purpose is the manufacture of products with no resulting release of combustion gases. Therefore, if a gasification/pyrolysis plant produces a number of products, one or more of which are subsequently burnt, then the WID applies to the whole plant. In cases where the products are burnt away from the gasification/ pyrolysis plant (remote units), the WID will apply both to the plants initially producing, as well as subsequently using, these products.

The implication of this guidance is that a full-scale commercial microwave pyrolysis process may be regulated under the WID if it combusts the gas generated by the pyrolysis process to supply power to the process. Further discussions would be required with the Environment Agency to clarify the regulatory position.

Facilities combusting the pyrolysis oil would also need to be WID-compliant, unless:

A: the pyrolysis oil as produced by the microwave pyrolysis process could be classed as a non-waste and could therefore be burnt in any installation; or

B: the pyrolysis oil is reprocessed in order to make a product that itself could be classed as non-waste.

5.3 Status of pyrolysis oil and gas

It is feasible that the pyrolysis oil could be classed as non-waste, but this would likely need to be negotiated on a process-specific basis with the Environment Agency. It is understood that SITA has followed this approach for it's plastics-to-diesel process (which includes both pyrolysis and refining stages) and have been successful in classifying the end-product as a non-waste. Further technical assessment (including analysis of the pyrolysis oil and discussions with the Environment Agency) would be needed in order to assess the feasibility of this approach for the microwave pyrolysis process.

In order to class the pyrolysis oil as non-waste, it may need further processing (e.g. fractional distillation or some other form of refining). This could be carried out as part of the process on site, or could be carried out by a third-party processor.

Designing, constructing and operating a refining process in addition to the pyrolysis process would entail additional capital and operating cost, would require additional space and may entail further planning or permitting constraints. Given the small scale of the process (less than 2,000 tpa), the cost of establishing a refining process may be prohibitive.

A number of waste oil processors operate blending and refining processes for waste oil which results in a product that meets the Environment Agency's End of Waste Protocol for Processed Fuel Oil or it separately satisfies the end of waste test for fuel, and can therefore be combusted in facilities that are not required to be regulated under WID.

If waste oil processors are able to accept the pyrolysis oil as a feedstock for preparing processed fuel oil (PFO), then it is possible that they would be willing to pay for this material, with a price that could be as high as £150/t. If the pyrolysis oil is not suitable for use in preparing PFO and is instead sold as recovered fuel oil (RFO) for use in WID-compliant facilities only, then the producer of the RFO would need to pay a gate fee to the WID-compliant facility, which from discussion with industry could be as much as £100 to £150/tonne. In order to determine the economic benefit of the pyrolysis oil it would be necessary to hold detailed discussions with waste oil processors, which may include testing of samples of the oil.

The commercial and regulatory status of the pyrolysis oil may need to be resolved by further discussions between the process developer, the Environment Agency and potential off-takers for the oil.

Pryolysis gas (non-condensable hydrocarbons) forms the largest product from the pyrolysis process. It is likely that this gas will need to be flared or used for energy generation on the site of production, since off-site transportation and use may be difficult. Further assessment of the regulatory, technical and financial factors associated with gas utilisation would be needed in order to determine the constraints and opportunities and how these impact on the economics of the process.

6.0 Summary and conclusions

The objectives of this project are to:
- identify the streams into which laminated packaging is sorted in existing MBTs and wet MRFs;
- estimate the quantity of laminated packaging in the incoming waste and various output streams;
- identify options for the separation of laminated packaging for subsequent recycling;
- consider the economic and technical feasibility of separating and recycling laminated packaging; and
- estimating the potential viability of such schemes.

6.1 Laminated packaging in existing MBTs

Five operational MBTs were visited, all of which accepted residual LACW in various parts of the country. In all cases, the majority of laminated packaging was reported to be sorted into the non-ferrous metal stream. Laminated packaging was present in some other streams (e.g. fines; 2D plastics etc) but in negligible quantities as a proportion of the output stream. Only one MBT removed laminated packaging (along with other "light" material) from the non-ferrous stream, using air separation (a chopper fan). The separated material is fed into the facility's RDF output. Operators expressed potential interest in separating laminated packaging from non-ferrous material, but only if it was financially viable. A significant potential driver for separating material from the non-ferrous stream was reported to be the enhanced price which could be obtained for non-ferrous material once contaminants had been removed.

6.2 Quantities of laminated packaging

Laminated packaging is not separately measured in most waste composition surveys, and composition surveys did not form part of the scope of this project. Quantities have therefore been estimated based on a number of sources.

A reassessment of the Alupro data suggests that approximately 41 ktpa of laminated packaging may enter the LACW waste stream per year. Most of this should be present in the residual LACW stream, although householders sometimes erroneously dispose of it with dry recyclables. The proportion of laminated packaging in the incoming waste is likely to be in the region of 0.13% to 0.26%.

6.3 Options for separation of laminated packaging

The following technologies have the potential to separate laminated packaging from various feedstocks:
- Hand picking – proven effective at removing laminated packaging from a variety of feedstocks.
- Eddy current separation – potential for removing laminated packaging from other non-ferrous metals when used in a cascade with appropriate settings.
- Optical sorting – potential for removing laminated packaging from both mixed and non-ferrous streams, particularly when combined with a metal detection system.
- Air separation – proven effective for removing light material (including laminated packaging) from a non-ferrous stream, but will not distinguish between laminated packaging and other plastic film.

6.4 Economic and technical feasibility of separating and recycling laminated packaging

There are no insurmountable technical obstacles to separating laminated packaging from residual LACW using one or more of the separation technologies identified. The technical feasibility will depend on site-specific factors such as available space, existing plant design and layout, and any constraints on operations such as hand-picking.

The significant cost differential between high grade aluminium scrap (mainly UBC with value up to £800/t) and low-grade non-ferrous material (MBT output with value of £200 - £300/t) would appear to be a significant driver towards further refining of non-ferrous outputs of MBT facilities by enhanced separation. Laminated packaging would be a by-product of this enhanced separation and could therefore be available for recycling.

6.5 Overall viability of separation and recycling schemes

Absent specific producer responsibility legislation and considering the negligible weight of laminated packaging as a proportion of the overall waste stream, it is likely that the viability of any scheme will be driven solely by economics, and possibly also with some planning and permitting constraints depending on the regulatory position with respect to the Waste Incineration Directive and the waste/non-waste status of the pyrolysis gas and oil

The cost of separating laminated packaging is estimated to be from £53 per tonne upwards. The net revenue from recycling laminated packaging is subject to considerable uncertainty, but may be lower than the cost of separation. This suggests that separating laminated packaging from residual LACW is unlikely to be financially viable considered as a stand-alone activity; and the financial driver for separation is more likely to be to enhance the value of the non-ferrous stream by removing contamination.

There are a number of uncertainties associated with the proposed recycling process that may affect the feasibility of any scheme:

- Regulatory status: it is not clear whether the pyrolysis process would need regulation under WID. If so, there may be additional site infrastructure, permitting and compliance costs and risks associated with co-locating the process at an existing MBT or MRF.
- Value and status of the resultant pyrolysis oil: a major product of the pyrolysis process by weight is pyrolysis oil. On a process and site specific level it may prove economically beneficial to apply to the Environment Agency to have pyrolysis oil deemed a non-waste, in which case it could be marketed as a fuel and its use would be outside waste regulation controls. However, if it is considered as a waste, then it would either require further refining (on or off-site) which may enable it to be classed as a non-waste; or it could only be combusted in WID-compliant facilities. In either case, the revenue that could be recovered from the pyrolysis oil would likely be much lower than would be the case for standard fuel oil. Further assessment of the on-site use of the pyrolysis oil and gas from the process would also be necessary.

Appendix A – Summary of site visits

Facility name:	Cotesbach MBT Facility
Operator:	New Earth Solutions
Throughput:	45,000 tpa
Source of waste:	Contract with Leicester County Council to treat residual LACW from Leicestershire Waste Collection Authorities (WCAs) Very small quantities of third-party trade waste also accepted.
Operational since:	Oct. 2011
General process description:	Front-end mechanical treatment: ■ Trommel ■ Overband magnets ■ Optical sorting ■ Wind sifting ■ Eddy current separation Back-end biological treatment: ■ Biostablisation of fines to produce RDF.
Occurrence of laminated packaging:	Laminated packaging is separated by ECS and visibly present in the non-ferrous output. Laminated packaging is estimated by site management to represent no more than 10% of non-ferrous stream. Non-ferrous outputs in total represents around 1% of total waste inputs. It is possible that laminated packaging present in fines from the trommel (<80mm) would end up in RDF since there is no ECS on this line, and also possible that it could be removed into the plastic film stream by wind sifters. Visual inspection of waste streams indicated negligible quantities of laminated packaging in either stream. *Non-ferrous output in skip:* 

Facility name:	Longley Lane MBT Facility
Operator:	Viridor
Throughput:	130,000 tpa
Source of waste:	Contract with Greater Manchester Waste Disposal Authority to treat residual LACW from WCAs in Greater Manchester
Operational since:	July 2011 (in commissioning at time of site visit)
General process description:	Front-end mechanical treatment: ■ Trommel ■ Overband magnets ■ Eddy current separation ■ Ballistic separator (paper & light plastics to RDF) ■ NIR (dense plastics to RDF) Back-end biological treatment: ■ Sub-40 mm fines to anaerobic digestion
Occurrence of laminated packaging:	All material except the sub-40mm fines passes through an ECS. Laminated packaging is present in both intermediate and oversize fractions from the trommel, and removed by the respective ECS into a single non-ferrous output bin. Laminated packaging was visually observed in the non-ferrous output bin as a relatively minor component (possibly around 5% or less). *Non-ferrous output in skip:* 
Further Comments:	The site also includes an adjacent dry MRF accepting mainly kerbside collected co-mingled dry recyclables. Laminated packaging is present in the dry MRF waste and separated by ECS into the non-ferrous stream, where it is removed by hand picking. Laminated packaging appears to be one of the main contaminants in the

	non-ferrous stream by volume. Dry MFR non-ferrous stream amounts to approximately 2,700 tpa. The picking station removes approximately 400L of contaminants per day from non-ferrous stream (estimated by site management observation that contaminant bin of approximately 50L capacity is filled around 8 times per day). Assuming bulk density of 0.1 t/m3 and 6 days working per week, this amounts to approximately 12.5 tpa assuming all of the removed material is laminated packaging. *Contaminants separated from non-ferrous material at MRF:* 

Facility name:	**Waterbeach MBT Facility**
Operator:	AmeyCespa
Throughput:	200,000 tpa design throughput (111,000 tpa of waste processed in 2011)
Source of waste:	Contract with Cambridgeshire County Council to receive residual LACW from Cambridgeshire WCAs.
Operational since:	November 2009
General process description:	Front-end mechanical treatment: ■ Trommel ■ Overband magnet ■ Hard particle separation ■ Ballistic separation (3D/2D) ■ 2D fraction – NIR to remove plastic film ■ 3D fraction – Overband magnet, ECS, and NIR to remove mixed plastics. Back-end biological treatment: ■ Composting of fines and other residuals to produce CLO
Occurrence of laminated packaging:	Material could not be inspected during processing due to temporary shutdown. Inspection of output bins indicated that the non-ferrous output includes an appreciable amount of laminated packaging (along with aseptic beverage containers e.g. tetrapak). Site management reports laminated packaging is present as a minor contaminant in other outputs, e.g. plastic film and CLO. Only the 3D fraction passes through an ECS. *Non-Ferrous Output:* 

Facility name:	**Canford MBT Facility**
Operator:	New Earth Solutions
Throughput:	75,000 tpa
Source of waste:	Contract to treat residual LACW from Bournemouth Borough Council and East Dorset District Council.
Operational since:	2003
General process description:	Front-end mechanical treatment: ■ Shredder ■ Trommel ■ Windshifter (heavies/lights) ■ Lights – overband magnet, NIR to separate plastic film from paper/card ■ Heavies – ballistic separator (2D/3D) ■ 2D heavies – NIR to separate plastic film from paper/card ■ 3D heavies - Overband magnet, ECS, and NIR to remove mixed plastics Back-end biological treatment: ■ Biostablisation to produce CLO/RDF
Occurrence of laminated packaging:	Laminated packaging was identified in the non ferrous output with small quantities seen in the <80mm bio fines and other streams. Only 3D heavies pass through the ECS, nonetheless this material evidently includes appreciable quantities of laminated packaging for it to appear in the non-ferrous output as a visible component. Site staff estimate that somewhere around 0.5% of total input may be laminated packaging, although this may include non-target material such as crisp packets etc. *Non-Ferrous Output:* 

Facility name:	**Byker MBT Facility**
Operator:	Sita
Throughput:	85,000 tpa
Source of waste:	Contract to treat residual LACW from Newcastle City Council
Operational since:	2006
General process description:	Front-end mechanical treatment: ■ Shredder ■ Trommel ■ Overband magnet (on oversize and undersize lines) ■ Eddy current separation (on oversize and undersize lines) ■ Air extraction system to remove light contaminants from non-ferrous stream Fines sent for composting at off-site facility. Residuals used for RDF.
Occurrence of laminated packaging:	Laminated packaging was identified in the non ferrous output with no significant quantities observed in any of the other outputs. Throughput of laminated packaging could not be quantified. The air extraction system is effective at removing some laminated packaging from non-ferrous stream, along with paper and plastic films. *Contaminants removed from non-ferrous stream by vacuum extraction:* 

Waste & Resources Action Programme

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